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The effects of magnesium supplementation on the incidence of cardiac complications after pediatric cardiac surgery

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Abstract

Background and Objective: The present study aimed to assess the role of magnesium sulfate ($MgSO_4$) supplementation after cardiac surgery in pediatric patients, evaluating the incidence of cardiac complications, such as arrhythmia.

Methods: In this study, 105 children scheduled for elective cardiac surgery were randomly divided into 3 groups. The first group, as the placebo group, received saline. Groups 2 and 3, on the other hand, respectively received 25 mg/kg and 50 mg/kg MgSO4 during the recovery phase of cardiac surgery.

Results: The results showed no significant difference among the study groups regarding the levels of Mg, Ca, and K at the time of admission to the Cardiac Intensive Care Unit (CICU). However, the patients receiving 50 mg/kg MgSO4 (group 3) had a significantly lesser occurrence of arrhythmia compared to the control group (group 1). Furthermore, the patients in groups 2 and 3 had a lesser length of CICU stay after surgery in comparison to group 1. No association was found between MgSO4 consumption and the types of arrhythmia and the time of mechanical ventilation.

Conclusions: Supplementation with MgSO4 after cardiac surgery seems to reduce the incidence of arrhythmia and length of CICU stay in pediatric patients. This effect on the incidence of arrhythmia seems to be dose related.

Keywords: Cardiac surgery, Complication, $MgSO_4$, Pediatric

Introduction

Magnesium is a crucial element for myocardial function (1). Magnesium has a vital role in the maintenance of the resting membrane potential and reduces electrophysiological effects of hyperkalemia. Magnesium deficiency can increase the risk for arrhythmias, coronary artery spasm, and contribute to neurologic irritability (2).

Based on evidences, hypomagnesemia is associated with the incidence of arrhythmias, and maintenance of normal magnesium levels can improve ventricular recovery and postoperative cardiac indexes, especially in the adults having undergone cardiac surgery (3-7).

Furthermore, administration of magnesium sulfate ($MgSO_4$) to the pediatric patients during cardiac surgery reduced the length of stay in pediatric Cardiac Intensive Care Unit (CICU), risk of mortality, mechanical ventilation time (8), and the incidence of hypomagnesaemia and junctional ectopic tachycardia (9). A dosage guideline for magnesium administration in CICU hasn't been well-

known. Nonetheless, Manrique et al (9) investigated administration of 25 mg/kg and 50 mg/kg $MgSO_4$ and concluded that this effect seemed to be dose related.

The present study aims to evaluate the previous findings regarding the effect of prophylactic administration of $MgSO_4$ on the occurrence of postoperative complications, such as type and incidence of arrhythmias and the length of CICU stay in the pediatric patients undergoing cardiac surgery.

Methods

Study population and design

The present study was conducted on 106 patients whose age ranged from 2 months to 15 years old. The patients were scheduled for elective cardiac surgery and had referred to Saadi Hospital affiliated to Shiraz University of Medical Sciences since August 2012 to December 2013. The participants were selected through convenience sampling and were then divided into three groups each containing 35 subjects using block randomization. The first group, as the placebo group, received saline, group 2 received 25 mg/kg MgSO4, and group 3 received 50 mg/kg MgSO4. It should be noted that the maximum dose of $MgSO_4$ did not exceed 2 g.

The patients with any medical disorder that consumed magnesium supplementation, the neonates whose mothers received $MgSO_4$, and the patients who had undergone emergency operations were excluded from the study.

The subjects in groups 2 and 3 received a single dose of $MgSO_4$ in the recovery room after the operation. However, no anti-arrhythmic drugs were administered to any of the patients during the operation. At the end of the surgical procedure, all the patients were transferred to CICU.

If clinically appropriate, the patients were weaned from the ventilator and extubated. Weaning from inotropic infusions in the CICU was guided by the standard hemodynamic criteria.

Study measurements

The Mg, Ca, and K levels were measured at the time of admission to CICU. Arterial blood (1 mL) was collected into a heparinized syringe /and was immediately analyzed by Ultra C analyzer (Nova Biomedical, Waltham, Mass). All the measurements were performed by the same operators and using the same machine. Quality controls were performed on each day of the study. In order to identify the types of arrhythmias, a 12-lead electrocardiogram was performed on arrival to the CICU and ECG (lead II, V) was monitored continuously for 24 hours. Whenever arrhythmia was recognized a printed report of the actual ECG was taken.

The classification of the surgery was assessed by the Aristotle level of complexity (Table 1). Intraoperative variables, including CPB time and XCT, were also recorded. Mechanical ventilation time, length of CICU stay, the number of patients who received dopamine, epinephrine, milrinone, and norepinephrine, and discharge status were noted, as well.

Statistical analysis

All the statistical analyses were performed using the SPSS statistical software (v. 19). Paired t-test, independent test, One-way ANOVA, and Kruskal–Wallis test were used for continuous variables, while chi-square and Fisher's exact tests were employed for categorical ones. $P<0.05$ was considered as statistically significant.

Results

The study results revealed no significant difference among the 3 study groups with respect to the demographics characteristics (Table 1). The 3 groups were also similar regarding the mean levels of Mg, Ca, and K at the time of admission.

The total incidence of arrhythmias was 23.6% among the 106 study patients. Besides, the results of unadjusted analysis showed a significant difference between group 3 and the placebo group regarding the incidence rate of arrhythmias (5% vs. 12%). However, no significant difference was observed among the three groups concerning the type of arrhythmias, including Ventricular Tachycardia (VT), JET, and H*eart Block.*

Also, no significant difference was found among the three groups regarding the percent of the patients who received dopamine, epinephrine, milrinone, and norepinephrine in CICU.

