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RESEARCH ARTICLE

The Effect of Perioperative Magnesium Sulphate on the Incidence of Atrial Fibrillation in Patients Undergoing Coronary Artery Surgery: A Double-Blinded Randomized Study

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Abstract

Background and aims: The study aimed was to assess the effect of magnesium on the incidence of atrial fibrillation undergoing coronary artery surgery.

Materials and Methods: A double-blinded randomized study included 276 patients classified into two groups (each=138): Group M–the patients received magnesium sulphate infusion (15 mg/kg/h). The infusion was started 20 min before induction, during surgery and the first postoperative 24 hours. Group C–the patients received an equal amount of normal saline. The variables included incidence of atrial fibrillation, amiodarone level of magnesium, potassium, troponin I and creatinine kinase-MB, ECG changes.

Results: The incidence of atrial fibrillation was 17(12.31%) patients in group M compared to 38(27.53%) patients in group C(P=0.002). The highest incidence was through the second day and it was 8(12.31%) patients in group M compared to 19(12.31%) patients in group C(P=0.042). The requirement for amiodarone was 17(12.31%) patients in group M compared to 38(27.53%) patients in group C(P=0.002). The blood level of magnesium and potassium was significantly higher in group M compared to group C(P<0.05). The troponin I level, CK-MB and ECG changes were lower in group M than group C(P<0.05). The magnesium sulphate decreases the incidence of atrial fibrillation in patients with ischemic heart diseases undergoing CABG. It decreases the requirement for amiodarone, incidence of perioperative myocardial infarction, the requirement of pharmacological and mechanical support.

Keywords: Magnesium Sulfate, Coronary Artery Bypass Grafting, Atrial Fibrillation, Amiodarone, Troponin I, Creatinine Kinase-Mb Isoenzyme.

1. Introduction

Atrial fibrillation is the most common arrhythmia after cardiac surgery and its peak incidence often occurs through the second or third postoperative day [1]. The incidence of atrial fibrillation is nearly 30% after coronary artery surgery, 40% in valve surgery and 50% of combined valve surgery and coronary artery surgery [2-4].

Hypomagnesaemia has been proposed as a cause for atrial fibrillation after coronary artery surgery and magnesium supplementation is used to prevent arrhythmia [5-7].

Magnesium plays an important role in preserving cardiac rhythm [8,9], reducing the coronary microvascular injury during reperfusion and preserving coronary microvascular function [10].

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Hypomagnesaemia can induce cardiac arrhythmias, especially in patients with ischemic heart disease [11].

It was hypothesized in the present study; the perioperative magnesium will decrease the incidence of atrial fibrillation after coronary artery bypass grafting (CABG) and therefore this study was done to assess the perioperative effect of magnesium sulphate on the incidence of atrial fibrillation undergoing coronary artery bypass grafting.

2. Materials and Methods

Outcomes: The primary outcome was the incidence of atrial fibrillation. A secondary outcome was the stability of postoperative hemodynamics, requirement for amiodarone and the safety of the study medication which was assessed by the occurrence of any adverse events. Patients: After obtaining informed consent and approval of local ethics and research committee (06/2020, 02/01/2020), a double-blinded randomized study (January 2020-December 2023) included 276 patients with coronary artery diseases [patients with ischemic heart disease or percutaneous transluminal coronary angioplasty, previous coronary artery bypass grafting (CABG)] undergoing elective coronary artery bypass grafting surgery under cardiopulmonary bypass and ventricular ejection fraction ≥40%. Exclusion criteria included patients with a history of atrial fibrillation, preoperative heart rate <50 beats/min, a pacemaker, atrioventricular block, congestive heart failure, acute myocardial infarction, valvular surgery, obstructive cardiomyopathy, pericardial disease, renal, hepatic impairment, or severe respiratory function disorder.

The patients were assessed using the New York Heart Association (NYHA), American Society of Anesthesiologists Physical Status Score (ASA) and Euroscore. The patients were classified into two equal groups (n=138 each), and the concealment of allocation was done by using random numbers generated through excel. Group M: (magnesium sulphate group). The patients received a continuous infusion of magnesium sulphate (without a loading dose) at 15 mg/kg/h. The infusion was started 20 minutes before induction and maintained during surgery and the first postoperative 24 hours. The medication was prepared by adding 5 gm magnesium sulphate in 50 ml syringe. Group C: (control group). The patients received an equal amount of normal saline.

All cases of atrial fibrillation were managed with amiodarone as a bolus dose of 300 mg over 30 minutes and continued as an infusion of 900 mg over 24 hours. For all patients and under local anesthesia before induction, a radial arterial cannula and central venous line were inserted to enable continuous hemodynamic monitoring. Induction was done by intravenous fentanyl (3-5 µg/kg), etomidate (0.3 mg/kg), and rocuronium (0.8 mg/kg). The anesthesia was maintained with oxygen/air (50%), sevoflurane (1-3%), fentanyl infusion (1-3 µg/kg/hr) and cisatracurium (1-2µg/kg/min). At the end of surgical intervention, the patients were prepared for weaning from cardiopulmonary bypass (CPB). If there was difficulty to wean from CPB, pharmacological support (dopamine, epinephrine, norepinephrine, or nitroglycerine) or mechanical support (intra-aortic balloon pump and pacemaker) were started. At the end of the surgery, the patients were transferred to the cardiac surgery intensive care unit (CSICU) with full monitoring.

