Original article

A retrospective study to establish the appropriate blood use guidelines for patients undergoing surgery: a single-center experience

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Abstract:

Introduction: *Currently, the demand for blood from surgical patients has increased; however, a shortage of blood supplies remains. Studying blood utilization indices, i.e., crossmatch-to-transfusion (C:T) ratio, transfusion probability (%T) and transfusion index (Ti), along with factors associated with red blood cell (RBC) transfusions, are necessary to establish guidelines for appropriate blood use.* ***Objective:*** *This retrospective study aimed to establish appropriate guidelines and identify factors associated with RBC transfusions at Sirindhorn Hospital.* ***Materials and Methods:*** *Data about patients undergoing surgery from October 2022 to September 2023 were collected from the hospital database, including demographic and preoperative laboratory data. Blood utilization indices were calculated according to type of surgery. Factors associated with transfusions were analyzed, then pre-transfusion testing guidelines were developed.* ***Results:*** *The C:T ratio, %T and Ti were analyzed among 1,041 surgical patients with 2,139 units of blood requests. Only 314 patients were transfused with 649 units (C:T ratio = 3.3, %T = 30.2, Ti = 0.6), indicating over-requested blood compared to actual use. When categorized by types of surgeries, only patients undergoing cardiovascular surgery used blood efficiently. Preoperative hemoglobin (Hb) and hematocrit (Hct) levels were independent factors associated with transfusions. According to surgical types with the largest number of blood requests, patients undergoing orthopedics, obstetrics, and general surgery should consider preoperative Hb levels before ordering blood for a complete crossmatch.* ***Conclusion:*** *The proposed pre-transfusion testing guidelines using optimal Hb level cutoffs improved all blood utilization indices. In addition, using type and screen in pre-transfusion testing could reduce unnecessary costs and workload, enabling an adequate supply of reserve blood in emergencies.*

Keywords : ● *Blood utilization indices* ● *Factors associated with transfusions* ● *Type and screen*

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นิพนธ์ต้นฉบับ

การศึกษาย้อนหลังเพื่อกำหนดแนวทางการใช้เลือดที่เหมาะสมสำหรับผู้ป่วยที่ต้องเข้ารับการผ่าตัด

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บทคัดย่อ

บทนำ *ปัจจุบันการขอเลือดสำหรับผู้ป่วยผ่าตัดมีแนวโน้มเพิ่มขึ้น แต่ปริมาณเลือดที่จัดหาได้ไม่เพียงพอ ทำให้ประสบปัญหาขาดแคลนเลือด จึงควรศึกษาข้อมูลดัชนีชี้วัดการใช้เลือดที่เหมาะสม คือ crossmatch-to-transfusion (C:T) ratio, transfusion probability (%T) และ transfusion index (Ti) ร่วมกับปัจจัยอื่นที่อาจส่งผลต่อการได้รับเลือด เพื่อกำหนดแนวทางการใช้เลือดอย่างเหมาะสม* ***วัตถุประสงค์*** *เพื่อศึกษาข้อมูลย้อนหลังในการกำหนดแนวทางการใช้เลือดร่วมกับศึกษาปัจจัยที่ส่งผลต่อการได้รับเลือดในโรงพยาบาลสิรินธร* ***วัสดุและวิธีการ*** *เก็บข้อมูลผู้ป่วยผ่าตัดจากระบบสารสนเทศของโรงพยาบาลตั้งแต่เดือนตุลาคม 2565 ถึงเดือนกันยายน 2566 ประกอบด้วย ข้อมูลทั่วไป และข้อมูลผลการตรวจทางห้องปฏิบัติการก่อนผ่าตัด โดยคำนวณค่าดัชนีชี้วัดการใช้เลือดที่เหมาะสมแบ่งตามประเภทการผ่าตัด วิเคราะห์ปัจจัยที่ส่งผลต่อการได้รับเลือด เพื่อกำหนดแนวทางการทดสอบก่อนการให้เลือด* ***ผลการศึกษา*** *ค่า C:T ratio, %T และ Ti ของผู้ป่วยที่ได้รับการผ่าตัดจำนวน 1,041 ราย มีการสั่งจองเลือดจำนวน 2,139 ยูนิต แต่ผู้ป่วยเพียง 314 ราย ที่มีการใช้เลือดจริง จำนวน 649 ยูนิต (C:T ratio = 3.3, %T = 30.2 และ Ti = 0.6) แสดงว่ามีการสั่งจองเลือดเกินความต้องการใช้จริง เมื่อจำแนกตามประเภทการผ่าตัดพบว่า ผู้ป่วยศัลยกรรมหัวใจและหลอดเลือดเท่านั้นที่มีการใช้เลือดเหมาะสม ปัจจัยที่เกี่ยวข้องกับการได้รับเลือด คือ ค่าฮีโมโกลบินและฮีมาโตคริตก่อนการผ่าตัด จากข้อมูลการผ่าตัดที่มีการสั่งจองเลือดมากที่สุด ผู้ป่วยศัลยกรรมกระดูก สูติศาสตร์ และ ศัลยกรรมทั่วไป ควรพิจารณาระดับฮีโมโกลบิน ก่อนการสั่งจองเลือดแบบ complete crossmatch* ***สรุป*** *การใช้แนวทางการทดสอบก่อนการให้เลือดโดยกำหนดค่าฮีโมโกลบินที่สอดคล้องกับประเภทการผ่าตัดจะช่วยพัฒนาค่าดัชนีชี้วัดการใช้เลือดให้เหมาะสมได้ นอกจากนี้การเตรียมเลือดแบบ type and screen ช่วยลดค่าใช้จ่ายการเตรียมเลือดที่ไม่จำเป็น ลดภาระงานเจ้าหน้าที่ และช่วยให้มีปริมาณเลือดสำรองเพียงพอในกรณีฉุกเฉิน*

