Original Article

A Study of Blood Utilization in Association with Specific Pediatric Procedures

Thipfun C, MNS[1], Khorana J, MD[2], Kaewdonduk W, BN[1], Tepmalai K, MD[2]

[1] Pediatric Nursing Section, Faculty of Medicine, Chiang Mai University, Chiang Mai, Thailand

[2] Division of Pediatric Surgery, Department of Surgery, Faculty of Medicine, Chiang Mai University, Chiang Mai, Thailand

Background: The average blood product ordered for elective pediatric procedures were double when compared to the data on the same procedures for adults. Most of the blood product preparation was not used.

Objective: To reduced unnecessary pre-operative blood orders and costs under patient safety rule.

Materials and Methods: The data were collected from pediatric patients that underwent transanal endorectal pull-through (TERPT), posterior sagittal anorectoplasty (PSARP), and colostomy closure over a 29 months period. A crossmatch-to-transfusion ratio (C/T ratio), transfusion probability (%T), and transfusion index (Ti) were calculated for each type of procedure. A new maximum surgical blood order schedule (MSBOS) was created and introduced. Total cost of blood preparation and transfusion were analyzed to assess the efficacy and safety of the new policy.

Results: One hundred eighteen pediatric patients were crossmatched pre-operatively. The number of units crossmatched varied in range between 1 and 4. Of the 239 units of blood crossmatched, only two units were transfused. TERPT had a %T of zero and a C/T ratio equal to infinity. PSARP and colostomy closure had a low transfusion probability (%T <5%), and a C/T ratio of more than 2:1. Implementing the new policy resulted in reduction in the cost of blood preparation and transfusion by 300 Baht (US$ 8.57) per person for TERPT and 180 Baht (US$ 5.14) per person for PSARP and colostomy closure.

Conclusion: The authors' analysis confirmed that excessive crossmatching occurred for several pediatric procedures. Regular auditing and revising of policies should be encouraged and applied in all procedures for better blood utilization and cost reduction in the future.

Keywords: MSBOS, Crossmatch, TERPT, PSARP, Closure colostomy

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Pediatric patients that underwent surgeries commonly require peri-operative blood preparation. For the patient safety, after assessing the patient's risk of bleeding and the potential need for red blood cell (RBC) transfusion, surgeons generally order the number of units of blood to be crossmatched for any given surgical procedures. Pre-operative blood ordering refers to obtaining either a type and screen (T/S) or a type and crossmatch (T/C). T/S determines the ABO group and the RhD type (type), and screening the patient's plasma for clinically significant antibodies require, typically, one hour. T/C needs 30 to 45 minutes to confirm compatibility between the donor and the recipient. The blood is removed from the pool only after the crossmatching is done.

Friedman et al described the maximum surgical blood order schedule (MSBOS) in 1976[(1)]. The work demonstrated that the appropriate use of T/S order was adequate for 63 common adult elective surgical procedures. After the schedule was applied, a decrease in the blood unit expiration, from 6.5% to 4.5%, was reported. Surgical techniques and patient management have developed rapidly, making the initial MSBOS less applicable to today's surgical procedures, and there has been a failure in updating these data over time. In 2013, Frank et al[(2)] revised and showed the result after implementing the revised

Correspondence to:

Tepmalai K.

Division of Pediatric Surgery, Department of Surgery, Faculty of Medicine, Chiang Mai University, 110 Intrawaroros Road, Chiang Mai 50200, Thailand.

Phone: +66-81-7832188, **Fax**: +66-53-936132

Email: pedsurgerycmu@gmail.com

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MSBOS. There was a 38% decreased in the number of T/S samples ordered without significant use of transfusion of uncrossmatched emergency release (type O) blood. This is because the physiological and the hematological characteristics in children are different from those of adults. Children have higher oxygen consumption, metabolic rate, and circulating blood volume[3]. The blood component therapy guidelines for adults cannot be applied to infants and toddlers. In pediatric procedures, there are very few reports of over-ordering blood products[4,5] and few institutes have applied MSBOS in their practices[6].

