Acta Clin Croat 2009; 48:19-26 Original Scientific Paper

THE ANALGESIC EFFECT OF MAGNESIUM SULFATE IN PATIENTS UNDERGOING THORACOTOMY

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SUMMARY – Magnesium can act as an adjuvant in analgesia due to its properties of calcium channel blocker and *N*-methyl-D-aspartate antagonist. The aim of our study was to determine if magnesium sulfate reduces perioperative analgesic requirements in patients undergoing thoracotomy procedure. Our study included 68 patients undergoing elective thoracotomy that received a bolus of 30-50 mg/kg $MgSO_4$ followed by continuous infusion of 500 mg/h intraoperatively and 500 mg/h during the first 24 hours after the operation, or the same volume of isotonic solution (control group). Intraoperative analgesia was achieved with fentanyl and postoperative analgesia with a mixture of fentanyl and bupivacaine through epidural catheter. The level of pain was estimated using Visual Analog Scale (VAS) and TORDA pain scales. Fentanyl consumption during the operation was significantly lower in the magnesium treated group compared to control group. There was no statistically significant difference in epidural bupivacaine and fentanyl consumption during 48 hours postoperatively between the magnesium treated and control group. The measured VAS score at all intervals was similar in both groups. Postoperative TORDA scores were similar in both groups during the first 24 hours; however, a statistically significant difference was recorded in 40-48 h measurements. Results of our study revealed that magnesium reduced intraoperative analgesic requirements and also contributed to effective control of the static component of postthoracotomy pain.

Key words: *Magnesium sulfate – therapeutic use; Pain, postoperative – therapy; Analgesics, opioid – therapeutic use; Thoracotomy*

Introduction

Thoracotomy is often performed in patients with preexisting lung disease such as lung cancer and chronic obstructive pulmonary disease. Therefore, this type of surgery is associated with the potential of severe pain, further impairment of lung function, delayed recovery and occurrence of chronic pain syndrome. To be able to understand why thoracotomy is associated with severe pain and therefore the necessity for high quality analgesia, it is important to understand the pathophysiology of tissue damage arising from thoracotomy procedure[1,2].

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Received November 28, 2008, accepted January 11, 2009

Incision following thoracotomy is more painful than most other surgical incisions because of the extensive innervation pathways of the anatomic structures that are damaged during the operation and because of continuous movement of the chest wall with respiration and coughing that is acting as a repetitive pain stimulus. The postthoracotomy pain is classified as somatic and visceral nociceptive and neuropathic, static and dynamic pain of highest intensity[3-5]. Effective perioperative analgesia may facilitate recovery and reduce morbidity by blunting autonomic, somatic and endocrine reflexes. Although thoracic epidural analgesia with local anesthetic and opioid is often regarded as a gold standard, increased evidence indicates that the use of *N*-methyl-D-aspartate (NMDA) antagonist will augment the action of basic analgesics[6-8].

Magnesium is the fourth most common mineral salt in human body and the second intracellular cation. Magnesium plays an important role in the structure and function of human body. It is important for most biological processes including supply with cellular energy and synthesis of nuclear acids and proteins, maintenance of electrical stability and cellular integrity preservation. Magnesium also contributes to muscle contraction, conduction of neuronal and pain impulses, and vascular tone regulation. Magnesium action as a calcium channel blocker and NMDA receptor antagonist could play an important role in postoperative pain, sensitization processes and hyperalgesia throughout the early postoperative period[9-14]. Despite the promising initial work, further clinical studies did not report consistent results on magnesium action as an adjuvant in perioperative analgesia[15-18].

The aim of our study was to assess whether the addition of intravenous magnesium sulfate during the operation and early postoperative period would result in improved perioperative analgesic efficiency and reduced analgesic requirements in patients undergoing thoracotomy procedure.

Material and Methods

Approval for this prospective, randomized double blind study was granted by the local ethics committee and written information was administered to the patients, who then gave their written informed consent. Sixty eight patients (53 male and 15 female) aged 25-76 (mean age 56.8) years, ASA physical status I-III, scheduled for elective thoracotomy were enrolled in the study. Exclusion criteria were allergy to magnesium sulfate or any other drug used in the study, major hepatic or renal failure, presence of neurologic disease, degree II-III AV block, extreme obesity, and treatment with opioids or calcium channel blockers.

