ORIGINAL ARTICLE

Annals of Agricultural and Environmental Medicine
www.aaem.pl

Plasma magnesium concentration in patients undergoing coronary artery bypass grafting

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Plasma magnesium concentration in patients undergoing coronary artery bypass grafting Kotlinska-Hasiec E, Makara-Studzinska M, Czajkowski M, Rzecki Z, Olszewski K, Stadnik A, Pilat J, Rybojad B, Dabrowski W. Ann Agric Environ Med. doi: 10.5604/12321966.1232762

Abstract

Introduction. Magnesium (Mg) plays a crucial role in cell physiology and its deficiency may cause many disorders which often require intensive treatment. The aim of this study was to analyse some factors affecting preoperative plasma Mg concentration in patients undergoing coronary artery bypass grafting (CABG).

Materials and method. Adult patients scheduled for elective CABG with cardio-pulmonary bypass (CPB) under general anaesthesia were studied. Plasma Mg concentration was analysed before surgery in accordance with age, domicile, profession, tobacco smoking and preoperative Mg supplementation. Blood samples were obtained from the radial artery just before the administration of anaesthesia.

Results. 150 patients were studied. Mean preoperative plasma Mg concentration was 0.93 ± 0.17 mmol/L; mean concentration in patients – 1.02 ± 0.16; preoperative Mg supplementation was significantly higher than in patients without such supplementation. Moreover, intellectual workers supplemented Mg more frequently and had higher plasma Mg concentration than physical workers. Plasma Mg concentration decreases in elderly patients. Patients living in cities, on average, had the highest plasma Mg concentration. Smokers had significantly lower plasma Mg concentration than non-smokers.

Conclusions. 1. Preoperative magnesium supplementation increases its plasma concentration. 2. Intellectual workers frequently supplement magnesium. 3. Smoking cigarettes decreases plasma magnesium concentration.

Key words
magnesium, supplementation, age, profession, community education

INTRODUCTION

Magnesium (Mg) is an intracellular cation and plays a crucial role in many metabolic processes. Its deficiency leads to many life-threatening disorders, particularly of the heart and central nervous system [1, 2]. The homeostasis of Mg depends on supplementation, accumulation and extraction with diuresis, stool and perspiration. Daily demand of Mg increases with age and ranges between 300–400 mg per day in adults [2]. Physiological plasma Mg concentration ranges from 0.8–1.2 mmol/L, and even the smallest changes in its plasma level reflects in its intracellular level, leading to cellular dysfunctions [1, 3]. Several pathologies, such as kidney diseases, diarrhoea, stress and neuroses, alcoholism and diabetes may reduce plasma Mg concentration. Moreover, its low concentration has been noted in patients treated with diuretics [2, 4, 5].

Many pathologies are observed in patients undergoing cardiac surgery, and cardiac surgery with cardiopulmonary bypass (CBP) affects plasma Mg concentration. Perioperative stress, normovolemic haemodilution during CBP and raised loss with diuresis significantly reduce its plasma concentration [6–8]. Interestingly, the degree of plasma Mg concentration depends on its preoperative level [8, 9]. The aim of the presented study is to analyse some factors affecting preoperative plasma Mg concentration in patients undergoing coronary artery bypass grafting (CABG).

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Received: 8 April 2013; accepted: 7 October 2014; *first published on January 2017*

MATERIALS AND METHOD

This prospective study was conducted in the Cardiac Surgery Clinic of the Medical University in Lublin, Poland. The study design was approved by the Committee for Bioethics of the the Medical University and written informed consent was obtained from all patients. Patients scheduled for elective coronary artery bypass grafting surgery (CABG) with CBP due to stable angina were included.

All participants received the same premedication: one day before surgery – oral lorazepam (Lorafen, Polfa, Poland) at the dose of 2 mg, and one hour before the induction of anaesthesia – intramuscular midazolam (Sopodorm, Polfa, Poland) with morphine hydrochloride (Morphicum hydrochloricum, Polfa, Poland) at the doses 0.01 mg/kg body wt. and 0.1 mg/kg body wt., respectively. General anaesthesia was induced using fentanyl (Fentanyl, Polfa, Poland), midazolam and etomidate (Etomidate, Braun, Germany). Muscle relaxation was obtained with a single dose of pancuronium (Pavulon, Jelfa, Poland). For CBP, standard cannulations of the ascending aorta and inferior vena cava through the right atrium were performed. During CBP, circulation and ventilation were maintained with a heart-lung machine (S III, Stöckert GmbH, Munich, Germany), and mean arterial pressure maintained between 45–105 mmHg.

