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Original Article (Pages: 1015-1020)

The Effect of Ringer Lactate as the Priming Solution of Cardiopulmonary Bypass Circuit on Plasma Potassium Levels after Open Heart Surgery in Children

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Abstract

Introduction

Conduct of cardiopulmonary bypass (CPB) due to the higher volume of priming solution in comparison to the total blood volume in children requires careful consideration. Recently attention has been focused on the potential risk of hyperkalemia in these patients. Given its significant effects on cardiac rhythm, hyperkalemia is considered a medical emergency.

Materials and Methods

In this cross-sectional study, sixty children scheduled for pediatric cardiac surgery weighing more than 5 kilograms with hematocrit (Hct) levels above 30% were enrolled. The prime solution used was Ringer-lactate. Venous blood was collected at defined time points: before, during and after CPB and at discharge. A P-value of less than 0.05 was considered statistically significant.

Results

Mean age of the studied patients was 3.69±2.77 year-old. A rise in potassium levels during surgery was recorded. Also a significant difference in the potassium levels before surgery and at discharge were observed (P<0.05). A significant drop and a subsequent rise in the Hct levels were seen overtime, whereas a significant decrease in the pH and bicarbonate levels were detected. Also, 31(51.6%) patients experienced cardiac arrhythmia after undergoing CPB.

Conclusion

A potassium-free (K^+-free) crystalloid that will offset the K^+ load of stored blood is highly anticipated in these patients.

***Key Words*:** Cardiopulmonary bypass, Children, Priming solution, Open heart surgery.

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Received date: Aug 5, 2015 Accepted date: Aug 22, 2015

Introduction

Surgery for congenital heart defects carries morbidity and mortality, especially for more susceptible patients, such as newborns, under weight and undernourished children. Anesthesia, surgery and CPB impose severe challenges to them. During CPB, mild to severe dysfunction occurs in many organs due to physiological alterations inherent to this technique. As blood is exposed to foreign surfaces, a series of inflammatory reactions that induce changes in capillary permeability are activated. Furthermore, the hemodilution causes by CPB lowers the osmotic pressure, resulting in edema that may compromise the normal function of many organs (1, 2).

Conduct of cardiopulmonary bypass (CPB) requires careful consideration to the circuit design, degree of hemodilution, choice of cannula, flow rates, priming fluid, degree of hypothermia and use of circulatory arrest. This is particularly true in pediatric cardiac surgery where the circulating volume of the child is small compared to the volume of the prime in comparison to adults (3).

In several recent studies attention has been focused on the potential risk of hyperkalemia in the rapid administration of allogeneic blood products in surgical candidates (4-8). Data from the Perioperative cardiac arrest (POCA) registry in infants and children clearly indicated that hyperkalemia resulting from massive blood transfusion is the second most common cause of perioperative cardiac arrest in infants and children (4, 5). Given its significant effects on cardiac rhythm, hyperkalemia is considered a medical emergency. Potassium, although predominantly an intracellular cation, it is the rise in its extracellular concentration which can cause arrhythmias resulting in much morbidity. Nevertheless, alterations in the hydro electrolytic balance may also induce cardiac arrhythmias in the early post-operative period leading to increased morbidity and mortality (2, 9).

We therefore conducted a prospective study to determine the changes in K^+ and other electrolytes in addition to hematocrit levels and pH following CPB in a pediatric cardiac surgery setting.

Materials and Methods

Sixty children scheduled for pediatric cardiac surgery with CPB were enrolled in this prospective cross-sectional clinical study. This study was performed over a twelve-month period, from March 2012 to March 2013 in a single center in Imam Reza Hospital, Mashhad-North East of Iran. The included patients weighed more than 5 kilograms and had an Hct levels above 30%.

Patients weighing less than 5 Kg, with a hematocrit less than 30% or above 50%, acute or chronic renal insufficiency, pulmonary hypertension, or chronic arrhythmia and those receiving medication prescribed for the control of these conditions were excluded from the study. Furthermore, patients for whom the surgical operation was stopped due to any reason before its ending point, with unpredicted urgent interventions required affecting the serum electrolyte balance or with personal changes in the priming solution by perfusionist, both in the solution type or by adding other supplements to the prime, were also excluded from the study.

