Research Article

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Retrograde autologous blood priming is an efficient technique for without, or minimally usage of blood infant cardiosurgery

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Abstract

Background: *Both severities of cardiac surgery and technical features of extracorporeal circulation circuit demands blood transfusion from donors, which involves a number of risks for the patient, especially with low body weight. Priming of the cardiopulmonary bypass circuit with patients' own blood [retrograde autologous priming (RAP)] is a technique used to limit haemodilution and reduce transfusion requirements.*

Methods*: the study included 250 children (131 boys, 119 girls) with congenital heart disease, operated on heart under CPB, weighing less than 20kg (18.45 ± 2.15) and 3.4 ± 1.7 years average age, who were divided into experimental (125 children) and control group (125children). In the control group, conventional CPB was performed (supplementing the priming with red blood cells), while in study group CPB was started after RAP via aortic cannula with recuperation till 45 % of cristaloid "priming". The hematocrit (Hct), lactate (Lac) levels at two perioperative time-points, and intraoperative and postoperative blood usage were recorded. There were no significant differences in CPB time, aortic cross-clamp time between groups.*

Results: *No hospital lethality occurred in the study and no surgical hemostasis was performed. Blood loss accounted for 6.2 ml/kg /24h. Postoperative transfusion of homologous blood (erythrocyte mass) needed 73 children, that make up only 29, 2 % of the whole study group. Amongst children who received transfusion on pump, the number of packed red blood cells was less in the RAP group than that in the standard priming group intraoperatively and perioperatively (0.54 ± 0.17 vs. 1.48 ± 0.68 units, P = 0.03; 0.94 ± 0.54 vs. 1.69 ± 0.69 units, P = 0.15). There were no significant differences in CPB time, aortic clamp, and Lac value between the two groups (P>0.05). Length of ICU and hospial stay were similar.*

Conclusions: *"priming"minimalisation and autologous blood priming, modified ultrafiltration (MUF) could diminish the necessity of perioperative blood transfusion in infant cardiac surgery.*

Introduction

Retrograde autologous priming (RAP) has been routinely applied in cardiac pediatric cardiopulmonary bypass (CPB). However, this technique is performed in pediatric patients weighing more than 20 kg, and research about its application in pediatric patients weighing less than 20 kg is still disputable. This study explored the clinical application of RAP in CPB in infant patients undergoing cardiac surgery. With the increasing number of performed cardiac surgeries, priming technique in cardiopulmonary bypass (CPB) has become an important area of research. Complex cardiovascular surgery will often require a large amount of banked blood or blood products, which are commonly limited, and may cause immune response problems, virus dissemination, and others. This encourages physicians to explore blood conservation measures that can reduce the need for allogeneic blood transfusion. At the same time, priming of conventional crystal solution in CPB will inevitably cause serious haemodilution and reduction of plasma colloid osmotic pressure, which will produce adverse effects[1-4].

It has been demonstrated that the applications of retrograde autologous priming (RAP) in adult rheumatic heart disease and cardiac surgeries for coronary heart diseases can improve the hematocrit (Hct) level, reduce postoperative chest drainage volume and allogeneic blood transfusion, indicating that RAP is a safe and cost-effective blood conservation technique [5-8]. The application of RAP in pediatric CPB reduce priming volume, and keeps a high Hct level during bypass [9]. In infants and young children blood volume is small, and therefore the effect of RAP on hemodynamic is greater than in adults. Therefore, the application of RAP to infants and young children is limited.

We have been successfully applying RAP to children < 20 kg. We believe that, as blood volume of infants is less than of adults, moderately reducing the volume of priming solution could result in an improved outcome in mitigating the haemodilution. In this study, we applied RAP in CPB in paediatric patients with body weight within 15 and 20 kg, and investigated whether it can reduce the perioperative blood transfusion volume.