All patients enrolled in the study received 7.5 or 15 mg of midazolam orally 1 hour before surgery as preoperative premedication. The patients with ASA physical status III and patients aged >65 received 7.5 midazolam orally 1 hour before surgery as preoperative premedication, and other patients received 15 mg midazolam. The dose of 5 mg bupivacaine was given to the patients classified as ASA physical status III and those aged >65.

Upon arrival in the operating room, ECG, invasive arterial pressure and pulse oximetry monitoring were established. Bispectral index (BIS) was used to assess the level of patient sedation; awareness and neuromuscular block were monitored using a TOF (train of four) peripheral nerve stimulator.

Fifteen minutes before induction of anesthesia, all patients received 2 μg/kg fentanyl with 5-10 mg 0.5% bupivacaine through epidural catheter (Th 4-Th 6). Induction was achieved with midazolam 0.03-0.05 mg/kg, fentanyl 2-4 μg/kg, propofol 0.8-1 mg/kg. Rocuronium (0.7-0.9 mg/kg) was given to facilitate orotracheal intubation. The patients classified as ASA III and patients aged >65 received lower doses of anesthetic agents.

After induction the patients were randomly assigned in a double blind fashion to one of the two groups:

- patients in the magnesium group received intravenously a bolus dose of 30-50 mg/kg 10% $MgSO_4$ in 100 mL of isotonic saline before skin incision, followed by continuous infusion of 500 mg/h $MgSO_4$ by perfusor (Braun, Melsungen, Germany);
- control group of patients received the same volume of isotonic saline.

The anesthesiologist was unaware of which solution was administered. Anesthesia was maintained with continuous infusion of propofol. Propofol effect-site target concentrations were adjusted to maintain BIS at 40-60 and adequate muscle relaxation TOF=1 was achieved with continuous infusion of rocuronium. Adequate analgesia was maintained with bolus doses of fentanyl 1-2 μg/kg if an increase in the mean arterial pressure or heart rate by more than 20% of preanesthetic values was noticed. Patients were ventilated with oxygen and nitrous oxide (FiO_2=0.5) and ventilator settings were adjusted to maintain normocapnia. At the end of the operation, antagonism of neuromuscular blockade was achieved with 0.01 mg/kg atropine followed by 0.025 mg/kg prostigmine.

During their 48-h stay at intensive care unit, all patients received continuous infusion of fentanyl 10 μg/mL with bupivacaine 1 mg/mL through epidural catheter. The magnesium group was also given continuous infusion of 10% $MgSO_4$ 500 mg/h for the first 24 hours of the operation, while control group received isotonic saline.

A standardized, horizontal 10-cm linear visual analog scale (VAS) and TORDA scale (0-3 points) were used to assess pain at rest and during deep breathing or coughing every four hours or more often if necessary. The rate

Table 1. Demographic data of patient groups

	Mg group	Control group	*t*-value	*P*-value	N 1	N 2	SD 1	SD 2
Age (yrs)	55.9	57.8	0.70442	0.483648	35	33	9.9	11.4
Weight (kg)	80.9	78.3	0.71547	0.476844	35	33	15.8	13.4
Systolic blood pressure (mm Hg)	138	139	–0.278127	0.781785	35	33	17	19
Diastolic blood pressure (mm Hg)	76	78	–0.978205	0.331545	35	33	10	12
Oxygen saturation (%)	94.9	95.3	–0.866679	0.389258	35	33	1.98	2.01

of epidural infusion was adjusted to maintain VAS score ≤3. Total amount of fentanyl administered during operation and total amount of fentanyl and bupivacaine administered during 48 h postoperatively were recorded for each patient. Blood samples for serum magnesium concentration determination were obtained before and just after the surgery and every 8 h during the first 24 hours.

In intensive care unit, hemodynamic and respiratory functions of the patients were monitored and complications recorded.

