



COMPARATIVE STUDY OF FRESH VERSUS OLD STORED BLOOD IN THE PRIMING OF EXTRACORPOREAL CIRCUIT IN CARDIOPULMONARY BYPASS FOR PEDIATRIC PATIENTS

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ABSTRACT

We aim to evaluate the metabolic effects of fresh (≤ 7 days) versus old (> 7 days) packed red blood cells (PRBCs) added to the priming solutions of pediatric patients undergoing cardiac surgery. Forty consecutive pediatric cardiac patients were divided into 2 groups. In group 1 fresh (≤ 7 days old) PRBCs were added to the priming solution, while in group 2 old (> 7 days old) PRBCs were added. In each group, blood samples were drawn from the PRBCs on arrival, after addition to the priming solution, after 10 minutes of prime circulation, after 30 minutes of beginning of cardiopulmonary bypass (CPB) and on patient's arrival to the pediatric intensive care unit (PICU). The levels of potassium, glucose, and the acid-base balance were assessed. There was a linear increase in potassium levels in packed red blood cell samples with increasing age of PRBCs, ranging from 5.5 to 17.8 mEq/L. Significant differences in the concentrations of potassium, glucose, and the acid-base balance were found when comparing old and fresh PRBCs in samples taken during the PRBCs and early prime time. Those differences resolved after 10 minutes of reconstitution of the priming solution. The age of the PRBCs had no effect on the samples taken during bypass and those taken in the pediatric intensive care unit. The significantly higher concentration of potassium and lower pH in old stored PRBCs has a minimal effect on the final constitution of priming solution before and during cardiopulmonary bypass in children undergoing corrective cardiac surgery.

INTRODUCTION

Currently available cardiopulmonary bypass (CPB) circuits still require a large priming volume and it may be more than the total blood volume of neonates and patient and institutional practices. Presently, banked PRBCs preserved in storage media are dispensed for priming the CPB circuit in infants and children to maintain the temperature-appropriate hematocrit levels, to prevent the hemodilution and adequate tissue oxygen delivery. However, use of PRBCs is associated with significant metabolic imbalances and its complications [1, 2]. Banked

infants. The main constituents of priming solutions are crystalloids, colloids, and packed red blood cells (PRBCs). The proportion of each varies depending on the size of the PRBC depending upon duration of storage, has many alterations occurring in its constituents, including increase in potassium levels.

Therefore many institutes as a protocol use only relatively fresh PRBCs in priming solution for the CPB as there is always apprehension of complications due to use of old PRBCs in pediatric population. However, the supply of



fresh PRBCs is always limited and might delay the procedures. We at our institute prospectively evaluated the effect of length of storage of PRBCs on the final constitution of the priming solution before and after CPB in children undergoing corrective cardiac surgery. Specific attention was given to potassium, and glucose levels and the acid-base balance.

MATERIALS AND METHODS

Blood samples were drawn from the patients and the CPB priming solutions of 40 consecutive pediatric patients undergoing cardiac surgery. Packed red blood cells were added to the prime as per the availability. Priming solution consisted of Ringer lactate, voluven, and fresh (≤ 7 days) stored PRBCs in 20 patients and Ringer lactate, voluven, and old (> 7 days old) stored PRBCs in 20 patients. Blood samples were first drawn from the patient after induction. Second sample was drawn from the PRBCs (stored at 4°C in citrate-phosphate-dextrose-adenine-1 [CPDA-1] preservative solution) immediately after it was brought to the operating room. This unit of PRBCs was then added to the pediatric CPB (PCPB) priming solution and some amount of priming solution was removed so as to achieve a hematocrit of 30% on CPB. The CPB priming solution was created according to our institutional protocol, which includes adding PRBCs (125 ± 60 mL) to 450 mL of Ringer lactate, 20 mL of voluven and medications (methylprednisolone, mannitol, heparin, and bicarbonate). Circulation of the priming solution with low flow of air at room temperature was started. Third sample was drawn from this final priming solution before initiation of CPB. Fourth blood sample was drawn 10 minutes after the patient was connected to the CPB pump. The last blood sample was drawn on arrival to the pediatric intensive care unit (PICU) after the conclusion of the operation.

Statistical Analysis

Comparisons between corresponding variables at different times in each group were carried out by using the

Student *t* test. Correlation between potassium levels and age of the PRBCs was determined by using the Pearson correlation test for parametric variables.

RESULTS

Forty infants and children undergoing corrective cardiac surgery on CPB were included in the study. In 20 patients, the PCPB circuit was primed with fresh stored PRBCs (≤ 7 days old) and in 20 patients with old stored PRBCs (> 7 days old). No statistical difference between the groups was detected in terms of age (1.15 ± 1.6 vs 1.05 ± 1.2 years, $p = 0.82$; age range, 1 day- 4.5 years), weight (5.6 ± 1.1 vs 5.6 ± 3.3 kg, $p = 1.00$; weight range, 2.3-14.8 kg), and duration of CPB (97 ± 55 vs 92 ± 48 minutes, $p = 0.76$) (table 1). The mean storage time in the fresh stored PRBC group was 3.2 ± 1.2 days (median, 3 days) and was significantly shorter compared with the storage time of the old stored PRBC group (13 ± 7.7 days; median, 11 days; $p = 0.0001$). There was a significantly lower concentration of potassium in ≤ 7 days PRBCs compared with that seen in PRBCs stored for more than 7 days (6.6 ± 0.7 vs 10.3 ± 3.8 mEq/L, $p < 0.0001$). A positive correlation was found between the age of the PRBCs and their potassium concentrations ($r = 0.4$, $p = 0.001$). Adding those PRBCs to the priming solution caused a significant increase in the potassium level at priming time 0 (5.0 ± 0.75 vs 9.65 ± 2.3 mEq/L, $p = 0.0001$) but diminished at 10 min after CPB had begun (4.15 ± 0.82 vs 4.36 ± 0.93 mEq/L, $p = 0.45$), and after discontinuation from CPB (3.59 ± 0.8 vs 3.68 ± 0.85 mEq/L, $p = 0.73$). Glucose levels were significantly lower in old PRBCs (284 ± 123 vs 406 ± 115 mg/dL, $P = 0.001$): the trend continued during early priming (85.5 ± 53 vs 94.8 ± 19 mg/dL, $P = 0.46$) but resolved after 10 minutes of priming (211 ± 197 vs 204 ± 66 mg/dL, $p = 0.88$). No significant difference in blood glucose levels was detected in samples taken at the beginning of CPB and on arrival to the PICU. A similar improvement in acid-base balance was noted once priming solution circulation continued for 10 minutes (Table 1).