Subjects and Methods

Subjects

The study included 250 children (131 boys, 119 girls) with congenital heart disease, operated on heart under CPB, weighing less than 20kg (18.45 ± 3.15) and 3.4 ± 1.7 years average age, who were divided into experimental (125 children) and control group (125children). Inclusion criteria were: body weight of 15-20 kg; preoperative hemoglobin (HB) level higher than, or equal to 100 g/L; and were elective for CPB intracardiac correction. Exclusion criteria were: CPB longer than 80 min and any difficulties impermissible during surgery. For this single-blind experiment, the patients were divided in control group (n=125) and the experimental group (n=125) using the random number table technique. Among the control group, 48 patients were submitted to auricular septal defect repairing (ASDR), 68 patients were submitted to ventricular septal defect repairing (VSDR), and 9 patients had tetralogy of Fallot (TOF) repair. Among the experimental group, 64 patients had VSDR, 44 patients had ASDR, and 17 patients had ASDR with correction of anomalous drainage one, two, or three pulmonary veins (ADPV). All patients in the control group completed the surgery, while 1 patient in the experimental group was excluded because the operation time was longer than 80 min. All the patients were operated by one operating team (surgeon, anestheziologist and perfusionist).

Diag-nosis	VSD with pulmonary hipertension (HPA)	VSD + Artery pulmonary stenosis (AP ste-nosis	ASD or fo-ramen ovale (FO)	ASD+ ADPV	ASD+ ADPV	Tetralo-gy Fallot
Nr. patients	131(68exp.+63 control)	1(control group)	91(43exp+48)	17(10exp.+7 control	1exp.	9(5exp.+4 control)
Operația	Suture or plastie	Plastie +w Comisuro-tomie of pulmonary Artery Valve	Suture or plastie	Plastie + Redresarea ADPV	Radical correc-tion	Radical correction

Surgical methods

A longitudinal incision was performed at the sternum median, and the heart was exposed. The ascending aorta and right atrium were isolated, and the aortic cannulae 12-14 Fr and venous cannulae 16-18 Fr were inserted, after standart heparinization (3mg per kg) respectively, to connect CPB circuit (standard for infants; composed by 1/4×1/4 inch tubing lines; total volume of priming 320 mL). The infants membrane oxygenators ("Capiox 05"- "Terumo", "Affinity Pixie"-"Medtronic", "Sorin Kids" -"Sorin Group") were used intraoperatively. After body temperature was cooled to 34°C, the ascending aorta was clamped, and the antegrade perfusion with pump potassium 40ml /hour , blood cardioplegia (20 mL/kg) was performed, followed by second intraoperative perfusion after 20-30 min interval (weight of left ventricle,(g) x 2 = ml of pump blood cardioplegia). The aortic clamp time was 20-70 min. The CPB continued to operate after ascending aorta was declamped, for a duration of not less than 1/4 of the aortic blocking time. After surgery, patients were monitored and treated in the intensive care unit (ICU).

RAP method

All children were actively supplemented with crystalloid or colloid solution before surgery, to avoid lack of circulating blood volume due to fasting.

For the experimental group a sodium chloride compound priming solution was used to pre-fill the circulation tubes and debubbling air. After the patients were heparinized, the aortic cannulation was connected, and the inner loop and connecting tubes were opened, so that the blood inside the arterial tube could slowly return and replace the same amount of priming solution (stored in a spare bag). When the tube from the oxygenator to the aortic cannulation site was completely filled with blood, the arterial tube was clamped. The vena cava cannulation was connected, and the occlusion clamp of venous drainage tube was slowly opened. The venous blood was used to completely replace the liquid inside the venous tube (antegrade autologous blood priming). Meanwhile, the same amount of liquid was pumped and stored in a spare bag. During surgery, blood pressure, electrocardiogram and blood oxygen saturation of patients were closely monitored. If necessary, vasoactive agents were used to reduce the adverse effect of RAP on hemodynamics. If systolic blood pressure dropped to <60 mmHg, 4-10 μg norepinephrine was immediately injected iv to elevate blood pressure. If no reaction on blood pressure was achieved after norepinephrine injection, the RAP was immediately interrupted, and the priming with suspended red blood cells and albumin was performed. In the control group, the volume of banked blood was calculated as follows: Volumebanked blood = 320 × Hcttarget - blood volume × (Hctpreoperative - Hcttarget)/Hctbanked blood. The fresh(<5 days age) blood, and 25ml of 20% albumin were added to CPB circuit to replace the exact volume of the priming solution.