Statistics

Continuous variables such as demographic data were analyzed using Student's t-test. Ordinal data (VAS and TORDA values) were analyzed using Mann-Whitney U test. Kruskal-Wallis ANOVA test was used for comparison of two groups and Tukey posthoc HSD test for determination of differences between the two groups. A P value of <0.05 was considered statistically significant.

Results

Sixty eight patients of both sexes, 15 (22.1%) of them female, mean age 56.8 (±10.6) years, were enrolled in the study. Magnesium group included 35 patients, eight (22.9%) of them female, and control group 33 patients, seven (21.2%) of them female. Patient characteristics of both groups are summarized in Table 1. Data are expressed as mean values ± SD. Both groups were comparable with respect to age, weight, initial hemodynamic parameters of systolic and diastolic blood pressure, and oxygen saturation (Table 1).

Intraoperative fentanyl consumption is illustrated in Table 2. Values are mean ±SD. Analysis of fentanyl consumption during operative procedure revealed that patients in magnesium treated group consumed significantly less ($P<0.005$) fentanyl than control group.

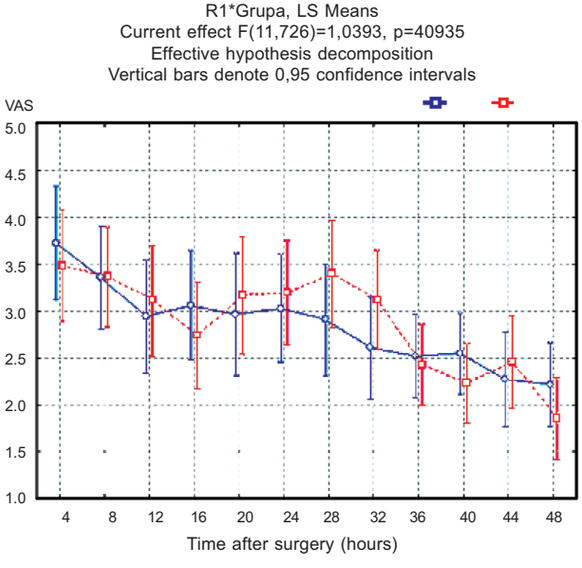

Fig. 1. VAS scores measured every 4 h during 48 h postoperatively.

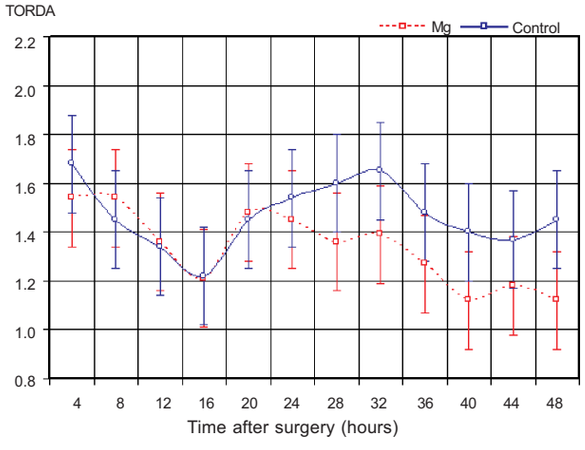

Fig. 2. TORDA pain scores measured during deep breathing and coughing every 4 h during 48 h postoperatively.

Table 2. Intraoperative opioid fentanyl consumption

	Mg group	Control group	*t*/*z**-value	*P*-value	N 1	N 2	SD 1	SD 2
Added fentanyl (μg)	0.164	0.248	–3.13183	0.002589	35	33	0.1040	0.1176
Added fentanyl (μg/kg)	0.002	0.003	–2.93408	0.004597	35	33	0.0015	0.0018
Cumulative dose of fentanyl (μg)	0.389	0.545	–5.90139	0.000000	35	33	0.1008	0.1182
Cumulative dose of fentanyl (μg/kg)	0.005	0.007	–5.65948	0.000000	35	33	0.0014	0.0018