Table 1. Demographic characteristics of both the groups

Parameters	≤ 7 days Old	> 7 days old	P Value
Age	1.15 ± 1.6	1.05 ± 1.2	0.82
Weight	5.6 ± 1.1	5.6 ± 3.3	1.00
Duration of CPB	97 ± 55	92 ± 48	0.76

CPB- cardiopulmonary bypass

Table 2. Acid-base balance, hematocrits, electrolytes and glucose level in both the groups

Parameters	PRBC ≤ 7 Days old					PRBC > 7 Days old				
	Patient	PRBC	Before CPB	During CPB	PICU	Patient	PRBC	Before CPB	During CPB	PICU
pH	7.47 ± 0.11	6.93 ± 0.17	7.17 ± 0.49	7.28 ± 1.18	7.44 ± 0.7	7.43 ± 0.10	6.74 ± 0.12	6.99 ± 0.13	7.43 ± 0.08	7.43 ± 0.07
HCT	37.36 ± 4.69	48.32 ± 11.87	24.90 ± 4.28	31.05 ± 3.67	36.47 ± 4.9	39.08 ± 8.12	44.31 ± 18.20	27.56 ± 6.79	30.91 ± 3.27	36.51 ± 5.28



Potassium	3.32 ± 0.54	6.89 ± 0.70	5.0 ± 0.75	4.15 ± 0.82	3.59 ± 0.8	3.52 ± 1.33	10.34 ± 3.85	9.6 ± 2.65	4.36 ± 0.93	3.68 ± 0.85
Sodium	140 ± 5.15	143.35 ± 24.13	156.88 ± 11.41	142.17 ± 5.2	144.29 ± 3.82	142.08 ± 5.84	150.51 ± 15.86	151.04 ± 21.98	144.45 ± 7.17	144.65 ± 5.21
Calcium	0.95 ± 0.28	0.22 ± 0.19	0.79 ± 0.12	1.19 ± 0.28	1.24 ± 0.28	1.13 ± 0.35	0.20 ±	0.25 ± 0.12	0.94 ± 0.14	1.34 ± 0.89
Glucose	104.02 ± 50.91	406.09 ± 115.41	94.80 ± 19.16	204.4 ± 66.61	213.48 ± 77.63	99.31 ± 39.35	284.06 ± 123.52	85.57 ± 53.27	211.83 ± 197.73	205.66 ± 53.57

PRBC- packed red blood cells, PICU- post intensive cardiac unit, HCT- hematocrit,

DISCUSSION

Studies in past have reported the effect of priming CPB circuits with either fresh or old stored PRBCs with variable results. Fresh PRBCs are presumed to be more physiological compared to stored PRBCs as they contain less potassium, have higher concentrations of glucose, and lower concentrations of lactate [3].

Our results demonstrate that although fresh PRBCs are more metabolically balanced, there is no significant difference in the composition of the solution after 10 minutes of initiation of CPB. Furthermore, this homogeneity in the composition of blood was maintained throughout CPB and in postoperative period. One of the major concerns with prolonged storage is excess potassium in the red cell supernatant, which can induce cardiac arrhythmias or arrest [4]. But this effect seems to be minimized, as seen in our study. This is probably because at a storage temperature of 4°C, the red cell sodium-potassium pump is essentially non-functional, and intracellular and extracellular levels of sodium and potassium gradually equilibrate. Furthermore, the hemolysis that occurs with the increasing duration of storage results in increased potassium levels in the supernatant. However, because the total volume of plasma in red cell concentrates is low, the total potassium burden is small [5]. The addition of PRBCs to a relatively large balanced solution decreases significantly the potential adverse effects associated with the relatively larger load of potassium and lactate. The pH of CPDA-1 is acidotic (5.5). When this solution is added to a unit of freshly drawn blood, the pH of the blood

immediately decreases to approximately 7.0 to 7.1[6]. As a result of accumulation of lactic and pyruvic acids by metabolism and glycolysis, the pH of PRBCs continues to decrease as found in our study. The pH of the fresh blood was 6.93 ± 0.17 while that of old blood was 6.74 ± 0.12 . A large portion of the acidosis can be accounted for by the high partial pressure of carbon dioxide as shown by Keidan *et al* [7]. However, once priming solution circulates with adequate ventilation, acid-base imbalance caused by the increase in the levels of carbon dioxide resolves within minutes of the circulation. Further, with availability of oxygen, sodium-potassium pump of the red blood cells become functional further reducing the potassium levels [8].

LIMITATION OF STUDY

Apart from small sample size, in this study we did not investigate the effects of old stored blood on oxygen affinity and delivery, the rate of hemolysis, or the level of cytokines and vasoactive mediators.

CONCLUSION

Our findings show that as far as potassium levels and acid-base balance are concerned, PCPB priming can be safely performed with old stored PRBCs.

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