CPB management

The surgeries were performed using CPB machine "Perfusion system 1" ("Terumo"). During CPB operation, the exogenous liquid input was reduced, and the conditions maintained as follows: colloid osmotic pressure >275 mosm/l, body temperature 32-34°C, average blood pressure >40 mmHg, CPB flow 120-150 mL/kg. When the average blood pressure dropped to <40 mmHg, 4-10 μg norepinephrine was immediately iv injected to elevate blood pressure. When BE achieve ratio -4-6 mmol/l, 20-30 mL of sodium chloride compound solution was iv injected. If, the RAP was immediately interrupted, and priming with fresh red blood cells, plasma and albumin was performed. After CPB, the modified ultrafiltration and transfusion of blood products were used according to the patient Hct level (target Hct >0.40) and normal colloid osmotic pressure.

CPB time, aortic clamp time, blood transfusion

Hct and lactate (Lac) levels were recorded before surgery. During surgery, the CPB time, aortic blocking time and the intraoperative blood transfusion were recorded. In addition, Hct and Lac values at 15 min after the beginning (T2) and at the end (T3) of CPB were recorded. After surgery, the mechanical ventilation time, ICU time, hospitalization duration and postoperative blood transfusion were recorded. In addition, the Hct value at 2 h after surgery (T4) was recorded.

Results

Overall treatment outcome

One case in the experimental group was excluded because the operation time was longer than 80 min. All patients of the experimental group completed RAP, and only 12 patients were administrated norepinephrine for unstable blood pressure.

The experimental group significantly reduced priming amount, and 101 patients had no allogeneic blood transfusion perioperatively, while 76 patients of the control group have not received allogeneic blood transfusion. Perioperative and postoperative transfusion of homologous blood (erythrocyte mass) needed 73 (24 children from experimental group and 49 from control group), that make up only 29,2% of the whole study group. All patients were discharged successfully, and exhibited no blood transfusion-induced complications during hospitalization.

General information

There were no significant differences in gender, age, body weight or other general information between two groups (P>0.05). Furthermore, the preoperative Lac, creatinine, urea and Hct levels between the two groups showed no significant difference (P>0.05 Tab 1.).

Table:1

Index	Experimental group (125)	Experimental group (125)	P
Age (months)	39,91±19,1	40,02±20,5	0,96
boys	66	65	
girls	55	56	
Body weight (kg)	18,47±2,7	18,1±1,91	0,23
Preoperative urea, mmol/l	3,96±0,59	4,14±0,6	0,37
Preoperative creatinine, mmol/L	28,91±4,71	29,87±4,75	0,94
Pre CPB hematocrite, %	34,73±2,19	36,97±2,71	0,72
PreCPB lactate,mmol/l	1,07±0,27	0,94±0,27	0,24

Comparison of intraoperative indicators

There were no significant differences of CPB time, aortic clamp time, T2-Lac or T3-Lac between the two groups (P>0.05). However, the T2-Hct and T3-Hct values, and intraoperative blood transfusion exhibited significant differences between the two groups (P<0.05; Tab 2.). Hct levels in the experimental group were lower than those in the control group, but still maintained at >0.25 (except in twelwe cases), which met the requirement for intraoperative blood management (added blood to 12children to target Hct >0.25). In addition, the blood gas results were normal, and there was no difference in oxygen metabolism between the two groups, indicating that hemodynamics was stable during CPB in both groups. In order to further improve the Hct level (the target being >0.40), the modified ultrafiltration was performed in both groups. According to the target hematocrite and return all the blood to patient, the volume of modified ultrafiltration was set as 320-450 mL.