As for pediatric patients that underwent an operation, the attending surgeon and the responsible anesthesiologist usually require RBC products before the operation is begun, especially for the youngest or the sickest patients, resulting in over-ordering of blood for pediatric procedures. Thomson et al reported that the average blood product ordered in U.S. children's hospitals was double when compared to the data on the same procedure for adults[5]. Furthermore, for pediatric patients with many comorbidities, larger amounts of pre-operative blood were kept in preparation than for healthier ones[5]. The rate of intra-operative transfusion in non-cardiac pediatric procedures was 2.78%, and many pediatric procedures were found to have very high peri-operative blood testing but no instances of transfusion[4].

Transanal endorectal pull-through (TERPT), posterior sagittal anorectoplasty (PSARP), and colostomy closure are common pediatric procedures and vary in decision for blood ordering. Absence of proper scientific guidelines may lead to over-ordering of blood pre-operation and inter-hospital variability in pediatric procedures. Therefore, the authors aimed to find an effective and economic solution to order blood for TERPT, PSARP, and colostomy closure.

Materials and Methods

After receiving approval from the Institutional Review Board at Chiang Mai University, the data were collected from pediatric patients that underwent surgery between January 2012 and October 2017. The inclusion criterion was as followed, patients under 15 years of age who had undergone TERPT, PSARP, and colostomy closure. The authors excluded emergency surgical procedures, cancelled surgeries, and patients that underwent transfusion pre-operatively. All data were obtained from the hospital databases, included age, gender, comorbidity, diagnosis, procedure, pre-operative RBC count, peri-operative blood loss, operative time, unit of packed red cells (PRCs) crossmatched pre-operatively, and unit of PRCs transfused peri-operatively. To evaluate the appropriate blood ordering and utilization in each procedure, the authors analyzed three variables, and the designation of excessive crossmatching was assigned as followed:

Crossmatch-to-transfusion ratio (C/T ratio) = Units of PRCs crossmatched/Units of PRCs transfused

A C/T ratio of 2.0 or above was taken as indicative of excessive crossmatching, and less than 50% of the crossmatches were transfused.

Transfusion probability (%T) = (Number of patients that underwent transfusion/Number of patients crossmatched) ×100

For a value of 30% and above, it was commonly considered that the procedure required transfusion.

Transfusion index (Ti) = Units of PRCs transfused/ Number of patients crossmatched

Ti signifies the appropriateness of the number of units crossmatched. A value greater than 0.5 was considered as indicating significant blood utilization.

MSBOS = 1.5×Ti was used to estimate the number of units to be crossmatched for the specific procedure. Based on this, a blood ordering policy was developed to reduce unnecessary compatibility testing and wastage of blood. After all the variables were calculated, the result was discussed by the pediatric surgeon and the anesthesiologist to reach an agreement and to create an in-house policy for these procedures.

The cost of blood preparation in the authors' hospitals is calculated based both on a T/S test and a crossmatch test, which cost, respectively, 120 Baht (US$ 3.43) and 180 Baht (US$ 5.14) per unit. In the present hospital, T/S takes one hour. When RBCs are needed unexpectedly, 30 minutes is required for the crossmatching (T/C) analysis. The appropriate blood use defined by the indices above was the primary outcome, and the secondary outcome was the creation of a policy that minimizes the resource wastage and estimates the cost saving from the new policy.

The statistical analysis was done by using Stata 11.0 (StataCorp LP, College Station, TX, USA). The categorical data were reported by count and percentage. The continuous data were reported by the mean and the standard deviation or the median and the range, depending on the data distribution. The comparative statistics used Fisher's exact test for the categorical data, and the Student's t-test or the Mann Whitney U test for continuous data.