After traditional aortic clamping, myocardial viability was preserved with repeated antegrade hyperkalaemic warm blood cardioplegia. During mild hypothermic CBP, the mean arterial pressure, haematocrit and blood gas parameters, as well as the lactate, sodium and potassium levels were measured. Distal anastomoses were performed during cardioplegic arrest, whereas proximal anastomoses were performed following resumed perfusion and a side–biting clamp. In patients requiring inotropic support, dopamine or dobutamine infusions were used at doses dependent on the patient's haemodynamic status. The effect of heparin was reversed using an adequate dose of protamine sulphate (Protaminum sulphuricum, Biomed, Warsaw, Poland).

After surgery, patients were sent to the postoperative intensive care unit (PICU). All the patients were ventilated using synchronised intermittent mandatory ventilation (SIMV) with pressure support. Patients were extubated 8–12 hours after surgery.

Study protocol and patient distribution. Before anaesthesia, blood samples were collected from the radial artery for total Mg measurements. Plasma Mg concentration was analysed in accordance with age, domicile (participants living in a village, small city (population less than 20,000), medium-size city (population from 20,000–100,000) and a big city (population higher than 100,000) [10], type of job (intellectual vs. physical), tobacco smoking (smokers vs. not smoking cigarettes) and preoperative Mg supplementation.

A spectrophotometric analysis was used to measure the plasma total Mg concentration. Blood samples were immediately centrifuged at 2,500 r/min, and the resulting plasma frozen at -20 °C. Next, xylidine blue was added to each of the defrosted samples. The plasma total Mg concentrations were determined using spectrophotometry with ultraviolet light at a wavelength of 520 nm (Spectrophotometer SPECORD M40, Zeiss, Jena, Germany).

Statistics. Means and standard deviations (SD) were calculated for parametric data. Categorical variables were compared using the χ^2 and Fisher exact tests, and the Yates correction was applied. The unpaired Student's t-test was used to analyse variables with normal distribution. Non-parametric data were statistically analysed using the Wilcoxon signed-rank test and the Kruskal–Wallis ANOVA test for initial detection of differences. P<0.05 was considered to be statistically significant. The statistical analysis was determined by Statistica 9 software. The power of all statistical tests was determined by G*Power software (1–β).

RESULTS

150 adult patients (21 females; 129 males) aged 65±7, undergoing elective CABG under general anaesthesia were studied. 43 lived in small villages, 33 lived in small cities, 44 in a medium-size city and 30 in a big city (Tab. 1). 61 participants worked intellectually and 89 physically (including agricultural work).

Mean value of plasma Mg concentration was 0.93±0.17 mmol/L in studied population. The highest plasma Mg concentration was noted in patients living in cities and the lowest in patients living in small villages (Fig. 1). In the studied population, 40% of the patients regularly

Table 1. Demographic data. medium city

		Studied population	Patients living in a small village	Patients living in a small city	Patients living in a middle city	Patients living in a large city
No.		150	43	33	44	30
Age		65 ± 7 (42 – 80)	66 ± 6 (52 – 72)	67 ± 6 (53 – 80)	65 ± 7 (51 – 78)	64 ± 8 (42 – 75)
BMI		26.45 ± 3.9	26.7 ± 4.1	26.3 ± 3.5	26.9 ± 4.2	25.5 ± 3.5
Sex	Female	21	8	3	6	4
	Male	129	35	30	38	26
Kind of work	Physical	89	30	21	22	16
	Intellectual	61	13	12	22	14
Hypertension		129 (86%)	37 (86%)	36 (78.79%)	35 (79.55%)	21 (70%)
Smoking cigarettes		73 (48.67%)	21 (48.83%)	19 (57.57%)	19 (43.18%)	14 (46.67%)
Cigarettes per day		17±8	16±8	17±8	21±8	14±6
History of smoking		44 (29.33%)	17 (39.53%)	7 (21.21%)	14 (31.82%)	6 (30%)