Cardiopulmonary bypass was established with cannulation of the ascending aorta and right atrium. The patients received cold blood cardioplegia in the standard ratio (4:1) four parts of blood from the cardiopulmonary bypass circuit, and one part potassium-rich crystalloid named Plegisol (Hospira, Inc, Lake Forest, IL, USA). The initial dose was 30 ml/kg body weight, and subsequent doses were 20 ml/kg given every 20 min. The temperature was reduced to 28°C while maintaining a perfusion pressure of 100-125 mmHg. In the two groups, the cardioplegia solution was given as two-thirds through the antegrade and one-third through the retrograde route and a hot shot (warm blood) antegrade dose was given just before the myocardium reperfusion.

Monitoring of patients: The monitoring included the heart rate, mean arterial blood pressure (MAP), a continuous electrocardiograph (ECG) with automatic ST-segment analysis (leads II and V), central venous pressure (CVP), blood level of magnesium, potassium, troponin I, and creatinine kinase-MB, urine output, required pharmacological and mechanical support in addition to the arterial blood gases. Transesophageal echocardiography (TEE) was done to obtain a standard sequence of cardiac images during surgery. Baseline and postoperative values were obtained by a cardiologist. Also, TEE assessed the right ventricle and valvular functions. In patients with postoperative ischemic changes in the ECG and elevated cardiac biomarkers, transthoracic echocardiography was done to diagnose the development of new regional wall motion abnormalities. Postoperative coronary

angiography was done for patients with elevated cardiac biomarkers to assess the patency of the coronary grafts. The values were serially collected at the following timepoints: T0: baseline reading; T1: 15 minutes after induction; T2: before cardiopulmonary bypass; T3:30 minutes after cardiopulmonary bypass; T4: on ICU admission; T5: 6th hour after ICU admission; T6: 12th hour after ICU admission; T7: 24th hour after ICU admission. The troponin level was checked before surgery, before CPB, at the time of ICU admission, at the 6th, 12th, 24th, 48th, and 72nd postoperative hours.

Sample size calculation: Power analysis was performed using the Chi-square test for independent samples on the effect of magnesium sulphate on the frequency of atrial fibrillation because it was the main outcome variable in the present study. A pilot study was done before starting this study because there are many debates about the results of previous studies of other authors because of different doses, timing and duration of magnesium administration during cardiac surgery and we used the same protocol as in another study by the same authors in cardiac surgery. The results of the pilot study (20 patients in each group) showed that the anticipated incidence was in 20 % of group M, and 35% of group C. Taking power 0.8, alpha error 0.05, and beta 0.2, a minimum sample size of 138 patients was calculated for each group.

The statistical analysis: Data were statistically described in terms of mean ± standard deviation (± SD), or frequencies (number of cases) and percentages when appropriate. A comparison of numerical variables between the study groups was done using the Student t-test for independent samples. Repeated measures analysis of variance (ANOVA) test was used to see the effect of magnesium sulphate on heart rate and mean arterial blood pressure at different follow-up intervals. For comparing categorical data, Chi-square (X^2) test was performed. P value less than 0.05 was considered statistically significant. All statistical calculations were done using computer program SPSS (Statistical Package for the Social Science; SPSS Inc., Chicago, IL, USA) version 20 for Microsoft Windows.

3. Results

Table 1 shows no significant difference in the demographic data, co-morbidities, preoperative medications, NYHA class, Euroscore and the ASA physical status score (P>0.05).

Table 1. *Preoperative data of patients (Data are presented as mean±SD, Number, %)*

Variable		Group M (n=138)	Group C (n=138)	P-value
Age (year)		59.16±10.30	57.82±10.23	0.279
Weight (Kg)		85.40±13.65	86.87±14.20	0.381
Gender	Male : Female	79:59	84:54	0.624
Diabetes mellitus		116	124	0.210
Hypertension		125	118	0.265
Ischemic heart diseases		138	138	1.000
Pulmonary hypertension		48	41	0.224
Ejection fraction (%)		47.47±5.25	46.64±4.90	0.175
Angiotensin-converting-enzyme inhibitors		76	68	0.398
Beta-blockers		106	102	0.675
Calcium channels-blockers		65	72	0.470
Aspirin		138	138	0.455
Statins		79	74	0.628
Stroke		-	-	
Carotid stenosis	<50%	39	34	0.585
	Unilateral	16	10	0.302
	Bilateral	23	24	0.872
Smoking	Current smokers	85	80	0.623
	Ex-smokers	18	26	0.249
NYHA	III: IV	83:55	86:52	0.804