Table 3. VAS score measured every 4 h during 48 h postoperatively

	Mg group	Control group	*t*-value	*P*-value	N 1	N 2	SD 1	SD 2
VAS-4	3.5	3.7	–0.56	0.57	35	33	1.771862	1.754863
VAS-8	3.4	3.4	0.02	0.98	35	33	1.733506	1.410190
VAS-12	3.1	2.9	0.41	0.68	35	33	1.966954	1.498737
VAS-16	2.7	3.1	–0.78	0.44	35	33	1.820518	1.519445
VAS-20	3.2	2.9	0.44	0.66	35	33	2.079108	1.629510
VAS-24	3.2	3.0	0.42	0.68	35	33	1.875539	1.402784
VAS-28	3.4	2.9	1.19	0.24	35	33	1.912805	1.444032
VAS-32	3.1	2.6	1.34	0.19	35	33	1.693785	1.412874
VAS-36	2.4	2.5	–0.28	0.78	35	33	1.378100	1.175830
VAS-40	2.2	2.5	–1.05	0.30	35	33	1.456945	0.971175
VAS-44	2.5	2.3	0.52	0.61	35	33	1.754706	1.097518
VAS-48	1.9	2.2	–1.13	0.26	35	33	1.593052	0.857233

VAS scores measured every 4 hours during the first 48 hours are shown in Table 3 and Fig. 1. VAS scores measured at all intervals were similar in both groups throughout the first 48 hours postoperatively and there was no statistically significant difference between the two groups.

TORDA scores of pain measured during deep breathing and coughing every 4 h during 48 h postoperatively are shown in Table 4 and Fig. 2. Postoperative TORDA scale scores were similar in both groups in the first 24 hours. Pain scores recorded at 24-48-h were slightly higher in control group, but the difference was not statisti-

Table 4. TORDA scores measured during deep breathing and coughing every 4 h during 48 h postoperatively

	Mg group	Control group	*t*-value	*P*-value	N 1	N 2	SD 1	SD 2
TORDA-4	1.5	1.7	0.75	0.46	33	35	0.753778	0.795998
TORDA-8	1.5	1.5	–0.52	0.60	33	35	0.616994	0.780002
TORDA-12	1.4	1.3	–0.12	0.90	33	35	0.603023	0.764771
TORDA-16	1.2	1.2	0.11	0.91	33	35	0.545297	0.689660
TORDA-20	1.5	1.5	–0.15	0.89	33	35	0.618527	0.918530
TORDA-24	1.5	1.5	0.53	0.60	33	35	0.616994	0.741337
TORDA-28	1.4	1.6	1.55	0.13	33	35	0.603023	0.650791
TORDA-32	1.4	1.7	1.74	0.09	33	35	0.555619	0.683540
TORDA-36	1.3	1.5	1.42	0.16	33	35	0.574060	0.658493
TORDA-40	1.1	1.4	1.99	0.05	33	35	0.545297	0.603909
TORDA-44	1.2	1.4	1.22	0.23	33	35	0.682575	0.598317
TORDA-48	1.1	1.5	2.29	0.03	33	35	0.545297	0.657216

Table 5. Consumption of epidural bupivacaine and fentanyl during 48 h postoperatively

	Mg group	Control group	t/z*-value	P-value	N 1	N 2	SD 1	SD 2
Epidural fentanyl (μg)	0.107	0.105	1.37653*	0.262438*	35	33	0.0373	0.0146
Epidural fentanyl (μg/kg)	0.001	0.001	1.13425*	0.783594*	35	33	0.0000	0.0000
Epidural bupivacaine (mg)	10.000	10.000			35	33	0.0000	0.0000
Epidural bupivacaine (mg/kg)	0.129	0.131	–0.38428	0.702009	35	33	0.0287	0.0221

Table 6. Preoperative and postoperative serum magnesium concentrations measured during 24 h in two study groups

	Mg group	Control group	*z*-value	*P*-value	N 1	N 2	SD 1	SD 2
Mg before surgery	0.9	0.8	1.28	0.20	35	33	0.207567	0.061169
Mg after surgery	1.2	0.7	6.74	0.00	35	33	0.197162	0.061632
Mg 8 h after surgery	1.3	0.8	6.50	0.00	35	33	0.277797	0.149207
Mg 16 h after surgery	1.2	0.7	7.07	0.00	35	33	0.139884	0.080458
Mg 24 h after surgery	1.3	0.7	6.90	0.00	35	33	0.182143	0.127364

cally significant. The last TORDA pain scores measured at 40 h and 48 h were statistically significantly higher in control group ($P=0.025$). Postoperative consumption of epidural bupivacaine and fentanyl during 48 h is shown in Table 5. There was no statistically significant difference in epidural bupivacaine and fentanyl consumption during 48 h postoperatively between the magnesium treated and control group.

