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ORIGINAL RESEARCH

The effects of perioperative low-dose magnesium sulfate infusion on postoperative pain in lumbar surgery

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Abstract

This paper aimed at evaluating the effect of low-dose perioperative magnesium sulfate ($MgSO_4$) on postoperative pain in lumbar surgery. Sixty adult patients were included in this randomized controlled double-blind study. After intubation, an infusion of $MgSO_4$ (10 mg/kg/h) and isotonic saline 0.9% (10 mg/kg/h) were administered in groups M and C, respectively. Heart rate and mean arterial pressure were recorded before and during surgery. Serum magnesium levels were recorded before and after the surgery. Perioperative remifentanil consumption and extubation time were recorded. In the post-anesthesia care room (PACU), Agitation-sedation with Richmond Agitation-Sedation Scale (RASS), the pain was evaluated with Visual Analogue Scale (VAS) and recorded at the baseline, at 5th, 10th, 15th and 30th minutes. Patients were transferred to surgical ward with intravenous patient-controlled analgesia (PCA) for postoperative analgesia and received diclofenac sodium for rescue analgesia if VAS >4. Postoperative VAS scores at 2nd, 4th, 6th and 24th hours, opioid consumption after 4 and 24 hours and rescue analgesic consumption for postoperative 24 h were recorded. In the PACU, RASS scores were statistically lower in group M than in group C ($p = 0.001$), and VAS scores were statistically lower at all measurement times in group M than in group C. In the surgical ward, VAS Scores were statistically lower in Group M at the 6th and 24th hours than in group C ($p = 0.015$, $p = 0.009$, respectively). The need for post-operative rescue analgesic was statistically lower in Group M ($p < 0.001$). The side effect incidence of both groups was similar. Our findings suggest that perioperative low-dose (10 mg/kg/h) $MgSO_4$ infusion reduces early post-op agitation, VAS scores and the need for analgesics up to 24 hours postoperatively. Low dose $MgSO_4$ infusion can be effectively applied for pain management in patients undergoing lumbar surgery.

Keywords

Lumbar surgery; Magnesium sulfate; Pain; Visual analogue score

1. Introduction

Effective postoperative pain management shortens the patients' recovery and hospital stay in patients undergoing lumbar surgery [1, 2]. In lumbar spine surgery such as laminectomy, vertebroplasty and lumbar stabilization, a multimodal analgesic approach applies to relieve pain and accelerate recovery. The aim is to minimize opioid use and its related side effects and to achieve synergistic analgesia using agents that act on different peripheral and central receptors [3, 4].

Agents used in the multimodal analgesic approach include Magnesium. Analgesic effects of Magnesium include inhibition of neuropathic pain, strengthening of opioid analgesia along with weakening of opioid tolerance [5].

The analgesic properties of magnesium result from its regulation of intracellular calcium influx and its antagonism of N-Methyl D-Aspartate (NMDA) receptors in the central nervous system. Magnesium is a non-competitive NMDA receptor antagonist. NMDA antagonists inhibit hyperalgesia by reducing the central release of glutamate [6].

Elements affecting the outcomes of the administration of magnesium include per and postoperative dose, bolus or infusion in different surgical operations. The dosage, method of administration and risks associated with magnesium used for analgesic applications are still debated. The relationship between the amount of Mg used and the analgesic efficacy is still unclear [7, 8].

This study aims at evaluating the effectiveness of perioperative low-dose magnesium sulfate ($MgSO_4$) use on postoperative pain in lumbar surgery cases.

2. Materials and methods

A randomized controlled analysis was conducted applying a double blinded approach, between April 2021 and November 2021 in Sisli Hamidiye Etfal Research and Training Hospital Neurosurgery Clinic.

This study included a set of 60 patients, aged 18 years and older, ASA (American Society of Anesthesiologists) physical status I–II, awaiting to undergo lumbar spinal surgery, under general anesthesia. Exclusion criteria included the presence of cardiac conduction disorders and/or cardiac comorbidities, use of Ca channel blockers, hepatic/renal failure and allergy to Mg.