ASA	III: IV	81: 57	88: 50	0.458
Euroscore (%)		13.46±3.20	12.90±3.08	0.139
Blood sugar (mmol/L)		6.86±1.26	7.07±1.30	0.174
Body surface area (m²)		1.75±0.22	1.74±0.19	0.686

Group M: *Magnesium sulphate group; Group C: Control group*

NYHA: *New York Heart Association; ASA: American Society of Anesthesiologists Physical Status Score*

Table 2 shows the changes in the heart rate and mean arterial blood pressure of patients during the procedure and through the first postoperative 24 hours in the ICU. There was no significant difference in the preoperative heart rate and mean arterial blood pressure of patients of the two groups (P>0.05). After magnesium sulphate infusion, the heart rate decreased in group M and increased in patients of group C and the difference between the two groups was significant (P<0.05). There were minimal changes in the mean arterial blood pressure in patients of the group M and an increase in the mean arterial blood pressure in the patients of group C and the difference between the two groups was significant (P<0.05).

Table 2. *Heart rate and mean arterial blood pressure of patients (Data are presented as mean±SD)*

Variable		Group M (n=61)	Group C (n=61)	P-value
Heart rate (bpm)	T0	77.54±11.80	76.75±10.60	0.559
	T1	74.30±10.45	77.50±11.30	0.040*
	T2	73.49±9.20	79.09±10.00	0.002*
	T3	71.90±9.40	79.66±10.30	0.001*
	T4	72.60±9.76	80.90±12.45	0.001*
	T5	71.88±10.30	82.34±13.10	0.003*
	T6	72.50±11.04	81.07±11.39	0.001*
	T7	74.42±11.58	83.00±12.10	0.002*
Mean arterial blood pressure (mmHg)	T0	107.35±13.18	105.90±12.95	0.357
	T1	105.63±13.00	109.84±14.65	0.012*
	T2	103.80±12.45	110.61±14.78	0.001*
	T3	103.26±13.55	111.22±15.75	0.001*
	T4	104.77±14.46	112.63±13.90	0.001*
	T5	105.10±15.87	112.25±14.08	0.001*
	T6	103.50±12.98	113.06±15.00	0.001*
	T7	106.57±14.12	114.40±15.32	0.001*

Group M: *Magnesium sulphate group; Group C: Control group*

**P<0.05 significant comparison between the two groups.*

T0: Baseline reading; T1: 15 minutes after induction; T2: before cardiopulmonary bypass; T3:30 minutes after cardiopulmonary bypass; T4: on ICU admission; T5: 6th hour after ICU admission; T6: 12th hour after ICU admission; T7: 24th hour after ICU admission

Table 3 shows the changes in the blood level of magnesium and potassium in the patients of the two groups. There was no significant difference in the preoperative blood magnesium and potassium level between the two groups (P>0.05), but after magnesium infusion, the blood magnesium level was higher during and after surgery in the patients of group M compared to patients of group C (P<0.05), and there were minimal changes in the potassium level in the patients of group M and a decrease in the patients of group C and the difference between the two groups was significant (P<0.05).

Table 3. *Blood magnesium and potassium (Data are presented as mean±SD, Number)*

Variable		Group M (n=138)	Group C (n=138)	P-value
Blood magnesium levels (mmol/L)	T0	1.13±0.15	1.15±0.14	0.253
	T1	2.15±0.29	1.27±0.22	0.001*
	T2	2.29±0.31	1.29±0.24	0.001*
	T3	2.33±0.32	1.26±0.26	0.001*
	T4	2.42±0.35	1.24±0.25	0.001*
	T5	2.46±0.40	1.25±0.19	0.001*
	T6	2.45±0.42	1.28±0.23	0.001*
	T7	2.47±0.44	1.21±0.25	0.001*
Blood potassium levels (mEq/L)	T0	4.45±0.30	4.51±0.32	0.109
	T1	4.41±0.33	4.33±0.30	0.066
	T2	4.35±0.30	4.01±0.29	0.001*
	T3	4.13±0.28	3.84±0.26	0.001*
	T4	4.14±0.27	3.90±0.30	0.001*
	T5	4.17±0.30	3.83±0.26	0.001*
	T6	4.10±0.26	3.88±0.29	0.010*
	T7	4,15±0.32	3.84±0.27	0.001*

Group M: *Magnesium sulphate group; Group C: Control group*

**P<0.05 significant comparison between the two groups*

T0: Baseline reading; T1: 15 minutes after induction; T2: before cardiopulmonary bypass; T3:30 minutes after cardiopulmonary bypass; T4: on ICU admission; T5: 6th hour after ICU admission; T6: 12th hour after ICU admission; T7: 24th hour after ICU admission.

