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Change of Blood Magnesium Level in Diabetes Patients Undergoing Off-pump Coronary Artery Bypass Grafting

Si-Young Seo[1], Seong-Min Moon[2], Kyung-Yae Hyun[1], Chong-Rak Kim[2] and Seok-Cheol Choi[1,†]

[1]Department of Clinical Laboratory Science, College of Health Sciences, Catholic University of Pusan
[2]Department of Biomedical Laboratory of Science, College of Smart Foods and Drugs, Inje University

We carried out this study to investigate differences of physiological variables between patients with (DM group) and without type II diabetes mellitus (Non-DM group) undergoing off-pump coronary artery bypass grafting (OPCABG). Postoperative Mg^{++} and Ca^{++} levels were lower, whereas Na^{+} level was higher in DM group than those in Non-DM group. ICU (intensive care unit) stay time in DM group was longer than that of Non-DM group. Postoperative platelet counts tended to decrease, whereas C-reactive protein (CRP) and cardiac troponin-I (cTNI) levels tended to increase in DM group compared with Non-DM group. Postoperative albumin level was lower, while blood urea nitrogen (BUN) and creatinine levels were greater in DM group than those in Non-DM group. DM group had higher incidence of post-operative arrhythmias than Non-DM group. These results reveal that type II DM patients undergoing OPCAB may have higher incidences of postoperative hypomagnesemia, hypocalcemia and arrhythmias, and increases of CRP, cTNI, BUN, and creatinine levels than in Non-DM patients undergoing OPCAB. The perioperative check and control (supplement) of Mg^{++} levels should be considered in cardiovascular surgery combined with DM.

Key Words: Magnesium (Mg^{++}), Diabetes, Off-pump coronary artery bypass grafting (OPCAB)

INTRODUCTION

Magnesium (Mg^{++}) is the fourth most abundant cation in the body and the second most abundant intracellular cation after potassium. Mg^{++} is a pivotal ion that is essential for life and intimately involved in over 300 enzymatic reactions, including glucose metabolism, fatty acid synthesis and breakdown (Zaloga et al., 2000). Indeed, Mg^{++} intimately part takes in maintaining the ionic cellular balance. An accumulating line of evidence strongly indicates that magnesium plays an essential role in the function of the cell membrane sodium-potassium ATPase pump (Ferrari et al., 1986). Especially, Mg^{++} controls the movements of Na^{+}, K^{+} and Ca^{++} ion across the myocardial cell membrane, which inhibit cell excitation and maintain resting membrane potentials, leading to a stable condition for cardiovascular system (Dacey, 2001; Gums, 2004).

Mg^{++} is subdivided into three major compartments of the body; about 65% in the mineral phase of skeleton, 34% in the intracellular space, and only 1% in the extracellular fluid (Barbagallo et al., 2003). Small intestine is the main site for Mg^{++} absorption, whereas Mg^{++} excretion is mainly performed through renal pathways. Serum Mg^{++} exists in three form; a protein-bound fraction (25% bound to albumin and 8% bound to globulins), a chelated fraction (12%), and the metabolically active ionized fraction (Saris et al., 2000).

Any metabolic disorders and/or drugs cause Mg^{++} deficiency or loss. Most of drugs induce Mg^{++} wasting by inhibiting tubular reabsorption of magnesium. Moreover, magnesium deficiency may result in induced intracellular levels of ATP and potassium and increased intracellular levels of sodium and calcium (Dacey, 2001). However, higher intracellular Mg^{++} concentrations inhibit calcium transport into the cell and from the sarcoplasmic reticulum. Therefore, intracellular calcium levels rise significantly in hypomagnesemia (Dacey, 2001). Hypomagnesemia occurs

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†Corresponding author: Seok-Cheol Choi, Department of Clinical Laboratory Science, College of Health Sciences, Catholic University of Pusan, Busan 609-757, Korea.
Tel: 051-510-0564, Fax: 051-510-0568
e-mail: scchoi@cup.ac.kr

in 40% of hospitalized patients, approximately 60% of postoperative patients (Chernow et al., 1998), 65% of medical intensive care unit (ICU) patients (Zaman et al., 1997), and up to 90% of surgical ICU patients (Koch et al., 1996). Postoperative hypomagnesemia and arrhythmias such as atrial fibrillation and supraventricular tachycardia were observed in 60~70% of cardiovascular surgery patients (Hazelrigg et al., 2004).