The visual analog scale (VAS) process was informed to all patients before the surgery. The participants were randomly divided into two groups using the sealed envelope method: the magnesium treatment group (Group M) (n = 30) and the control group (Group C) (n = 30). The patients were not premedicated. In the operating room, standard ASA monitoring involving electrocardiography, non-invasive blood pressure, and pulse oximetry were applied to all patients.

Propofol (2 mg/kg) and fentanyl (1 mcg/kg) was used for anesthesia induction. Endotracheal intubation was carried out with rocuronium (0.6 mg/kg). Anesthesia was maintained with sevoflurane (end-tidal concentration 2–2.5%) and remifentanil infusion to maintain the bispectral index between 40–60. After intubation, ventilated patients were kept in a volume-controlled mode with tidal volume at 6–8 mL/kg, respiratory rate at 12–14 breaths/min, and end-tidal volume of carbon-dioxide (ETCO2) controlled at 30–45 mmHg. Initial serum magnesium levels of the patients were measured at the beginning of the surgery; and subsequently an infusion of $MgSO_4$ (10 mg/kg/h) in 100 mL of normal saline (NS) and an infusion of 100 mL of NS (10 mg/kg/h) were initiated in groups M and C, respectively. The infusions were prepared by an anesthesiologist who was not involved in the study. At baseline (T0) and the (T1) 5th, (T2) 10th, (T3) 15th, (T4) 30th, (T5) 45th and (T6) 60th minutes of the surgery to HR, systolic and diastolic blood pressures (SBP-DBP) were recorded. Hypotension was defined as a systolic blood pressure of less than 90 mmHg or a 20% decrease of pre-induction with reference to baseline values and treated by bolus ephedrine (5 mg). Heart rate (HR) below 40 beats per minute was defined as bradycardia and treated by bolus 0.5 mg atropine. All patients received 1 g of paracetamol + 100 mg of tramadol within 15 minutes of the skin surgical closure. Sevoflurane and remifentanil infusion were stopped at the completion of the skin surgical closure. Because only 0.6 mg/kg rocuronium was used at induction of anesthesia, neuromuscular agent reversed by low-dose atropine 0.5 mg and low-dose neostigmine 1.5 mg before extubation. Operation time, extubation time and remifentanil consumption during surgery were recorded.

In the PACU, at the baseline (T0) and the (T1) 5th, (T2) 10th, (T3) 15th and (T4) 30th minutes the agitation-sedation was evaluated with the RASS scale (0 awake, 1 restless, 2 restless-frequent aimless movements, 3 agitated (pulls out tubes or catheters), 4 belligerent violent behaviors); and the level of pain was evaluated using the VAS scale (range 1 to 10) and recorded by an unbiased anesthesiologist. Patients were transferred to surgical ward with iv Patient-controlled analgesia (PCA) pump, prepared using pethidine hydrochloride (2 mg/mL) and ondansetron (0.02 mg/mL). 10 mg bolus, 10 minutes' lock time, no background infusion was set. Diclofenac sodium was used for rescue analgesia if VAS >4. Pain scores were recorded at the (T0) 2nd, (T2) 4th, (T3) 6th and (T4) 24th hours postoperatively. Ondansetron 4 mg was administered as a rescue anti-emetic. Total opioid consumption in the first 4th and 24th hours and additional analgesic need was recorded. Side effects recorded included postoperative nausea and vomiting (PONV), tremor, hypotension and bradycardia. In the PACU and surgical ward, analgesic consumption and side effects were logged by an unbiased anesthesiologist.

