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Changes in Ionized and Total Magnesium Concentration during Spinal Surgery

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Background: The incidence of postoperative hypomagnesemia in patients undergoing spinal surgery has been reported to be 70%. Ionized magnesium is considered to be the biologically active form, but until the early 1990s, only the total magnesium concentration could be measured. Currently, the ionized magnesium concentration as well as total magnesium concentration can be assessed due in part to the development of a selective electrode. The aim of this study was to more fully characterize the changes in the total and ionized magnesium concentrations in patients undergoing elective spinal fusion surgery.

Methods: The total and ionized magnesium, creatinine, albumin, urinary magnesium concentration, hematocrit, total amount of fluid administration, transfusion, blood loss, and urine output were evaluated both preoperatively and postoperatively in each patient.

Results: The total and ionized magnesium concentrations decreased from 0.783 mM/L and 0.529 mM/L preoperatively to 0.717 mM/L and 0.511 mM/L during the postoperative period, respectively.

Conclusions: The incidence of total hypomagnesemia during spinal surgery was 15% but the incidence of ionized hypomagnesemia was only 3%. **(Korean J Anesthesiol 2007; 52: S 37∼41)**

Key Words: ionized magnesium, spinal surgery, total magnesium.

INTRODUCTION

The development of hypomagnesemia in postoperative or critically ill patients has been reported in previous studies.[1,2] Hypomagnesemia has been associated with prolonged intensive care unit (ICU) hospitalization and increased mortality in both medical and surgical patients.[3-5] However, only a few orthopedic patients with a magnesium deficiency have been reported in the medical literature.[6] Place et al.[7] demonstrated a 70% incidence of hypomagnesemia in patients after spinal surgery. However, only the total magnesium (Mg) concentrations were measured; ionized magnesium (iMg) concentrations were not, even though this form of magnesium is the physiologically active unbounded portion.[8] In fact, studies comparing Mg and iMg concentrations have revealed a poor correlation, particularly after cardiopulmonary bypass or a massive transfusion.[9,10] The need for parallel measurement of Mg and iMg concentrations was suggested.[11] Therefore, an investigation into the relationship between Mg and iMg and perioperative morbidity was more important.

Ionized magnesium comprises approximately 70% of Mg in blood, and only a fraction of this is available for biological processes.[12] However, due to previous difficulties in the measurement of iMg concentrations in the clinical setting, changes in iMg concentrations has not been sufficiently studied.[13,14] Nowadays, a selective electrode that measures iMg concentrations, which is clinically important, was developed and has become clinically available.[15]

We performed a study that more fully characterizes the changes in serum Mg and iMg concentrations in patients undergoing elective spinal fusion surgery.

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MATERIALS AND METHODS

After obtaining Institutional Review Board approval from our hospital, along with written informed consent from the patients and their relatives, we enrolled 30 adult patients who were to undergo spinal surgery (Table 1). Patients who exhibited elevated serum creatinine levels (> 0.11 mM/L) in the preoperative evaluation, or patients with a history of renal and metabolic disease were excluded from the study.

Based on our pilot study, we calculated that a sample size of 30 patients would be required in order to detect a difference between the preoperative and postoperative period ionized magnesium levels (0.53 mM/L and 0.51 mM/L, with an α-error of 0.05 and a power of 0.8). We decided that the criteria of total and ionized hypomagnesemia in this assay are less than 0.65 and 0.4 mM/L, respectively.

General anesthesia was induced with 5 mg/kg thiopental sodium, 2µg/kg fentanyl, and 0.6 mg/kg rocuronium. The patients were ventilated via endotracheal tube with sevoflurane, O_2, and air. Anesthetic management of these patients, including administration of crystalloid or blood products, was entirely at the discretion of the individual anesthesia providers and was not influenced by our protocol. All patients underwent routine arterial catheter and urinary catheter placement. Arterial blood samples were obtained directly after the initiation of anesthesia and also at the end of surgery. The samples were analyzed immediately after collection, in an adjacent laboratory, in the following manner: a standard heparinized blood gas syringe by ion-selective electrode (AVL988 to 4, AVL List, Medical instrument, Graz, Austria) was used to determine pH and iMg levels, and an additive-free glass tuned by an automated dry-slide reflectance method (Vitros, Johnson & Johnson, Rochester, USA) was used for Mg and albumin. Urine was collected throughout the surgery, in contamination-free container via a Foley catheter. A urine sample was taken at the end of surgery in order to measure the urinary magnesium concentration and also to calculate Mg excretion. Urinary magnesium excretion can be calculated by using the following formula:

FEMg = (UMg × PCr) / (O.7 × PMg) X UCr × 100 (%).

