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Original Article

A retrospective study of intraoperative blood transfusion in children with congenital heart disease

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ABSTRACT

This study aims to analyze the characteristics and influencing factors of intraoperative blood transfusion in children with congenital heart disease (CHD) and explore the preoperative blood preparation protocols and risk indicators for intraoperative blood transfusion. It retrospectively analyzed data from 243 patients under the age of 18 undergoing CHD surgery from December 2018 to March 2022. The patients were divided into four groups in terms of the following surgical methods: ventricular septal defect (VSD) repair (group A), atrial septal defect (ASD) repair (group B), VSD and ASD repair (group C), and others (group D). Influencing factors for intraoperative blood transfusion in different surgical methods and outcomes were assessed. (1) Among the 243 cases, 185 (76.13%) cases received intraoperative blood transfusion, 176 (72.43%) cases received red blood cell (RBC) transfusion, and 30 (12.35%) cases received plasma transfusion. The RBC transfusion rate of group C was 91.21%, which was significantly higher than those of the other three groups (P<0.05). The plasma transfusion rate of group D was 24.32%, which was significantly higher than those of the other three groups (P<0.05). (2) There was no significant difference in the volume of RBC preparation, intraoperative blood loss, intraoperative RBC transfusion, and postoperative hemoglobin (Hb) between the four groups (P>0.05). The preoperative weight and Hb of group C were lower than those of the other three groups; however, only the difference between group B and group C was statistically significant (P<0.05). (3) The influencing factors for intraoperative RBC transfusion, such as age, preoperative weight, and Hb, were negatively correlated in the four groups. (4) No adverse reactions of blood transfusion were found in the four groups. The postoperative infection rates of group C and group D were 31.33% and 29.73%, respectively, which were higher than those of group A and group B (9.72% and 16.28%, respectively) (P<0.05). The average duration of hospitalized days of group C and group D were higher than those of group A and group B (P<0.05). This study suggests that the individualized blood preparation should be achieved according to the characteristics of intraoperative blood transfusion in children with CHD and the evaluation of the risk of intraoperative blood transfusion.

Keywords: congenital heart disease, intraoperative blood transfusion, blood usage analysis

INTRODUCTION

Congenital heart disease (CHD), one of the most common cardiovascular diseases during childhood, is a potential cause of death, for which cardiopulmonary bypass surgery is the predominant treatment. Pre-

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filling of stored red blood cells (RBCs) is necessary for extracorporeal circulation hematocrit and oxygen supply in children due to their low weight, large relative priming volume, strong metabolism, large demands for oxygen and substrate, and poor oxygen reserve capacity. However, studies have shown that allogeneic blood transfusion resulted in the risk of transfusion-related infectious diseases and other adverse reactions, and excessive transfusion increased complications and mortality in critically ill patients[1–2]. Although no blood priming or autologous umbilical cord blood priming has been studied or applied, their application is limited due to specific requirements for patients. Therefore, allogeneic blood priming remains a commonly used method[3–5]. This paper retrospectively studied the characteristics of intraoperative blood usage in children with CHD, and explored preoperative blood preparation protocols and risk indicators for intraoperative blood transfusion.

SUBJECTS AND METHODS

Subjects

A total of 243 patients (165 males and 78 females) under the age of 18 were enrolled in this study, who had received cardiopulmonary bypass surgery in a hospital from December 2018 to March 2022. The surgery methods used included ventricular septal defect (VSD) repair, atrial septal defect (ASD) repair, VSD and ASD repair, endocardial cushion defect (ECD) repair, ligation of patent ductus arteriosus (PDA), valvuloplasty, valvular replacement, and tetralogy correction.

Data collection and management

Data collection included: (1) preoperative indicators: diagnosis, gender, age, weight, hemoglobin (Hb), platelets, white blood cells (WBCs), and blood preparation; (2) intraoperative indicators: surgical methods, intraoperative blood loss, Hb after blood transfusion, and intraoperative blood transfusion; (3) postoperative indicators: average duration of hospitalized days, adverse reactions due to blood transfusion, postoperative infection, and mortality.

Grouping

The patients were divided into four groups based on surgical methods: VSD repair (group A), ASD repair (group B), VSD and ASD repair (group C), and others (group D). Surgery-related factors were analyzed and the influencing factors for intraoperative blood transfusion in different surgical procedures were screened.

Statistical analysis

SPSS 24 statistical software was applied for statistical analysis. Measuring data were expressed as mean ± standard deviation (SD) or percentage. Chi-square test and *t*-test were adopted. $P<0.05$ was considered statistically significant.

