

Variations in Electrolytes Level After Del-Nido Cardioplegia Administration in Patients Undergoing Congenital Heart Defects Surgery

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ABSTRACT

Objective: To evaluate the variation (increase or decrease) in Electrolytes level after del-nido cardioplegia administration in patients undergoing on pump congenital heart defect surgery.

Study Design: The design used in this study was descriptive cross-sectional.

Place and Duration of Study: The study was carried out at Pediatric Cardiac Surgery Department of Armed Forces Institute of Cardiology in Rawalpindi, Pakistan from Oct 2021 to Dec 2021.

Methodology: Patients undergoing congenital heart surgery were the subject of interest in this study. The sample size was 147. Non-probability consecutive sampling technique was used. Patients undergoing on pump Congenital Heart Surgery, patients with age < 30 years, patients of both gender were included in our study. Patients with surgery of multiple stages (abdominal surgery, palliative surgery), Emergency patients, Chronic renal failure patients, Re-do operations were excluded from our study.

Results: Sample size was 147 with anticipated percentage 10.7% having 78(53.1%) males and 69(46.9%) females who underwent congenital cardiac surgery. Statistical test was applied and results are significant. There was significant difference in the means of electrolyte levels after administration of Del-Nido Cardioplegia (p -value <0.05).

Conclusion: Our study concluded that after Del-Nido Cardioplegia administration, imbalance in electrolytes levels (Sodium, Potassium, and Calcium) occur which causes hyperkalemia, hyponatremia and hypercalcemia. Prolonged cardiopulmonary bypass time and cross clamp time are risk factors for increased delnido cardioplegia administration.

Keywords: Congenital cardiac surgery, Del-nido cardioplegia solution, Electrolytes, Hypercalcemia, Hyperkalemia, Hyponatremia.

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INTRODUCTION

Most heart surgeries are carried out on still heart. Cardioplegia solution is a pharmaceutical therapy given during heart surgery to deliberately and temporarily still the heart. In the early 1950's Dr. Melrose used first cardioplegic solution during cardiopulmonary bypass. He also identified that a reversible heart arrest induced by high levels of potassium citrate. The myocardial membrane is depolarized by influx of potassium which causes release of Ca ions and contraction and ultimately results in diastolic arrest. The most important component of cardiopulmonary bypass is cardioplegia solution which reduces myocardial oxygen consumption by cooling the heart and making it still to provide surgeon a clear field to work on. It creates electrical quiescent and decreases ischemic effects of heart on bypass.¹ A minimal number of studies have been conducted on the simultaneous pre-operative and post-operative changes in electrolytes levels.

The cardioplegia solution provided a bloodless and motionless field in addition to cardioprotection. Infusion of cold cardioplegia solution in coronary circulation is most common technique for achieving asystole.² To accomplish this goal, firstly, we place the patient on CPB using heart-lung machine which provides gas exchange for the lungs and blood circulation of heart. Afterwards, there is isolation of heart from the rest of blood circulation by placing aortic cross-clamp on the ascending aorta. During isolation, heart is unable to receive any blood flow. So, there is no oxygen for metabolism. Moreover, it is very essential to administer cardioplegia solution to the entire myocardium to protect from any damage and ensure asystole. The ECG changes eventually occurs and heart rate become zero. The metabolic rate of heart muscle decreases by cardioplegia solution resulting in prevention of cell death during ischemic period.³

For the very first time in history, del-nido cardioplegia was made to use in paediatric patients.⁴ It is unique Four parts crystalloids to One part whole blood formulation that is used in single dose 20 ml/kg

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through ante-grade at 8-12 degree centigrade and retrograde at 4 degree centigrade. Del-nido cardioplegia reduce cross clamp time as single dose is effective for 90 minutes.⁵ Del-nido is almost 60ml solution composed of KCl, Mannitol, Lignocaine and MgSO₄ and bicarbonate.

Cardioplegia Components Quantity

KCl=26ml, Mannitol=16ml, Lignocaine=6.5ml, MgSO₄=4ml, Bicarbonate=13ml.