"U" and "P" refer to the urine and plasma concentrations of magnesium and creatinine.

The values are represented as the mean ± standard deviation, or as the number of patients. Changes in variables affecting preoperative to postoperative values were analyzed with paired t-test. The relationships between the percent change in iMg, Mg and albumin and between recording parameters (intravenous fluid, urine loss, transfusion and blood loss) was examined with a correlation test. A P value < 0.05 was considered statistically significant.

RESULTS

Total hypomagnesemia developed in 13% of the patients, but ionized hypomagnesemia developed in only 3% after spinal surgery.

Eleven patients received packed red blood cells (mean, 227 ml; range, 200 to 1,200 ml). No patients received fresh frozen plasma. All patients received normal saline (mean, 2,341 ml; range, 1,300 to 5,800 ml), while nineteen patients also received colloid without magnesium (mean, 282 ml; range, 100 to 500 ml). No patients received supplemental magnesium boluses (Table 2).

Mg and iMg decreased significantly, as compared with preoperative values (P = 0.0001 and 0.0033, respectively) (Fig. 1). Hematocrit and albumin decreased, too (Table 3).

The response variables were defined as the percent change

Table 1. Patient Demographics

Sex (M/F)	11/19
Age (yr)	50.5 ± 14.3
Weight (kg)	64.1 ± 11.6
Height (cm)	154.5 ± 10.2
Duration of operation (min)	220.8 ± 68.1

Values are expressed as mean ± SD, or as number of patients.

Table 2. Patient Inputs and Outputs

	Input	Output
Crystalloid (ml)	2,341 ± 996	
Colloid (ml)	282 ± 231	
Blood (ml)	227 ± 356	817 ± 651
Urine (ml)		510 ± 413
Total (ml)	2,850	1,327

Values are expressed as mean ± SD.

Table 3. Patients Laboratory Data

	Preoperative value	Postoperative value
Ionized magnesium (mM/L)	0.529 ± 0.031	0.511 ± 0.032*
Total magnesium (mM/L)	0.783 ± 0.064	0.717 ± 0.055*
Hematocrit (%)	37.7 ± 5.0	32.9 ± 4.2*
Albumin (g/dl)	3.79 ± 0.35	3.11 ± 0.51*
Urine magnesium (mM/L)		0.915 ± 0.701
FEMg (%)	2.4 ± 1.7	2.7 ± 1.9

Values are expressed mean ± SD. FEMg: Urinary magnesium excretion fraction = (UMg × PCr)/(0.7 × PMg) × UCr × 100 (%). *: $p < 0.05$ compared to preoperative value.

in Mg and iMg during the preoperative and postoperative measurements, which was calculated as ratio of the postoperative values over preoperative values. The Mg concentrations does not correlate with the iMg (correlation coefficient = 0.358, P = 0.052) (Fig. 1). The percent change of iMg correlated well with the percent change of albumin (correlation coefficient = 0.393, P = 0.032). The percent change of Mg correlated with blood loss, transfusion requirement and percent change of albumin (correlation coefficient = -0.465, -0.445, 0.4, P = 0.009, 0.014, 0.028) (Fig. 2). There was not a significant correlation between urine Mg and the percent changes of either iMg or Mg. The FEMg of preoperative and postoperative value was 2.4 ± 1.7% and 2.7 ± 1.9%, respectively.

DISCUSSION

Our results showed that both Mg and iMg levels decreased conservatively during spinal surgery. Place et al.[7] previously performed a study on this topic and reported a 70% incidence of total hypomagnesemia in patients who underwent spinal fusion surgery. It has been shown that hypomagnesemia occurs in 40% of hospitalized patients,[16] approximately 60% of postoperative patients,[6] 65% of medical intensive care unit patients, and in 90% of patients in the surgical intensive care unit.[17] The incidence of hypomagnesemia in our study seems to be very low, because the amount of fluid administration and transfusion might be less than other studies.

The etiologies of postoperative hypomagnesemia in patients undergoing spinal fusion are suggested as follows: First, hypomagnesemia may be dilutional as a result of an increased extracellular fluid volume.[18] In this study, the significant

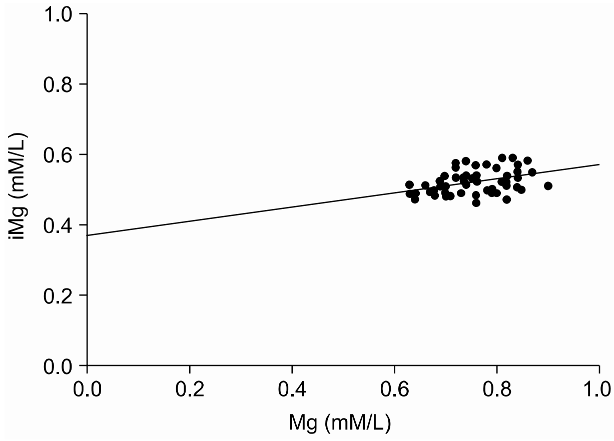

Fig. 1. Relationship between the changes in total magnesium (Mg) and ionized magnesium (iMg) concentrations. Correlation coefficient between Mg and iMg was 0.358 and P value was 0.052.