It was estimated that, for this trial, for a 0.8 effect size between the groups, 90% Power, an 0.05 alpha level of significance and a sample of 56 patients (a case group consisting of 28 patients, a control group consisting of 28 patients) would be sufficient. Accordingly, this research was conducted with 60 patients (30 patients in both the study and control groups). SPSS (15.0, IBM, Armonk, NY, USA) for Windows program was used for statistical analysis. Descriptive statistical analysis parameters used included numbers and percentages for categorical variables, mean, standard deviation, minimum, maximum and median for numerical variables. Rates in independent groups were compared using the Chi-square test. Comparisons of numerical variables across independent groups were performed with Student's *t*-Test, provided the data was normally distributed. The Mann Whitney U test was applied for data that was not normally distributed. The statistical alpha significance level was considered as $p < 0.05$.

3. Results

Demographic and surgical data were comparable between the two groups (Table 1). In the peri-operative follow-up, the HR was statistically lower in Group M at the 10th and 15th minutes than Group C ($p = 0.043$ and $p = 0.009$, respectively). At the 60th and 45th minutes, SBP and DBP were significantly higher in group M than Group C ($p = 0.038$ and $p = 0.020$, respectively). There were no statistically difference treatment incidents of hypotension, bradycardia, arrhythmias or tachycardia between in two groups $p > 0.05$ (Table 2).

In the PACU, at T0: RASS in Group M was statistically lower than Group C ($p = 0.001$). At all measurement times in the PACU, VAS scores were statistically lower in Group M than in Group C ($p = 0.006$, $p = 0.032$, $p = 0.042$, $p = 0.021$, $p = 0.010$, baseline, 5th, 10th, 15th and 30th minutes) (Table 3).

Post-Op VAS scores in Group M were statistically lower at 6th and 24th-hours respectively ($p = 0.015$, $p = 0.009$, respectively). The total first 4 and 24 hours' post-op opioid consumptions were similar in both groups M and C ($p = 0.664$ and $p = 0.607$, respectively). Moreover, post-op additional analgesics consumption in Group M was statistically lower than Group C ($p < 0.001$) (Table 4). There was no statistical difference in the preoperative magnesium levels of the groups ($p = 0.140$). The postoperative serum magnesium level in Group M was statistically higher than Group C ($p < 0.001$) (Table 5). The complication rates of both groups were similar (Table 6).

TABLE 1. Demographic data and operative characteristics.

		Group M	Group C	*p***
Demographics				
Age (yr), Mean ± SD (Min–Max)		58.4 ± 9.5 (44–80)	60.3 ± 11.0 (36–82)	0.484*
Sex n (%)	Male	13 (43.3%)	12 (40.0%)	0.793#
	Female	17 (56.7%)	18 (60.0%)	
Weight, Mean ± SD Min–Max (Median)		79.2 ± 7.9 65–96 (80)	75.6 ± 9.1 53–92 (76)	0.184
ASA 1/2		13/17	12/18	0.793#
Operative characteristics				
Operation	Lumbar disc herniation	27 (90.0%)	28 (93.3%)	1.000#
	Lumbar listhesis	0 (0.0%)	1 (3.3%)	
	Lumbar Stenosis	1 (3.3%)	0 (0.0%)	
	Stabilization	2 (6.7%)	1 (3.3%)	
Duration of surgery (min), Mean ± SD Min–Max (Median)		141.2 ± 61.6 60–300 (130)	127.5 ± 54.5 57–260 (120)	0.374
Duration of anesthesia (min), Mean ± SD Min–Max (Median)		156.0 ± 60.5 72–310 (142.5)	142.0 ± 56.1 65–280 (130.0)	0.347
Extubation time (min), Mean ± SD Min–Max (Median)		7.9 ± 2.6 5–15 (8)	7.3 ± 2.4 5–12 (7)	0.334
Total Remifentanil consumption (mcg), Mean ± SD Min–Max (Median)		302.8 ± 196.2 110–1100 (232.5)	266.5 ± 147.7 70–715 (250.0)	0.554

**Student t Test; **Mann Whitney U test; #Chi-square test; ASA: American Society of Anesthesiologists; SD: Standard deviation.*

4. Discussion

The findings in this paper indicate that perioperative 10 mg/kg/h $MgSO_4$ infusion during lumbar surgery reduces VAS scores at PACU first 30 minutes and at the 6th, 24th hours postoperatively. Furthermore, the postoperative analgesic requirements up to 24 hours were similarly reduced. Post-op RASS value was statistically lower in Group M. None of the groups required a treatment for hemodynamic changes, and complication rates for both groups were similar.