Conventional coronary artery bypass grafting (CABG) has been performed with cardiopulmonary bypass (CPB). Heart-lung machine system for CPB includes hemodilution, Hartmann solution, citrate, diuretics (mannitol and furosemide), and another drugs. Such priming compositions may induce hypomagnesemia frequently after cardiovascular surgery. Some studies have reported that Mg^{++} administration at pre-, intra-, and post-operative periods prevents hypomagnesemia and secondary arrhythmias (McIntosh et al., 1989; Toraman et al., 2001). Nevertheless, today CABG without CPB (OPCAB) is universal and cardiovascular patients with diabetes mellitus (DM) are increasing. DM patients have hypomagnesemia due to magnesium wasting through urination (Barbagallo et al., 2003; Dacey, 2001).

There were little studies for changes of magnesium levels in OPCAB patients with DM. Thus, we carried out this study to determine the change of blood Mg^{++}, secondary alterations of other electrolytes and organ markers levels and to compare the differences between OPCAB patients with and without DM.

MATERIALS AND METHODS

1. Study population

From January 2005 to December 2007, seventy patients scheduled for OPCAB participated in this study; thirty five patients were OPCAB subject without DM (n=35, Non-DM group) and the rest of patients was OPCAB subject with type II DM (n=35, DM group). Patients were excluded if they had liver and renal disorders, ejection fraction <30%, previous cerebral problems, and arrhythmias such as atrial fibrillation.

2. Operative procedures

All of patients received general anesthesia. After median sternotomy, left internal mammary artery, left radial artery, and great saphenous vein were harvested from the all patients for OPCAB. 80~100 mg of heparin was intravenously injected and the heart was exposed. Cardiac apex were lifted for fixing appointed sites of anastomoses using cardiac holding apparatus (Octopus, Medtronic Inc., USA), and three vessels were anastomosed by one operator. After the anastomoses, blood flow were well reopened and 0.8~1.0 folds protamine of used heparin was administered.

1) Analyses of variables

Following variables were measured in all patients for comparing differences between the two groups.

2) Total leukocyte and platelet counts

Patients' total leukocyte (T-leukocyte) and platelet counts were measured by Auto Hematology Analyzer (BC-2800 ver., Shenzhen Mindary Bio-Medical Eletronics Co., Ltd., Germany) at pre-operative (Pre-OP), ICU, post-operative 24 hr (PO-24 hr), post-operative 48 hr (PO-48 hr) and post-operative 72 hr (PO-72 hr).

3) Blood magnesium and other electrolytes levels

Blood collected from patient's radial artery was analyzed for determining Mg^{++}, Ca^{++}, Na^{+} and K^{+} levels at pre-operative (Pre-OP), ICU, post-operative 3 hr (PO-3 hr), post-operative 12 hr (PO-12 hr), post-operative 24 hr (PO-24 hr), and post-operative 48 hr (PO-48 hr). Analysis instrument was Nova state profile M critical care analyzer (Nova Biomedical, Walthm MA, USA).

4) Biochemical and organ markers

Serum AST (aspartate aminotransferase), ALT (alanine aminotransferase), total protein, albumin, total bilirubin (liver markers), BUN (blood urea nitrogen), creatinine (renal markers), and cTNI (cardiac troponin-I) levels (cardiac marker) were measured at Pre-OP, ICU, PO-24 hr, and PO-48 hr. Biochemical markers in serum were analyzed by Autohumalyzer 9500 (Human Lab., Germany). cTNI was measured by Immunolgy autoanalyzer (Bayer, USA) with cardiac troponin-I kit (Bayer, USA).