RESULTS

Intraoperative transfusion rate

Among the 243 cases, 185 (76.13%) cases received intraoperative blood transfusion, 176 (72.43%) cases received RBC transfusion, and 30 (12.35%) cases received plasma transfusion. Platelet or cryoprecipitate transfusion was not applied in the four groups. The transfusion rates of RBC components in groups A, B, C, and D were 63.89%, 58.14%, 91.21%, and 59.46%, respectively, indicating that the rate in group C was the highest, and the difference was statistically significant ($P<0.05$). Plasma transfusion rates of the four groups were 12.50%, 13.95%, 6.59%, and 24.32%, respectively, showing that the rate of group D was significantly higher than that of the other three groups, and the difference had statistical significance ($P<0.05$) (***Table 1***).

Table 1 **Intraoperative blood transfusion in different surgical methods**

Groups (*n*)	RBC component transfusion			Plasma transfusion		
	Cases (*n*)	Transfusion rate (%)	Per capita infusion volume (U)	Cases (*n*)	Transfusion rate (%)	Per capita infusion volume (mL)
Group A (72)	46	63.89	1.24±0.38	9	12.50	192.22±108.60
Group B (43)	25	58.14	1.40±0.48	6	13.95	238.33±131.21
Group C (91)	83	91.21	1.36±0.41	6	6.59	163.33±125.96
Group D (37)	22	59.46	1.35±0.85	9	24.32	201.11±237.46
Total (243)	176	72.43	1.33±0.49	30	12.35	198.33±158.46

The chi-square test was used to compare the blood transfusion rate between the four groups. Blood transfusion rates in the four groups: *P* values of group A/C and group B/C were 0.00; the *P* value of group C/D was 0.003. Plasma transfusion rates in the four groups: the *P* value of group C/D was 0.005. RBC transfusion rates in the four groups: *P* values of the group A/C, group B/C and group D/C were all 0.00. RBC: red blood cell.

Intraoperative RBC transfusion

The blood reserve per capita was (2.09±0.61) U, per capita blood loss was (41.25±64.31) mL, per capita blood consumption was (1.33±0.49) U, and postoperative Hb was (120.81±16.41) g/L. The difference between the groups was not statistically significant (P>0.05). The intraoperative blood loss in group C was lower than those in the other three groups, but the difference was not statistically significant (P>0.05). The preoperative weight and Hb of group C were lower than those of the other three groups, but only the difference between group B and group C was statistically significant (P<0.05) (***Table 2***).

Table 2 **RBC transfusion in different groups**

Groups (n)	Per capita weight (kg)	Pre-transfusion Hb (g/L)	Post-transfusion Hb (g/L)	Intraoperative blood loss (mL)	Per capita blood preparation (U)	Per capita blood usage (U)	Increased value of Hb (g/L)
Group A (72)	10.80±5.98	118.46±13.89	117.72±14.11	42.39±42.33	2.18±0.63	1.24±0.38	−0.67±15.76
Group B (43)	12.15±8.31	128.44±14.27	117.44±14.25	57.00±99.35	2.08±0.49	1.40±0.48	−11.4±18.26
Group C (91)	7.93±3.30	114.43±15.26	122.89±16.80	30.36±28.17	2.07±0.68	1.36±0.41	7.59±22.36
Group D (37)	10.66±9.58	117.91±21.52	123.23±20.63	62.05±122.58	2.00±0.31	1.35±0.85	5.18±27.05
Total (243)	9.62±6.41	117.91±16.25	120.81±16.41	41.25±64.31	2.09±0.61	1.33±0.49	2.43±21.80

A univariate ANOVA test was used, and the P value of preoperative body weight between group A and group C was 0.021, which was statistically significant. Preoperative Hb was statistically significant between group B and group C with a P value of 0.001. RBC: red blood cell. Hb: hemoglobin.

Analysis of factors for intraoperative RBC transfusion

There were statistically significant differences in age, preoperative weight and preoperative Hb between transfusion and non-transfusion patients (P<0.05) (***Table 3***).

Prognosis

No adverse reactions of blood transfusion were found in the four groups. The postoperative infection rates in groups C and D were significantly higher than those in groups A and B (P<0.05). The average duration of hospitalized days in groups C and D were longer than those in groups A and B (***Table 4***).

