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OPTIMAL ELECTROLYTE MANAGEMENT AFTER CARDIAC SURGERY: A RETROSPECTIVE OBSERVATIONAL STUDY

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ABSTRACT

Introduction: Electrolyte imbalance after cardiac surgery is an established finding which leads to higher incidence of ventricular and supraventricular arrhythmias. Patients undergoing cardiac surgical procedures under cardiopulmonary bypass is the most important cause of electrolyte depletion. Preventing electrolyte disorders is thus an important goal of therapy in such patients. Though the measurement of levels of potassium is done regularly, other electrolytes such as magnesium, and calcium are measured far less frequently. We therefore conducted the present study to assess electrolyte levels in such patients and the optimum level of these to avoid complications.

Methods: Levels of magnesium, potassium, calcium and sodium were measured in 160 consecutive patients undergoing various cardiac surgical procedures undergoing extracorporeal circulation were examined. The normal reference values for these electrolytes in our laboratory were as follows (all in mmol/l): magnesium 0.8–1.1, potassium 3.8–4.8, calcium 2.20–2.60 and sodium 135–145. The patients were divided in two groups keeping a cut of as follows (all in mmol/l): magnesium 1.0, potassium 4.0, calcium 2.5 and sodium 135, Group 1 has lower than the cut of mark and group 2 had higher than the cut of mark. Intravenous potassium supplementation and magnesium supplementation was received at the time of surgery. Serum magnesium, potassium, calcium and sodium concentrations were determined on ICU admission and 6, 24 and 48 hrs later.

Results: There was significant differences were found either in the primary end point (hours of intubation) or in the secondary end points (length of inotropic support, new atrial fibrillation, ventricular tachycardia or ventricular fibrillation, length of intensive care unit stay, ICU or hospital mortality).

Conclusion: Patients undergoing cardiac surgery with extracorporeal circulation are at high risk for electrolyte depletion, despite intraoperative supplementation. The probable mechanism is a combination of increased urinary excretion and intracellular shift induced by a combination of extracorporeal circulation and decreased body temperature during surgery (hypothermia induced diuresis). Our findings may partly explain the high risk of tachyarrhythmia in patients who have undergone cardiac surgery. Prophylactic supplementation of potassium, magnesium and calcium should be seriously considered in all patients undergoing cardiac surgical procedures, should be kept at higher normal range.Levels of these electrolytes should be monitored frequently in such patients.

KEYWORDS : Cardiac Surgery, Electrolyte Disorders, Hypokalaemia, Hypomagnesaemia, Magnesium, Potassium

Introduction

Electrolytes such as potassium, magnesium and calcium play important roles in cellular metabolism and in the regulation of cellular membrane potentials of cardiac muscle. Neuromuscular dysfunction and severe cardiac arrhythmias are established findings in depletion of above electrolytes.[1] Hypokalaemia can induce cardiac arrhythmias, and that it is associated with other adverse effects such as rhabdomyolysis, renal failure and hyperglycaemia.[2]

Regulating potassium levels is well recognized in cardiac surgery intensive care units and potassium levels are measured frequently.In contrast, magnesium and calcium are measured far less frequently. Studies have shown that hypomagnesaemia is associated with increased morbidity and mortality in the cardiac ICU and administering magnesium has been shown to reduce mortality and infarction size in these patients.[3,4]

Hypomagnesaemia can cause cardiac arrhythmias, neuromuscular irritability, hypertension and metabolic effects like decreased insulin sensitivity.[5,6] Magnesium has the property of scavenging of free radicals and in the prevention of reperfusion injury which is common in cardiac surgery under cardiopulmonary bypass.[7,8] Low serum calcium levels can also induce arrhythmias (shortening of QT interval), cardiovascular depression.[9,10] and congestive heart failure that is unresponsive to inotropic agents.[11,12] These cardiovascular effects may occur in the absence of specific electrocardiographic changes. Thus, lower electrolyte levels can have severe adverse effects on the clinical course of post cardiac surgery patients.

When more than one electrolyte is deficient then it may have cumulative effects and the impacts of electrolyte disorders may be more pronounced.These impacts of electrolyte disorders may be more pronounced in patients undergoing cardiac surgery, who are already at increased risk for tachyarrhythmia and other haemodynamic complications.[13,14] Keeping an optimum level of these electrolyte is thus an important goal of therapy in this category of patients.Cardiac surgery is performed under induced hypothermia with a temperatures between 32°C and 34°C, in order to reduce tissue oxygen demand and electrolyte imbalance occurrs mainly during this cooling phase. We therefore conducted the present study to assess electrolyte levels in such patients and the optimum level of these to avoid complications.