Results

The percentages of the 118 patients that underwent

TERPT, PSARP, and colostomy closure between 2012 and 2015 were 55.9%, 21.2%, and 22.9%, respectively, as shown in Table 1. Among the patients, 84 (71.2%) were male and 34 (28.8%) were female. The mean pre-operative hemoglobin and hematocrit were 11.4 g/dl (7.4 to 18.4) and 34.76% (24.8 to 54.8). The mean operating time, the mean blood loss, and the number of units crossmatching for each procedure were 112.65±42 minutes and 13.92±27.32 ml for TERPT, 118.80±48.87 minutes and 14±7.78 ml for PSARP, and 139.81±51.99 minutes and 27.78±24.39 ml for colostomy closure, as shown in Table 2. One hundred eighteen pediatric patients were crossmatched pre-operatively for a minimum of one-unit PRC. The number of units crossmatched varied, depending on the junior medical staff. The median number of the blood preparation units was 2 (range 1 to 4).

Table 1. Demographic data

Characteristic	n (%)
Sex	118
Male	84 (71.2)
Female	34 (28.8)
Age	
0 to 12 months	65 (55.08)
1 to 3 years	36 (24.32)
3 to 6 years	13 (11.02)
>6 year	4 (3.39)
Diagnosis	
Hirschsprung's disease	66 (55.93)
Anorectal malformation	48 (40.68)
Hirschsprung's disease and anorectal malformation	2 (1.69)
Others	2 (1.69)
Procedure	
TERPT	66 (55.9)
PSARP	25 (21.2)
Colostomy closure	27 (22.9)
Hematocrit (mg%), Mean±SD	34.76±5.22
0 to 12 months	33.72±4.78
1 to 3 years	35.70±5.31
3 to 6 years	37.36±6.18
>6 year	34.8±5.71

TERPT=transanal endorectal pull-through; PSARP=posterior sagittal anorectoplasty; SD=standard deviation

Of the 239 units of blood crossmatched, only two units were transfused in two patients intraoperatively (Table 3). Transfusion of one patient was during a difficult colostomy closure from severe adhesion in his abdomen, and exploratory laparotomy was done in this case. For colostomy closure, exploratory laparotomy is not required in every case. The surgeon made as is the norm, an elliptical incision in the skin around the colostomy stoma, and anastomosis was done through a small incision. The operative time for this patient was 285 minutes, which was higher than the mean operating time (139.81±51.99 minutes), and the intra-operative blood loss was 100 ml, which is higher than usual as the mean operative blood loss was 27.78±24.39 ml. Another case was the 13-month-old child who underwent transfusion during the PSARP procedure. The pre-operative hematocrit was low (25%), and iron deficiency anemia was diagnosed and treated in this patient.

PSARP in rectovesical fistula had the longest operative time and the highest volume of blood loss

Table 2. Operative time, estimated blood loss, and number of crossmatches for each procedure

Procedure (n)	Operative time (minute) Mean±SD	Estimated blood loss (ml) Mean±SD	Number of crossmatches (unit) Mean±SD
TERPT (66)	112.65±42	13.92±27.32	2.11±0.58
PSARP (25)	118.8±48.87	14±7.78	1.88±0.44
Vestibular fistula (6)	95±15.49	14.17±10.21	2.17±0.41
Rectourethral fistula (9)	107.78±27.96	11.67±6.61	1.89±0.33
Rectovesical fistula (3)	191.67±94.65	23.33±5.77	1.67±0.58
No fistula (7)	122.14±43.67	12.86±5.67	1.71±0.49
Closure colostomy (27)	139.81±51.99	27.78±24.39	1.96±0.59
Total (118)	120.77±46.82	17.11±24.36	2.02±0.56

TERPT=transanal endorectal pull-through; PSARP=posterior sagittal anorectoplasty; SD=standard deviation

Table 3. Transfusion data according to type of surgery

Operation	n	Number of patients crossmatched	Number of units crossmatched	Number of units transfused intraoperatively	C/T ratio	%T	Ti
TERPT	66	66	137	0	Infinity	0	0
PSARP	27	27	55	1	55	3.7	0.03
Closure colostomy	28	28	54	1	54	3.57	0.04