Serum magnesium concentrations measured preoperatively and during the first 24 h of the operation are shown in Table 6. Preoperative magnesium concentration was similar in both groups. As expected, 24 h postoperatively serum magnesium concentration was significantly higher in the magnesium treated group ($P<0.001$), however, all values were within the normal range (0.7-1.3 mmol/L).

Discussion

This prospective, randomized, double blind study was designed to assess the effects of magnesium sulfate on perioperative fentanyl consumption, postoperative epidural fentanyl and bupivacaine consumption, and postoperative analgesia in patients undergoing thoracotomy.

The main results of the study demonstrated that 30-50 mg/kg magnesium sulfate given as a bolus before the skin incision followed by infusion of 500 mg/h magnesium sulfate intraoperatively induced an analgesic-sparing effect as shown by the significant decrease in fentanyl consumption during the operation ($P<0.001$).

Many studies confirmed the efficacy of opioid sparing effect in patients given magnesium sulfate perioperatively. In their study in patients undergoing vitrectomy, Schulz-Stubner *et al.*[19] recommended the use of magnesium sulfate as a safe analgesic adjuvant. Magnesium is well known for its action as a physiologic calcium channel blocking agent while also inhibiting the neurotransmitter and katecholamine release. Based on this evidence, Schulz-Stubner *et al.* conclude that one of the mechanisms described is responsible for lower intraoperative opioid consumption[19].

On the other hand, in a very recent investigation, Ryu *et al.* showed that the infusion of magnesium sulfate during TIVA with propofol and remifentanil did not reduce propofol infusion while remifentanil consumption was not changed significantly[20]. Seyhan *et al.* compared the effects of magnesium sulfate on intraoperative fentanyl consumption in patients undergoing gynecologic procedure and found no between-group difference[21].

However, there are two possible mechanisms of the magnesium adjuvant analgesic effect. The first theory includes activation of NMDA receptors. NMDA receptor is an amino acid receptor responsible for excitatory synaptic transmission with binding sites positive for excitatory amino acid glutamate and negative for ketamine or magnesium. The activation of pain pathways is explained by stimulation of NMDA receptors of dorsal

horn with excitatory neurotransmitters, initiating the process of central sensitization[22,23].

In the present study, we administered a dose of magnesium that was most likely to achieve the effect without any adverse reaction. We assumed the dose of magnesium administered in our study to be responsible for the rise in its cerebrospinal fluid concentration, therefore depressing the electrophysiologic effect of NMDA receptors. The second theory includes the action of magnesium as a calcium channel antagonist. The analgesic effect of calcium channel antagonists could be mediated by a rise in the nociceptive threshold because of calcium influx into the cell. This calcium influx is responsible for the release of neurotransmitters connected with nociception and inflammatory response[22]. In our study, the pain levels measured by use of VAS were similar at all measurement intervals in both groups throughout the first 48 hours postoperatively, without any statistically significant difference. Postoperative TORDA scale scores were also similar in the two groups in the first 24 hours. At 24-48 h, the measured pain values were slightly higher in the control group, however, the difference was not statistically significant. The last TORDA pain score measurement at 40 h and 48 h yielded a statistically higher level in the control group (P=0.025)

There are many techniques to achieve adequate postthoracotomy analgesia, but epidural analgesia is considered as the "gold standard" because of its superiority in comparison with intercostal or intrapleural regional techniques or use of systemic opioids[24]. In our study, the VAS pain score at rest during the first 24 h of about 3 and subsequently less than 3 confirmed the combination of the local anesthetic bupivacaine and potent opioid fentanyl to provide efficient control for static postthoracotomy pain.