5) Inflammatory marker

Serum CRP (C-reactive protein) level was analyzed at

Table 1. Demographic characteristics of the two groups

Characteristics	Group	
	Non-DM (n=35)	DM (n=35)
Gender (male : female)	25 : 10	22 : 13
Age (year)	60.48±8.78	62.62±9.32
Height (cm)	163.10±7.30	163.30±8.70
Weight (kg)	63.18±8.98	67.35±11.27
Body surface area (m^2)	1.68±0.14	1.72±0.17
Left ventricular ejection fraction (%)	60.06±8.59	54.64±13.28
Previous diagnosis (number of case)		
Hypertension	27 (77.14%)	23 (65.71%)
Hyperlipidemia	14 (40%)	7 (20%)
Left main tract disease	14 (40%)	14 (40%)
Stable angina	4 (11.42%)	3 (8.57%)
Unstable angina	25 (71.42%)	23 (65.71%)
Myocardial infarction	6 (17.14%)	9 (25.71%)
Pre-operative blood pressure (mmHg)		
Systole	121.34±15.61	125.60±16.22
Diastole	76.34±9.86	78.08±9.97
Pre-operative lipid profile (mg/dL)		
Total cholesterol	190.73±44.01	192.55±49.37
Triglyceride	170.62±90.84	132.55±87.93
High density lipoprotein-cholesterol	36.87±11.80	36.78±10.20
Low density lipoprotein-cholesterol	114.28±40.08	111.65±41.71
Pre-operative diabetes profile		
Fasting glucose (mg/dL)	111.88±15.53	220.85±105.50**
Hemoglobin A_1C (%)	6.08±0.91	8.02±1.97*
Fructosamine (umol/L)	210.40±10.13	295.50±68.11**

Data were expressed as mean ± standard deviation (SD) or percentage (%).
DM, diabetes mellitus.
*, P<0.05; **, P<0.01 (compared with Non-DM group)

Pre-OP and Pre-OP 7 day for assessment of inflammation in the two groups.

6) Postoperative incidence of arrhythmias

On the postoperative periods, incidence of arrhythmias was evaluated.

7) Data analysis and statistics

Most of variables were applied with unpaired t-test for comparing differences between the two groups. χ^2 test was used for evaluating incidence of arrhythmias. Statistical program was SPSS (version 12.0 K for Windows, SPSS Inc.) and Statistical significance was accepted with $P \leq 0.05$. Most of data were expressed as mean ± SD (standard deviation).

Table 2. Comparison of operative and postoperative data between the two groups

Variable	Group	
	Non-DM	DM
Operation time (min)	285.02±48.77	290.88±38.67
POMV time (hr)	16.77±2.95	17.51±7.31
ICU stay time (hr)	61.88±23.94	75.88±29.45*
Hospitalization (day)	17.60±7.00	19.40±8.12
PO 24 hr-BV (mL)	576.11±354.27	489.09±167.23
PO-blood transfusion (mL)		
Packed red blood cell	97.14±213.49	125.71±238.05
Fresh frozen plasma	51.42±190.00	40.00±116.82

Data were expressed as mean ± SD.
*, P<0.05 (compared with Non-DM group).
Abbreviation: POMV, post-operative mechanical ventilation; ICU, intensive care unit; PO, post-operative; BV, bleeding volume

RESULTS AND DISCUSSION

1. Characteristics of study population

Characteristics of study population were summarized in Table 1. Fasting glucose and hemoglobin A_1C levels and administrated amount of fructosamine were significantly higher in DM group than in Non-DM group, but there were not different in other variables between the two.

2. Perioperative data

Excepting the ICU stay time, there were no significances in other variables between the two groups (Table 2). ICU stay time in DM group was longer than that in Non-DM group (P<0.05). This finding suggests that cardiovascular disease combined with diabetes mellitus causes post-operative complication and prolonged ICU stay time. Prolonged ICU stay time may induce higher hospital coast and nosocomial infection, leading to increase of morbidity and mortality (Lee et al., 2008). Thus, cardiovascular disease patients combined with DM may be in need of an attentive perioperative care.