Magnesium has been observed to increase the effects of other analgesic agents, even if not considered among primary analgesics [4, 6, 7]. Tramer *et al.* [9] suggested that perioperative $MgSO_4$ use was associated with a reduction of analgesic requirement and an improvement in the postoperative sleep quality. Levaux *et al.* [10] used $MgSO_4$ for the first time in patients undergoing spinal surgery and an improvement in postoperative analgesia was reported. Different from our results, authors reported significantly reduced opioid consumption at postoperative 6th, 12nd and 24th hour with the use of 50 mg/kg bolus Mg administration. The optimal intraoperatively administered magnesium dose in the multimodal analgesic protocol remains contested in literature. The superiority of one of the Mg sulfate varieties amongst bolus, bolus and infusion or infusion has not been confirmed in literature [1, 2, 8]. Dehkordy ME *et al.* [11] used $MgSO_4$ 50 mg/kg in 100 mL NS over 15 minutes using an initial bolus, before the administration of induction followed by a continuous 15 mg/kg/h infusion during the spinal fusion operations. The authors reported that perioperative $MgSO_4$ infusion leads to improvement in postoperative analgesia and reduced morphine consumption postoperatively. Tsaousi G *et al.* [1] used $MgSO_4$ at 20 mg/kg before induction followed by 20 mg/kg/h during lumbar laminectomy. They concluded that magnesium infusion could induce perioperative analgesia and reduce analgesic needs up to 24 hours postoperatively. In our study we administered low dose of Mg to the patients, as opposed to the aforementioned literature studies. Similar results were obtained with regards to the decrease in VAS values with a low-dose of Mg infusion. The findings in this paper suggest that low-dose Mg infusion effectively decreases the need of analgesics even though similar opioid consumption were observed. While analgesic effects of Mg have been demonstrated by the aforementioned studies, some studies could not prove these results [7]. Ghaffaripour S *et al.* [7] have shown that the infusion of $MgSO_4$ was ineffective in reducing patients' pain and opioid requirement during the first 24 hours after laminectomy surgery. In this study, a loading dose of $MgSO_4$ (30 mg/kg) was administered within 5 to 10 minutes followed by a maintenance dose of 10 mg/kg/h up to the end of the surgery. However, in our study, a significant effect on postoperative analgesia was observed, despite the application of a low dose of Mg (10 mg/kg/h).

Hypotension is one of the most common side effects of Mg. Ahmadi *et al.* [12] applied catecholamines in systolic pressures below 60 mm Hg in their study on thoracotomies. Similarly, Albrecht E *et al.* [6] screened 25 studies in a meta-analysis and reported that bradycardia was the most common side effect in

TABLE 2. Perioperative hemodynamic characteristics.