คำสำคัญ : ● *ดัชนีชี้วัดการใช้เลือด* ● *ปัจจัยที่เกี่ยวข้องกับการได้รับเลือด* ● *การเตรียมเลือดแบบ type and screen*

วารสารโลหิตวิทยาและเวชศาสตร์บริการโลหิต. 2568;35:97-107.

Introduction

Currently, the use of blood among patients undergoing surgery increases worldwide, resulting in an inadequate blood supply. However, donor recruitment faces challenges from aging populations and the pandemic of emerging diseases.[1-3] Thus, patient blood management (PBM), comprehensive care to manage anemia and preserve a patient's blood, is required and emphasized to provide appropriate blood use. The World Health Organization has established a policy of integrating multidisciplinary care to improve patient outcomes in patients requiring blood transfusions by implementing PBM, which is based on three pillars: detection and management of anemia and iron deficiency; minimization of blood loss and optimization of coagulation; and, lastly, leveraging and optimizing the patient-specific physiological tolerance of anemia.[4] In addition, the rational use of blood should be considered. The standard guidelines recommend periodic reviews and monitoring of blood use.[1,5] Three indicators used to identify appropriate blood use include crossmatch-to-transfusion ratio (C:T ratio), transfusion probability (%T) and transfusion index (Ti), described below.

In clinical practices, blood-ordering physicians typically request more units of blood than the surgical patients will receive in order to provide a safety margin in the event of unexpected hemorrhage.[6] Moreover, preoperative ordering patterns might be more habit-driven than clinically necessary, leading to an inappropriate C:T ratio of more than 2.0, %T less than 30, and Ti less than 0.5, which may result in shortening blood shelf life, waste of materials and human resources in the blood bank and loss of rare blood types.[7-10] A retrospective study to investigate blood use among patients undergoing elective surgery at Bangkok Metropolitan Administration General Hospital revealed the overuse of blood with a C:T ratio of 3.5, and suggested that type and screen (T&S) could reduce the total cost of blood preparation compared to complete crossmatch.[11] A similar finding in a recent study at Songklanagarind Hospital, Songkhla Province, demonstrated the excessive ordering of blood units with variations according to the type of surgical procedures. The maximum surgical blood order schedule (MSBOS) was established as guidelines to prepare appropriate blood units in surgery and reduce excess blood preparation.[12]

The independent risk factors, including sex, age, body mass index, preoperative hemoglobin (Hb), and intraoperative blood loss have been identified and used as predictive and protective factors for red blood cell (RBC) transfusion, especially in various types of orthopedic surgery.[13-16] The possibility of receiving RBC transfusions was high among female patients with low preoperative Hb.[14,15] Furthermore, perioperative drop in Hb was a risk factor associated with transfusions.[16] A retrospective study in a German University Hospital revealed that independent predictors for RBC transfusions among children undergoing surgery consisted of preoperative anemia, younger age, female, certain types of surgery and postoperative complications.[17] Further, patients undergoing total hip or knee arthroplasty with preoperative Hb levels less than 12.0 g/dL had a higher chance of receiving RBC transfusions; thus, complete crossmatching should be reserved for these patients.[18,19] Patients whose preoperative Hb levels greater than 12.0 g/dL can employ T&S.[19] However, these suggestions on pre-transfusion testing were based on identified risk factors, although efficiency of blood use was not evaluated. Therefore, additional studies concerning the factors associated with receiving RBC transfusions are beneficial in providing strategies to ensure effective PBM among surgical patients.

This retrospective study aimed to establish guidelines for appropriate blood use in patients undergoing surgery and identify possible factors associated with RBC transfusions at Sirindhorn Hospital.

Materials and Methods

The study was approved by the Human Research Ethics Committee of Thammasat University (Science), (HREC-TUSc) Pathum Thani, Thailand (COA No. 060/2567) and the Human Research Ethics Committee of Bangkok (U015hh/67_EXP), according to the Declaration of Helsinki. Data of patients undergoing surgery at Sirindhorn Hospital from October 2022 to September 2023 were retrospectively collected from the hospital's information system. Patient data included demographic data, type of surgery, number of RBC units requested, number of units used and preoperative laboratory test results consisting of Hb, hematocrit (Hct), and platelet (PLT) count.

Blood utilization indices, including C:T ratio, %T, and Ti, were calculated.[7] The C:T ratio is calculated using the number of RBC units crossmatched divided by the number of RBC units transfused. A ratio of 2.0 or below indicates efficient blood use. The %T is calculated using the number of patients transfused divided by the number of patients crossmatched times 100. A value of 30% or above indicates significant blood use. The Ti is calculated by the number of RBC units transfused divided by the number of patients crossmatched. A value of 0.5 or above indicates significant blood utilization.

