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Cardiac Surgery

The Role of Postoperative Magnesium Infusion in Minimizing Ventricular Arrhythmia Risk after Cardiopulmonary Bypass

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Abstract **Original Research Article**

Introduction: Cardiopulmonary bypass increases the incidence of postoperative ventricular arrhythmias in cardiac surgery. Magnesium, which is essential for cardiac function and may prevent arrhythmias, is frequently reduced after cardiac surgery. ***Aim of the Study***: This study aimed to investigate the preventive effects of magnesium infusion in reducing the occurrence of ventricular arrhythmias in individuals who have undergone cardiopulmonary bypass. ***Methods***: This study, done at Bangabandhu Sheikh Mujib Medical University, Dhaka, from July 2020 to June 2022, involved 120 participants in two groups: one received magnesium sulfate following standard cardiopulmonary bypass surgery (Group A), and the other did not (Group B). Both groups were monitored in the ICU with continuous ECG tracking and assessed for ventricular arrhythmias postoperatively on days 0–3. The inclusion criteria comprised adult cardiac patients in preoperative sinus rhythm with normal magnesium levels, excluding those with a history of ventricular arrhythmias or specific medical conditions. Data collected through a questionnaire, interviews, and medical records were analyzed using SPSS version 26. ***Result***: The mean age of the patients in Group A was 53.83±14.54 years and in Group B was 54.50 ± 10.50 years. The mean difference in postoperative Mg++ was statistically significant ($p<0.05$) in POD 0, POD 1, POD 2, and POD 3. In this study, there were more VA-positive patients in Group B than in Group A; 16.67% had positive ventricular arrhythmia (PVC 8.3%, VT 3.33%, VF 5.00%), while 83.33% were negative VA. Group B had 66.67% negative VA and 33.33% positive VA (PVC 15.00%, VT 10.00%, VF 8.33%). ***Conclusion***: This study identified that the postoperative Mg infusion after cardio pulmonary bypass reduces the incidence of postoperative arrhythmias in cardiac patients. Based on the findings, we recommend using intravenous magnesium as an alternative to prevent ventricular arrhythmias after CPB in cardiac patients.

Keywords: Magnesium infusion, cardiopulmonary bypass, ventricular arrhythmia.

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INTRODUCTION

CPB is a type of extracorporeal circulation that provides circulatory and respiratory support and temperature management to patients undergoing heart and great vessel surgery. Cardiopulmonary bypass is a vital component of many cardiac surgeries, enabling complex interventions but also introducing risks, including postoperative ventricular arrhythmias. These abnormal heart rhythms, originating in the ventricles, can compromise patient outcomes [1, 2]. Magnesium has a significant effect on cardiac tissues. It is required for the preservation of the resting membrane potential [3]. Magnesium reduces the outward flow of potassium while also inhibiting the inflow of calcium, hence preserving the electrochemical gradient. A magnesium shortage can impede cardiac conduction, increase the incidence of arrhythmias, predispose to coronary artery spasms, and contribute to neurological irritability [4]. Magnesium has demonstrated the ability to decrease platelet aggregation, inhibit the release of catecholamines during stressful events like tracheal intubation, and lower systemic and coronary vascular resistance [5, 6]. Magnesium seems to play a crucial role in preventing arrhythmias following cardiac surgery in adults and may contribute to enhancing cardiac contractile indices after undergoing cardiopulmonary bypass (CPB) [7, 8]. The prevalence of hypomagnesemia during and after cardiac surgery has been widely documented in the adult population. Plasma and whole-body magnesium depletion occurs in cardiac patients following cardiac surgery [9, 10]. Postoperative arrhythmias constitute a significant factor contributing to morbidity and mortality following cardiac surgery for congenital heart disease. During the early postoperative phase, individuals with congenital heart disease are particularly susceptible to rhythm disturbances. The occurrence of cardiac arrhythmias following myocardial revascularization has been linked to factors such as low cardiac output, an unfavorable balance of myocardial oxygen, stroke, prolonged hospitalization, and heightened mortality risk [11, 12]. Electrolyte imbalances can significantly contribute to the development of cardiac rhythm disturbances. Total plasma hypomagnesemia is a prevalent occurrence in patients undergoing cardiopulmonary bypass (CPB) [13, 14]. Even though there is evidence supporting the use of empirical magnesium sulfate administration to cardiac surgical patients to reduce the risk of postoperative cardiac arrhythmias, the adoption of prophylactic magnesium treatment has remained a topic of controversy [15]. The administration of magnesium sulfate has been associated with adverse events, including hypotension and prolonged nondepolarizing neuromuscular block, respiratory failure, increased defibrillation energy requirements, and cardiac arrest in cases of overdose. This study aimed to examine the efficacy of a postoperative magnesium infusion that has been proposed for the prevention of ventricular arrhythmias after cardiopulmonary bypass.