The prime solution used in this study was Ringer-lactate which was prepared using the hospital protocol in accordance with the procedure and age of the patient. The volume of prime was determined by the patient's weight, according to standard protocols. The prime solution was prepared immediately before the commencement of the procedure.

The study protocol was approved by the Ethics Committee of the Research Council of Mashhad University of Medical Sciences. An informed consent was signed by each parent prior to study entrance.

Anesthetic management was standardized, using isofluorane and fentanyl. Patients were monitored with a five-derivation electrocardiogram (ECG) and ST analysis, invasive blood pressure monitoring, central venous pressure, pulse oximetry, capnography, arterial blood gas analysis, rectal and nasopharyngeal temperatures and hourly diuresis control. Systemic anticoagulation was induced with heparin 300 IU/kg for an Activated clotting time (ACT) of more than 480 seconds. Crystalloid cardioplegia was used in all patients. The CPB was conducted with a roller pump and a microporous membrane oxygenator (Baby RX, Terumo, and Santiago, Chile). Also, none of the patients received supplements of K or Mg.

Samples of venous blood were collected at defined time points: t1: before CPB, t2: during CPB, t3: after CPB termination and t4: at discharge. Samples were measured immediately on a Stat Profile M analyzer (Nova Biomedical, Waltham, MA) for hematocrit level, electrolytes, ionized calcium ($Ca2^+$), lactate, bicarbonate and PH. Data were collected prospectively and are expressed as mean± standard deviation. Student's t-test was used wherever appropriate to assess differences between groups for statistical significance. A P-value of less than 0.05 was considered statistically significant. SPSS statistical software version 13 was used for data analysis.

Results

In total, 60 infants who were candidates for open heart surgery were enrolled in the study. All cases underwent cardiopulmonary bypass (CPB). The results of standard monitoring obtained from gasometry and electrolytes at the beginning, during and after cardiopulmonary bypass and also the type and number of probable arrhythmias established during or after surgery were recorded. Among the studied cases 34 (56.7%) were male and 26 (43.3%) female. The mean age of the studied patients was 3.69±2.77 years, ranging from 0.12 to 10 years. When comparing different age groups with one-year difference, the highest number was related to the 2-year-old group as 13.1%.

Repeated measures test indicated a rise in potassium levels during surgery. Bonferroni correlation showed a significant difference in the potassium level before surgery and at discharge (P=0.007). At other time points no meaningful difference was recorded. A significant difference was seen in the plasma sodium level before, during and after the operation in comparison to the discharge points (P=0.001, P<0.001, P<0.001, respectively).

Serum bicarbonate level showed a significant decrease during time and a meaningful difference in the bicarbonate concentration before surgery was detected with that after surgery and at discharge (P=0.046, P=0.021, respectively).

A significant rise in the lactate concentration during the study was observed. The lactate level before surgery significantly differed from that during and after surgery and at discharge (P=0.001, P<0.001, P<0.001, respectively). Moreover, the concentration during surgery and at admission also showed a meaningful difference (P=0.004). Freidman test showed no meaningful changes in the calcium level at different time points.

Repeated measures test showed a significant decrease in the pH level over time. Bonferroni correction also indicated a meaningful difference in the pH level before surgery and that at discharge ($P<0.001$).

A significant drop and a subsequent rise in the Hct level was seen overtime. Bonferroni correction revealed a meaningful difference before surgery with that during surgery, after surgery and at discharge ($P<0.001$, $P<0.001$, $P=0.003$, respectively), also the difference was meaningful when comparing the Hct level during and after surgery with that at discharge ($P<0.001$). Table.1, fully demonstrates the changes in the studied indices at different time points.

Among the 60 studied cases, 31 (51.6%) of them experienced cardiac arrhythmia after undergoing CPB. In total, 13 (21.6%) had sinus tachycardia whereas one patient had Atrial fibrillation (AF). Moreover, cardiac block occurred in 13 (21.6%) cases while 4 (6.6%) experienced PVC. No malignant ventricular dysrhythmia occurred, and all dysrhythmias were either atrial or junctional in nature.