The TORDA pain score measurements between 1 and 2 reported in the magnesium and control group confirmed the need of better control of dynamic postthoracotomy pain, especially on coughing in both groups. The lower values of TORDA pain intensity score in the magnesium group at all measurement intervals may have resulted from its action as a non-competitive NMDA receptor antagonist. The propagation of intense nociceptive stimuli during deep breathing and coughing after thoracotomy could be modulated by limiting NMDA mediated facilitating processes.

In our study, there was no statistically significant difference in cumulative epidural doses of fentanyl and bupivacaine postoperatively between the magnesium treated and control group patients. Intravenous administration of magnesium during 24 h postoperatively did not reduce bupivacaine and fentanyl consumption and had no analgesic sparing effect in thoracotomy patients.

One of the possible explanations for persistence of pain during the postoperative period is activation of dorsal horn NMDA receptors with excitatory transmitters, which in turn leads to calcium entry into cell initiating the cascade of central sensitization. Because magnesium has been known to produce a voltage-dependent blockade of NMDA receptors, its potential analgesic effects on postoperative analgesic consumption have been widely investigated and reported in the literature[13,16,19,25-28]. Tramer *et al.* report that patients undergoing lower abdominal surgery with magnesium supplementation consumed by 30% less morphine in the postoperative period compared with control group[25]. Similar to these clinical trials, several studies demonstrated significant reduction in postoperative fentanyl, morphine and piritramide consumption after knee, uterus and lumbar operation[15,16,26].

On the other hand, in a very recent investigation Ryu *et al.* showed that the infusion of magnesium sulfate during TIVA with propofol and remifentanil did not reduce propofol infusion while remifentanil consumption was not changed significantly either peri- or postoperatively[20]. Seyhan *et al.* compared the effects of magnesium sulfate on postoperative fentanyl consumption in gynecologic surgery and did not find any difference between the groups[21]. In all these studies magnesium was used as an adjuvant to other intravenously administered analgesic drugs.

We assumed that postoperative pain after thoracotomy is provoked by very strong nociceptive noxious mechanical stimuli (tissue injury) on mechano-heat receptors (first pain) and polymodal receptors (second pain). This nociceptive somatic and visceral pain was successfully controlled and relieved with bupivacaine and fentanyl administered epidurally.

In current literature, we found only one study that included patients receiving magnesium and undergoing thoracotomy procedure[29]. Therefore, most studies were conducted in patients with lower nociceptive response to surgical trauma, without dynamic pain component[15,25]. Magnesium sulfate is safe to use. In the present study, we chose bolus doses of 30-50 mg/kg magnesium sulfate, continuous infusion of 500 mg/h during the operation and for 24 h postoperatively, based on previous investigations. After surgery, patients in the

magnesium treated group showed higher serum magnesium levels compared to patients in the control group treated with isotonic saline, as expected, but all values were in the normal range (0.7-1.3 mmol/L). However, magnesium toxicity begins at serum concentration of 2.5-5 mmol/L, which is much higher than the highest measured level in both groups in our study.

Conclusion

This prospective, randomized, double blind study was designed to assess the effects of magnesium sulfate on perioperative fentanyl consumption, postoperative epidural fentanyl and bupivacaine consumption, and postoperative analgesia in patients undergoing thoracotomy. Results of our study showed the cumulative dose of fentanyl to be statistically lower in the magnesium treated group as compared to control group ($P<0.003$ *vs.* $P<0.005$). The VAS pain scores at rest during the first 24 h of about 3 and less than 3 confirmed that a combination of the local anesthetic bupivacaine and potent opioid fentanyl could effectively control static postthoracotomy pain.

The measured pain scores using TORDA scale between 1 and 2 reported in the magnesium and control groups confirmed the need of better control of dynamic postthoracotomy pain, especially on coughing in both study groups. The lower values of TORDA pain intensity score in the magnesium group at all measured intervals may have resulted from its action as a non-competitive NMDA receptor antagonist. The propagation of intense nociceptive stimuli during deep breathing and coughing after thoracotomy could be modulated by limiting NMDA mediated facilitating processes.