	Group M		Group C		*p***
	Mean ± SD	Min–Max (Median)	Mean ± SD	Min–Max (Median)	
Peri-Operative HR					
T0	81.2 ± 18.8	45–121 (78.5)	85.3 ± 10.3	55–108 (85.0)	0.304*
T1	71.6 ± 13.1	45–101 (69.0)	78.4 ± 16.2	51–113 (79.5)	0.076*
T2	67.0 ± 10.6	47–92 (65.0)	73.8 ± 14.5	50–113 (73.0)	0.043
T3	64.6 ± 10.7	52–96 (61.5)	70.5 ± 11.6	49–94 (66.0)	0.009
T4	64.7 ± 9.1	54–87 (62.0)	67.5 ± 11.0	48–99 (64.5)	0.230
T5	64.7 ± 7.9	53–82 (62.0)	68.3 ± 9.9	57–99 (66.0)	0.162
T6	64.4 ± 7.6	52–82 (63.5)	65.6 ± 5.1	55–80 (63.0)	0.689*
Peri-Operative SBP					
T0	121.5 ± 17.1	85–147 (124.0)	116.8 ± 15.9	82–156 (120.0)	0.106
T1	109.6 ± 13.5	80–135 (109.5)	105.4 ± 13.9	82–131 (102.0)	0.240*
T2	103.9 ± 11.5	88–135 (102.0)	102.8 ± 14.5	75–142 (100.0)	0.684
T3	99.7 ± 11.2	81–125 (98.5)	100.4 ± 10.3	80–119 (98.0)	0.821*
T4	98.7 ± 9.5	75–120 (98.0)	97.7 ± 8.8	73–115 (97.5)	0.674*
T5	101.8 ± 10.4	84–125 (100.0)	98.5 ± 8.3	83–116 (96.5)	0.233
T6	105.3 ± 8.4	92–125 (104.0)	100.8 ± 6.3	90–111 (99.5)	0.038
Peri-Operative DBP					
T0	77.4 ± 13.8	52–108 (76.5)	74.3 ± 12.2	56–110 (75.5)	0.729*
T1	68.8 ± 11.0	44–91 (67.5)	68.1 ± 13.8	44–96 (65.5)	0.574
T2	65.7 ± 10.9	44–93 (65.0)	64.5 ± 13.6	41–114 (62.5)	0.715*
T3	63.6 ± 11.3	40–83 (62.5)	62.7 ± 8.6	50–82 (61.5)	0.711*
T4	61.1 ± 8.3	47–80 (61.0)	59.3 ± 7.1	43–75 (59.5)	0.371*
T5	64.3 ± 7.4	50–80 (63.0)	60.0 ± 9.0	45–81 (57.0)	0.020
T6	63.5 ± 8.7	40–76 (64.5)	59.5 ± 12.8	7–89 (60.5)	0.087

**Student t Test; **Mann Whitney U test; T0, T1, T2, T3, T4, T5 and T6 refer to baseline, 5th, 10th, 15th, 30th, 45th and 60th minutes respectively. HR: Heart rate; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; SD: Standard Deviation.*

perioperative intravenous administration of Mg. Farouk I *et al.* [13] investigated the cardiac output and stroke volume from the patients using Mg and comparable levels between the control and the test groups.

In this study, HR was statistically lower in Group M at the 10th and 15th minutes during the operation in the perioperative hemodynamic follow-ups. Diastolic pressure at the 45th minute and systolic pressure at the 60th minute during the operation were statistically significantly higher in Group M. However, none of the aforementioned events were significant enough to have an effect on the clinical practice and consequently no additional treatment was required. This could be related to the low dose Mg that provides more stable hemodynamics.

Perioperative Mg administration can increase sedation [14, 15]. Kiran S *et al.* [15] investigated the effects of a single dose of $MgSO_4$ during inguinal hernia surgery and reported that patients who received Mg were more sedated. In our study, the RASS value of the Mg group was statistically significantly lower in the post-op initial follow-up (T0) but not significant at other time points. We attributed this difference to the fact that T0 is the special time point of early extubation. The patients in group M felt less pain due to analgesic effect of Mg during extubation period, leading to less agitation in first minutes.

The use of Mg was not common among anesthesiologists. Perceived lack of evidence and lack of experience were the foremost limiting factors for magnesium application [8]. Consistent with most of the current studies and practices, $MgSO_4$ was only applied perioperatively and a low dose of Mg (10 mg/kg/h) was used to allow a wide safety margin. On the other hand, some of the anti-inflammatory effects of $MgSO_4$ may be related to the correction of subclinical hypomagnesemia [12]. In this paper, at the end of the operation, the blood Mg level was statistically higher in study group than the control group

TABLE 3. RASS and VAS scores recorded in PACU.