3. Total leukocyte and platelet counts

Table 3 shows perioperative results of total leukocyte

Table 3. Comparison of total leukocyte and platelet counts at pre and postoperative periods between the two groups

Sampling period \ Group \ Variable	Total leukocyte ($\times 10^3/\mu L$)	Platelet ($\times 10^6/\mu L$)
	Non-DM vs DM	Non-DM vs DM
Pre-OP	7.27±2.04 vs 7.26±1.88	250.22±58.64 vs 242.00±65.17
ICU	10.57±3.46 vs 9.66±3.31	154.80±43.79 vs 155.57±51.36
PO-24 hr	11.27±2.96 vs 11.34±3.37	191.34±57.95 vs 182.57±46.35
PO-48 hr	10.86±3.52 vs 10.89±3.68	170.57±54.07 vs 165.34±46.69
PO-72 hr	9.12±2.79 vs 8.97±3.67	214.48±102.76 vs 89.02±71.14

Data were expressed as mean ± SD.
There were no significant differences between the two groups (P>0.05)

Table 4. Comparison of blood coagulation test at perioperative period between the two groups

Variable \ Period \ Group	Non-DM vs DM	
	Pre-OP	ICU
PT (sec)	11.43±0.77 vs 11.53±0.85	13.96±1.01 vs 13.58±1.27
PT (INR)	0.96±0.05 vs 0.98±0.06	1.17±0.07 vs 1.15±0.09
aPTT (sec)	26.21±6.11 vs 27.05±8.05	31.72±5.25 vs 32.93±13.32
ACT (sec)	123.14±18.01 vs 123.88±15.62	124.77±13.58 vs 124.57±17.67

Data were expressed as mean ± SD.
There was no significant difference between the two groups (P>0.05).
Abbreviation: PT, prothrombin time; INR, international normalized ratio; aPTT, activated partial thromboplastin time; ACT, activated clotting time

and platelet counts in the two groups. Although there were no significances between the two groups, in platelet counts at post-operative periods, recovery rate to Pre-OP level was greater in Non-DM group than in DM group. Low magnesium levels promote coagulation and platelet aggregation. Magnesium has an antiplatelet effect that can reduce clotting by reducing thromboxane B2 synthesis. In this study, lower tendency of platelet counts in DM group may result from lower Mg^{++} levels in Non-DM group (Table 3). Besides, as everybody knows, slower recovery of platelet counts after cardiovascular surgery may cause post-operative bleeding, much transfusion, and prolonged ICU stay time (Lee et al., 2008). Finally, shorter operation time may need for improving postoperative recovery of cardiovascular surgery patients combined with DM.

4. Blood ionized magnesium

Fig. 1 reveals changes of blood ionized magnesium (Mg^{++}) levels in the two groups.

Preoperative Mg^{++} level was not different between the two groups. However, Mg^{++} levels in ICU, PO-6 hr, PO-12 hr, and PO-24 hr were lower in DM group than those in Non-DM group (P<0.01), while that in Non-DM group showed faster recovery to Pre-OP level compared with DM

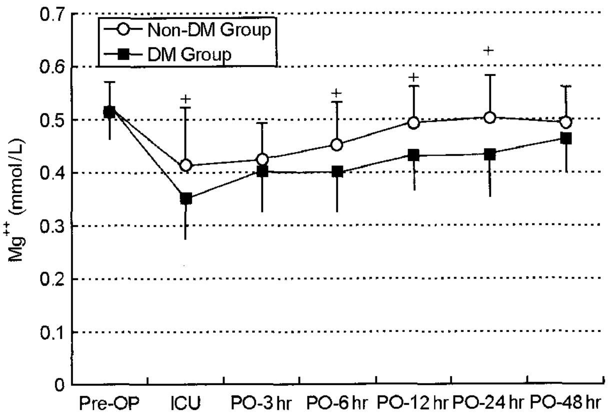

Fig. 1. Changes of Mg^{++} levels in Non-DM and DM group during seven phases of perioperation. Mg^{++} levels in DM group were lower than those in Non-DM group at the other periods exception with the exception of Pre-OP and PO-48 hr phases (+, P<0.01). Pre-OP=before operation, ICU=intensive care unit; PO-3 hr = 3 hr after termination of operation, PO-6 hr = 6 hr after termination of operation, PO-12 hr = 12 hr after termination of operation, PO-24 hr = 24 hr after termination of operation, PO-48 hr = 48 hr after termination of operation.