Patients were stratified into transfusion and non-transfusion groups. Subsequently, demographic and preoperative laboratory data were compared to identify independent factors associated with RBC transfusions. The significant risk factors were used to develop the pre-transfusion testing guidelines. We proposed guidelines for appropriate blood utilization for the top three surgery types that have the highest blood ordering with an inappropriate C:T ratio. Blood utilization indices were recalculated using the existing dataset to demonstrate the efficiency of the proposed guidelines.

Statistical analysis

Demographic information was summarized using descriptive statistics. Categorical variables were expressed as frequencies and percentages. Continuous variables were presented as mean ± standard deviation (SD) or median with interquartile range (IQR), as appropriate. Baseline characteristics were compared between surgical patients who did and did not receive RBC transfusions using a parametric statistical test (independent t-test) or non-parametric statistical tests (chi-square and Mann Whitney U tests), as appropriate. Bonferroni adjustment was performed in post-hoc analysis following a chi-square test with multiple comparisons. All risk factors associated with RBC transfusions were analyzed using univariate and multivariate logistic regressions, with results displayed as odds ratio (OR) and 95% confidence interval (CI). Furthermore, the variance inflation factor (VIF) was evaluated among the covariates in a logistic model to assess potential collinearity. Variables demonstrating a VIF > 10.0, indicative of collinearity, were selected as one independent variable in the multivariate logistic regression analysis. Before conducting univariate logistic regression, preoperative Hb, Hct and PLT counts were categorized into two groups. Preoperative Hb and Hct were stratified using the optimal cutoff, demonstrating the maximum sensitivity and specificity to differentiate patients with RBC transfusions determined by receiver operating characteristic (ROC) curve analysis. The PLT count was stratified by the lower limit of the reference interval of the PLT count used in our hospital (140.0 × 10^3/μL). All statistical analyses were conducted using IBM SPSS Statistics, Version 25.0 (IBM Corp., Armonk, NY, USA). A *p*-value less than 0.05 was considered statistically significant.

Results

Regarding patients requesting blood for surgery at Sirindhorn Hospital from October 2022 to September 2023, a total of 1,096 patients' data was collected; however, 55 patients with incomplete data were excluded. The remaining 1,041 patients were categorized into two groups: the transfusion group (n = 314) and the non-transfusion group (n = 727). The study population consisted of 246 male patients (23.6%) and 795 female patients (74.6%); the male-to-female ratio was 1.0:3.2.

Their ages ranged from 12 years to 93 years, with a median age of 47 years. The preoperative laboratory results revealed that Hb levels ranged from 3.9 to 18.5 g/dL with a median of 11.7 g/dL, Hct levels ranged from 13.5 to 55.0% with a mean of 36.3%, and PLT counts ranged from 40.0 to 596.0×10^3/μL with a median of 274.0×10^3/μL. No significant differences in sex and PLT counts were noted between the two groups ($p > 0.05$); however, the ages of patients in the transfusion group were significantly higher than those in the non-transfusion group ($p < 0.001$), as shown in Table 1.

The categories of surgical types were associated with patients receiving transfusions according to data analysis using the chi-square test. After post-hoc analysis using Bonferroni adjustment, only orthopedics, obstetrics, general surgery and cardiovascular surgery showed strong correlation with patients receiving RBC transfusions (Bonferroni adjusted p value < 0.004). Moreover, preoperative levels of Hb and Hct were significantly lower in patients of the transfusion group than in patients of the non-transfusion group ($p < 0.001$), as shown in Table 1.

The numbers of blood requests and RBC transfusions by surgical types are shown in Table 2. The types of surgeries with the highest number of blood requests were orthopedics (n = 422), followed by obstetrics (n = 369), general surgery (n = 75) and cardiovascular surgery (n = 68), respectively. Interestingly, only cardiovascular surgery had appropriate blood utilization indices (C:T

Table 1 Comparison of demographic and laboratory data between the transfusion and no transfusion groups among 1,041 patients from October 2022 to September 2023

Characteristic	Total (n = 1,041)	Transfusion (n = 314)	No transfusion (n = 727)	*p*-value
Sex				0.162[a]
- Male (%)	246 (23.6)	83 (26.4)	163 (22.4)	
- Female (%)	795 (76.4)	231 (73.6)	564 (77.6)	
Age (years)				< 0.001[c]
- Median (IQR)	47.0 (30.0, 66.0)	56.5 (36.0, 69.0)	42.0 (29.5, 65.0)	
Type of surgery (%)				< 0.001[a]
- Orthopedics	422 (40.5)	101 (32.2)	321 (44.2)	< 0.001*
- Obstetrics	369 (35.4)	84 (26.8)	285 (39.2)	< 0.001*
- General surgery	75 (7.2)	36 (11.5)	39 (5.4)	< 0.001*
- Cardiovascular surgery	68 (6.5)	65 (20.7)	3 (0.4)	< 0.001*
- Gynecology	55 (5.3)	20 (6.4)	35 (4.8)	0.306
- Neurosurgery	25 (2.4)	6 (1.9)	19 (2.6)	0.495
- Otolaryngology	15 (1.4)	1 (0.3)	14 (1.9)	0.046
- Urology	11 (1.1)	1 (0.3)	10 (1.4)	0.125
- Joint and Rheumatism	1 (0.1)	0 (0.0)	1 (0.1)	N/A
Hemoglobin (g/dL)				< 0.001[c]
- Median (IQR)	11.7 (10.5, 12.9)	10.5 (9.0, 11.9)	12.1 (11.0, 13.2)	
Hematocrit (%)				< 0.001[b]
- Mean ± SD	36.3 ± 5.9	33.0 ± 6.5	37.8 ± 4.8	
PLT count (×10^3 /μL)				0.090[c]
- Median (IQR)	274.0 (223.0, 328.0)	277.0 (217.0, 354.0)	273.0 (225.0, 320.0)	