		Group M	Group C	$p^{\#}$
PACU/Ajitasyon-RASS n (%)				
T0	0	25 (83.3%)	11 (36.7%)	0.001
	1	5 (16.7%)	15 (50.0%)	
	2	0 (0.0%)	4 (13.3%)	
T1	0	26 (86.7%)	21 (70.0%)	0.257
	1	3 (10.0%)	8 (26.7%)	
	2	1 (3.3%)	1 (3.3%)	
T2	0	28 (93.3%)	25 (83.3%)	0.196
	1	1 (3.3%)	5 (16.7%)	
	2	1 (3.3%)	0 (0.0%)	
T3	0	28 (93.3%)	28 (93.3%)	1.000
	1	2 (6.7%)	2 (6.7%)	
T4	0	27 (90.0%)	27 (90.0%)	1.000
	1	3 (10.0%)	3 (10.0%)	
		Mean ± SD / Min–Max (Median)	Mean ± SD / Min–Max (Median)	p^{**}
PACU/VAS				
T0		1.67 ± 1.75 / 0–7 (1.0)	2.97 ± 2.14 / 0–10 (3.0)	0.006
T1		1.63 ± 1.81 / 0–7 (1.0)	2.60 ± 1.92 / 0–8 (2.0)	0.032
T2		1.50 ± 2.08 / 0–7 (0.5)	2.30 ± 2.07 / 0–8 (2.0)	0.042
T3		1.33 ± 1.90 / 0–7 (0.5)	2.07 ± 1.70 / 0–7 (2.0)	0.021
T4		0.90 ± 1.23 / 0–4 (0.0)	1.87 ± 1.72 / 0–7 (1.5)	0.010

***Mann Whitney U test; #Chi-square Test; T0, T1, T2, T3 and T4 refer to baseline and the 5th, 10th, 15th and 30th minutes, respectively. PACU: post-anesthesia care room; VAS: Visual Analogue Scale; SD: Standard deviation; RASS: Richmond Agitation-Sedation Scale.*

TABLE 4. Post-Op VAS Score, opioid consumption and additional analgesics need.

	Group M	Group C	p^{**}
	Mean ± SD / Min–Max (Median)	Mean ± SD / Min–Max (Median)	
Post-Op/VAS Score			
T0	2.47 ± 2.29 / 0–8 (2.0)	2.93 ± 1.46 / 1–7 (3.0)	0.117
T1	2.23 ± 1.87 / 0–7 (2.0)	2.60 ± 1.19 / 0–5 (2.0)	0.125
T2	1.90 ± 2.19 / 0–10 (1.5)	2.33 ± 1.45 / 0–6 (2.0)	0.068
T3	1.23 ± 1.65 / 0–6 (0.5)	1.93 ± 1.34 / 0–5 (2.0)	0.015
T4	0.76 ± 1.30 / 0–5 (0.0)	1.33 ± 1.15 / 0–5 (1.0)	0.009
Post-Op/Opioid Consumption			
T0–4	29.3 ± 25.2 / 0–90 (20)	23.0 ± 13.2 / 10–70 (20)	0.664
T0–24	41.0 ± 38.7 / 0–160 (25)	38.7 ± 22.7 / 10–120 (30)	0.607
Post–Op/additional analgesics n (%)			
T0–4	4 (13.3%)	22 (73.3%)	<0.001#
T0–24	3 (10.0%)	20 (66.7%)	<0.001#

***Mann Whitney U test; #Chi-square Test; T0, T1, T2, T3 and T4 refer to baseline, 2nd, 4th, 6th and 24th hours, respectively. T0–4 and T0–24 refer to first 4 and first 24 hours postoperatively, respectively. VAS: Visual Analogue Scale; SD: Standard deviation.*

TABLE 5. Pre and postoperative magnesium (Mg) levels.