Methods

The retrospective, observational study was carried out in cardiac surgery intensive care unit of Northeastern Indira Gandhi Regional Institute of health and Medical Sciences, Shillong, Meghalaya.

Subject population

Adult patients undergoing cardiac surgery under cardiopulmonary bypass were included with the following exclusion criteria:

1. Pediatric (below 18 years) and congenital cardiac surgery
2. Emergency cardiac surgery
3. Off- pump cardiac surgery

Anaesthetic management

The anaesthesia protocol comprised fentanyl and midazolam for induction, rocuronium for myorelaxation, and midazolam, propofol for anaesthesia maintenance. Patients were extubated in the ICU according to standard protocol.

Surgical and cardiopulmonary bypass management

Surgical procedures included coronary bypass graft (*n* = 40), valve replacement (*n* = 105), combinations of these (*n* = 5) and Bentall procedure for dissection of the ascending aorta (*n* = 10). Extracorporeal circulation was employed in all patients. Standard technique was used for all operations in surgical procedure, sternotomy and cardiopulmonary bypass. Myocardial protection consisted of intermittent anterograde of cold blood cardioplegia (Composition: calcium chloride 17.6 mg in 100 mL, magnesium chloride 325.3 mg in 100 mL, potassium chloride 119.3 mg in 100 mL, sodium chloride 643 mg in 100 mL) mixed with blood at a ratio of 1:4.

The normal reference values for these electrolytes in our laboratory were as follows (all in mmol/l): magnesium 0.8–1.1, potassium 3.8–4.8, calcium 2.20–2.60 and sodium 135–145. Serum magnesium, potassium, calcium and sodium concentrations of were post cardiac surgery ICU admission in 160 consecutive patients undergoing cardiac surgical procedure under cardiopulmonary bypass analysed, 80 patients each group who meets criteria of grouping as mentioned below, on ICU admission and 6, 24 and 48 hrs later. The patients were divided in two groups keeping a cut of as follows (all in mmol/l): magnesium 1.0, potassium 4.0, calcium 2.5 and sodium 135, Group 1 has lower than the cut of mark and group 2 had higher than the cut of mark. Intermittent dose of potassium, magnesium, calcium and sodium infusion was used to keep the target values for group 2.

All patients underwent continuous, bedside, ECG monitoring with automated, alarmed, arrhythmia detection and recall during their stay in ICU. Twelve-lead ECG recordings were performed before surgery and at ICU admission. The episode of arrhythmia were interpreted by an intensive care physician.

Hemodynamic variables, including arterial blood pressure, heart rate, left atrial pressure, and central venous pressure, were monitored continuously, and hourly urinary output was recorded.

The primary endpoint was intubation time; the secondary endpoints included: length of inotropic support, new atrial fibrillation, ventricular arrhythmias, bradycardia, length of ICU stay, and ICU and hospital mortality.

Outcome

The primary outcome was mean time to extubation (in hours). The secondary endpoints were the need for inotropic support, length of inotropic support in hours, according to the standard methodology, the appearance of new atrial fibrillation, ventricular tachycardia (sustained or paroxysmal) or ventricular fibrillation, bradycardia, lenght of ICU stay, and ICU and hospital mortality.

Statistical analysis±Values of variables with repeated measures were compared using an analysis of variance for repeated measures. The Bonferroni post hoc test was used to find differences in the comparison between groups. Continuous variables were analyzed by means of Student's t test and categorical variables with the chi-square test. Data are expressed as % or mean SD. Statistical significance was set at $p < 0.05$. Analyses were car- ried out with SPSS 14.0 for Windows.

Results

There were significant differences between the two groups with regard to the primary outcome (hours of intubation) or the secondary outcomes. There were differences in the need for vasoactive support, or in the hours with vasoactive support, ICU stay, or mortality.

The new atrial fibrillation (Table 1) incidence of was higher in the group 1(14, 18%) than in the group2 (8, 8%) which is statistically significant (P=0.013). Ventricular tachycardia was seen in 4(5%) in group1 and 2(2.5%) in Group2. One patient in the group 1 required cardioversion. Ventricular fibrillation (Table 1) was seen in 2(2.5%) and 1(1.25%) in Group1 and Group2 patients respectively. All patients successfully cardioverted except three. There was five(6.25%) deaths in group 1 and three(3.75%) deaths in group 2 in the ICU.

The hours of intubation, ionotropic support, duration of ionotropic support, ICU stay are shown in table 1.