Table 4 shows the changes in the blood level of troponin I and creatinine kinase-MB, ECG changes, postoperative myocardial infarction, and incidence of atrial fibrillation in the patients of the two groups. There was no significant difference between the two groups in the blood levels of troponin I and creatinine kinase-MB before surgery or CPB (P>0.05). After CPB, the troponin I and creatinine kinase-MB increased in patients of the two groups, but the increase was lower in patients of the group M than patients of group C through the 1st 24 postoperative hours, then the levels started to decrease through the 2nd and 3rd postoperative days and the difference between the two groups was significant (P<0.05). The incidence of postoperative atrial fibrillation was lower in group M than group C. The total incidence of atrial fibrillation was 17 patients in group M and 38 patients in group C (P=0.002). The incidence after CPB was three patients in group M and five patients in group C (P=0.719), in the first postoperative day, it was three patients in group M and seven patients in group C (P=0.333), through the 2nd day, it was eight patients in group M and 19 patients in group C (P=0.042), and through the 3rd day, it was three patients in group M and seven patients in group C (P=0.333). The number of patients who required amiodarone was 17 patients in group M and 38 patients in group C (P=0.002). The number of patients associated with ECG changes (ST-segment changes) was 20 patients in group M and 34 patients in group C (P=0.048). The number of patients who suffered from postoperative myocardial infarction was 11 patients in group M and 23 patients in group C (P=0.043). The number of patients associated with postoperative new regional wall motion abnormalities was 11 patients in group M and 23 patients in group C (P=0.043). The number of patients who suffered from postoperative myocardial infarction and associated occluded coronary grafts was 6 patients in group M and 16 patients in group C (P=0.045).

Table 4. *Blood levels of troponin I and creatinine kinase-MB, atrial fibrillation, amiodarone, ECG changes, myocardial infarction, and postoperative coronary angiography (Data are presented as mean±SD, Number)*

Variable		Group M (n=138)	Group C (n=138)	P-value
Troponin I (ng/ml)	Baseline	0.63±0.13	0.65±0.14	0.219
	Before CPB	0.67±0.13	0.66±0.14	0.539
	ICU admission	1.38±0.35†	1.53±0.46†	0.003*
	6th hour	1.65±0.44†	1.79±0.55†	0.020*
	12th hour	1.78±0.53†	2.03±0.67†	0.001*
	24th hour	1.95±0.74†	2.18±0.92†	0.022*
	48th hour	1.62±0.50†	1.78±0.71†	0.031*
	72nd hour	1.24±0.24†	1.50±0.40†	0.001*
Creatinine kinase-MB (ng/ml)	Baseline	4.84±1.16	4.63±1.24	0.147
	Before CPB	5.06±1.26	4.88±1.22	0.229
	ICU admission	5.53±1.62	5.96±1.76	0.035*
	6th hour	6.80±2.49†	7.75±2.75†	0.002*
	12th hour	7.57±2.60†	8.32±2.80†	0.021*
	24th hour	8.25±2.73†	9.05±2.84†	0.017*
	48th hour	7.18±2.33†	8.02±2.39†	0.003*
	72nd hour	6.12±1.38†	6.53±1.55	0.018*
Atrial fibrillation	Total number	17 (12.31%)	38 (27.53%)	0.002*
	After CPB	3 (12.31%)	5 (12.31%)	0.719
	24th hour	3 (12.31%)	7 (12.31%)	0.333
	48th hour	8 (12.31%)	19 (12.31%)	0.042*
	72nd hour	3 (12.31%)	7 (12.31%)	0.333
Amiodarone		17 (12.31%)	38 (27.53%)	0.002*
ECG changes (ST-segment changes)		20 (14.49%)	34 (24.63%)	0.048*
Myocardial infarction		11 (7.97%)	23 (16.66%)	0.043 *
Regional wall motion abnormalities.		11 (7.97%)	23 (16.66%)	0.043 *
Coronary angiography (occluded grafts)		6 (4.34%)	16 (12.59%)	0.045*

Group M: *Magnesium sulphate group; Group C: Control group*

**P<0.05 significant comparison between the two groups*

†P<0.05 significant compared to the preoperative reading within the same group.

ICU admission: Reading at ICU admission; 6th hour: Reading at 6th hour after ICU admission; 12th hour: Reading at 12th postoperative hour; 24th hour: Reading at 24th postoperative hour; 48th hour: Reading at 48th postoperative hour; 72nd hour: Reading at 72nd postoperative hour.

CPB: Cardiopulmonary bypass; ECG: Electrocardiogram

Table 5 shows the intraoperative data and the outcomes of patients of the two groups. There was no difference in the number of coronary grafts, cardiopulmonary bypass time and cross-clamping time between the two groups (P>0.05). The dose of pharmacological support (dopamine, epinephrine, norepinephrine, and nitroglycerine) was lower in the patients of group M than the patients of group C (P=0.001). The number of patients who required intra-aortic balloon pump and the pacing was lower in group M compared to the patients of group C (P=0.042, P=0.038 respectively). The blood glucose increased in patients of the two groups, but the increase was lower in group M than group C (P=0.003). There was no difference in the incidence of stroke between the two groups (P=0.679), but the incidence of cognitive dysfunction (delirium) was lower in group M than group C (P=0.021). There was no difference in the incidence of renal failure between the two groups (P=0.783). The ICU and hospital lengths of stay were shorter in patients of group M than group C (P=0.014, P=0.022 respectively). The incidence of mortality was lower in patients of group M than group C, but the difference was insignificant (P=0.538).