C/T=crossmatch to transfusion ratio; %T=transfusion probability; Ti=transfusion index; TERPT=transanal endorectal pull-through; PSARP=posterior sagittal anorectoplasty

Table 4. Preparation of blood, and cost involved in preparing blood

	n	T/S (Baht)	T/C (Baht)	Total cost of blood preparation and transfusion (Baht)
Number of units crossmatched	232	120×118=14,160 (US$ 404.57)	180×239=43,020 (US$ 1,229.14)	57,180 (US$ 1,633.71)
Number of units transfused	2	120×2=240 (US$ 6.86)	180×2=360 (US$ 10.28)	600 (US$ 17.14)

T/S=type and screen; T/C=total crossmatch

US$1=35 Baht

Table 5. Transfusion policy suggested by study

Operation	n	Number of units crossmatched	MSBOS =1.5×Ti	Suggested new policy	Estimated blood preparation cost per procedure per person upon incorporating new policy	Estimated cost saving (Baht)
TERPT	66	137	0	None	-	41,100 (US$ 1,174.28)
PSARP	27	55	0.05	T/S only	120 Baht (US$ 3.43)	9,900 (US$ 242.86)
Closure colostomy	28	54	0.04	T/S only	120 Baht (US$ 3.43)	9,720 (US$ 277.71)

MSBOS=maximum surgical blood order schedule; Ti=transfusion index; TERPT=transanal endorectal pull-through; PSARP=posterior sagittal anorectoplasty; T/S=type and screen

because laparotomy was usually required (Table 3). However, the RBC transfusion rate was not found to have been affected, and there was no differentiation between the other types of anorectal malformation.

TERPT had a transfusion probability of zero and a C/T ratio equal to infinity. PSARP and colostomy closure had low transfusion probability (transfusion probability of less than 5%) and a C/T ratio more than 2:1. Cost analysis was performed, as shown in Table 4. The total cost for blood preparation was 57,180 Baht (US$ 1,633.71), while the total cost for blood transfusion was 600 Baht (US$ 14.14). Table 5 demonstrates the current blood usage. In accordance with the findings, suggestions are made for formulating new policies. PSARP and colostomy closure can be managed with pre-operative T/S and no blood bank test in TERPT. A cost-saving analysis was performed based on the new policy. The estimated cost for pre-operative blood preparation was 120 Baht (US$ 3.43) per person for PSARP and colostomy closure, and zero for TERPT.

The new policy was applied between 2016 and 2017 as shown in Table 6. No transfusion was required during this peri-operative period. The total cost of blood preparation and transfusion for these three procedures at the authors' hospital decreased by 300 Baht per person for TERPT (US$ 8.57), and 180 Baht per person per for PSARP and colostomy closure (US$ 5.14) after implementation of the new policy.

Discussion

There are many strategies that can decrease or

Table 6. After transfusion policy was applied between July 2016 and October 2017

Operation	n	Number of units crossmatched	MSBOS=1.5×Ti	Total cost of blood preparation per procedure per person (Baht)	Total cost of blood preparation and transfusion (Baht)
TERPTa	32	2	0	-	-
PSARPb	28	28	0	120 Baht (US$ 3.43)	3,360 (US$ 96.04)
Closure colostomy	19	19	0	120 Baht (US$ 3.43)	2,280 (US$ 65.17)

MSBOS=maximum surgical blood order schedule; Ti=transfusion index; TERPT=transanal endorectal pull-through; PSARP= posterior sagittal anorectoplasty

prevent blood loss. Minimally invasive procedures and new devices have been invented and widely used in operative fields, thus optimizing blood loss[7-10] and lead to some procedures that do not need blood transfusion such as laparoscopic Nissen fundoplication[4]. Detection of pre-operative anemia and treat before the operation is associated with decrease in post-operative complications and transfusion rates[11-13]. In procedures that have high risk of massive bleeding, tranexamic acid should be considered for reducing both blood loss and amount of blood transfused[11,14-16]. Additionally, cell salvage could be considered in hospitals that have appropriately trained staff[11,17].