IQR, Interquartile range; N/A, Not applicable; SD, Standard deviation

[a]Chi-square test; [b]Independent t-test; [c]Mann-Whitney U test; *Adjusted $p < 0.004$ (Bonferroni adjustment)

Table 2 Blood utilization indices according to surgery types

Type of surgery	Number of blood requested		Number of blood transfused		Blood utilization indices		
	Cases	Units	Cases	Units	C:T ratio	%T	Ti
Orthopedics	422	822	101	160	5.1	23.9	0.4
Obstetrics	369	611	84	133	4.6	22.8	0.4
General surgery	75	198	36	76	2.6	48.0	1.0
Cardiovascular surgery	68	306	65	227	1.3	95.6	3.3
Gynecology	55	118	20	41	2.9	36.4	0.7
Neurosurgery	25	46	6	7	6.6	24.0	0.3
Otolaryngology	15	17	1	1	17.0	6.7	0.1
Urology	11	19	1	4	4.8	9.1	0.4
Joint and Rheumatism	1	2	0	0	N/A	0.0	0.0
Total	1,041	2,139	314	649	3.3	30.2	0.6

C:T ratio, crossmatch-to-transfusion ratio; %T, transfusion probability; Ti, transfusion index; N/A, not applicable

ratio = 1.3, %T = 95.6, and Ti = 3.3). For orthopedics, obstetrics, and general surgery, the C:T ratios were 5.1, 4.6, and 2.6; %T were 23.9, 22.8, and 48.0, and Ti were 0.4, 0.4, and 1.0, respectively.

When we analyzed for factors associated with transfusions, including sex, age, types of surgeries, Hb levels, Hct levels, and PLT counts among 1,041 patients, no association between sex and transfusions was observed ($p = 0.162$). However, an increase in age was significantly associated with transfusions (OR = 1.016, 95%CI: 1.009-1.022, $p < 0.001$). The ratios between patients in the transfusion and the non-transfusion groups were compared and categorized according to surgical types. Patients undergoing general surgery showed a comparable ratio, serving as a reference to compare with other surgical types. Only patients undergoing cardiovascular surgery indicated a statistically significantly higher chance of receiving transfusions (OR = 23.472, 95%CI: 6.773-81.346, $p < 0.001$). In contrast, patients undergoing orthopedic and obstetric surgeries had a significantly lower chance of receiving transfusions (OR = 0.341, 95%CI: 0.206-0.565, $p < 0.001$, and OR = 0.319, 95%CI: 0.191-0.534, $p < 0.001$), compared with that of patients undergoing general surgery. Additionally, patients with preoperative Hb levels < 12.0 g/dL and Hct levels < 36.0% had a significantly higher chance of receiving transfusions (OR = 3.604, 95%CI: 2.676-4.848, $p < 0.001$ and OR = 3.427, 95%CI: 2.591-4.531, $p < 0.001$), while patients with thrombocytopenia (PLT counts < $140.0x10^3$/μL) showed no association with RBC transfusions ($p = 0.346$), as shown in Table 3.

Using univariate logistic regression to analyze the different factors affecting patients with RBC transfusions among 422 orthopedic patients, patient's age had no association with requiring a blood transfusion ($p = 0.142$). In contrast, the following factors revealed a statistical significance on blood transfusions: first, female patients were more likely than male patients to receive blood transfusions (OR = 2.170, 95%CI: 1.264-3.726, $p = 0.005$). Second, preoperative Hb levels < 12.0 g/dL and Hct levels < 38.0% showed a higher risk of RBC transfusions (OR = 9.506, 95%CI: 5.635-16.035, $p < 0.001$, and OR = 8.307, 95%CI: 4.963-13.903, $p < 0.001$). Variables with statistical significance in univariate analysis were further analyzed using multivariate logistic regressions. However, significant collinearity was observed between preoperative Hb levels (VIF = 14.289) and Hct levels (VIF = 14.305) only. When analyzing data using multivariate logistic regression, we found that only preoperative Hb levels (< 12.0 g/dL) and Hct levels (< 38.0%) were independent risk factors associated with receiving RBC transfusions among patients undergoing orthopedic

Table 3 Comparison of various factors associated with RBC transfusions among 1,041 patients