Table 5. *Intraoperative data and outcome of patients (Data are presented as mean±SD, Number, %)*

Variable			Group M (n=138)	Group C (n=138)	P-value
Elective CABG	Number of patients		138	138	1.000
	Number of grafts	2	38	42	0.690
		3	69	75	0.546
		4	31	22	0.282
CPB time (minute)			88.20±18.50	84.92±15.83	0.114
Cross clamping time (minute)			74.30±9.48	72.65±8.70	0.133
Dopamine (µg/kg/min)			5.35±1.26	6.38±1.44	0.001*
Epinephrine (µg/kg/min)			0.05±0.03	0.07±0.04	0.001*
Norepinephrine (µg/kg/min)			0.05±0.03	0.08±0.05	0.001*
Nitroglycerine (µg/kg/min)			0.56±0.40	0.71±0.52	0.001*
Intra-aortic balloon pump			14	27	0.042*
Pacing after weaning of CPB			27	43	0.038*
Blood sugar (mmol/L)			8.46±1.40	9.53±1.61	0.003*
Neurological complications	Stroke		2	4	0.679
	Cognitive dysfunction		29	47	0.021*
Renal failure			6	8	0.783
ICU length of stay (days)			3.74±1.22	4.12±1.35	0.014*
Hospital length of stay (days)			8.90±2.25	9.54±2.37	0.022*
Mortality			4	7	0.538

Group M: Magnesium sulphate group; Group C: Control group
**P<0.05 significant comparison between the two groups.*
CABG: Coronary artery bypass graft surgery; CPB: Cardiopulmonary bypass; ICU: Intensive care unit.

4. Discussion

The present study showed that the perioperative magnesium sulphate infusion decreased the incidence of atrial fibrillation and the requirement for amiodarone in patients with ischemic heart diseases undergoing elective coronary artery bypass grafting. The highest incidence of atrial fibrillation was through the 2nd postoperative day in the two groups. The heart rate and arterial pressure were better controlled by the magnesium sulphate compared to the control group. The weaning from CPB was easier in group M than group C and the requirement for pharmacological and mechanical support was lower in group M than group C. The ECG changes (rhythm and ST-segment) and cardiac markers (troponin I and CK-MB isoenzyme) were lower in group M than group C. Magnesium sulphate decreased the ICU and hospital length of stay.

The results of the present study correlate with other studies. Naghipour et al [12] showed that magnesium sulfate significantly decreased the incidence of all types of postoperative arrhythmia after cardiac surgery and Kaplan et al [13] found the highest incidence of atrial fibrillation was through the 2nd postoperative day. A meta-analysis of 35 studies showed that postoperative intravenous magnesium administration reduces the incidence of atrial fibrillation without significant adverse events [14]. Another meta-analysis of seven studies showed that intravenous magnesium significantly reduces the incidence of postoperative atrial fibrillation after CABG and five of these studies used magnesium sulphate as an infusion after surgery in the ICU (infusion ranges from 24 to 72 hours postoperatively) and the other two studies gave magnesium sulphate as a bolus dose after anesthesia induction. This meta-analysis shows diversity in the dosing, timing and duration of magnesium administration that may affect the outcome [15] and other studies showed similar results [8,16-20]. Jannati et al [20] showed that postoperative magnesium sulfate prevents the hypomagnesemia, therefore preventing the arrhythmia after CABG.

Patients with severe coronary artery disease are associated with a high incidence of hypomagnesmia [21]. The hypomagnesmia during cardiac surgery may be related to many reasons such as diuretics, hemodilution of CPB, hyperglycemia, increased

catecholamines, ionized magnesium chellation with heparin or blood preserving solution in case of allogenic transfusion or myocardial hypoxia thus, patients undergoing CABG are at risk of hypomagnesemia [6,22- 25].