Table 1: Comparing the Studied Parameters before, during and after CPB and at Discharge

Variables	Before CPB	During CPB	After CPB	At discharge
Potassium	3.43±0.51	3.60± 0.77	3.69 ±0.75	3.92± 1.03
Sodium	137.53 ±5.290	136.46 ±4.729	137.78 ±5.840	141.0± 6.362
Bicarbonate	20.87 ±2.53	19.64 ±3.21	19.45 ±3.00	19.08± 3.26
Lactate	1.134 ±0.634	2.018± 0.906	2.316± 1.086	2.661± 1.415
Ca	1.38± 0.691	1.30 ±0.552	1.31± 0.476	1.25± 0.437
PH	7.35± 0.10	7.32 ±0.093	7.31 ±0.090	7.31± 0.090
Hct	35.83 ±7.69	25.06 ± 5.38	25.77 ± 5.86	31.52± 5.70

Discussion

Cardiopulmonary bypass is an unusual state, which can result in significant physiological alterations, particularly in neonates and infants. A smooth onset of CPB is vital and depends on patient, surgeon and perfusion-related factors. Neonates and infants present a difficult group, because onset of CPB leads to major fluid shifts as the circulating volume of the child is much smaller compared to the volume of the prime in comparison to adults (3, 10).

The prime volume used in cardiopulmonary bypass in pediatric open heart surgery can have profound effects on the blood physiology of the patient. One of these effects is alterations in serum electrolyte (3). Among them potassium can change the final outcomes due to early and profound effects on the electrophysiological function of the heart. Regarding cellular damage, hypothermia and the use of different supplements in the prime solution and even the prime solution itself, changes in potassium levels either as an increase or decrease is highly probable (2).

Numerous variables may influence extracellular potassium regulation, such as acid-base state, sympathetic activity, insulin, urine output, previous diuretic therapy, vasoactive drugs and blood transfusions (11). Since this was a single-center study, anesthesia care, CPB technique and surgical interventions were fairly uniform for all patients. There are many different therapeutic methods for treating hyperkalemia (12).

Prevention is still the key factor in avoiding such complications. The use of blood that is less than seven days old in cases younger than 1 year of age or with massive blood volumes transfusion, washing the blood product prior to administration, using a K^+-free solution and slow transfusion (4). In the majority of cases, K^+ concentration returns to the normal range within a few minutes of the establishment of CPB. In Lopez et al. study the plasma level of K reduced by 13.7% after modified ultra filtration (P<0.001) vs. Mg showed no significant reduction (3).

In the study by Stammers and colleagues arterial pH did not change during the weaning or post-CPB period. However, hyperkalemia caused a significant decline in venous pH in the same period. They concluded that measurement of venous pH may be an early marker indicating myocardial dysfunction (13).

In the present study a significant reduction was observed in the pH level during the study. The difference between the pH level before surgery and at discharge was also significant. Vohra et al. (2) studied 320 pediatric bypass cases before and immediately after CPB establishment. Stored blood was compared with irradiated blood according to body weight. They concluded that blood primes result in high potassium concentrations in the prime fluid, mainly irradiated blood; yet do not result in hyperkalemia during CPB except when irradiated blood prime is used in infants < 5Kg. They also reported that Hct was well maintained with the use of blood prime.

In the current study the K^+ level of post-CPB was slightly higher than that before CBP, yet showing no meaningful difference. However, the K^+ level at discharge showed a significant difference with that before CBP. Although no obvious harmful consequences were observed coming off CPB in our children, this is a cause for concern and more precise studies are highly recommended to study the postoperative course in such patients.

Jian et al. study examining the effect of magnesium prime solution in CPB of children reported that this solution can prevent hypomagnesaemia during and after CPB besides reducing urinary potassium loss after CPB (14). In general, all primes require a crystalloid solution that is physiologically compatible, but most of these contain potassium. Normal saline although K^+-free, lacks other important anions and buffering agents. Therefore a K^+-free crystalloid that will offset the K^+ load of stored blood is highly anticipated in these patients.