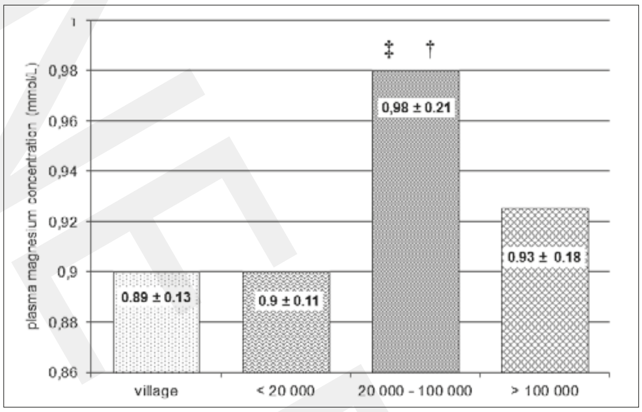

Figure 1. Mean plasma magnesium concentrations in patients living in village, small city (population less than 20,000), medium city (populati range 20,000–100,000) and big city (population more than 100,000)

supplemented Mg – 25.58% of patients living in small villages, 33.33% of patients living in small cities, 52.27% of patients living in medium-size cities and 50% of patients living in big cities. Patients, who lived in medium sized cities supplemented Mg more often than those living in small villages (χ^2=6.51; p=0.01 with χ^2_{Yates}=5.43; p=0.02) and more often than those living in small cities (χ^2=4.59; p=0.03 with χ^2_{Yates}=3.59; p=0.05).

The frequency of smoking was similar in all groups (Fig. 2). Plasma Mg concentration was significantly lower in smokers and its mean value was 0.87±0.13 mmol/L (Fig. 3).

Mean plasma Mg concentration was 0.96±0.17 mmol/L in patients who had intellectual work, and was significantly higher (p < 0.05) than in patients working physically, in whom the plasma Mg concentration was 0.9 ± 0.16 mmol/L. Magnesium level decreased in the elderly, and a rapid decline was observed in patients after the age of 65 (Fig. 4).

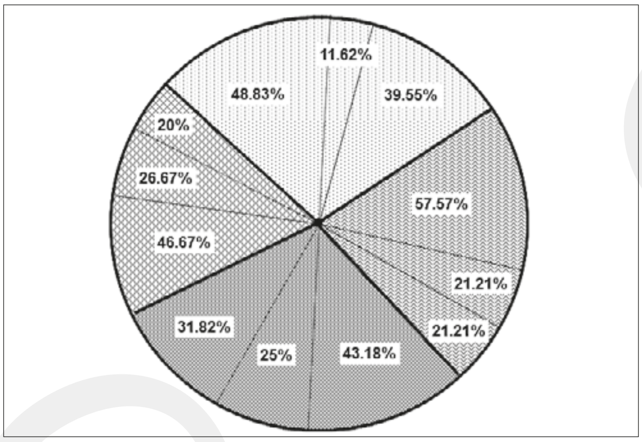

Figure 2. Percentage of smokers in accordance with domicile in participants living in a village: 48.83% smoked regularly before surgery, 11.62% never smoked and 39.55% smoked in the history. In patients living in a small city (population less than 20,000), 57.57% smoked regularly before surgery, 21.21% never smoked and 21.21% smoked in the history. In patients living in a medium size city (population range 20,000–100,000) 43.18% smoked regularly before surgery, 25% never smoked and 31.82% smoked in the history. In patients living in a big city (population more than 100,000), 46.67% smoked regularly before surgery, 26.672% never smoked and 20% smoked in the history. Frequency of smoking was similar in all groups

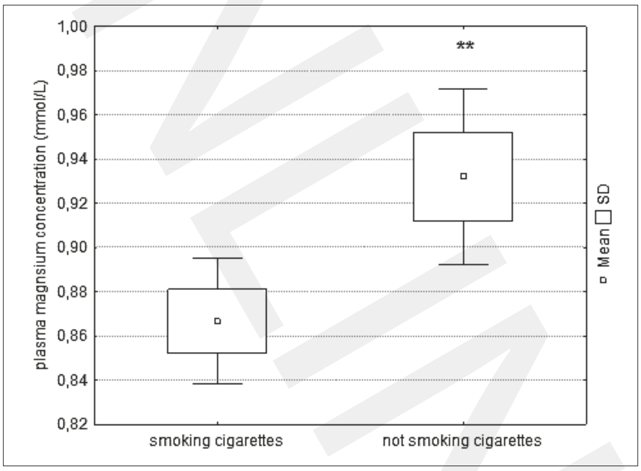

Figure 3. Changes in plasma magnesium concentration in patients who smoked cigarettes and patients, who did not smoke