A water soluble component, KCl, used for treatment of severe lack of potassium and prevention of hypokalemia. It provides rapid depolarized arrest. An osmotic diuretic, Mannitol, used in acute kidney failure patients to force urine production. Due to hyperosmolarity, Mannitol has ability of scavenging free radicals and edema production. Lidocaine is local anaesthetic that works by causing temporary numbness. Lidocaine is an anti-arrhythmic agent. MgSO₄ works as an anti convulsants and a cardiovascular drug. MgSO₄ blocks calcium channel. It is used to increase myocardial injury. Bicarbonate scavenger hydrogen ion and help to maintain the body's acid-base (pH) balance. It also decrease postoperative ventricular arrhythmias and reduced ICU stay.⁶ For cardioplegia delivery, a common practice is reduced metabolic rate with hypothermia. Hypothermia reduces oxygen and phosphate usage.⁷

Aortotomy performed in aortic insufficient patients, where aortotomy give access to coronary ostia for direct cardioplegia delivery.⁸ For this purpose handheld ostia cannulas are used. After first dose which lasts for almost 60 to 90 minutes and if required then surgeon ask for second dose. In aortic insufficiency cases, retrograde delivery can be more useful.

In cellular metabolism, electrolytes play an important part. It is also used in transformation of energy and regulation of membrane potential. Reduction of these electrolytes can cause severe arrhythmias. The main cause of greater electrolytes reduction are diuretics use and hemodilution. Moreover, hypokalemia has associated with increased risk of hypoglycaemia.⁹

Maintaining normal electrolytes level during CPB is very important. Normal concentrations are;

Electrolytes Quantity

Na (Sodium) 136-145 mEq/L, K (Potassium) 3.5-5.0 mEq/L, Ca (Calcium) 1.5-2.1 mEq/L.

Cardioplegia solution has more ion other than K (potassium) like Ca(calcium), Na(sodium) and Mg

(magnesium). They are used for decreasing contractility and also used for preservation of myocardium. Potassium induces Cardiac arrest. High level of Potassium is called hyperkalemia which causes Arrhythmia. Sodium controls symptoms of heart failure by balancing fluid. Serum sodium levels of less than 130 during CPB causes increase risk of postoperative Stroke.¹⁰ Sodium adversely affects Central Nervous System as low sodium causes heart failure. And calcium is involved in myocardial contractility.

METHODOLOGY

The descriptive cross-sectional study was carried out at Pediatric Cardiac Surgery Department of Armed Forces Institute of Cardiology/National Institute of Heart Diseases (AFIC/NIHD) from October to December 2021. The study design was descriptive cross-sectional. Sample size was 147 as calculated from WHO sample size calculator by using anticipated percentage (10.7%).¹¹ So we had collected the data from 147 patients who were subjected to Congenital Heart Surgery at AFIC/NIHD, Rawalpindi. The sampling technique used was Non-Probability consecutive sampling.

Inclusion Criteria: Patients undergoing on pump Congenital Heart Surgery, patients with age <30 years, patients of both gender were included in our study.

Exclusion Criteria: Patients with surgery of multiple stages(abdominal surgery, palliative surgery), Emergency patients, Chronic renal failure patients, Re-do operations were excluded from our study.

Prior to data collection, formal approval from Institutional IERB was taken(27/12/R&D/2021/139). Data was collected from the patient's history and post-operative patient's Performa after taking the proper consent from the Institutional ethical Review Board-IERB. Data was collected from pediatric operation theater on daily basis. Taking patients ABGs before and after cross-clamp removal of bypass surgery, gender, age, height, weight, BSA, disease, surgical procedure, CPB time, Cross-clamp time and mortality was noted down. Data collection procedure was smooth and easy. Data was analysed by using IBM statistical Package for Social Sciences (SPSS) version 24 and MS Excel. Categorical variables like gender, disease was expressed in frequency and percentage. Similarly all the continuous variables like age, CPB time, CXT time, pr ABG's was expressed as their mean and standard deviation(SD). To determine the variations, electrolytes divide into 3 pairs. Pair-1 consist of sodium value before and after cardioplegia,

Pair-2 is calcium value before and after cardioplegia, Pair-3 is potassium value before and after cardioplegia. Inferential statistics was applied to check the significance level of the results. *p*-value less than or equal to 0.05 (*p*<0.05) was considered significant by taking 95% CI and 5% margin of error.