DISCUSSION

The incidence rate of CHD in neonates is 0.4%–1%[6]. Reports suggest that only 30%–40% of severe cases can survive to the age of 10 without surgical correction[7]. Therefore, for children with CHD, surgical correction needs to be carried out under cardiopulmonary bypass, which requires the patient's blood to contact with artificial pipes, dilution, heparinization, *etc*., leading to blood cell damage and coagulation disorders. As a consequence, the infusion of allogeneic RBCs and plasma is necessary to maintain oxygen supply and improve coagulation function. Pediatric patients are more dependent on allogeneic RBC transfusion during cardiopulmonary bypass due to their small blood volumes[8]. Studies showed that 20% of blood transfusion in the United States was associated with cardiac operations[9]. During most CHD surgeries, components including RBCs, plasma, platelets, and cryoprecipitate were infused, even if the blood test indicators were normal or slightly lower than normal[10]. In China, the perioperative blood transfusion rate of cardiac surgery in cardiovascular hospitals was 41.7%[11]. Studies suggested that the volume of blood transfusion in patients with CHD was associated with poor prognosis, and some confirmed the correlation between the transfusion of perioperative blood products and adverse events in children with CHD[12–15]. As with a high transfusion rate, allogeneic blood transfusion also has its limitations. In addition, taking the shortage of blood resources in China into account, preoperative transfusion risk assessment and preparation are very important.

In this study, the blood transfusion rate of different surgical procedures was 76.13% which was similar to the 79.33% reported by Che *et al*[16]. The patients who underwent VSD and ASD repair at the same time had the least intraoperative blood loss of (30.36±28.17) mL, but the intraoperative blood transfusion rate was 92.31% and the RBC transfusion rate was 91.21%, both exceeding 90% and significantly higher than those of other corrective surgeries. On the one hand, this was due to the difficulty of surgery, while on the other hand, it was related to low preoperative body weight and low preoperative Hb. The preparation of RBC components should be emphasized during preoperative blood preparation and intraoperative blood transfusion for such operations. Meanwhile, in the case of enough supply, leukocyte elimination, irradiation, and the heating of blood should also be focused on to minimize the occurrence of adverse

Table 3 **Factors for intraoperative RBC transfusion in different groups**

Groups	Group A (72)			Group B (43)			Group C (91)			Group D (37)		
	Transfusion	Without transfusion	*P* value	Transfusion	Without transfusion	*P* value	Transfusion	Without transfusion	*P* value	Transfusion	Without transfusion	*P* value
	46 (*n*)	26 (*n*)		25 (*n*)	18 (*n*)		83 (*n*)	8 (*n*)		22 (*n*)	15 (*n*)	
Age (years)												
50%	1.0	3.5		2.0	7.0		0.42	3.5		0.75	3.0	
25%	0.79	2.75		1.0	3.0		0.27	2.25		0.25	1.0	
75%	2.0	5.25		3.25	13.25		0.895	8.25		2.0	5.0	
			0.001			0			0.031			0.188
Weight (kg)												
50%	9.25	15.0		11.0	17.0		5.56	17.4		10.0	12.0	
25%	6.9	13.0		8.38	13.88		5.13	10.38		4.9	9.0	
75%	11.25	20.38		13.63	41.13		9.0	21.75		29.6	16.0	
			0			0.002			0.032			0.244
Preoperative platelet	280.74±66.05	293.5±81.47	0.472	302.72±87.54	280.11±84.28	0.401	318.84±89.84	249.5±83.42	0.054	253.09±88.8	248.27±88.51	0.888
Preoperative Hb	118.46±13.89	126.42±10.37	0.013	128.44±14.27	132.44 15.37	0.385	114.43±15.26	137.38±42.64	0.173	117.91±21.52	144.27±16.96	0
Intraoperative blood loss	42.39±42.33	45.77±40.02	0.741	57.0±99.35	82.22±113.53	0.444	30.36±28.17	76.25±77.63	0.140	62.05±122.58	52.33±56.15	0.777
Operation time (minutes)	157.22±37.51	146.08±29.42	0.197	167.04±48.73	156.89±52.68	0.518	153.10±29.55	163.5±52.58	0.598	189.36±65.14	156.67±62.05	0.129
Gender (male/female)	22/24	13/13	0.862	13/12	9/9	0.90	35/48	5/3	0.673	13/9	7/8	0.470

The mean difference was used for data conforming to a normal distribution, while the *t* test was used for inter-group comparison. The median was used for inter-group comparison of measurement data conforming to the ortho-Tai distribution, and the rank sum test was used for inter-group comparison. RBC: red blood cell. Hb: hemoglobin.