Objectives

The objective of this study was to investigate the preventive effects of magnesium infusion on reducing the occurrence of ventricular arrhythmias in individuals who have undergone cardiopulmonary bypass.

METHODOLOGY & MATERIALS

This prospective observational study was conducted in the Department of Cardiac Surgery at Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, Bangladesh, from July 2020 to June 2022. This study enrolled patients who fulfilled the inclusion and exclusion criteria and were admitted to the Cardiac Surgery Department. This research included 120 patients in total, subdivided into two groups: Group A (n = 60) consisted of patients who received 30 mg/kg of magnesium sulfate in 100 ml of normal saline intravenously over 10 minutes, while Group B (n = 60) consisted of individuals who did not receive magnesium. The surgical procedure was performed using the standard cardio-pulmonary bypass technique. All patients were sent to the intensive care unit (ICU) after their surgeries, where they were intubated and placed on ventilation. Patients from both Group A and Group B got continuous monitoring of heart rate and rhythm using continuous ECG monitoring from a cardiac monitor in the intensive care unit. Patients in the treated group received daily intravenous magnesium sulfate (30 mg/kg) in 100 ml of normal saline over 10 minutes intravenously on the 4 hours after release of the aortic cross clump (0 POD), 1st, 2nd, and 3rd postoperative days. Before surgery, 12 lead ECGs were performed, followed by 8 hourly up to the third postoperative day. Serum magnesium levels, comprising other electrolytes (Na^+, K^+, Cl^-, and HCO_3^-), were measured before surgery, before magnesium injection, and 4 hours after magnesium infusion up to the 3rd postoperative day. Following the surgical procedure, patients were evaluated in the Intensive Care Unit (ICU) on the 0th, 1st, 2nd, and 3rd postoperative days to identify any instances of ventricular arrhythmias. Adult (18 or older) cardiac patients who were in preoperative sinus rhythm, undergoing cardiopulmonary bypass surgery with normal blood magnesium levels (1.8–2.4 mg/dl), and willing to give informed consent were the inclusion criteria for the research. A history of ventricular arrhythmias, the use of anti-arrhythmic medications, and specific medical conditions, such as a recent myocardial infarction, congenital heart disease, hepatic dysfunction, renal dysfunction, or a thyroid disorder resulting in electrolyte imbalance were excluded. A semi-structured questionnaire, face-to-face interviews, and a review of medical records were used to collect the data. The acquired data was carefully examined before data processing. The data were analyzed using SPSS version 26.

RESULT

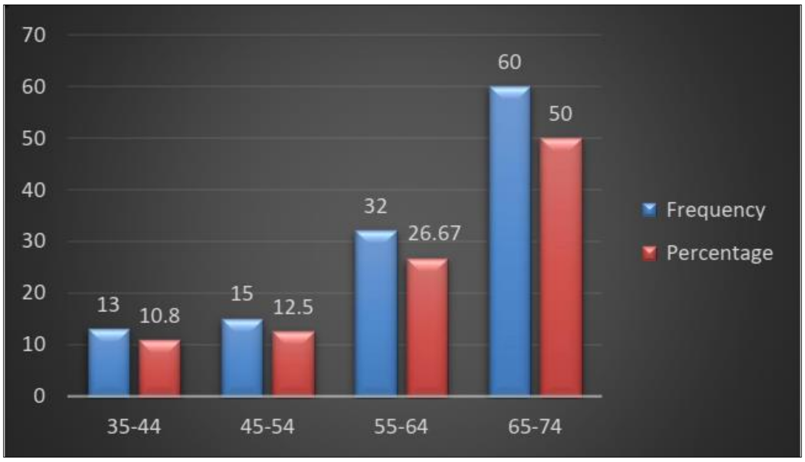

Figure 1: Age distribution of the patients

Figure 1 shows that majority (50%) of our patients were aged 65-74 years old, followed by 26,67%, 12.5% & 10.8% were aged between 55-64, 45-54 & 35-44 years old respectively. We found the Mean ± SD of age in Group A was 53.83±14.54 years and Group B was 54.50 ± 10.50.

