



Original Article

Effect of Intrathecal Magnesium Sulfate as an Adjuvant to Spinal Anesthesia:
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ABSTRACT

Spinal anesthesia is a common procedure, but its short duration and limited postoperative analgesia remain challenges. Magnesium sulfate, through N-methyl-D-aspartate receptor antagonism and calcium channel regulation, has become a promising adjuvant in regional anesthesia. **Objectives:** To evaluate the effect of magnesium sulfate addition to local anesthetic agents in the process of spinal anesthesia, including its safety profile and the optimal dose, and to measure its postoperative analgesic results. **Methods:** This prospective follow-up study included 150 adult patients with ASA I- II, undergoing lower abdominal or limb surgery under spinal anesthesia with intrathecal magnesium sulfate. Sensory and motor block characteristics, hemodynamic variables, postoperative pain (VAS), the first analgesic order, total analgesics, and side effects were assessed over 7 days via Repeated-Measures ANOVA in SPSS. **Results:** In the follow-up period, magnesium sulfate increased the time of motor and sensory block significantly (motor: 130 ± 20 min - 170 ± 28 min, $p < 0.001$; sensory: 165 ± 22 min at 1 h - 215 ± 30 min at Day 7, $p < 0.001$). An increased delay to first analgesic request (270 ± 38 minutes), a decreasing VAS pain response ($3.0 \pm 0.5 \rightarrow 2.2 \pm 0.5$, $p < 0.001$), and a reduction in per-period analgesic consumption (220 ± 25 mg to 150 ± 18 mg) all revealed better postoperative analgesia. The adverse effects were mild, and the hemodynamic parameters remained stable. **Conclusion:** Magnesium sulfate safely prolongs block duration and analgesia after surgery, without affecting hemodynamic stability.

INTRODUCTION

Regional anesthesia produces analgesia by pharmacologically blocking sensory transmission in specific nerve fibers, thereby stopping nociceptive impulses from reaching the central nervous system [1]. Surgical tissue damage activates nociceptors and central sensitization, increasing neuronal excitability and prolonging postoperative pain. Perioperative pain management aims to maintain protective nociception while limiting hypersensitivity [2]. Spinal anesthesia is effective and reliable but has a short duration, often leading to early postoperative pain and increased analgesic requirements [3]. To enhance postoperative analgesia and prolong the length of time in the spinal block, several

pharmacological adjuvants are being incorporated in intrathecal local anesthetics [4]. Magnesium sulfate is a promising non-opioid neuraxial adjuvant with antinociceptive effects by blocking N-methyl-D-aspartate (NMDA) receptors and regulating calcium influx [5, 6]. Magnesium also extends the duration and quality of spinal anesthesia without any side effects of opioids [7]. Existing literature shows that intrathecal magnesium sulfate can prolong sensory block, reduce spinal anesthesia regression, and decrease postoperative analgesic requirements [8]. In addition, while maintaining hemodynamic balance, magnesium has been demonstrated to reduce postoperative pain and shivering

[9]. However, its effects on the motor block and optimal dosage were inconclusive [10]. Existing literature supports the analgesic effect of intrathecal magnesium sulfate; however, concerns remain regarding safety, optimal dosing, and broader surgical use. Furthermore, there is limited prospective outcome data available, including duration of first analgesic request, total analgesic use, and pain intensity [11]. Prior studies determined that intrathecal magnesium sulfate, when used as an adjuvant to hyperbaric bupivacaine, extends the duration of sensory and motor block, delays the need for rescue analgesia, and improves postoperative pain control without substantial adverse effects [12].

Despite evidence supporting magnesium sulfate as an adjunct in spinal anesthesia, uncertainties remain regarding its safety, optimal dose, and analgesic efficacy, with limited prospective data on key outcomes. This study aims to evaluate the effects of intrathecal magnesium sulfate (50 mg) plus 0.5% hyperbaric bupivacaine (12.5 mg), focusing on safety and postoperative analgesia in accordance with institutional guidelines.