Table:2

Index	Experimental group (125)	Control group (125)	P
CPB time,min	51,07±16,71 24,91±12,27	52,05±18,95	0,81
Aortic clamp time,min	24,91±12,27	24,48±12,41	0,64
T2 Lac mmol/l (during CPB)	1,34±0,97	1,047±0,69	0,32
T2 Ht %(during CPB)	25,07±0,27	27,82±0,54	0,01
T3 Lac mmol/l(end of surgery)	1,91±0,14	2,05±0,27	0,24
T3 Ht %(during CPB)	40,91±4,5	41,85±1,92	0,003
Intraoperative blood transfuzion	12	29	0,00

Postoperative indicators

There was no significant difference in T4-Hct value, mechanical ventilation time, ICU time, hospitalization duration or postoperative blood transfusion between the two groups (P>0.05;Table 3). At 2h postoperative, Hct levels in experimental group were higher than the control group, but the difference was not significant.

Table: 3

Index	Experimental group (125)	Control group (125)	P
T4 Ht% after 2 hour of surgery(in ICU)	41,85±0,27	40,97±0,47	0,31
Mechanical ventilation time, min	270,22±9,51	279,11	0,84
ICU time, days	2,1±0,45	1,91±0,34	0,51
Postoperative blood transfuzion	12	20	0,91

Discussion

There exist various degrees of hemodilution in CPB, which may exhibit advantages such as reduced peripheral vascular resistance, improved microcirculation perfusion, and reduced blood destruction. Excessive hemodilution may lead to kidney damages and affect other organs' perfusion. Therefore, moderate hemodilution is an important part of CPB management [10]. Blood conservation has already been vastly studied in CPB research, which includes preoperative autologous preservation, intraoperative hemodilution, and autologous transfusion [11, 12]. Many years of clinical trials, as well as the improvement of membrane oxygenators and CPB tube lines, resulted in the progress of adult CPB, advancing from blood priming to almost bloodless priming, currently. In pediatric CPB, priming amount should be relatively larger. Therefore, the need for allogeneic blood priming still cannot be avoided in small children. However, apart from having a high risk for immune response problems and disease transmission, banked blood may have shortcomings such as decreased erythrocyte deformability, hemolysis, acidosis, abnormal inflammatory responses of white blood cells, and others [13-15]. Therefore, in recent years, studies are aiming at reducing allogeneic blood priming in pediatric patients, and important progress has been achieved in children and infants with enough body weight (>20 kg).

This study targeted pediatric patients with body weight within 15-20 kg. Our results indicated that the experimental group, which did not use banked blood, obtained outcomes similar to the control group. Patients with body weight <20 kg have less blood volume then necessary for RAP, which would likely affect hemodynamic stability. Therefore, to perform RAP, blood volume should be positively supplemented before surgery, thus avoiding inadequate circulating blood volume, caused by fasting. During this operation, the patient's blood pressure, echocardiogram and oxygen saturation should be closely monitored, and anesthesiologists, surgeons and CPB physicians should cooperate closely. Vasoactive drugs should be administered when necessary to reduce the adverse effects of RAP towards hemodynamics. As for patients who show poor heart functions, or signs of intolerance for the RAP technique, the operation should be interrupted promptly. Furthermore, this technique must consider the overall condition of the patients, and a combination with other blood conservation methods, such as modified ultrafiltration, might be considered to achieve the best blood-protective effects and improve prognosis [16,17].

In cardiac surgery, the probability of using allogeneic blood in infants and young children is relatively higher than in adults. At present, blood source is relatively limited, therefore using less or not using any banked blood can be an advantage. The successful application of RAP in children with body weight <20 kg can result in satisfactory Hct levels in CPB, and maintain stable hemodynamics. This can effectively ease the situation of lack of banked blood, and avoid the risk of various complications and infectious diseases related to blood transfusion. In conclusion, RAP can effectively reduce the hemodilution in CPB when using less or not using any banked blood, while meeting the intraoperative perfusion conditions, and decreasing the perioperative blood transfusion volume in pediatric patients [18,19].

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