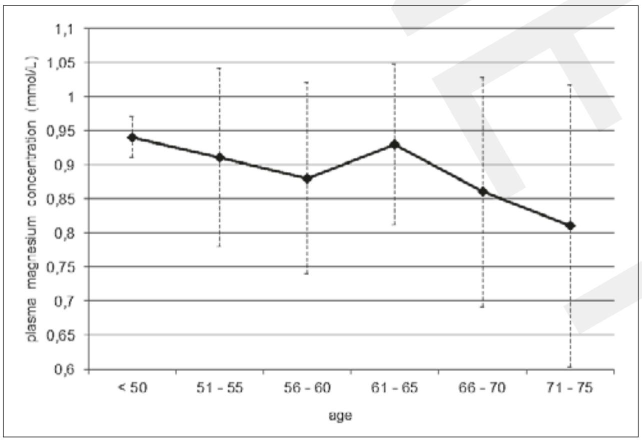

Figure 4. Changes in a mean plasma magnesium concentration according to age

DISCUSSION

The presented study demonstrates the profitable effect of regular Mg supplementation on its plasma concentration before cardiac surgery. Intellectual workers supplemented Mg more frequently than physical workers. Additionally, patients living in cities with an average population (20,000–100,000) had the highest plasma Mg concentration. Interestingly, patients living in medium-size cities supplemented Mg more often than those who lived in small villages. Smoking cigarettes significantly decreases plasma Mg concentration. Plasma Mg concentration decreased in elderly patients.

There is a strong evidence that Mg plays a very important role in patients undergoing cardiac surgery. Perioperative hypomagnesaemia is associated with different forms of cardiac arrhythmias, particularly with atrial fibrillation [8, 11, 12]. Magnesium stabilizes mitochondrial ion transport and calcium channel activity improving the cellular bioenergic status, which prevent abnormal pacemaker activity [1, 13, 14]. Intra-cardiac Mg reduces β-adrenergic stimulation [13], and interestingly, a 7% reduction of intra-cardiac Mg increases 5-fold the multivariate risk of postoperative atrial fibrillation in patients undergoing CABG [15]. For this reason, several authors have proposed perioperative infusion of Mg as a prophylactic treatment of post-operative cardiac arrhythmia [8, 11, 12, 14].

Magnesium also plays an important role in perioperative neuroprotection. It plays a crucial role in the regulation of calcium channel function and N-methyl-D-aspartate receptors (NMDA), and intracellular/mitochondrial metabolism [16]. Moreover, the blood–brain barrier (BBB) integrity strongly depends on brain Mg content, and increase in BBB permeability correlates with a decline in cerebral magnesium concentrations [17, 18]. Experimental and clinical studies have documented a neurprotective effect mediated by Mg in treatment of brain injury [19,20]. Nevertheless, a single use of Mg in post-traumatic neuroprotective treatment has been strongly controverted in recent years, and several authors have strongly suggested supporting other pharmacologic treatments by Mg infusion in patients after traumatic brain injury [19].

Plasma Mg concentration affects perioperative adrenergic response. An intraoperative infusion of magnesium sulphate significantly reduces the adrenergic response for surgical stress mediated by plasma epinephrine and norepinephrine concentrations [9, 21]. Moreover, Mg attenuates the haemodynamic response on intubation in hypertensive patients [22]. Importantly, the majority of studied patients were treated for hypertension.

Cardiac surgery with CBP contributes to low plasma Mg concentrations and the degree of this disorders strongly depends on the preoperative plasma Mg concentration [6, 8, 9]. Perioperative adrenergic reaction, increase in Mg depletion with urine, inadequate Mg supplementation and perioperative treatment may lead to hypomagnesaemia. However, intraoperative blood dilution during CBP is the most important factor contributing to perioperative hypomagnesaemia [23]. Several authors have shown a 17% decrease in plasma Mg concentration following normovolemic haemodilution [24, 25]. Importantly, the preoperative Mg supplementation significantly improve its plasma concentration, reduces perioperative Mg disorders, reduces surgically-related adrenergic response, and improves the post-operative outcome [8, 9]. Unfortunately, the majority of studied patients did not supplement Mg pre-operatively and 86% of them were treated for hypertension.

Finally, the presented analysis shows some factors affecting pre-operative plasma Mg concentration in patients undergoing elective CABG with CBP. Pre-operative magnesium supplementation is most important because it significantly increases its preoperative plasma concentration. Interestingly, intellectual workers frequently supplemented magnesium. Smoking cigarettes decreased plasma magnesium concentration. The highest plasma Mg concentration was noted in patients living in cities with an average population (20,000–100,000) and the lowest in patients living in small villages.

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