Variable	Odds ratio (OR)	95%CI	p-value
Female	0.804	0.593-1.092	0.162
Age (years)	1.016	1.009-1.022	< 0.001
Type of surgery			
- General surgery	Reference	-	-
- Orthopedics	0.341	0.206-0.565	< 0.001
- Obstetrics	0.319	0.191-0.534	< 0.001
- Cardiovascular surgery	23.472	6.773-81.346	< 0.001
- Gynecology	0.619	0.304-1.262	0.187
- Neurosurgery	0.077	0.010-0.619	0.016
- Otolaryngology	0.108	0.013-0.889	0.039
- Urology	0.342	0.123-0.952	0.040
- Joint and Rheumatism	0.000	N/A	1.000
Hemoglobin < 12.0 g/dL	3.604	2.676-4.848	< 0.001
Hematocrit < 36.0 %	3.427	2.591-4.531	< 0.001
PLT count < 140 $\times 10^3$/μL	1.503	0.644–3.509	0.346

CI, confidence interval; N/A, not applicable; PLT, platelet

surgery. Similar findings were observed among patients undergoing obstetrics and general surgery; preoperative Hb and Hct levels at a certain cutoff were identified as independent risk factors associated with receiving RBC transfusions. Preoperative Hb levels less than 11.0 g/dL (OR = 3.313, 95%CI: 1.932-5.681, $p < 0.001$) and Hct levels less than 33.0% (OR = 4.127, 95%CI: 2.447-6.960, $p < 0.001$) among patients undergoing obstetric surgery, while preoperative Hb levels less than 10.0 g/dL (OR = 22.857, 95%CI: 6.893-75.797, $p < 0.001$) and Hct levels less than 30.0% (OR = 28.171, 95%CI: 8.071-98.329, $p < 0.001$) among patients undergoing general surgery showed an association with blood transfusions, as shown in Table 4.

Based on our results and related studies concerning the reliability of Hb over Hct levels,[20-22] the preoperative Hb level at the optimal cutoff was selected to develop the proposed guideline on appropriate blood utilization among patients undergoing orthopedics, obstetrics and general surgery. For orthopedics, obstetrics, and general surgery, the Hb level cutoffs were < 12.0 g/dL, < 11.0 g/dL, and < 10.0 g/dL, with a strength of 76, 74 and 83% sensitivity and 75, 54 and 82% specificity, respectively. Pre-transfusion testing including complete crossmatch and T&S will be suggested to patients undergoing these surgical types (Figure 1). When we implemented these proposed guidelines in the existing dataset, the efficiency of blood use demonstrated employing blood utilization indices i.e., C:T ratio, %T and Ti was improved regarding all types of surgery (Figure 2). Additionally, blood utilization status returned to significant blood use levels in general surgery with C:T ratio, %T and Ti of 1.4, 97.3% and 2.1, respectively.

Discussion

This study analyzed data on blood use and factors associated with RBC transfusions in patients undergoing surgery at Sirindhorn Hospital to develop guidelines for appropriate blood utilization. Among 1,041 patients undergoing surgery, the overall C:T ratio, %T and Ti were 3.3, 30.2% and 0.6, respectively. The C:T ratio was higher than an optimal ratio of 2.0, demonstrating an excess of preoperative blood preparations, similar to the study among patients undergoing elective surgery

Table 4 Factors associated with RBC transfusions among orthopedics, obstetrics and general surgery patients

Variable	Odds ratio (OR)	95%CI	*p*-value
Orthopedics			
Female	2.170	1.264-3.726	0.005
Age (years)	1.011	0.997-1.025	0.142
Hemoglobin < 12.0 g/dL	9.506	5.635-16.035	< 0.001
Hematocrit < 38.0 %	8.307	4.963-13.903	< 0.001
PLT count < 140.0×10^3 /μL	0.525	0.062-4.413	0.553
Obstetrics			
Age (years)	1.016	0.979-1.054	0.407
Hemoglobin < 11.0 g/dL	3.313	1.932-5.681	< 0.001
Hematocrit < 33.0 %	4.127	2.447-6.960	< 0.001
PLT count < 140.0×10^3 /μL	1.722	0.421-7.039	0.449
General surgery			
Female	0.933	0.376-2.319	0.882
Age (years)	0.983	0.951-1.017	0.328
Hemoglobin < 10.0 g/dL	22.857	6.893-75.797	< 0.001
Hematocrit < 30.0%	28.171	8.071-98.329	< 0.001
PLT count < 140.0×10^3 /μL	1.088	0.145-8.159	0.934