The cardioprotective of magnesium sulphate against postoperative atrial fibrillation may be related to different mechanisms. Honarmand et al [26] showed that the preoperative administration of magnesium sulphate minimized the changes in the heart rate, and arterial blood pressures related to laryngoscopy and tracheal intubation by inhibition of the catecholamine release from adrenal glands [27], and calcium antagonist effect [28]. Magnesium plays an important role in preserving cardiac rhythm by stabilizing myocardial cell membrane function and causes prolongation of atrial and atrioventricular nodal refractory periods, which may facilitate rate and rhythm control [8,9,29,30]. Also, the magnesium reduces the coronary microvascular injury during reperfusion and preserves coronary microvascular function [31]. The magnesium stabilizes the myocytes through its effect on calcium transport and minimizing the intracellular calcium (calcium-antagonist effect), therefore inhibits a variety of cellular enzymes, transport systems, mitochondrial function, preserves the cellular adenosine triphosphatase and energy-dependent cellular processes [10], inhibits the catecholamines release [32], therefore it decreases the automaticity and excitability of the heart [33,34]. The magnesium inhibits the platelet function and it influences the clotting cascade as a calcium antagonist [35], therefore, magnesium may produce anticoagulant effect and it maintains the patency of the coronary arteries or the grafts [36], one of the main causes of atrial fibrillation after cardiac surgery may be related to myocardial ischemia [37,38]. Also, the magnesium increases the cellular sensitivity to insulin and glucose that provides better control of blood sugar [39]. Acute hyperglycemia is associated with increased platelet and leukocyte activation [40] that may lead to clot formation or an increase in the thrombus size and myocardial injury [41]. Magnesium sulfate administration maintains and increases the blood level of magnesium which decreases the resting membrane potential and decreases the tendency to abnormal impulse by increasing the intracellular potassium concentration magnesium dependent sodium-potassium ATPase activity, thus increasing the membrane threshold potential [42].

Contrary to the present study, Najafi et al [43] showed that routine magnesium administration has no significant effect on blood magnesium level and incidence of perioperative arrhythmia. Cook et al [44] showed that prophylactic magnesium sulphate administration as 5 gm intravenous started at the removal of the aortic cross-clamp, followed by daily 4-hour infusions for the first postoperative four days 4 did not reduce the incidence of atrial arrhythmias after cardiac surgery. Kaplan et al [13] showed that prophylactic magnesium sulfate infusion alone is not sufficient for the prophylaxis of atrial fibrillation after cardiac surgery and other studies showed a similar result [5,45,46]. These studies used magnesium postoperatively in the ICU. Mohammadzadeh et al [46] showed that magnesium sulphate administration did not significantly improve the incidence of arrhythmias in hypo- and normo-magnesium in patients after CABG and concluded there was no significant correlation between postoperative serum levels of magnesium and arrhythmia during the postoperative three days.

After reviewing a lot of articles about the role of magnesium sulphate for atrial fibrillation in cardiac surgery, there are many debates, conflicts and controversies about the benefits of perioperative magnesium administration in patients undergoing cardiac surgery and this may be related to many reasons; (1): different doses; (2): different timing of administration; (3): different duration of administration; (4): selection of the indication and patients; (5) the blood level of magnesium in not monitored frequently although its value is the same as potassium level.

There are limitations to the present study. First, it was done in a single center; and second, there are no articles talking about the fixed protocol for magnesium sulphate administration during cardiac surgery to compare the results with the findings in the present study and to conclude the optimum dose, timing, and duration of magnesium infusion. Therefore, the authors of the present study recommend doing other studies on magnesium sulphate in cardiac surgery to show the optimum dose, timing, and duration of magnesium sulphate administration and to show the best benefits of the magnesium sulphate administration for ischemic heart disease undergoing CABG.

5. Conclusion

The magnesium sulphate decreases the incidence of atrial fibrillation and the requirement for amiodarone

in patients with ischemic heart diseases undergoing CABG. It decreases the incidence of perioperative myocardial infarction and the requirement of pharmacological and mechanical support.

Abbreviations

CPB: Cardiopulmonary bypass

CABG: Coronary artery bypass grafting

CK-MB: Creatine Kinase-MB

MAP: Mean arterial blood pressure

NYHA: New York Heart Association

ASA: American Society of Anesthesiologists Physical Status Score

ECG: Electrocardiogram

SD: Standard deviation

P-RBC: Packed- red blood cells

ICU: Intensive care unit

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Authors Contributions

Rabie Nasr: He was responsible for anesthesia of the cases, collection the data of patients, analysis of results and the writing of discussion.

Ahmed Soliman: He was responsible for analysis of results and the writing of discussion

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Conflict of Interests

The authors declare that they have no conflict of interests.