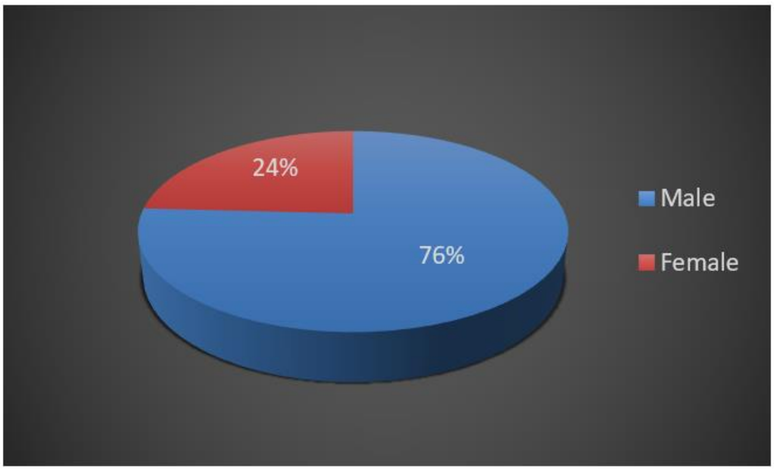

Figure 2: Distribution of our patients by gender

Figure 2 shows the gender distribution of the patients where most of the patients (76%) were male and (24%) were female.

Table 1: Electrolytes levels across the pre-operative period

Pre-operative electrolytes	Group A (n=60)	Group B (n=60)	p-value
Mean Mg^{++}(mg/dl)	2.09 ± 0.135	2.03 ± 0.19	0.135
Mean Na^{+} (mEq/L)	141.67 ± 5.60	138.65 ± 6.51	0.825
Mean K^{+} (mmol/l)	3.89 ± 0.19	3.78 ± 0.19	0.907
Mean Cl- (mmol/l)	1.11 ± 0.18	1.10 ± 0.12	0.68
Mean HCO3- (mmol/l)	1.66 ± 1.15	2 ± 1	0.423

Table 1 presents the pre-operative mean Mg++ levels, which were 2.09 ± 0.135 in Group A and 2.03 ± 0.19 in Group B. The mean Na+ levels were 141.67 ± 5.60 in Group A and 138.65 ± 6.51 in Group B. Additionally, the mean K+, Cl- and HCO3- levels in Group A were 3.89 ± 0.19, 1.11 ± 0.18 and 1.66 ± 1.15, respectively, while in Group B, they were 3.78 ± 0.19, 1.10 ± 0.12 and 2 ± 1, respectively. Importantly, these differences were not statistically significant.

Table 2: Comparison of the post-operative magnesium and other electrolytes level between the groups

Electrolyte Levels		Post operative		P-value
		Group A	**Group B**	
0 POD	Mean Mg++ (mg/dl)	2.33 ± 0.24	1.79 ± 0.11	0.001
	Mean Na+ (mEq/l)	143.67 ± 4.6	137.65 ± 6.61	0.67
	Mean K + (mmol/l)	3.8 ± 0.18	3.98 ± 0.16	0.911
	Mean Cl- (mmol/l)	1.01 ± 0.12	1.1 ± 0.21	0.758
	Mean HCO3- (mmol/l)	1.50 ± 0.70	2 ± 1.41	0.500
1 POD	Mean Mg++ (mg/dl)	2.25 ± 0.18	1.8 ± 0.08	0.001
	Mean Na+ (mEq/l)	140.19 ± 7.21	139 ± 7.51	0.725
	Mean K + (mmol/l)	4.01 ± 0.02	3.88 ± 0.03	0.897
	Mean Cl- (mmol/l)	0.99 ± 0.11	1.00 ± 0.13	0.875
	Mean HCO3- (mmol/l)	1 ± 0.00	1.33 ± 0.57	0.423
2 POD	Mean Mg++ (mg/dl)	2.3 ± 0.21	1.91 ± 0.19	0.001
	Mean Na+ (mEq/l)	137.68 ± 6.31	138.65 ± 6.51	0.825
	Mean K + (mmol/l)	3.91 ± 0.03	3.76 ± 0.19	0.641
	Mean Cl- (mmol/l)	1.1 ± 0.02	1.12 ±0.08	0.728
	Mean HCO3- (mmol/l)	1.33 ± 0.57	1.66 ±1.15	0.423
3 POD	Mean Mg++ (mg/dl)	2.18 ± 0.17	1.91 ± 0.12	0.03
	Mean Na+ (mEq/l)	145.67 ± 2.61	143.25 ± 2.51	0.741
	Mean K + (mmol/l)	3.91 ± 0.17	3.90 ± 0.19	0.951
	Mean Cl- (mmol/l)	1.10±0.02	1.10 ± 0.03	0.788
	Mean HCO3- (mmol/l)	2±1	2.33 ± 1.52	0.227