CI, confidence interval; N/A, not applicable; PLT, platelet

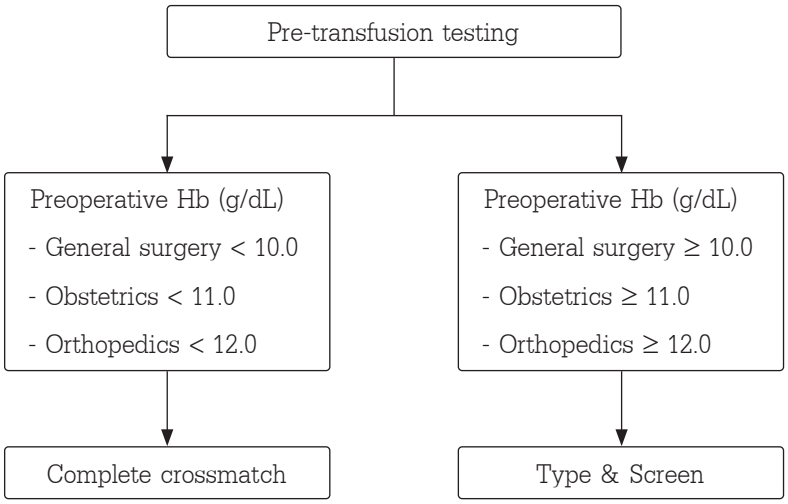

Figure 1 Proposed guidelines for pre-transfusion testing among orthopedics, obstetrics and general surgery patients

at Bangkok Metropolitan Administration General Hospital.[11] Regarding types of surgeries, the most efficient blood use was observed in cardiovascular surgery with a C:T ratio of 1.3, comparable with those related reports in Thailand (C:T ratio of 1.53) and India (C:T ratio of 1.34).[12,23] Interestingly, the surgeries with the most blood requests related to inefficient blood utilization comprised of orthopedics, followed by obstetrics (and gynecology) and general surgery, which is consistent with studies conducted among patients receiving elective surgeries in Thailand.[11,12]

The factors associated with RBC transfusions were analyzed among transfusion and non-transfusion groups. Using univariate analysis, surgical patients with increased

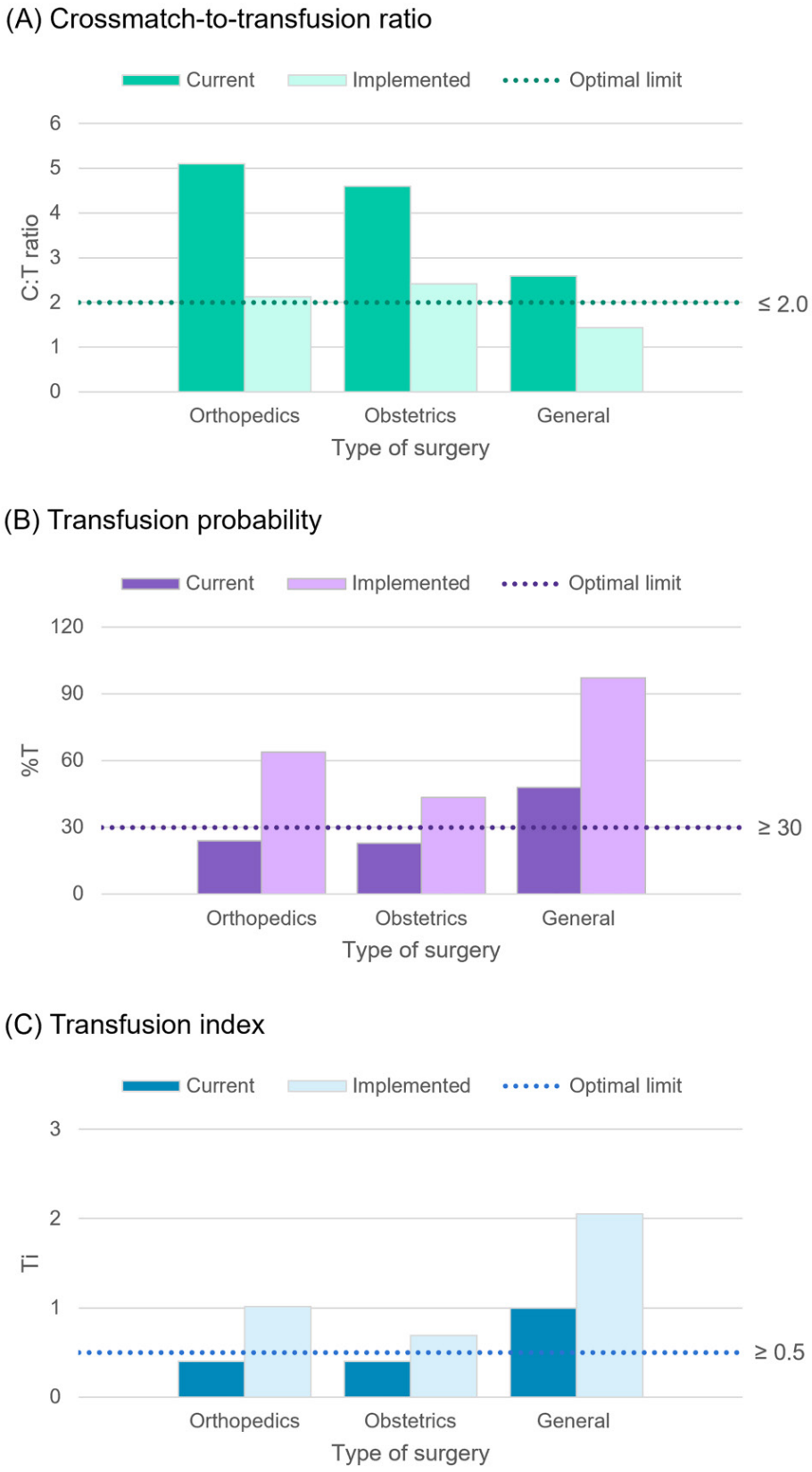

Figure 2 Blood utilization indices, (A) crossmatch-to-transfusion ratio, (B) transfusion probability and (C) transfusion index, calculated using the existing dataset among patients undergoing orthopedics, obstetrics and general surgery before and after implementing the proposed guidelines.