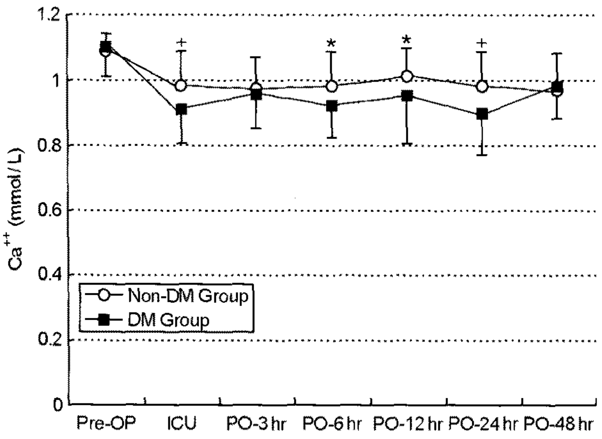

Fig. 2. Changes of Ca^{++} levels in the two groups during seven phases of perioperation. Ca^{++} levels in DM group were lower than those in Non-DM group at ICU, PO-6 hr, PO-12 hr, and PO-24 hr phases (*, $P<0.05$, +, $P<0.01$).

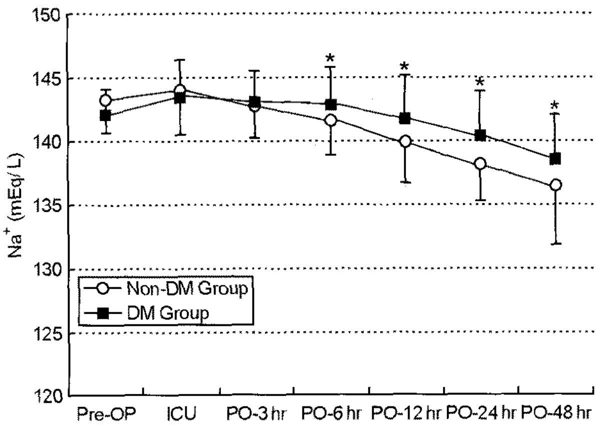

Fig. 3. Changes of Na^{+} levels in the two groups during seven phases of perioperation. Na^{+} levels in DM group were higher than those in Non-DM group at PO-6 hr, PO-12 hr, PO-24 hr, and PO-48 hr phases (*, $P<0.05$)

group. Even though, to date, mechanisms of perioperatively lower Mg^{++} level in OPCAB patients combined with DM (DM group) have been poor understood, adverse effects of hypomagnesemia or Mg^{++} deficiency have been well known. Renal tubular reabsorption of Mg^{++} is decreased in presence of sever hyperglycemia (McNair et al., 1982). Chronic Mg^{++} deficiency is associated with multifocal cellular necrosis, accumulation of intracellular calcium, increased platelet aggregation, coronary vasoconstriction, atherogenesis, and cardiac arrhythmia (Baxter et al., 1996).

In this present, postoperatively slower recovery of platelet counts in DM group may be attributed to lower Mg^{++} level. Mg^{++} improves endothelial function (Shechter et al., 1999), protects against the deleterious effects of reactive oxygen species, and inhibits calcium overload occurs after ischemia-reperfused myocardium (Woods et al., 1992). Especially, because peri-operative coronary artery spasm still remains a serious problem in OPCAB, it is clinically important that hypomagnesemia in DM group is one of the triggers of coronary artery spasm after OPCAB. Mg^{++} has strong vasodilator properties (Arsenian, 1993). Such actions of hypomagnesemia may contribute to coronary artery spasm after OPCAB.

Therefore, in OPCAB patients combined with DM, peri-operative control of Mg^{++} level is very important consideration. Mg^{++} administration has been reported to protect the myocardium against ischemia and reduce reperfusion injury (Shattock, 1997). In addition, clinical studies have demonstrated that Mg^{++} supplement reduces acute platelet-dependent thrombosis (Shechter et al., 1999). Recently, Moon et al. (Moon et al., 2007) also demonstrated that peri-operative Mg^{++} supplement ameliorates inflammation and myocardial damage.

On the other hand, Koch et al. reported that 18% of ICU patients had decline of total serum Mg^{++}, 21% of ICU patients had decreased Mg^{++}, and 14.7% of ICU patients decreased iMg^{++} together with normal level of total serum Mg^{++}. Thus, for regulating patient's Mg^{++} level in ICU, we should measured ionized magnesium (Mg^{++}, physiologically active type) other than total serum magnesium level. In plasma, is magnesium found as a protein-bound and a free, ionized form. The ionized, free magnesium (iMg^{++}) is the most physiologically important fraction because it regulates electrolyte transport, the production of cellular energy, and the activity of membrane pumps.