Table 4 **Prognosis of patients in different groups**

Groups (*n*)	Cases receiving blood component transfusion (*n*)/transfusion rate (%)	Average duration of hospitalized days	Postoperative infections (*n*)/infection rate (%)	Adverse reactions (*n*)	Deaths (*n*)/ mortality (%)
Group A (72)	48/66.67	15.58±6.41	7/9.72	0	1/1.39
Group B (43)	26/60.47	13.72±5.90	7/16.28	0	1/2.33
Group C (91)	84/92.31	19.16±9.34	26/31.33	0	0/0
Group D (37)	27/72.97	18.86±7.09	11/29.73	0	1/2.70
Total (243)	185/76.13	17.09±7.92	51/20.99	0	3/1.23

The chi-square test was used to compare the blood component infusion, postoperative infection rate, and mortality between the four groups, and the difference was statistically significant ($P<0.05$). Blood component infusion rates in the four groups: the *P* value was 0.00 in group A/C and group B/C, and 0.003 in group C/D. Infection rates in the four groups: the *P* value was 0.003 in group A/C and 0.008 in group A/D. There was no significant difference in mortality between the four groups ($P>0.05$). The average length of hospital stay in the four groups: the *P* value was 0.02 in group A/C, 0.01 in group B/C, and 0.018 in group B/D.

reactions. Other corrective operations except for the repair of ventricular septum and atrial septum had the most intraoperative blood loss of (62.05±122.58) mL, and the intraoperative blood transfusion rate was 72.97%, which was higher than the single repair of ventricular septum and atrial septum. However, in these operations, the RBC transfusion rate was only 59.46%, and their higher plasma transfusion rate (24.32%) increased the overall blood transfusion rate. In addition to RBC components, a certain amount of plasma should be prepared for such patient's preoperative blood preparation. Plasma should be prepared in small doses for children with low weight and low circulation loading to avoid waste. Although there were differences in RBC transfusion rates between different surgical methods, there were no statistical differences in per capita RBC preparation volume, intraoperative per capita RBC transfusion, and postoperative Hb. Meanwhile, the preoperative blood preparation volume (2.09±0.61) U was higher than the intraoperative transfusion volume (1.33±0.49) U in each group. Hence, 2 units of preoperative RBC are suitable for correction operations of CHD under the age of 18. The specific blood volume should be calculated according to the patient's age, weight, and preoperative Hb. What's more, the preparation of small doses of RBC is necessary for children with low weight.

There is a risk of adverse reactions with blood transfusion. In this study, no adverse reactions were found during all cases of blood transfusion; however, fever occurred after the operation. RBCs transfused in this study underwent leukocyte filtration within 24 hours after whole blood collection, and some were irradiated. In addition, evidence showed that postoperative fever was common in children with CHD, which was related to traumatic metabolic reactions, extracorporeal circulation systemic reactions, hypothermia, drainage tube, drugs, blood transfusion, and infection[17]. However, whether postoperative fever is directly related to intraoperative blood transfusion remains unknown. Here, the postoperative infection rate of 243 patients was 20.99%, which was consistent with a previous study showing a postoperative infection rate of 16.4%–30.8%[18–19]. Among these studies, one case presented with enteritis, while the remaining cases had pneumonia. In addition, the intraoperative blood transfusion rate, infection rate, and average hospitalized days of patients simultaneously undergoing VSD and ASD repair, or non-ventricular septal and atrial septal repair were higher than those of patients undergoing atrial septal and ventricular septal repair alone, suggesting that blood transfusion may increase the infection risk and hospitalization period. The univariate analysis of intraoperative blood transfusion and non-transfusion patients showed that age, body weight, and preoperative Hb were all risk indicators for intraoperative RBC transfusion. The probability of intraoperative RBC transfusion was higher in children with young age, low body weight, and low preoperative Hb. The children undergoing both VSD and ASD repair had the highest blood transfusion rates, the highest risk of postoperative infection, and the longest hospitalized stay, possibly due to lower mean age and weight.

In addition to adverse reactions and infections, there was no statistical difference in mortality between the four groups. The number of cases simultaneously undergoing VSD and ASD repair was the largest, but the mortality rate was 0, while the number of cases undergoing other surgical methods was smaller with no deaths. The results are inconsistent with the existing mortality increased by blood transfusion, which may be limited by the number of cases and the retrospective study itself. Therefore, further verification is needed.

In summary, more than 75% of the children with CHD in this study needed preoperative blood preparation with RBCs as the main component. The total amount of blood preparation can be limited to 2 units. The basic conditions of the children were fully evaluated and analyzed before surgery, such as age, weight, and preoperative Hb concentration. Intraoperative blood loss was estimated according to the difficulty and complexity of the operation. Based on these data, suitable blood transfusion programs were formulated, and blood products were fully prepared to improve the quality of transfusion and achieve individualized transfusion treatment for children with CHD.

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