age possessed a higher chance to receive transfusions than those of younger ages (OR = 1.016, 95%CI: 1.009-1.022, $p < 0.001$), and female patients undergoing orthopedic surgery were more likely to receive blood transfusions than male patients (OR = 2.170, 95%CI: 1.264-3.726, $p = 0.005$). However, when analyzing data with other variables using multivariate analysis, preoperative Hb and Hct levels were the only factors for predicting RBC transfusion. This discrepancy highlights the importance of considering both collective and individual variable effects.[24] Among patients undergoing orthopedics, obstetrics and general surgery, preoperative Hb and Hct levels of less than 12.0, 11.0 and 10.0 g/dL and 38, 33 and 30%, respectively, were significant factors affecting RBC transfusions. Due to a high correlation between Hb and Hct variables, we selected Hb levels to develop the proposed guidelines because of their reliable test results compared with Hct levels analyzed by automated analyzers.[20-22] When we implemented guidelines concerning the existing dataset, all blood utilization indices were significantly improved (Figure 2). Related studies revealed a high probability of receiving transfusions was observed among patients undergoing total hip or knee arthroplasty with preoperative Hb levels < 12.0 g/dL.[18,19] Hence, complete crossmatch should be reserved only for orthopedic patients with preoperative Hb levels < 12.0 g/dL to provide efficient blood utilization and reduce laboratory workload and costs.[11,18,19] Regarding the recommendation by the Centers for Disease Control and Prevention (CDC), anemia was defined as Hb levels of < 11.0 g/dL for pregnant women (first or third trimester).[25] This criterion is consistent with the ROC analysis-derived cutoff to predict RBC transfusions among patients undergoing obstetric surgery. Thus, in our study, T&S is suggested in patients undergoing obstetric surgery with preoperative Hb levels of ≥ 11.0 g/dL. Even though the proposed pre-transfusion testing guidelines using optimal Hb level cutoffs demonstrated overall improved blood utilization indices employing the existing dataset, the C:T ratio of orthopedic and obstetric surgery still did not meet the standard criterion. These results indicated inappropriate numbers of RBC unit preparations in those surgeries, suggesting the implementation of MSBOS as an effective strategy to reduce excess blood preparation in elective surgery.[26,27] We also calculated the cost of complete crossmatch for 866 patients undergoing surgery mentioned above using the sum of ABO grouping, Rh(D) typing, antibody screening test, and crossmatching for each unit. It revealed that when we replaced complete crossmatch using T&S in cases with less likelihood of having transfusion following the proposed guidelines, the crossmatching cost could be reduced by 50%. Importantly, patients with positive antibody screening tests would still require a complete crossmatch before undergoing surgery.[1,28]

This study encountered limitations. First, blood utilization indices in some surgical types could not be calculated reliably due to the limited number of patients. Second, intraoperative parameters (surgical procedure, operative time and blood loss) and other confounders (BMI, diagnosis and medication) that may also influence RBC transfusions, were not included in the study.

Conclusion

Blood utilization indices are helpful metrics to assess the efficiency of blood use and should be reviewed and monitored regularly. Inefficient blood use, indicated by the C:T ratio, was remarkably observed in orthopedic, obstetric, and general surgeries. The only independent risk factors associated with RBC transfusions identified in those types of surgery were preoperative Hb and Hct levels, with variation among surgical types. The proposed pre-transfusion testing guidelines using optimal Hb level cutoffs improved all blood utilization indices. In addition, using T&S to prepare blood units could reduce unnecessary costs and staff workload, thus providing an adequate supply of reserve blood in emergencies.