In our study, there was no statistically significant difference in the cumulative epidural doses of bupivacaine and fentanyl postoperatively between the magnesium treated and control group patients.

References

1. BARASH PG, CULLEN BF, STOELTING RK. Clinical anesthesia, 4th ed. Philadelphia: Lippincott Williams and Wilkins, 2001.
2. GOLDSTRAW P. Principles of thoracic surgery. In: BREWIS RAL, CORRIN B, GEDDES DM, GIBSON GI, editors. Respiratory medicine, Vol 1, 2nd ed. London: WB Saunders, 1995;395-413.
3. DAJCZMAN E, GORDON A, KREISMAN H, WOLKOVE N. Long-term postthoracotomy pain. Chest 1991;99:270-4.
4. KAPLAN JA, SLINGER PD. Thoracic anesthesia, 3rd ed. Philadelphia: Churchill Livingstone, 2003.
5. de la ROCHA AG, CHAMBERS K. Pain amelioration after thoracotomy: a prospective, randomised study. Ann Thorac Surg 1984;37:239-42.
6. KEHLET N, DAHL JB. The value of multi-modal or balanced analgesia in postoperative pain relief. Anesth Analg 1993;77: 1048.
7. GRAVLEE GP, RANCK RL, editors. Pain management in cardiothoracic surgery. Philadelphia: JB Lippincott, 1993;220.
8. DELILKAN AE, LEE CK, YONG NK, ONG SC, GANENDRAN A. Postoperative local analgesia for thoracotomy with direct bupivacaine intercostal blocks. Anaesthesia 1973;28:561-7.
9. FERRANTE FM, CHAN VWS, ARTHUR GR, ROCCO AG. Interpleural analgesia after thoracotomy. Anesth Analg 1991;72:105-9.
10. KONRAD M, SCHLINGMANN KP, GUDERMANN T. Insights into the molecular nature of magnesium homeostasis. Am J Physiol Renal Physiol 2004;286:599-605.
11. FOX Ch, RAMSOOMAIR D, CARTER C. Magnesium: Its proven and potential clinical significance. South Med J 2001;94:1195-201.
12. DUBE L, GRAURY J-C. The therapeutic use of magnesium in anesthesiology, intensive care and emergency medicine: a review. Can J Anesth 2003;50;732-64.
13. WILLIAMS RJP. Magnesium: an introduction to its biochemistry. In: BIRCH NJ, ed. Magnesium and the cell. London-Boston: Ac Press, 1993;15-80.
14. BIRCH NJ, editor. Magnesium and the cell. London-Boston: Academic Press, 1993;289.
15. KARA H, SAHIN N, ULUSAN V, AYDOGDU T. Magnesium infusion reduces perioperative pain. Eur J Anesthesiol 2002;19:52-6.
16. KOINING H, WALLNER T, MARHOFER P, ANDEL H, HORAUF K, MAYER N. Magnesium sulfate reduces intra- and postoperative analgesic requirements. Anesth Analg 1998; 87:206-10.
17. LYSAKOWSKI C, DUMONT L, CZARNETZKI C, TRAMER MR. Magnesium as an adjuvant to postoperative analgesia: a systematic review of randomized trials. Anesth Analg 2007; 104:1532-9.
18. TRAMER MR, GLYNN DP, CHRIS J. An evaluation of a single dose of magnesium to supplement analgesia after ambulatory surgery: randomised controlled trial. Anesth Analg 2007;104:1374-9.
19. SCHULZ-STUBNER S, WETTMANN G, REYLE-HAHN SM, ROSSAINT R. Magnesium as a part of balanced general anesthesia with propofol, remifentanil and mivacurium: a double blind, randomized, prospective study in 50 patients. Eur J Anesthesiol 2001;18:723-9.
20. RYU JH, KANG MH, PARK KS, DO SH. Effects of magnesium sulphate on intraoperative anaesthetic requirements and

postoperative analgesia in gynaecology patients receiving total intravenous anesthesia. Br J Anaesth 2008;100:397-403.