Our study had certain limitations. The sample size was not strong enough to demonstrate the influences of other variables interfering with the extracellular potassium concentration. Regarding the special age group enrolled in this study and the few studies performed in children so far, major changes in the priming solution or adding other supplements to evaluate the clinical outcomes were not possible.

Conclusion

A potassium-free (K^+-free) crystalloid that will offset the K^+ load of stored blood is highly anticipated in these patients.

Acknowledgment

The authors would like to thank the Research Council of Mashhad University of Medical Sciences (MUMS) for financially supporting this study. The paper was derived from a student thesis (Approval No. 6352).

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

1. Aggarwal NK, Das SN, Sharma G, Kiran U. Efficacy of combined modified and conventional ultrafiltration during cardiac surgery in children. Ann Card Anaesth. 2007 Jan; 10(1):27-33.

2. López R, Lema G, González A, Carvajal C, Canessa R, Carrasco P, Lazo V, Hudson C, Gonzalez R, Frangini P. Plasma levels of potassium and magnessium after modified ultrafiltration in pediatric cardiac surgery with cardiopulmonary bypass. Perfusion. 2012 Jan; 27(1):40-2.

3. Vohra HA, Adluri K, Willets R, Horsburgh A, Barron DJ, Brawn WJ. Changes in potassium concentration and haematocrit associated with cardiopulmonary bypass in paediatric cardiac surgery. Perfusion. 2007 Mar; 22(2):87-92.

4. Martin DP, Gomez D, Tobias JD, Schechter W, Cusi C, Michler R. Severe hyperkalemia during cardiopulmonary bypass: etiology and effective therapy. World J Pediatr Congenit Heart Surg. 2013 Apr; 4(2):197-200.

5. Bhananker SM, Ramamoorthy C, Geiduschek JM, et al. Anesthesia-related cardiac arrest in children: update from thepediatric perioperative cardiac arrest registry. Anesth Analg. 2007; 105(2): 344-350.

6. Baz EM, Kanazi G, Mahfouz RA, Obeid MY. An unusual case of hyperkalemia-induced cardiac arrest in a paediatric patient during transfusion of a ‘‘fresh 6-day old blood unit’’. Transfus Med. 2002; 12(6): 383-386.

7. Parshuram CS, Joffe AR. Prospective study of potassiumassociated acute transfusion events in pediatric intensive care.Pediatr Crit Care Med. 2003; 4(1): 65-68.

8. Smith HM, Farrow SJ, Ackerman JD, Stubbs JR, Sprung J. Cardiac arrests associated with hyperkalemia during red blood cell transfusion: a case series. Anesth Analg. 2008; 106(4): 1062-1069.

9. Delaney J, Moltedo J, Dziura J, et al. Early postoperative arrhythmias after pediatric cardiac surgery. J Thorac Cardiovasc Surg 2006; 131: 1296–1301.

10. Maehara T, Novak I, Wyse RKH, Elliott MJ. Perioperative monitoring of total body water by bioelectricalimpedance in children undergoing open heart surgery. Eur J Cardiothorac Surg 1991; 5(5): 258–65.

11. Guyton A, Hall J. Rhythmical excitation of the heart. In: Textbook of medical physiology. Philadelphia, PN: Elsevier Saunder, 2006, pp 116–122.

12. Masilamani K, van der Voort J. The management of acute hyperkalaemia in neonates and infants. Arch Dis Child. 2012; 97(4): 376-380.

13. Stammers AH, Mills N, Kmiecik SA, Petterson CM, Liu JL, Nichols JD, et al. The effect of electrolyte imbalance on weaning from cardiopulmonary bypass: an experimental study. J Extra Corpor Technol 2003 Dec; 35(4):322-5.

14. Jian W, Su L, Yiwu L the effects of magnesium prime solution on magnesium levels and potassium loss in open heart surgery. Anesth Analg. 2003; 96(6):1617-20.