6. References

1. Lauer MS, Eagle KA, Buckley MJ, DeSanctis RW. Atrial fibrillation following coronary artery bypass surgery. Prog Cardiovasc Dis 1989;31:367–78.
2. Banach M, Goch A, Misztal M, Rysz J, Jaszewski R, Goch JH. Predictors of paroxysmal atrial fibrillation in patients undergoing aortic valve replacement. J Thorac Cardiovasc Surg 2007;134:1569–76.
3. Shrivastava R, Smith B, Caskey D, Reddy P. Atrial fibrillation after cardiac surgery: Does prophylactic therapy decrease adverse outcomes associated with atrial fibrillation. J Intensive Care Med J Intensive Care Med 2009;24:18–25.
4. Hakala T, Halonen J, Mäkinen K, Hartikainen J. Prevention of atrial fibrillation after cardiac surgery. Scandinavian Cardiovascular Journal 2007;41:72–8.
5. Archbold RA, Zaman AG.Magnesium for atrial fibrillation after coronary artery bypass graft surgery: its role in aetiology and prevention. Crit Care Resusc 2000;2:260–8.
6. Satur CMR, Anderson JR, Jennings A, Newton K, Paul GM, Unikrishnan N et al. Magnesium flux caused by coronary artery bypass operation: three patterns of deficiency. Ann Thorac Surg 1994;58:1674–8.
7. Aranki SF, Shaw DP, Adams DH, Rizzo RJ, Couper GS, VanderVliet M et al. Predictors of atrial fibrillation after coronary artery surgery: current trends and impact on hospital resources. Circulation 1996;94:390–7.
8. Toraman F, Karabulut EH, Alhan C, Dagdelen S, Tarcan S. Magnesium infusion dramatically decreases the incidence of atrial fibrillation after coronary artery bypass grafting. Ann Thorac Surg 2001;72:1256–62.
9. Christiansen EH, Frost L, Andreasen F, Mortensen P, Thomsen PE, Pedersen AK. Dose-related cardiac electrophysiological effects of intravenous magnesium. A double-blind placebo-controlled dose response study in patients with paroxysmal supraventricular tachycardia. Europace 2000;2:320–6.
10. Yamamuro A, Akasaka T, Tamita K, Yamabe K, Katayama M, Takagi T et al. Coronary flow velocity pattern immediately after percutaneous coronary intervention as a predictor of complications and in-hospital survival after acute myocardial infarction. Circulation 2002;106:3051–6.
11. Polderman KH, Girbes AR. Severe electrolyte disorders following cardiac surgery: a prospective controlled observational study. Crit Care 2004;8:R459–66.
12. Naghipour B, Faridaalaee G, Shadvar K, Bilehjani E, Khabaz AH, Fakhari S. Effect of prophylaxis of magnesium sulfate for reduction of postcardiac surgery arrhythmia: Randomized clinical trial. Ann Card Anaesth 2016;19:662–7.
13. Kaplan M, Kut MS, Icer UA, Demirtas MM. Intravenous magnesium sulfate prophylaxis for atrial fibrillation after coronary artery bypass surgery. J Thorac Cardiovasc Surg 2003;125:344–52.
14. Fairley JL, Zhang L, Glassford NJ, Bellomo R. Magnesium status and magnesium therapy in cardiac surgery: A systematic review and meta-analysis focusing on arrhythmia prevention. J Crit Care 2017;42:69–77.
15. Gu WJ, Wu ZJ, Wang PF, Aung LH, Yin RX. Intravenous magnesium prevents atrial fibrillation after coronary artery bypass grafting: a meta-analysis

of 7 double-blind, placebo-controlled, randomized clinical trials. Trials 2012;20;13:41.