RESULTS

Continuous data is expressed as Mean±SD. Paired t-test was applied to show the significance between dependent and independent variables i.e., to find association between prolong cross clamp time(CXT) and prolong cardiopulmonary bypass time (CPB). A total of 147 patients were included in this study. Out of which 78 (53.1%) were males and 69 (46.9%) were females, who underwent congenital cardiac surgery from 5 November to 30 December 2021 were included in this study. The mean age of the study population was 12.98 ± 7.73 years as shown in socio-demographic data in Table-I.

Table-I: Socio-Demographic data

Variable(N=147)	Mean±SD
Age (years)	12.98±7.73
Height (cm)	132.65±30.62
Weight (kg)	38.42±19.11
BSA (m ²)	1.17±0.43

BSA=Body surface area

The spectrum of congenital heart defects are shown in Figure-1.

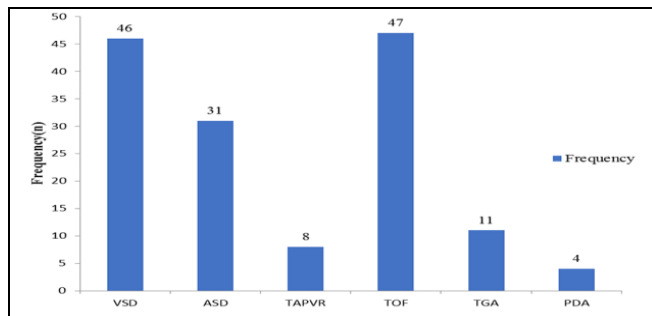


Figure-1: Frequency of Congenital Heart Defects in study participants

VSD=ventricular septal defect, ASD=atrial septal defect, TAPVR=Total anomalous pulmonary venous return, TOF=tetrology of folate, TGA=transposition of great artery, PDA= Patent ductus arteriosus

The categorization data of cross clamp time (CXT) time and cardiopulmonary bypass (CPB) time of study population was <90 min and >90min as shown in Table-II.

Paired T-test between the three pairs was significant. *p*-value of pair-1 (Sodium value before and after cardioplegia), pair-2 (Calcium value before and

after cardioplegia) and pair-3(Potassium value before and after cardioplegia) was less than 0.05 as mentioned in Table-III.

Table-II: Categorization of CPB & CXT Time of Study Population

Variables	CPB Time		CXT time	
	<90 min	>90 min	<90 min	>90 min
Frequency	24 (16.4%)	123 (83.6%)	64 (43.5%)	83 (56.5%)

*CPB time(Cardiopulmonary by pass time), CXT time (cross clamp time)

Table-III: Comparision of cardioplegia (CPG) with electrolytes

Pairs	Electrolytes	Mean±SD (mEq/L)	<i>p</i> -value
Pair 1	Before CPG Na+	139.24±3.33	0.03
	After CPG Na+	141.35±5.47	
Pair 2	Before CPG Ca++	1.71±0.19	0.02
	After CPG Ca++	1.90±0.39	
Pair 3	Before CPG K+	4.28±0.53	0.04
	After CPG K+	4.58±0.84	

CPG= Cardioplegia, Na= Sodium, CA= Calcium, K= Potassium

In our study congenital heart defect like ASD, VSD, TOF, TAPVR, TGA, PDA patients were observed as in (Figure-1).

DISCUSSION

In Cardiac Surgery, cardioplegia’s role can not be ignored. The del-nido cardioplegia solution successfully used in pediatric cardiac procedures. The main benefit of del-nido cardioplegia solution is to avoid the administration of multiple doses during procedures which become the reason of short cross clamp time.

One of the past studies aimed at comparing the Del-Nido with St Thomas cardioplegia in adult cardiac procedures, and compare the outcomes. 209 patients were included which were divided in two groups on the basis of cardioplegia solution used. The DC group (n=114) and BC group (n=95). Del-nido solution was given as single dose and parameters were noted. There were shorter CPB time and CXT in DC group than BC group. In DC group, inotropes requirement was less in comparison of BC group. For long cardiac procedures, del-nido solution can be safely used, as single dose and intra and post operative outcomes were much better than st.thomas solution.¹¹

Another study in which patients undergoing CABG or DVR surgery were retrospectively studied. There were total of 100 patients; 50 in st. thomas group (ST group) and 50 in del-nido group(DN group). In ST group, 34 patients undergo CABG and in DN group 36 patients and DVR was performed in 16 patients in ST group and 14 patients in DN group. The mean age of patients was 51.86±13.4 (range 16-74 yr).¹² And mean age of our study is 12.98±7.73 years (range:1-30 years).