In the authors' practice, TERPT did not require blood transfusion. The present result was the same as those of many previous studies that had reported intra-operative blood loss in TERPT in the range of 0.5 to 19 ml[18,19]. A few studies had reported the peri-operative transfusion to be in the range of 13.6% to 25%[20-22], which could have been due to variations in techniques and older age. A transfusion probability of zero and a C/T ratio equal to infinity means that TERPT had insignificant blood loss and no transfusion was required. Furthermore, if a procedure had a transfusion probability of less than 5, it means that it requires hardly any blood transfusion, so there may be no need to order blood.

The complication rate of colostomy closure has been reported to be in the range of 1.5% to 28.6%[23,24], in which anastomosis leakage, wound infection, and incisional hernia have been commonly found. Intra-operative blood loss has been reported in the adult series, ranging from 142 to 468 ml[25-27], but in children, bleeding has been rarely reported[23,24]. Fernandez et al[4] reported that colostomy is one of the pediatric procedures in which over-ordering of blood is the norm. Normally, closure colostomy does not require transfusion; however, transfusion is required in difficult cases and in cases where surgeons consider doing anastomosis via exploratory laparotomy. In such instances, blood could be prepared for specific reasons. Because the result showed a low value for transfusion probability and Ti and a high C/T ratio, there was no need to order blood for the procedure.

There are many types of anorectal malformation, and PSARP is a common procedure for this disease. Cases of "high" malformation (rectovesical fistula), however, require an abdominal-assisted procedure. In such cases, the operative time and the blood loss are higher than the other types but there is no increase in the rate of transfusion. One of the authors' patients had to receive blood transfusion because of improper treatment of iron deficiency anemia. His initial hemoglobin was 7 g/dl. In such patient, once bleeding started, even if it was in small amounts, blood transfusion was required.

Based on the findings, suggestions for a new policy were made after discussions with anesthesiologists, addressing the concern for the safety of patients. Then PSARP and colostomy closure can be managed safely with a pre-operative T/S. In addition, for TERPT, blood ordering would not be required. The authors found the guideline for MSBOS for elective pediatric procedures at the Great Ormond Street Hospital. It showed the lists of units of RBCs crossmatched for each procedure and the type of crossmatch. The guideline recommends T/S for the pull-through procedure and PSARP, including both minimal PSARP and PSARP. For colostomy closure, one unit of RBCs for complete crossmatch is suggested[6]. The authors applied the new policy between July 2017 and October 2017. It was re-audited in October 2017 and showed that neither of these three procedures required blood transfusion nor emergency release blood. The present result was different from that of the Great Ormond Street Hospital. The reason might be variations in the techniques used in the operation or differences in the threshold of the transfusions. However, as this is the first policy, it may need to be re-audited and improved in the future.

Conclusion

The present result confirms that over-order blood crossmatching continues and should be modified. All medical teams should understand the reasons for a change. While saving cost is one of the concerns, more importantly, it is that the inappropriate crossmatching increases blood wastage and adds to the burden of the blood transfusion service which, in turn, might delay provision in an emergency case or make unavailable urgently needed blood products. Regular auditing and revising of policies should be encouraged and applied in all procedures for better blood utilization in the future.

What is already known on this topic?

Pre-operative blood preparation is necessary in pediatric operative procedure for patient safety reason. Blood products over-ordering was commonly found. Few studies stated the proper MSBOS in pediatric procedure.

What this study adds?

Common elective pediatric surgical operations were TERPT, PSARP and closure colostomy. This study found unnecessary blood products ordering and created a new policy for better blood utilization with safety and cost saving.

Conflicts of interest

The authors declare no conflict of interest.

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