5. Other electrolytes levels

Ca^{++} and Na^{+} levels showed diverse changes at perioperative periods (Fig. 2 and 3). Ca^{++} levels in DM group were lower ($P<0.05$ or $P<0.01$), whereas Na^{+} levels in DM group were higher than those in Non-DM group at peri-operative periods ($P<0.05$). Many calcium channels are Mg^{++} dependent. Higher higher intracellular Mg concentrations inhibit calcium transport into the cell and from the sarcoplasmic reticulum. Therefore, intracellular calcium levels rise significantly in hypomagnesemia (Dacey, 2001). Mg^{++} deficiency may result in reduced intracellular levels of ATP and potassium and increased intracellular levels of sodium and calcium (Dacey, 2001). Patients with hypomagnesemia often have calcium deficiency (Al-Ghamdi et al., 1994; Flatman et al., 1981). Thus, lower Ca^{++} levels in DM group resulted from decreased Mg^{++} levels. Low Ca^{++} levels may induce decrease of cardiac contraction.

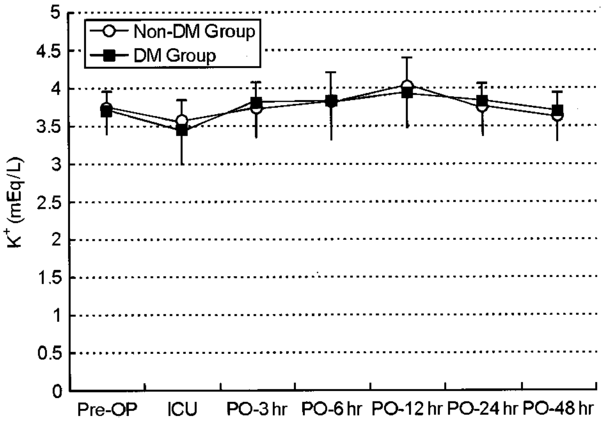

Fig. 4. Changes of K^+ levels in the two groups during seven phases of perioperation. There were no significant differences between two groups at any sampling times (P>0.05).

Finding of this study reveals that DM group has higher Na^+ levels compared Non-DM group at PO-6 hr, PO-12 hr, PO-24 hr and PO-48 hr. This observation may reflect declined renal function in DM patients because DM often lead to renal disorder. Although perioperatively Na^+ levels in DM group were within normal range, if OPCAB patients combined with DM have higher Na^+ levels, they may suffer retention of body fluid and second edema with complications at post-operative periods. Such conditions may cause slower patient's recovery, prolonged ICU stay time, and increased morbidity and mortality.

In K^+ levels, there were no significant differences between the two groups at any sampling times (Fig. 4). Previous studies suggested that Mg^{++} deficiency often leads to hypokalemia (Al-Ghamdi et al., 1994). One explanation may be a possible of potassium supplement by patient's physician for the correction of hypokalemia. The most of frequent treatment postoperatively in ICU is potassium supplement for regulating potassium level. However, further studied should be needed for clarifying the discrepancy between this study and other studies.

Table 5. Comparison of biochemical markers at perioperative periods between the two groups