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References

1. *Cohn CS, Delaney M, Johnson ST, Katz LM, Schwartz J. Technical manual. 21st ed. Bethesda, MD: AABB; 2023.*
2. *Chiem C, Alghamdi K, Nguyen T, Han JH, Huo H, Jackson D. The impact of COVID-19 on blood transfusion services: A systematic review and meta-analysis. Transfus Med Hemother. 2021;30:1-12.*
3. *World population prospects 2022: Summary of results. United Nations Department of Economic and Social Affairs. [Internet] 2022 [cited on 2024 Nov 30]. Available from: https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/wpp2022_summary_of_results.pdf.*
4. *The urgent need to implement patient blood management: policy brief. World Health Organization. [Internet] 2021 [cited on 2024 Nov 30]. Available from: https://iris.who.int/bitstream/handle/10665/346655/9789240035744-eng.pdf?sequence=1.*
5. *Maramica. Standards for blood banks and transfusion service. 19th ed. Washington, DC: AABB; 2017.*
6. *Friedman BA. An analysis of surgical blood use in United States hospitals with application to the maximum surgical blood order schedule. Transfusion. 1979;19:268-78.*
7. *Zewdie K, Genetu A, Mekonnen Y, Worku T, Sahlu A, Gulilalt D. Efficiency of blood utilization in elective surgical patients. BMC Health Serv Res. 2019;19:804. doi: 10.1186/s12913-019-4584-1.*
8. *Ali Z, Khan T, Jangra K, Ubaid S, Bashir H, Wani AA. An evaluation of the practice for the requisition of blood products and its utilization in neurosurgical patients undergoing elective surgery at a tertiary care hospital. Anesth Essays Res. 2020;14:160-5.*
9. *Yazdi AP, Alipour M, Jahanbakhsh SS, Gharavifard M, Gilani MT. A survey of blood request versus blood utilization at a University Hospital in Iran. Arch Bone Jt Surg. 2016;4:75-9.*
10. *Guduri P, Shastry S, Raturi M, Shenoy A. Surgical blood ordering schedule for better inventory management: an experience from a tertiary care transfusion center. Med J Armed Forces India. 2020;78:283-90.*
11. *Chusri W, Somkitsiri S, Suntornopas B, Nathalang O. An approach to blood utilization in elective surgery at BMA General Hospital. J Hematol Transfus Med. 2018;28:17-23.*
12. *Jitmun P, Chatmongkolchart S. Efficacy of blood utilization in elective surgery for non-COVID patients during COVID-19 outbreaks. J Health Sci Med Res. 2025;43:e20241058. doi: 10.31584/jhsmr.20241058.*
13. *Pavão DM, Heringer EM, Almeida GJ, de Faria JLR, Pires E Albuquerque RS, de Sousa EB, et al. Predictive and protective factors for allogenic blood transfusion in total knee arthroplasty. A retrospective cohort study. J Orthop. 2023;40:29-33.*
14. *Salt E, Wiggins AT, Rayens MK, Brown K, Eckmann K, Johannemann A, et al. Risk factors for transfusions following total joint arthroplasty in patients with rheumatoid arthritis. J Clin Rheumatol. 2018;24:422-6.*
15. *Song K, Pan P, Yao Y, Jiang T, Jiang Q. The incidence and risk factors for allogenic blood transfusion in total knee and hip arthroplasty. J Orthop Surg Res. 2019;14:1-6.*
16. *Dacombe PJ, Kendall JV, McCann P, Packham IN, Sarangi PP, Whitehouse MR, et al. Blood transfusion rates following shoulder arthroplasty in a high volume UK centre and analysis of risk factors associated with transfusion. Shoulder Elbow. 2019;11:67-72.*
17. *Piekarski F, Neef V, Meybohm P, Rolle U, Schneider W, Zacharowski K, et al. Independent risk factors for RBC transfusion in children undergoing surgery. Analysis of 14,248 cases at a German University Hospital. Children (Basel). 2021;8:1-9.*
18. *Nuñez JH, Mora L, Carbonell C, Barro V, Casaccia M, Pérez M, et al. Is routine blood typing and screening necessary before primary total hip or knee arthroplasty in the 21st century? Transfusion. 2022;62:316-23.*
19. *Likitvorasak P. Factors relating to allogenic blood transfusion in patients undergoing hip arthroplasty in Prachuap Khiri Khan Hospital. Reg 4-5 Med J. 2022;41:98-107.*
20. *Lehner J, Greve B, Cassens U. Automation in Hematology. Transfus Med Hemother. 2007;34:328-39.*
21. *Buttarello M. Laboratory diagnosis of anemia: are the old and new red cell parameters useful in classification and treatment, how? Int J Lab Hematol. 2016;38(Suppl 1):123-32.*
22. *Livshits L, Bilu T, Peretz S, Bogdanova A, Gassmann M, Eitam H, et al. Back to the "Gold Standard": how precise is hematocrit detection today? Mediterr J Hematol Infect Dis. 2022;14:e2022049. doi: 10.4084/MJHID.2022.049.*
23. *Mangwana S, Bedi N, Yadav P, Chugh R. Optimization of blood transfusion services: analysis of blood requisition and utilization practices in cardiac surgical patients in a tertiary care hospital, India. Glob J Transfus Med. 2017;2:47-51.*
24. *Hair JF, Black WC, Babin BJ, Anderson RE. Multivariate data analysis. 8th ed. London: Cengage Learning; 2019.*
25. *Kanu FA, Hamner HC, Scanlon KS, Sharma AJ. Anemia among pregnant women participating in the special supplemental nutrition program for women, infants, and children - United States, 2008-2018. MMWR Morb Mortal Wkly Rep. 2022;71:813-9.*
26. *Woodrum CL, Wisniewski M, Triulzi DJ, Waters JH, Alarcon LH, Yazer MH. The effects of a data driven maximum surgical blood ordering schedule on preoperative blood ordering practices. Hematology. 2017;22:571-7.*
27. *Guduri PR, Shastry S, Raturi M, Shenoy A. Surgical blood ordering schedule for better inventory management: An experience from a tertiary care transfusion center. Med J Armed Forces India. 2022;78:283-90.*
28. *Boral LI, Henry JB. The type and screen: a safe alternative and supplement in selected surgical procedures. Transfusion. 1977;17:163-8.*