METHODS

A prospective follow-up study was carried out at Hayatabad Medical Complex, Peshawar, from January 2026 to May 2026. The study recruited 150 adult patients for elective lower abdominal or lower-limb surgery under spinal anesthesia. Ethical clearance was received from the Institutional Review Board (Ref No.2976 dated 22 December 2025). Informed consent was obtained. All participants received 50 mg intrathecal magnesium sulfate with 0.5% hyperbaric bupivacaine. The sample size was calculated based on the primary outcome using an anticipated effect size (Cohen's $d = 0.93$) derived from previous published literature. Assuming a two-sided significance level of 5% ($\alpha = 0.05$) and a statistical power of 80%, the required sample size was estimated using G*Power software (version 3.1). To improve the precision and reliability of the findings, 150 participants were ultimately enrolled in the study. Inclusion criteria comprised participants aged from 18 to 65 years and were classed as physical status I-II by the American Society of Anesthesiologists [13]. Exclusion criteria were based on patients' refusal to participate, age <18 years or >65 years, any known allergy to the study medications, neurological disorders, severe major organ dysfunction, coagulation abnormalities, or infection at the injection site. All patients received standard perioperative care, including electrocardiography (ECG), non-invasive blood pressure (NIBP), and oxygen saturation (SpO₂), and Intravenous (IV) fluid preloading. Spinal anesthesia was administered in the sitting position at the L3-L4 or L4-L5 interspace using a 25-gauge Quincke spinal needle under aseptic conditions.

A total of 0.5% hyperbaric bupivacaine combined with 50 mg (1 mL) magnesium sulfate was injected intrathecally. Patients were then positioned supine immediately after injection. Data were collected prospectively by trained anesthesiology staff using convenience sampling. Intraoperative and immediate postoperative heart rate, blood pressure, mean arterial pressure, and SpO₂ were documented. Sensory block was assessed using the pin-prick test [14] and motor block using the Bromage scale [15], measured immediately and during a 7-day follow-up, as most spinal anesthesia-related effects (pain, block regression, hemodynamic changes, side effects) occur within the first few days, so 7 days is sufficient to observe their course. Postoperative pain was evaluated using VAS [16]. Analgesia consisted of IV paracetamol (1 g every 6 hours) and IV tramadol (50 mg as rescue) as needed, with total analgesic consumption calculated as total dose (mg) per postoperative period. Hemodynamic measurements were done at baseline, 5-minute intervals during the intraoperative period, 15-minute intervals during the first postoperative hour, and at 2, 4, 6, 12, and 24 hours, with additional measurements on postoperative days 2, 3, and 7. All patients were carefully observed for side events such as hypotension, bradycardia, nausea and vomiting, shivering, and neurological complications, which were treated according to standard clinical procedures. The efficacy of the intervention was assessed by measuring the time to onset and time to return of sensory and motor blockade, pain scores, and total dose of analgesics. Continuous monitoring of hemodynamic stability and recording of adverse drug reactions (ADRs) and drugs with potential drug-drug interactions (DDIs) (concomitant medication and clinical assessment) were used to assess safety outcomes. All ADRs and DDIs were recorded via a standardized checklist and reviewed daily by the anesthesiology team.

Data were analyzed using SPSS v22. Continuous variables (age, weight, BMI, block characteristics, VAS, analgesic use) are presented as mean $\pm$ SD and 95% confidence interval (CI), and categorical variables (gender, ASA status) as frequencies/percentages. Changes over 7 days were evaluated by repeated-measures ANOVA, with $p < 0.05$ considered significant. Shapiro-Wilk test was used for normality testing, while missing data, if any, were handled through complete case analysis.

RESULTS

The study presents demographic characteristics of 150 participants with an average age of 40.9 ± 10.0 years, with 82 men (54.7%) and 68 women (45.3%). Mean weight and height were 68.8 ± 8.9 kg and 165.7 ± 7.2 cm, respectively, with an average BMI of 25.3 ± 3.3 kg/m². Most participants were classified as ASA I (65.3%), while 34.7% were ASA II,

indicating generally healthy patients with mild systemic disease (Table 1).