Group / Period / Variable	Non-DM vs DM			
	Pre-OP	ICU	PO-24 hr	PO-48 hr
Total-protein (mg/dL)	6.98±0.64 vs 6.82±0.61	4.30±0.55 vs 4.26±0.55	5.30±0.50 vs 5.18±0.66	5.56±0.58 vs 5.36±0.52
Albumin (mg/dL)	4.15±0.51 vs 4.03±0.38	2.68±0.30 vs 2.62±0.39	3.38±0.29 vs 3.27±0.34	3.44±0.28 vs 3.26±0.28*
AST (U/L)	29.34±19.15 vs 30.45±15.84	29.22±18.45 vs 25.82±12.67	46.74±26.86 vs 50.11±69.10	41.74±22.43 vs 43.14±59.53
ALT (U/L)	36.68±32.06 vs 36.68±26.49	29.45±22.70 vs 23.77±13.56*	37.62±25.86 vs 29.20±13.39	40.94±29.04 vs 30.17±15.28
Total-bilirubin (mg/dL)	0.65±0.30 vs 0.63±0.29	0.76±0.30 vs 0.74±0.26	0.87±0.41 vs 0.86±0.41	0.68±0.32 vs 0.64±0.25
BUN (mg/dL)	15.05±4.36 vs 19.14±9.31**	12.05±3.10 vs 14.28±7.56	13.62±3.16 vs 7.20±8.63*	13.14±4.55 vs 19.40±10.03**
Creatinine (mg/dL)	1.01±0.19 vs 1.05±0.39	0.70±0.16 vs 0.78±0.30	0.87±0.19 vs 0.96±0.37	0.86±0.19 vs 1.03±0.43*
Troponin-I (ng/mL)	0.45±1.64 vs 0.54±1.18	1.74±2.10 vs 2.16±2.44	5.15±5.74 vs 5.96±6.53	4.17±3.47 vs 4.70±8.04

Data were expressed as mean ± SD.
*, P<0.05; **, P<0.01 (compared with Non-DM group).
Abbreviation: AST, aspartate aminotransferase; ALT, alanine aminotransferase; BUN, blood urea nitrogen

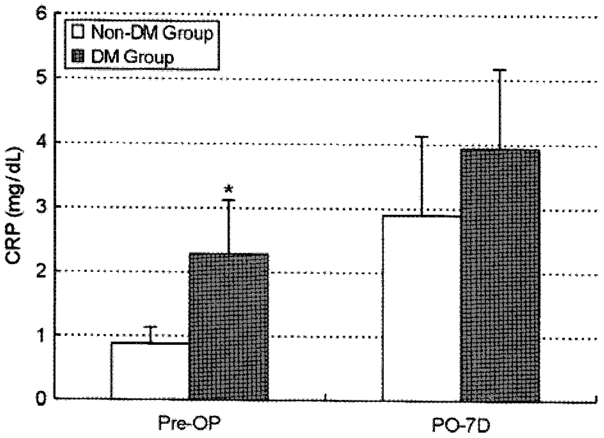

Fig. 5. Changes of C-reactive protein (CRP) levels in the two groups during two phases of perioperation. CRP level at Pre-OP was significant higher in DM group than in Non-DM group (*, $P<0.05$). There was no differences between two groups at PO-7D, but increased tendency ($P>0.05$). PO-7D=postoperative 7 day.

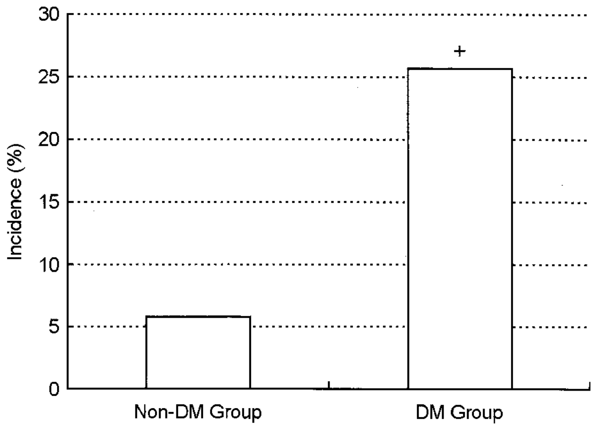

Fig. 6. Incidence of postoperative arrhythmias in the two groups. Incidence of post-operative arrhythmias in DM group was higher than that in Non-DM group (+, $P<0.01$).

6. Biochemical and cardiac marker

Changes of biochemical and cardiac marker levels in the two group were summarized in Table 5. Although DM group had lower albumin level compared Non-DM group ($P<0.05$ or $P<0.01$), in other liver markers (total protein, AST, ALT, and total bilirubin), there were no significance between the two groups. BUN levels in DM group were higher than those in Non-DM group through sampling periods. Creatinine level was higher in DM group than in Non-DM group ($P<0.05$). BUN and creatinine represent renal function and thus, this result reflects that Non-DM group had possible depression of kidney function at pre- and postoperative periods. Many studies demonstrated that patients with type II DM endure renal tubular injury and renal dysfunction, leading to hypomagnesemia due to excessive extraction of Mg^{++} (Dacey, 2001; Gums, 2004).