21. SEYHAN TO, TUGRUL M, SUNGUR MO, KAYACAN S, TELCI L, PENBECI K, AKPIR K. Effects of three different dose regimens of magnesium on propofol requirements, haemodynamic variables and postoperative pain relief in gynaecological surgery. Br J Anesth 2006;96:247-52.
22. ISERI LT, FRENCH JH. Magnesium: nature's physiological calcium blocker. Am Heart J 1984;108:188-94.
23. CODERRE TJ, MELZACK R. The role of NMDA receptor-operated calcium channels in persistent nociception after formalin induced tissue injury. J Neurosci 1992;12:3671-5.
24. El-BAZ NM, FABER LP, JENSIK RJ. Continuous epidural infusion of morphine for treatment of pain after thoracic surgery: a new technique. Anesth Analg 1984;63:757.
25. TRAMER MR, SCHNEIDER J, MARTI RA, RIFAT K. Role of magnesium sulfate in postoperative analgesia. Anesthesiology 1996;84:340-7.
26. LEVAUX Ch, BONHOMME V, DEWANDRE PY, BRICHANT JF, HANS P. Effect of intraoperative magnesium sulphate on pain relief and patient comfort after major lumbar orthopaedic surgery. Anestehsia 2003;58:131-5.
27. WILDER-SMITH CH, KNOPFLI R, WILDER-SMITH OHG. Perioperative magnesium infusion and postoperative pain. Acta Anaesthesiol Scand 1997;41:1023-7.
28. KO SH, LIM HR, KIM DC, HAN YJ, CHOE H, SONG HS. Magnesium sulfate does not reduce postoperative analgesic requirements. Anesthesiology 2001;95:640-6.
29. SENTURK M, OZCAN PE, TALU GK. The effects of three different analgesia techniques on long term postthoracotomy pain. Anesth Analg 2002;94:11-5.

Sažetak

ANALGEZIJSKI UČINAK MAGNEZIJ SULFATA U BOLESNIKA PODVRGNUTIH TORAKOTOMIJI

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Magnezij može djelovati kao pomoćno sredstvo u analgeziji zbog svojih svojstava blokatora kalcijevih kanala i antagonista N-metil-D-aspartata. Cilj ove studije bio je utvrditi smanjuje li magnezij sulfat perioperacijske potrebe za analgezijom u bolesnika podvrgnutih zahvatu torakotomije. U studiju je bilo uključeno 68 bolesnika podvrgnutih elektivnoj torakotomiji koji su primili bolus od 30-50 mg/kg $MgSO_4$ i potom kontinuiranu infuziju od 500 mg/h te 500 mg/h tijekom prva 24 sata nakon operacije ili isti volumen izotonične otopine. Intraoperacijska analgezija postignuta je fentanilom, a poslijeoperacijska mješavinom fentanila i bupivakaina kroz epiduralni kateter. Razina boli procijenjena je pomoću vizualne analogne ljestvice (VAS) i ljestvice za bol TORDA. Potrošnja fentanila tijekom operacije bila je značajno manja u skupini koja je dobivala magnezij u usporedbi s kontrolnom skupinom. Nije bilo statistički značajne razlike između skupine koja je primala fentanil i kontrolne skupine u epiduralnoj potrošnji bupivakaina i fentanila tijekom 48 sati poslije operacije. Izmjerene vrijednosti VAS bile su slične u dvjema skupinama u svim mjernim točkama. Poslijeoperacijske vrijednosti TORDA bile su slične u dvjema skupinama tijekom prva 24 sata, ali je statistički značajna razlika zabilježena u mjerenjima nakon 40-48 sati. Rezultati dobiveni u ovoj studiji pokazali su kako magnezij snižava intraoperacijske potrebe za analgezijom te doprinosi učinkovitoj kontroli statične sastavnice boli poslije torakotomije.

Ključne riječi: *Magnezij sulfat – terapijska primjena; Bol, poslijeoperacijska – liječenje; Analgetici, opioidni – terapijska primjena; Torakotomija*