Nonetheless, the two treatment groups spent a significantly shorter time in the CICU after the surgery compared to the placebo group (8.05±5.59 days in group 1, 7.37±7.71 days in group 2, and 6.31±4.25 days in group 3; $P<0.05$). However, no significant difference was observed between the patients in groups 2 and 3 concerning the length of CICU stay after the surgery ($P>0.05$). The comparison of clinical variables in the 3 study groups has been presented in Table 2.

Discussion

Magnesium is one of the important intracellular cations and is an obligatory cofactor for many

Table 1. Baseline demographic and medical history characteristics by study group

Characteristics		Group 1: Placebo	Group 2: Mg = 25 mg/kg	Group 3: Mg = 50 mg/kg	P value*
Age (y) Median (range)		11 (3-18)	12 (5-18)	9 (5-17)	0.16
Gender n(%)	Female	22(64)	12(36)	18(52)	
	Male	12(36)	22(64)	16(46)	
Mg Level (mg/dL) (Mean±S.D)		1.8±0.2	2.8±0.3	2±0.2	0.09
Ca level (mg/dL) (Mean±S.D)		8.3±0.9	8.3±0.8	8.2±0.8	0.9
K level (mEq/L) (Mean±S.D)		3.8±0.6	3.7±0.5	3.8±0.5	0.75
Preoperational Diagnosis n (%)					
	L.to.R.shunt	15(42)	12(35)	16(47)	
	Obstructive lesion	4 (11)	8(24)	6(18)	
	regurgitant lesion	1(3)	2(6)	1(3)	
	cyanotic lesion	13(36)	11(32)	10(29)	
	single ventricle				

enzyme systems, such as energy metabolism.

Several studies have confirmed the role of hypomagnesemia in development of postoperative complications and the prophylactic effect of MgSO4 supplementation during or after surgery (10). Furthermore, the occurrence of early postoperative arrhythmias is a predictor for late complications, such as late arrhythmias and ventricular dysfunction (11, 12). Thus, desirable postoperative outcomes are associated with prevention of these arrhythmias.

The mechanism of action of magnesium may be associated with its stabilizing role in myocyte ionic channels leading to myocardial protection and electrical equilibrium. The prophylactic effect of magnesium might also be related to its capacity to decrease the catecholamine release from the adrenal medulla and adrenergic nerve endings (13). In addition, animal studies have shown that MgSO4 reduced the degree of myocardial necrosis and ischemia–reperfusion injury (14). The critical Mg level that protects the myocardium is unknown, but it may differ in different pathologic conditions, surgical strategies, and degrees of injury (9).

In newborns and children, because of immature myocardium, most of the calcium required for myocardial contraction is provided by the sarcoplasmic reticulum which is still underdeveloped and has a reduced storage capacity for calcium. Therefore, they are more susceptible to arrhythmias and myocardial dysfunction after cardiac surgery.

The results of pooled analysis of 15 randomized controlled trials showed that compared to placebo, intravenous magnesium was effective in prevention of postoperative atrial fibrillation (AF) (14).

Moreover, Dittrich et al (15) showed that supplementation of magnesium chloride decreased the overall incidence of postoperative arrhythmias after congenital heart surgery in both children and adults.

Dorman et al (2) also used 30 mg/kg $MgSO_4$ and reported a lower incidence of hypomagnesemia in the experimental group compared to the placebo group after surgery for congenital heart disease.

The previous findings have suggested that supplementation of magnesium reduced the frequency of heart related problems detected in the CICU. Nevertheless, no doses have been recommended for $MgSO_4$ administration in heart surgery pediatric patients.

In the study by Manrique et al (9), none of the patients who received 50 mg/kg $MgSO_4$ had JET in the CICU, whereas the incidence of JET was 6.7% and 17.9% in the patients who received 25 mg/kg $MgSO_4$ and the placebo, respectively.

In the present study, similar to the study by Manrique et al (9), two doses of MgSo4 were utilized for reevaluating the effect of these doses and making attempt to access a standard guideline. The study results demonstrated that administration of 50 mg/kg $MgSO_4$ to the children undergoing cardiac surgery reduced the incidence of arrhythmias. This finding is comparable to that of the aforementioned study. Hence, it can be concluded that the effect of magnesium on reduction

of heart related problems is dose related (9).

In the study by Munoz et al (8), the pediatric patients with hypomagnesemia during CPB had a longer CICU stay as well as a longer period of mechanical ventilation.

The findings of the study by Manrique et al (9), on the other hand, showed no significant difference between the two treatment groups and the placebo group regarding the length of CICU stay. Yet, they reported that magnesium supplementation could reduce the overall incidence of arrhythmias and associated with reduce CICU length of stay.

One of the limitations of this study was that the incidence of arrhythmias was not assessed over a prolonged postoperative period. Another limitation was not measuring the intracellular magnesium that might be an important indicator of hypomagnesaemia and arrhythmias. Also, the effect of MgSO4 on different types of arrhythmias was not separately investigated. Thus, further studies with larger sample sizes are required to be conducted on the issue.

Conclusion

Administration of a single dose of MgSO4 was a safe practice which could have prophylactic effects on the incidence of heart arrhythmias. Yet, it seemed to be dose related. Moreover, supplementation of MgSO4 was associated with a shorter length of CICU stay.

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Conflicts of interest: None declared.

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