16. Miller S, Crystal E, Garfinkle M, Lau C, Lashevsky I, Connolly SJ. Effects of magnesium on atrial fibrillation after cardiac surgery: a meta analysis. Heart 2005;91:618–23.
17. Naito Y, Nakajima M, Inoue H, Hibino N, Mizutani E, Tsuchiya K. Prophylactic effect of magnesium infusion against postoperative atrial fibrillation. Kyobu Geka 2006;59:793–7.
18. Bakhsh M, Abbas S, Hussain RM, Ali Khan S, Naqvi SM. Role of magnesium in preventing post-operative atrial fibrillation after coronary artery bypass surgery. J Ayub Med Coll Abbottabad 2009;21:27–9.
19. Shepherd J, Jones J, Frampton GK, Tanajewski L, Turner D, Price A. Intravenous magnesium sulphate and sotalol for prevention of atrial fibrillation after coronary artery bypass surgery: a systematic review and economic evaluation. Health Technol Assess 2008;12:iii-iv, ix–95.
20. Jannati M, Shahbazi S, Eshaghi L. Comparison of the Efficacy of Oral versus Intravascular Magnesium in the Prevention of Hypomagnesemia and Arrhythmia after CABG. Braz J Cardiovasc Surg 2018;33:448–53.
21. Smetana R. Cardiovascular medicine - the importance of magnesium in coronary artery disease and acute myocardial infarction. In: Smetana R, editor. Advances in magnesium research: 1: Magnesium in cardiology, London: John Libbey & Company Ltd; 1997. p. 5–11.
22. Wilkes NJ, Mallett SV, Peachey T, Di Salvo C, Walesby R. Correction of ionized plasma magnesium during cardiopulmonary bypass reduces the risk of postoperative cardiac arrhythmia. Anesth Analg 2002;95:828–34.
23. Aglio LS, Stanford GG, Maddi R, Boyd JL, Nussbaum S, Chernow B. Hypomagnesemia is common following cardiac surgery. J Cardiothorac Vasc Anesth 1991;5:201–8.
24. Munoz R, Laussen PC, Palacio G, Zienko L, Piercey G, Wessel DL. Whole blood ionized magnesium: age-related differences in normal values and clinical implications of ionized hypomagnesemia in patients undergoing surgery for congenital cardiac disease. J Thorac Cardiovasc Surg 2000;119:891–8.
25. Millane TA, Ward DE, Camm AJ. Electrophysiology, pacemaking, and arrhythmia: is hypomagnesemia arrhythmogenic? Clin Cardiol 1992;15:103–8.
26. Honarmand A, Safavi M, Badiei S, Daftari-Fard N. Different doses of intravenous Magnesium sulfate on cardiovascular changes following the laryngoscopy and tracheal intubation: A double-blind randomized controlled trial. J Res Pharm Pract 2015;4:79–84.
27. James MF, Beer RE, Esser JD. Intravenous magnesium sulfate inhibits catecholamine release associated with tracheal intubation. Anesth Analg 1989;68:772–6.
28. Turlapaty PD, Altura BM. Magnesium deficiency produces spasms of coronary arteries: Relationship to etiology of sudden death ischemic heart disease. Science 1980;208:198–200.
29. Treggiari-Venzi MM, Waeber JL, Perneger TV, Suter PM, Adamec R, Romand JA. Intravenous amiodarone or magnesium sulphate is not cost-beneficial prophylaxis for atrial fibrillation after coronary artery bypass surgery. Br JAnaesth 2000;85:690–5.
30. Kurian GA. Effect of intraoperative magnesium supplementation in plasma antioxidant levels trace elements and electrolyte balance in CABG. J Clin Basic Cardiol 2007;10:11–15.
31. Rasmussen HS, Thomsen PE. The electrophysiological effects of intravenous magnesium on human sinus node, atrioventricular node, atrium, and ventricle. Clin Cardiol 1989;12:85–90.
32. Pasternak K, Dabrowski W, Dobija J, Wrońskal J, Rzecki Z, Biernacka J. The effect of preoperative magnesium supplementation on blood catecholamine concentrations in patients undergoing CABG. Magnes Res 2006;19:113–22.
33. Altura BM, Altura BT. Role of magnesium in pathophysiological processes and the clinical utility of magnesium ion selective electrodes. Scand J Clin Lab Invest Suppl 1996;224:211–34.
34. Kolte D, Vijayaraghavan K, Khera S, Sica DA, Frishman WH. Role of magnesium in cardiovascular diseases. Cardiol Rev 2014;22:182–92.
35. Gries A, Bode C, Gross S, Peter K, Bohrer H, Martin E. The effect of intravenously administered magnesium on platelet function in patients after cardiac surgery. Anesth Analg 1999;88:1213–9.
36. Gawaz M. Antithrombocytic effectiveness of magnesium. Fortschr Med 1996;114:329–32.
37. Koletsis EN, Prokakis C, Crockett JR, Dedeilias P, Panagiotou M, Panagopoulos N et al. Prognostic factors of atrial fibrillation following elective coronary artery bypass grafting: the impact of quantified intraoperative myocardial ischemia. J Cardiothorac Surg 2011;6:127.
38. Echahidi N, Pibarot P, O'Hara G, Mathieu P. Mechanisms, prevention, and treatment of atrial fibrillation after cardiac surgery. J Am Coll Cardiol 2008;51:793–801.
39. Volpe S. Magnesium, the metabolic syndrome, insulin resistance, and type 2 diabetes mellitus. Crit Rev Food Sci Nutr 2008;48:293–300.
40. Desai MY, Dalal D, Santos RD, Carvalho JA, Nasir K, Blumenthal RS. Association of body mass index,

metabolic syndrome, and leukocyte count. Am J Cardiol 2006;97:835–8.

41. Badimon L, Padró T, Vilahur G. Atherosclerosis, platelets and thrombosis in acute ischaemic heart disease. Eur Heart J Acute Cardiovasc Care 2012;1:60–74.
42. Knudson K, Abrahamsson J. Antiarrhythmic effects of magnesium sulphate. Report of three cases. Acta Anaesthsiol Scand 1995;39:850–4.
43. Najafi M, Haghighat B, Tafti HA. Relationship between serum magnesium level and arrythmias following post-coronary artery bypass grafting. Middle East J Anaesthesiol 2007;19:661–72.
44. Cook RC, Humphries KH, Gin K, Janusz MT, Slavik RS, Bernstein V et al. Prophylactic intravenous magnesium sulphate in addition to oral {beta}-blockade does not prevent atrial arrhythmias after coronary artery or valvular heart surgery: a randomized, controlled trial. Circulation 2009;120:163–9.
45. Kohno H, Koyanagi T, Kasegawa H, Miyazaki M. Three-day magnesium administration prevents atrial fibrillation after coronary artery bypass grafting. Ann Thorac Surg 2005;79:117–26.
46. Mohammadzadeh A, Towfighi F, Jafari N. Effect of magnesium on arrhythmia incidence in patients undergoing coronary artery bypass grafting. ANZ J Surg 2018;88:612–5.