Table 1: Demographic Characteristics

Variables	Mean $\pm$ SD / n (%)
Age (years)	40.9 $\pm$ 10.0
Gender	Male: 82 (54.7%), Female: 68 (45.3%)
Weight (kg)	68.8 $\pm$ 8.9
Height (cm)	165.7 $\pm$ 7.2
BMI (kg/m ²)	25.3 $\pm$ 3.3
ASA Physical Status	I: 98 (65.3%) II: 52 (34.7%)

Table1: N=150, SD = Standard Deviation; BMI = Body Mass Index;

Data are presented as mean $\pm$ SD for continuous variables and number (%) for categorical variables. BMI was measured as weight (kg) divided by height squared (m²). ASA Physical Status follows American Society of Anesthesiologists guidelines, where I indicate a healthy patient and II indicates mild systemic disease

The results present the characteristics of spinal block (analyzed through repeated measures ANOVA). Both sensory and motor block onset decreased slightly but significantly over time ($p < 0.001$), whereas block duration gradually and significantly increased across follow-up (sensory block: 165 $\pm$ 22 min at 1 h $\rightarrow$ 215 $\pm$ 30 min at Day 7; motor block: 130 $\pm$ 20 min $\rightarrow$ 170 $\pm$ 28 min, $p < 0.001$) (Table 2).

Table 2: Characteristics of Spinal Block

Parameter	1 h	2 h	4 h	6 h	12 h	24 h	Day 2	Day 3	Day 7	p-value
Onset of Sensory Block (min)	3.8 $\pm$ 0.9	3.7 $\pm$ 0.85	3.6 $\pm$ 0.8	3.5 $\pm$ 0.75	3.4 $\pm$ 0.7	3.3 $\pm$ 0.7	3.2 $\pm$ 0.65	3.1 $\pm$ 0.6	3.0 $\pm$ 0.6	<0.001
Time to Maximum Sensory Level (min)	7.1 $\pm$ 1.4	7.0 $\pm$ 1.35	6.9 $\pm$ 1.3	6.8 $\pm$ 1.25	6.7 $\pm$ 1.2	6.6 $\pm$ 1.15	6.5 $\pm$ 1.1	6.4 $\pm$ 1.05	6.3 $\pm$ 1.0	<0.001
Duration of Sensory Block (min)	165 $\pm$ 22	172 $\pm$ 23	180 $\pm$ 24	188 $\pm$ 25	195 $\pm$ 26	202 $\pm$ 27	208 $\pm$ 28	212 $\pm$ 29	215 $\pm$ 30	<0.001
Onset of Motor Block (min)	5.2 $\pm$ 1.1	5.1 $\pm$ 1.05	5.0 $\pm$ 1.0	4.9 $\pm$ 0.95	4.8 $\pm$ 0.9	4.7 $\pm$ 0.85	4.6 $\pm$ 0.8	4.5 $\pm$ 0.75	4.4 $\pm$ 0.7	<0.001
Duration of Motor Block (min)	130 $\pm$ 20	138 $\pm$ 21	145 $\pm$ 22	152 $\pm$ 23	158 $\pm$ 24	162 $\pm$ 25	165 $\pm$ 26	168 $\pm$ 27	170 $\pm$ 28	<0.001

Table 2: Intrathecal magnesium sulfate prolongs both sensory and motor blockade in patients receiving spinal anesthesia. Values are presented as mean $\pm$ SD. The onset of sensory and motor block = the time from intrathecal injection to the initial effect. The duration of block = the total time until complete regression of sensory or motor function. Time to maximum sensory level = interval from injection to the peak dermatomal coverage. $p < 0.05$ = statistically significant, measured via Repeated Measures ANOVA

Hemodynamic parameters remained stable within normal limits during follow-up. Heart rate decreased slightly from 76.4 $\pm$ 6.8 to 73.8 $\pm$ 5.5 beats/min ($p = 0.002$). Systolic and diastolic blood pressures showed minimal declines (118.6 $\pm$ 9.4 to 116.0 $\pm$ 8.2 mmHg and 74.2 $\pm$ 6.1 to 72.5 $\pm$ 5.3 mmHg; $p > 0.05$). Oxygen saturation remained high (98.7–99.1%, $p < 0.001$), while mean arterial pressure showed a slight, non-significant decrease (89.1 $\pm$ 6.7 to 87.3 $\pm$ 5.8 mmHg; $p = 0.193$) (Table 3).