Despite of no difference between the two groups ($P>0.05$), troponin-I (cTNI) levels in DM tend to be increased through all sampling periods. This finding indicates that cardiovascular patients combined with DM may have higher myocardial injury compared with Non-DM patients. However, this opinion should be determined by further studies. Mg^{++} may limit myocardial damage, perhaps by inhibiting calcium influx into ischemic myocardial cells (Ferrari et al., 1986). Mg^{++} may reduce coronary artery tone, thus improving distal blood flow to ischemic myocardium and membrane stabilization (Flatman et al., 1981; Herzog et al., 1996). These pathologic mechanisms contribute to higher cTNI levels at peri-operative periods in DM group.

7. C-reactive protein (CRP)

CRP level at Pre-OP (baseline) was higher in DM group than in Non-DM ($P<0.05$) and it at PO-7D also was so high, but not significant ($P>0.05$, Fig. 5). Some authors shown a potential neuroprotective and anti-inflammatory reaction of Mg^{++} in animal models (McIntosh et al., 1989). Pakfetrat et al., habe been recently demonstrated that there was a significant negative correlation between serum Mg^{++} and serum CRP in hemodialysis patients. Mg^{++} deficiency has been hypothesized to active macrophages and enhance the inflammatory response (Weglicki et al., 1992). These observations imply that hypomagnesemia is responsible for inflammatory reaction. Thus, our finding suggests that hypomagnesemia in DM group has higher CRP levels compared with Non-DM group at peri-operative periods.

8. Incidence of post-operative arrhythmias

Fig. 6 shows incidence of post-operative arrhythmias. Incidence of post-operative arrhythmias in DM group (25.71%, 9 of 35 patients) was higher than that in Non-DM group (2%, 2 of 35 patients) ($P<0.05$). Type of post-operative arrhythmias in DM group includes atrial fibrillation (4 patients), ventricular fibrillation (1 patient), premature ventricular contraction (1 patient), sinus tachycardia

(2 patients), and sinus bradycardia (1 patient). Higher incidence of post-operative arrhythmias in DM group is attributable to postoperative hypomagnesemia. As shown in this study, atrial fibrillation (AF) is a common complication of cardiovascular surgery (Hoeldtke et al., 1985). The mechanisms of the high incidence of AF observed after OPCAB and noncardiac thoracic surgery are not well understood and controversial. Two factors have been consistently related to the development of postoperative AF. These are advanced age and pre-operative withdrawal of β-adrenoceptor antagonist therapy (McNair et al., 1982). advancing age is associated with increasing norepinephrine level, and one postulated reason for this is increasing sympathetic outflow (Hoeldtke et al., 1985). It has also previously been demonstrated that taking β-adrenoceptor antagonists may have elevated circulating norepinephrine levels (de Leeuw et al., 1977). These data indicate that sympathetic activation may be important in the pathogenesis of AF after cardiac and noncardiac surgery. Noradrenaline, through β-adrenergic stimulation and increase of cyclic adenosine monophosphate (AMP), stimulates a large efflux of Mg^{++} from cardiac cells. This transport is major dimensions and can move up to 20% of total cellular Mg^{++} within a few minutes (Romani et al., 1990). Magnesium suppresses catecholamine-induced abnormal pacemaker activity and has the potential to prevent cardiac arrhythmias, the mechanisms of which are increased automaticity and reentry circuits (Hasegawa et al., 1989; Wesley et al., 1989). Lower serum Mg^{++} levels as well as lower myocardial Mg^{++} concentrations were found to be associated with increased incidences of AF (Zaman et al., 1997). Finally, in this study, decreased Mg^{++} levels in DM group might induce higher post-operative arrhythmias compared with Non-DM group.

In conclusion, OPCAB patients combined with diabetes may favor possible of peri-operative Mg^{++} loss and thus, peri-operative check and control of blood Mg^{++} level should be done for them. However, because overzealous correction of serum Mg^{++} can lead to undesirable side effects, such as hypotension, depression of patellar reflexes, nausea, flushing, somnolence, weakness, and prolonged intubation, its appropriate supplement or correction should be determined by further studies.

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