Table 2 indicates that the mean magnesium (Mg++) levels in Group A on the '0', 1st, 2nd, and 3rd postoperative days (POD) were 2.33 ± 0.24, 2.25 ± 0.18, 2.3 ± 0.21, and 2.18 ± 0.17, respectively. In Group B, the corresponding levels were 1.79 ± 0.11, 1.8 ± 0.08, 1.91 ± 0.19, and 1.91 ± 0.12. Statistically significant differences were observed in '0', 1st, 2nd, and 3rd POD. However, sodium (Na+), potassium (K+), Chloride (Cl-) and Bicarbonate (HCO3-) levels did not show statistically significant differences from '0' to the 3rd POD.

Table 3: Distribution of patients by ventricular arrhythmia (VF, VT and PVC)

Ventricular Arrhythmia		Group A		Group B		P value
		Frequency	**Percentage**	**Frequency**	**Percentage**	
	Total	10	16.67	20	33.33	0.118
	Ventricular fibrillation	3	5.00	5	8.33	
Positive	Ventricular tachycardia	2	3.33	6	10.00	
	Premature ventricular contraction	5	8.33	9	15.00	
Negative	Total	50	83.33	40	66.67	

The ventricular arrhythmia of the patients in the study is displayed in Table 3. In group A, 16.67% of patients experienced a positive ventricular arrhythmia (VF 5%, VT 3.33%, and PVC 8.33%), whereas the remaining 83.33% had VA negative results. Group B had 66.67% VA negative patients and 33.33% VA positive cases (VF 8.33%, VT 10.00%, and PVC 15.00%). Compared to group A, group B had a higher percentage of VA-positive patients but was not statistically significant.

Table 4: CPB characteristics of the respondents

Variable		Group A (%)	Group B (%)
Age		53.83±14.54	54.50 ± 10.50
Weight		86.09±1.68	72.5±9.35
Comorbidities	Hypertension	25	21.67
	Diabetes	51.67	55
	Stroke	23.33	23.33
Surgery status	Duration of CPB (min)	117.19±4.41	105.54±4.71
	Duration of cross-clamp (min)	90.75± 3.49	80.69±3.97
	A Mean duration of ICU stay (hours)	80.23 ± 8.45	60.45 ±9.26

In terms of comorbidities, Group A has 25 cases of hypertension, 51.67 cases of diabetes, and 23.33 cases of stroke. On the other hand, Group B reports an average of 21.67 cases of hypertension, 55 cases of diabetes, and 23.33 cases of stroke. Regarding surgery status, the duration of cardiopulmonary bypass (CPB) in Group A is a mean of 117.19±4.41 minutes, whereas in Group B, it is 105.54±4.71 minutes. The duration of the cross-clamp is 90.75±3.49 minutes in Group A and 80.69±3.97 minutes in Group B. Additionally, the duration of ICU stay in hours is 80.23±8.45 for Group A and 60.45±9.26 for Group B.