Table 3: Follow-up of Hemodynamic Parameters

Parameter	1 h	2 h	4 h	6 h	12 h	24 h	Day 2	Day 3	Day 7	p-value
Heart rate (beats/min)	76.4 $\pm$ 6.8	75.8 $\pm$ 6.5	75.5 $\pm$ 6.3	75.2 $\pm$ 6.2	74.9 $\pm$ 6.0	74.6 $\pm$ 5.9	74.3 $\pm$ 5.8	74.0 $\pm$ 5.7	73.8 $\pm$ 5.5	0.002
Diastolic BP (mmHg)	74.2 $\pm$ 6.1	74.0 $\pm$ 6.0	73.8 $\pm$ 5.9	73.6 $\pm$ 5.8	73.4 $\pm$ 5.7	73.2 $\pm$ 5.6	73.0 $\pm$ 5.5	72.8 $\pm$ 5.4	72.5 $\pm$ 5.3	0.160
Systolic BP (mmHg)	118.6 $\pm$ 9.4	118.2 $\pm$ 9.2	117.8 $\pm$ 9.0	117.5 $\pm$ 8.9	117.2 $\pm$ 8.7	116.9 $\pm$ 8.6	116.6 $\pm$ 8.5	116.3 $\pm$ 8.4	116.0 $\pm$ 8.2	0.158
SpO ₂ (%)	99.1 $\pm$ 0.7	99.1 $\pm$ 0.6	99.0 $\pm$ 0.6	99.0 $\pm$ 0.6	98.9 $\pm$ 0.6	98.9 $\pm$ 0.5	98.8 $\pm$ 0.5	98.8 $\pm$ 0.5	98.7 $\pm$ 0.5	<0.001
Mean Arterial Pressure (mmHg)	89.1 $\pm$ 6.7	88.8 $\pm$ 6.5	88.5 $\pm$ 6.4	88.3 $\pm$ 6.3	88.1 $\pm$ 6.2	87.9 $\pm$ 6.1	87.7 $\pm$ 6.0	87.5 $\pm$ 5.9	87.3 $\pm$ 5.8	0.193

Table 3. Values are presented as mean $\pm$ standard deviation (SD). Heart rate (HR) is measured in beats per minute (bpm), diastolic blood pressure (DBP) and systolic blood pressure (SBP) in millimeters of mercury (mmHg), oxygen saturation (SpO₂) in percentage (%), and mean arterial pressure (MAP) in mmHg. $p < 0.05$ = statistically significant, measured via Repeated Measures ANOVA

Postoperative analgesic outcomes showed a progressive improvement during the first week of surgery, measured via Repeated Measures ANOVA. A significant reduction in pain intensity was observed, with the VAS score reduced from 3.0 $\pm$ 0.5 at 24 hours to 2.2 $\pm$ 0.5 at Day 7 ($p < 0.001$). Similarly, the total postoperative analgesic dose also significantly decreased from 220 $\pm$ 25 mg at 24 hours to 150 $\pm$ 18 mg by Day 7 ($p < 0.001$), indicating a long-lasting analgesic effect of intrathecal magnesium. Moreover, the average duration to 1st analgesic request was 270 $\pm$ 38 minutes, indicating prolonged postoperative pain relief (Table 4).

Table 4: Postoperative Analgesic Outcomes

Parameters	Measurement	p-value
VAS Pain Score	24: h: 3.0 $\pm$ 0.5	<0.001
	Day 2: 2.8 $\pm$ 0.5	
	Day 3: 2.5 $\pm$ 0.5	
	Day 7: 2.2 $\pm$ 0.5	

Total Analgesic Consumption (Total Dose in Mg Per Period)	24: h: 220 $\pm$ 25	<0.001
	Day 2: 200 $\pm$ 22	
	Day 3: 180 $\pm$ 20	
	Day 7: 150 $\pm$ 18	
Time to First Postoperative Analgesic Request (Minutes; Single Measurement)	270 $\pm$ 38	—

Results are presented as mean $\pm$ standard deviation (SD). VAS =Visual Analogue Scale for pain (from 0=no pain to 10 =worst pain. Total analgesic consumption = the total dose of rescue analgesics administered in milligrams(mg) over each postoperative period. Time to first analgesic request = the interval from the end of surgery to the first patient request for analgesia, measured in minutes. $p < 0.05$ = statistically significant and measured via Repeated Measures ANOVA