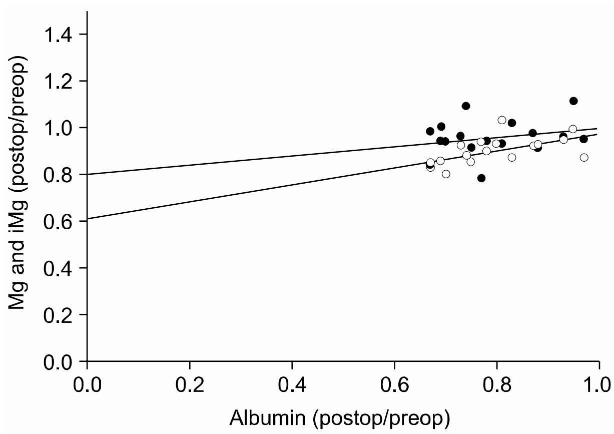

Fig. 2. Changes in total magnesium (Mg) and ionized magnesium (iMg) concentrations, compared to the changes of albumin concentration during surgery. ○: postoperative Mg concentration divided by preoperative Mg concentration, ●: iMg concentration divided by preoperative iMg concentration, Postop/Preop: Postoperative/Preoperative. Correlation coefficient between changes of Mg or iMg and changes of albumin concentration were 0.4 and 0.393, and P values were 0.028 and 0.032, respectively.

decrease in serum albumin reflects hemodilution by intravenous fluid administration. However, the relationship between iMg and Mg concentrations, in which both fractions were not affected to similar degree, support the theory that a simple dilutional mechanism is not enough to account for the hypomagnesemia. Ionized magnesium concentrations decreased to a lesser degree than Mg concentrations (3.4% vs 8.5%), a finding that is consistent to some degree with the active regulation of iMg levels. An iMg shift between the intracellular and extracellular compartments could have contributed to the changes in iMg concentrations. Mg from within the cell may have lessened the effect of extracellular dilution on serum iMg concentrations. The significance of extracellular redistribution of magnesium is unknown and remains a possible explanation for the changes in serum iMg.

Second, chelating with proteins or drugs such as citrate is another possible reason for the decrease in iMg.[19] Hypomagnesemia has been reported to be associated with massive transfusions.[20] The formation of citrate-magnesium salt from citrate included in blood administered during surgery is thought to be a possible reason for the decrease in the ionized fraction of magnesium. In this study we infused just small amount of blood; iMg is unlikely to be significantly affected by transfusion in this case. Another chelating agent in serum is albumin. Albumin has negative charge, so it has ability to bond to positively charged ion. The decrease in Mg concentrations correlated closely with the degree of hypoalbuminemia, indicating a reduction in the protein bound fraction of Mg. A decrease in albumin itself would in fact lead to a decrease in the protein bound fraction of Mg without affecting the iMg levels.

Third, causes of postoperative hypomagnesemia in patients undergoing spinal surgery may be due to excessive urinary magnesium loss from diuretics or surgical stress. If this were an important mechanism for hypomagnesemia, one would expect a correlation between the urine magnesium loss and a magnesium serum levels. However, urine Mg losses did not correlate with changes in either ionized or total serum magnesium levels. In hypomagnesemic patients with normal renal function, FEMg is a very useful diagnostic tool. A value more than 4% is indicative of inappropriate magnesium loss,[21] but our result showed FEMg was only 2.7%.

Although, further studies are needed to evaluate the relationship between hypomagnesemia symptom and magnesium concentration, we found the following characteristics regarding magnesium changes: Total and ionized magnesium concentrations decreased significantly (8.5% and 3.4%, respectively) as compared with preoperative values.

In conclusion, the incidence of total hypomagnesemia was 13%, but the incidence of ionized hypomagnesemia was only 3% after spinal surgery. And main cause of postoperative hypomagnesemia in spinal surgery might be a dilution effect, because chelation was negligible by minimal transfusion and low FEMg. Therefore, it will be better to waiting for fluid redistribution than magnesium replacement after spinal surgery.

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