Table 1:Post operative data analysis

	Group 1	Group 2
Hours intubated	12.4±3.6	9.2±3.4
Inotropes or vasopressors (n)	(70)87.5%	(66)82.5%
Hours	41.4±21.8	32.8±14.9
Ventricular trachyacardia	4 (5%)	2(2.5%)
New atrial fibrillation (n)	14(18%)	8(8%)
Ventricular Fibrillation (n)	2(2.5%)	1(1.25%)
Patients requiring antiarrhythmic medication (amiodarone or other β blocker)	18(22.5)	9(11.25)
Hours ICU stay (Hrs)	73.8 ± 45.6	67.0 ± 34.9
ICU mortality (n)	5(6.25%)	3(3.75%)

Discussion

Patients undergoing cardiac surgical procedures with extracorporeal circulation are at high risk for electrolyte depletion. This occurs inspite of cardioplegia solution contained high doses of potassium and magnesium, and that potassium supplementation was given throughout the surgical procedure.[9,10] This occurs due to increased urinary excretion due to tubular dysfunction and intracellular shift, induced by a combination of extracorporeal circulation and induced hypothermia at surgery.[7] The mechanism of the tubular dysfunction is unknown.Certain catecholamine are of regular use like dopamine, dobutamine, adrenaline, Noradrenaline and diuretics can contribute significantly to the electrolyte depletion.[15,16] But high electrolyte excretion also occurred in patients not given diuretics and so the effect cannot be explained by diuretics alone. The most reasonable explanations for electrolyte shifts is the occurrence of changes in acid-base status.[12] To avoid this in our patients acid-base status, we regularly monitored and no major changes were noted.

Insulin resistance may be another reason for potassium and magnesium loss. The effects of extracorporeal circulation are difficult to assess. Hypomagnesaemia in patients undergoing open heart surgery is well documentet and presumed to be due to haemodilution and excessive excretion.[15,16] We strongly suspect that this phenomenon of low electrolyte is related to intraoperative hypothermia. Although all patients undergoing cardiac surgery with extracorporeal circulation were had induced hypothermia to approximately 32°C during surgery. We suspect that this might have led to moderate electrolyte loss in these patients.[12,13] Low levels of magnesium, and, to a lesser degree, calcium and potassium were observed despite despite adequate replacement is done at the time of surgery. The concomitant presence of hypomagnesaemia, which can lead to significant renal losses of potassium.[8]

Hypokalaemia, Hypomagnesemia and hypocalcaemia after cardiac surgery is not uncommon, and it has evidence of association in major adverse cardiac events.[17,18] Magnesium and potassium has definite beneficial role in ventricular dysrhythmias though its benefit in atrial fibrillation in post coronary artery bypass surgery is contested.[19,20,21] Many meta-analyses have shown that potassium and magnesium reduces the risk of atrial fibrillation after cardiac surgery.[22] In our study, 12% of patients had hypomagnesemia immediately after cardiac surgery and this finding correlates with the other studies.[22,23]Hence the practices involving the perioperative use of potassium and magnesium in adult cardiac surgery vary widely.[25] Mild hypocalcaemia is frequently asymptomatic, although this depends partly on the presence of other electrolyte disorders and on the speed with which hypocalcaemia develops. Hypocalcaemia in our patients was generally mild, and might have been caused in part by magnesium deficiency (which is a frequent cause of hypocalcaemia). No visible symptoms of hypocalcaemia, such as tetany, were observed. But in an meta-analysis, Shiga *et al.* stressed the significant heterogeneity between trials with regard to supraventricular and ventricular arrhythmias, which limits the impact of their conclusions.[9] Though the sample size of our study is relatively small in number, the low rate of sustained ventricular arrhythmias after cardiac surgery, ranging from 0.4% to 1.4%, may also make any possible changes difficult to detect.[26]

In this study, we found that the primary endpoint that is duration of the intubation time was significantly higher than in group1 then group2. These findings are matching with suggestions of the England *et al.* study, which found non-statistically significant trends in the patient with higher potassium and magnesium towards a shorter period of intubation and a lower incidence of respiratory failure.[27]The vasoactive support requirement and hours of vasoactive support of the two groups were significantly different which suggests that the possible slight increase in the cardiac index induced by higher potassium, magnesium and calcium.[27] This outcome variable suggests changes in myocardial contractility. Though this can be impressed that the routine post operative echocardiography at one week does not suggest any difference in ventricular function.

Though the 24 hous Holter ECG monitoring is ideal for detecting cardiac arrhythmias, but the monitoring system employed maintains all the ECG register in the memory and an automated alarm system; all printout records throughout the study period can be were reviewed.

Limitations of this study: 1. The sample size is limited. 2. The serum concentration of electrolyte does not reflect the intracellular concentration of magnesium. 3. Perhaps a more specific arrhythmia detector, such as a Holter, would have highlighted additional changes. 4. All concomitant medications received by the two groups of patients were not included into the database which might have potential impact the outcomes

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