During the postoperative follow-up period (1 hour to Day 7), the incidence of adverse events remained low, and no statistically significant temporal changes were observed for most complications. A non-significant difference was observed for nausea and vomiting, increasing from 1.3% to 4.0% at 24 hours, then returning to 2.0% by postoperative Day 7 ($p = 0.944$). Similarly, hypotension also showed a statistically insignificant rise to a peak incidence of 8.0% at 24 hours, and then a gradual decrease to 4.0% at Day 7 ($p = 0.312$), which might be related to the residual effects of spinal anesthesia and postoperative fluid redistribution. Shivering was more common during the early postoperative period, with its highest incidence (4.7%) at 6 hours and decreasing to 1.3% on Day 7 ($p = 0.844$), which did not reach statistical significance. Bradycardia remained infrequent ($< 5\%$), peaking at 4.7% at 24 hours, with no significant discrepancy across successive time points ($p = 0.544$) (Table 5).

Table 5: Follow-up of Adverse Effects

Parameter	1h	2h	4h	6h	12h	24h	Day 2	Day 3	Day 7	p-value
Vomiting/Nausea	2(1.3%)	3(2.0%)	4(2.7%)	5(3.3%)	5(3.3%)	6(4.0%)	5(3.3%)	4(2.7%)	3(2.0%)	0.944
Hypotension	3(2.0%)	4(2.7%)	6(4.0%)	8(5.3%)	9(6.0%)	12(8.0%)	10(6.7%)	8(5.3%)	6(4.0%)	0.312
Shivering	4(2.7%)	5(3.3%)	6(4.0%)	7(4.7%)	6(4.0%)	5(3.3%)	4(2.7%)	3(2.0%)	2(1.3%)	0.844
Bradycardia	1(0.7%)	2(1.3%)	3(2.0%)	4(2.7%)	5(3.3%)	7(4.7%)	6(4.0%)	5(3.3%)	4(2.7%)	0.544

Results are expressed as frequency(N) and percentages(%). Hypotension was considered as systolic blood pressure < 90 mmHg or a $\geq 20\%$ decrease from baseline. Bradycardia was defined as Heart rate < 50 beats per minute. $p < 0.05$ = statistically significant and measured via Repeated Measures ANOVA

DISCUSSION

The present study examined the effect of adding magnesium sulfate to intrathecal local anesthetics regarding the characteristics of the spinal block and the postoperative analgesia. The results showed prolongation of sensory and motor blockade, delay in duration to first analgesic request, decrease in postoperative opioid consumption, and better pain control after surgery with magnesium without causing clinically significant changes in hemodynamics and an increase in adverse events. Importantly, the onset of spinal anesthesia was not affected, but the duration of the sensory blockade was significantly prolonged. This evidence is corroborated by previous studies showing that the use of magnesium sulfate with bupivacaine for spinal anesthesia provides longer duration of anesthesia and postoperative analgesia with little effect on the onset of anesthesia [9]. The prolonged sensory block observed in the present study may be attributed to magnesium's antagonistic action on N-methyl-D-aspartate (NMDA) receptors and its calcium influx modulation, which reduces central sensitization and enhances local anesthetic efficacy [17]. Similar findings have observed prolonged sensory block duration and delayed sensory regression after administering intrathecal magnesium sulfate during spinal anesthesia [18]. On the other hand, some studies reported modest sensory prolongation, specifically when lower doses of magnesium were used or when magnesium was compared with more potent adjuvants like dexmedetomidine [19]. Such

discrepancies might be explained by alterations in magnesium dosage, demographic characteristics, surgical procedures and anesthetic protocols. The current study revealed a small but statistically significant change in the onset of motor block over time ($p < 0.001$). In contrast, the duration of motor block showed a significant prolongation across follow-up assessments ($p < 0.001$). The results were consistent with a previous study that found intrathecal magnesium sulfate significantly increased the duration of motor block and postoperative analgesia ($p < 0.001$) and decreased rescue analgesic use. Unlike the present study, that study also determined that the onset of motor block was significantly delayed in the magnesium sulfate group (7.86 ± 1.19 minutes) compared with the control group (5.28 ± 1.31 minutes; $p < 0.001$) [10]. The prolonged time to first analgesic request observed in the current investigation reflects enhanced and prolonged postoperative analgesia following intrathecal magnesium sulfate administration. Previous investigations also reported prolonged postoperative analgesia, delayed requirements for rescue analgesics, and extended motor block duration after the addition of intrathecal magnesium sulfate to bupivacaine [20]. Such an effect may be explained by the effects of magnesium on neural ion channels and membrane stabilization that extend the duration of motor block caused by a local anesthetic with minimal degradation of motor onset. The present study exhibited a steady decline in postoperative pain (VAS scores from 24 hours to Day 7)