A similar study to determine hyperkalemic effect on myocardial function from weaning off from bypass. A hypothermic porcine model was reported. It was used to evaluate the effects of hyperkalemia. During bypass and post bypass (after 10 minutes from weaning off), arterial and venous samples were taken. Then samples were analysed. Hyperkalemia causes severe arrhythmias. During weaning or post bypass, there is no change in arterial pH but on the other side venous pH declined. So, dysrhythmia is early indicating by measurement of venous pH.¹³ Our study results also shows that patients facing hyperkalemia when cross clamp removed early because surgeon complete cardiac procedure but the effect of del-nido cardioplegia remaining.

Another study which was conducted to evaluate the abnormalities of electrolytes during CABG.¹⁴ In this study, 100 patients were selected. Values of electrolytes intra-operatively were noted. The mean±SD of K(potassium) was 4.65±0.9 and range was 2.9 to 7.4. The mean±SD of Na(sodium) was 137.95±4.6 and range was 127-152.

In our study, we determine the imbalance of electrolytes before and after del-nido cardioplegia and our sample size is 147 patients. The mean±SD of sodium after del-nido cardioplegia administration was 141.35±5.47 and mean±SD of potassium was 4.58±0.84.

Another study to determine myocardial protection of custodial cardioplegia in valve surgery. There were total 362 patients divided into 2 groups. Group-A has 181 patients using custodial cardioplegia and Group-B has 181 patients using blood cardioplegia undergoing valve surgery. Blood transfusion and hospital readmission rate were better in Group-A.¹⁵

Another study in which we determine post cross-clamp ventricular fibrillation in CABG patients. There were total 200 patients. 100 patients in Group-1 using del-nido cardioplegia solution and 100 patients in Group-2 using conventional blood solution. 24 patients of Group-2 and 4 patients of Group-1 developed post cross-clamp ventricular fibrillation. The occurrence of ventricular fibrillation is lower in Group-1 as compare to Group-2. So, del-nido solution is preferred for preventing myocardial injury as compare to blood solution.¹⁶

A similar study which was conducted to evaluate which cardioplegia, blood or crystalloid better to protect myocardium. There were 12 cases. Group-I, 6 cases using conventional blood solution and Group-II, 6 cases using crystalloid solution. ATP fell 18%±3.4%

after 30 min of reperfusion in Group-II. It was unchanged in Group-I. Left ventricular and total coronary blood flow fell in Group-II ($p<0.01$). Blood cardioplegia are better and have several advantages as compared to crystalloid solution during long term arrest.¹⁷

Another study which was conducted to determine short term outcomes in AVR patients. There were total of 240 patients. Group-A has 178 patients using del-nido solution and Group-B has 62 patients using whole blood solution. Aortic cross clamp time and bypass time were shorter in Group-A as compared to Group-B.¹⁸

In our study, TOF and VSD are common congenital heart defects. 147 patients undergoing congenital heart defect surgery were studied in our study with mean age of 12.98±7.73years. The concentration of electrolytes (Sodium, Potassium and Calcium) change after del-nido cardioplegia administration. Effect of del-nido cardioplegia remained, when cross clamp removed early and it become the cause of hyperkalemia. Sudden rapid decreases in sodium levels may occur because of hemodilution.

LIMITATIONS OF STUDY

The results are limited to the patients from one institute (AFIC/NIHD), so results cannot be generalized to whole population. Sample size was small. The study duration was short.

CONCLUSION

Our study concluded that after del-nido cardioplegia solution administration, imbalance in electrolytes levels (Sodium, Potassium, Calcium) occur which causes hyperkalemia, hypernatremia, hypercalcemia. Prolonged CPB (cardiopulmonary bypass) time and CXT (cross-clamp time) are risk factors for increased del-Nido cardioplegia administration.

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Conflict of Interest: None.

Author's Contribution

Following authors have made substantial contributions to the manuscript as under:

MN: Manuscript writing, drafting and editing

MIA: Intellectual contribution, concept and final approval

MSU: Proof reading, Intellectual contribution, final approval

NA: Analysis, manuscript writing and proof reading

HK: Analysis, manuscript writing and proof reading

ZC: Data management, data collection & manuscript writing
Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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