	Group M		Group C		*p*
	Mean ± SD	Min–Max (Median)	Mean ± SD	Min–Max (Median)	
Mg					
Pre-op	2.06 ± 0.21	1.53–2.40 (2.10)	1.98 ± 0.21	1.70–2.53 (1.925)	0.140*
Post-op	2.52 ± 0.39	1.63–3.83 (2.52)	1.92 ± 0.19	1.64–2.50 (1.875)	<0.001**

**Student t Test; **Mann Whitney U test; SD: Standard deviation.*

TABLE 6. Complications.

	Group M n (%)	Group C n (%)	*p*
Complications			
Nausea	2 (6.7%)	2 (6.7%)	1.000
Vomiting	2 (6.7%)	1 (3.3%)	1.000
Bradycardia	0 (0.0%)	0 (0.0%)	-
Hypotension	0 (0.0%)	0 (0.0%)	-
Itching	0 (0.0%)	0 (0.0%)	-

(1.63 mg/dL and 3.83 mg/dL, respectively). However, in this study, the maximum values did not increase to a level that could cause any side effects or complications [12]. In the study by Silva Filho SE *et al.* [14], magnesium blood concentrations were recorded throughout the study. Authors found out that the magnesium plasma concentration remained stable, at a range of 1.93–3.33 which is a similar range to our study. Intravenous administration of Mg is well tolerated most of the time [16–18]. Burning sensation or pain on injection along with agitation, drowsiness and nausea are among the reported side effects. Hypotension, respiratory depression and narcosis constitute some of the potential effects from high magnesium plasma concentrations. Normally, the blood Mg level ranges from 1.7 mg/dL to 2.3 mg/dL. In this presented study, at the end of the operation, the blood Mg level was statistically higher in study group than the control group; 2.52 ± 0.39 mg/dL and 1.92 ± 0.19 mg/dL, respectively. Blood Mg concentrations >6.2 mmol/L^{-1} can cause cardiac arrest [19]. In this study, the complication rates in the two groups were similar. Some side effects were observed. Nausea was recorded in 2 cases in each group while vomiting occurred in 2 cases in group M and in a single case in group C.

The size of the study samples constitutes one of the limitations of this study considering only 60 patients. Larger samples could have improved the results. Considering that after lumbar surgery pain might persist for up to 48 hours, a longer follow-up period could be required.

5. Conclusions

The findings in this study revealed that during lumbar surgery, perioperative low-dose (10 mg/kg/h) $MgSO_4$ infusion reduces early post-op agitation and analgesic needs up to 24 hours postoperatively. Thus, perioperative infusion of low-dose $MgSO_4$ being effective and safe can be considered for pain management in patients undergoing lumbar surgery. Further investigations using larger samples are needed to assess reliable and effective dosage of $MgSO_4$.

ABBREVIATIONS

DBP, Diastolic Blood Pressure; HR, Heart Rate; Mg, Magnesium; $MgSO_4$, Magnesium sulfate; NMDA, N-Methyl D-Aspartate; PCA, Patient Controlled Analgesia; PONV, Postoperative Nausea and Vomiting; RASS, Richmond Agitation-Sedation Scale; SBP, Systolic Blood Pressure; VAS, Visual Analogue Score.

AVAILABILITY OF DATA AND MATERIALS

The data used to support the findings of this study are available from the corresponding author upon request.

AUTHOR CONTRIBUTIONS

AS, SO, MA—study conception and design; MA, HŞT, LK, AY—data collection; AS, SO, HŞT—analysis and interpretation of results; AS, SO, LK, AY—draft manuscript preparation; AS, SO, AY—critical revision of the article; MA, HŞT, LK—other (study supervision, fundings, materials, *etc.*). All authors reviewed the results and approved the final version of the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was approved by the Clinical Trials Ethical Committee of Sisli Hamidiye Etfal Research and Training Hospital (number: 3254 27.04.2021). Written informed consent were obtained from all patients.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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