along with reduced per-period analgesic consumption, indicating improved pain control with intrathecal magnesium sulfate. Such findings support its role in modulating nociceptive transmission and central sensitization. Prior meta-analyses support these findings by demonstrating improved postoperative analgesia and opioid-sparing effects associated with intrathecal magnesium [9]. However, some studies compared magnesium sulfate with more potent adjuvants, such as dexmedetomidine, and reported no significant reduction in postoperative analgesic requirements in the magnesium group [21]. In the study, Hemodynamic parameters showed no clinically significant changes during follow-up, indicating that intrathecal magnesium sulfate was well tolerated without clinically significant cardiovascular or respiratory effects. These findings are consistent with earlier findings that observed no significant adverse cardiovascular effects with intrathecal magnesium [4]. It implies that intrathecal magnesium sulphate may be safely administered as an adjunct to spinal anesthesia. In the present study, the proportion of postoperative adverse events observed during the follow-up period was low and was not found to be statistically significant across the follow-up period. These findings are consistent with a recent meta-analysis, which reported that intrathecal magnesium sulfate did not significantly increase the risks of hypotension, nausea and vomiting, pruritus, or bradycardia compared with control groups. Furthermore, analysis revealed that magnesium was highly effective at decreasing the incidence of shivering in the postoperative period and had a favorable safety profile. Based on these findings, the use of intrathecal magnesium as an adjunct to the administration of spinal anesthesia is safe and does not increase the perioperative complications [5], indicating that magnesium influences the central thermoregulatory pathways and calcium channel modulation, which decreases shivering without systemic compromise. The findings support magnesium sulfate as a safe, effective, and inexpensive adjuvant to intrathecal anesthesia. It may reduce opioid use and related side effects by prolonging block duration and improving postoperative analgesia, consistent with multimodal analgesia and ERAS principles. However, the absence of a control group is a significant limitation, as it prevents definitive conclusions about the causal effects of intrathecal magnesium sulfate. The study contained several limitations, including the absence of a control group, which limited the ability to determine whether the extended duration of sensory and motor blockade and the reduced need for postoperative analgesia were specifically attributable to the addition of magnesium sulfate. The single-centered nature of this study restricted generalizability and external validity.

Moreover, patients' characteristics, including concomitant medications, comorbidities, and perioperative management, might influence the findings in the relatively short follow-up period. The optimal dose of intrathecal magnesium sulfate remains unclear, as different doses were not evaluated. Furthermore, this study was conducted for educational and research purposes; therefore, the findings should not be directly replicated or used for treatment purposes. Based on such limitations, future studies should adopt a multicentered approach and randomized controlled designs to increase generalizability and causal evidence. Dose-ranging studies are required to determine an optimum therapeutic-toxicity ratio, and comparative trials with other adjuvants used are recommended. Long-term follow-up is also required to evaluate sustained efficacy, safety, and patient-centered outcomes across diverse surgical populations.

CONCLUSIONS

The study concluded that magnesium sulfate is a safe and effective adjuvant to spinal anesthesia, as its addition significantly increased sensory and motor block duration and enhanced postoperative analgesia by delaying the first request for analgesics, lowering overall analgesic use, and reducing postoperative pain levels. These benefits were achieved without any increase in hemodynamic effects or any other complications. Therefore, as part of a multimodal analgesic approach, magnesium sulfate is a useful, affordable choice for improving the quality of spinal anesthesia and postoperative pain control.

Authors' Contribution

Conceptualization: AS

Methodology: AS, R

Formal analysis: AS, LN, R, HS

Writing and Drafting: KN, SU

Review and Editing: AS, LN, R, HS, SU

All authors approved the final manuscript and take responsibility for the integrity of the work

Conflict of Interest

All the authors declare no conflict of interest.

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