DISCUSSION

Electrolyte abnormalities, particularly hypomagnesemia, play an important role in cardiac rhythm disturbance [2]. This observational study evaluated the role of magnesium infusion in the prevention of ventricular arrhythmias after cardiopulmonary bypass (CPB). A total of 120 patients who were treated with magnesium underwent cardiopulmonary bypass. Patients were divided into group A (n = 60) who were treated with 10 mmol (2.47 g) of intravenous magnesium sulfate daily for 3 days after surgery, and group B (n = 60) did not receive the magnesium. The mean age of both groups was 53.83±14.54 and 54.50±10.50 years, respectively. Similar types of studies were conducted by Kohno and his associates. (Figure 1) The analysis revealed no statistically significant difference in mean age between Group A and Group B patients ($p < 0.05$). The highest percentage in both groups was in the 41–50 age range, consistent with a previous study reporting a mean age of 59.6 years [16]. In another study, the mean age for the magnesium group was 62±6.7 years, and for the control group, it was 61.4±8.7 years, with a non-significant p-value of 0.56 [17]. In the present study, 76% of patients were male and 24% were female. (Figure 2) Zangrillo and his associates found 94% of their study cases in the male gender group, and Kohno and associates found 88% of their study cases in the male gender group, which is consistent with the findings of this study [18]. The overall pre-operative mean magnesium level of the patients was 2.09 ± 0.135 mg/dl in group A and 2.03 ± 0.19 mg/dl in group B. Both pre-operative mean magnesium statuses were matched between the two groups ($p = 0.135$). There was no statistical difference between the two groups. Both preoperatively and postoperatively, there was no statistical difference between the two groups in terms of serum electrolytes other than serum magnesium. The mean difference in Mg++ was statistically significant ($p < 0.05$) between patients in Group A and Group B postoperatively on 0, 01, 02, and 03 postoperative days (POD). However, the differences in other electrolytes were statistically not significant ($p < 0.05$) between the two groups [19]. In another study, we found that Mg++ levels in the experimental group were 2.07 (on admission), 3.05 (POD#0), 3.15 (POD#1), 3.99 (POD#2), and 2.63 (POD#3). In the control group, the corresponding levels were 2.09, 1.7, 1.69, 1.91, and 2.13, respectively. Out of 120 study subjects, operative ventricular arrhythmias were significantly higher in the untreated group than compared to the treated group, and there is no statistically significant difference between the two groups. The mean postoperative magnesium level in group B was 1.79±0.11 mg/dl, 1.8±0.08 mg/dl, 1.91±0.19 mg/dl, and 1.91±0.12 mg/dl in 0, 1st, 2nd, and 3rd POD, respectively. The two groups were statistically significant in their mean postoperative serum magnesium level up to 0, 1st, 2nd, and 3rd postoperative days. (p = 0.001, 0.001, 0.001, and 0.03, respectively). In another study, we found the mean Mg++ was 1.6±0.1 and 1.9±0.2 before and after supplementation, respectively, in Group A during 0 POD.

The mean Mg++ was 1.8±0.2 and 2.0±0.2 before and after supplementation, respectively, in Group A during 1st POD; The mean Mg++ was 1.9±0.2 and 2.1±0.2 before and after supplementation, respectively, in Group A during 2nd POD. The mean Mg++ was 2.0±0.1 and 2.3±0.1 before and after supplementation, respectively, in Group A during the 3rd POD. The mean difference was statistically significant ($p < 0.05$) between before and after supplementation of Mg++ in Group A in 0 POD, 1 POD, 2 POD, and 3 POD [20]. In our study, the postoperative magnesium levels at 4 hours increased significantly in group A as compared to baseline levels and levels at rewarming, However, in group B, magnesium levels at 4 hours postoperatively were lower than the levels seen during the rewarming period of CPB; this may be due to the infusion of magnesium. Dorman *et al*., and Dittrich *et al*., in their randomized clinical trials demonstrated the association between the supplementation with magnesium and the decrease in overall incidence of postoperative arrhythmias in adults after surgery for congenital heart disease [21, 22]. Manrique *et al*., measured the incidence at the time of ICU admission, but they measured it over 24 hours; they also used a dosage of 50 mg/kg $MgSO_4$, which was higher than our study (30 mg/kg). Also, magnesium was infused in the CPB circuit during rewarming by Manrique *et al*., whereas we gave magnesium post-CPB [20]. At the study dosages of magnesium, adverse effects due to hypermagnesemia are nearly impossible in patients with normal renal function, and the treatment cost is also very low. Therefore, postoperative intravenous magnesium infusion can be routinely considered for the prevention of postoperative ventricular arrhythmias.

Limitations of the Study

Our study was a single-center study. We could only study a few adverse effects within a short study period. A low incidence of arrhythmias limits the number of patients for analysis. A similar study with a large number of patients may show a significant difference between the two groups. A study with a large number of patients will be needed to validate our results.

Conclusion and Recommendations

The findings from this prospective observational study suggest that post-operative magnesium infusion into the cardiac surgical procedure serves as an effective measure in reducing the occurrence of postoperative arrhythmias in cardiac patients. Given these results, we advocate for considering intravenous magnesium as a viable alternative to prevent ventricular arrhythmias following cardiopulmonary bypass (CPB) in the context of cardiac procedures. This recommendation is particularly relevant due to the observed positive impact, low incidence of adverse effects in patients with normal renal function, and cost-effectiveness associated with magnesium infusion.

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