Section: Anesthesia

Original Research Article

EFFECT OF SINGLE-DOSE INTRAVENOUS MAGNESIUM SULPHATE ON POSTOPERATIVE ANALGESIA FOLLOWING BRACHIAL PLEXUS BLOCK

Ashita Mowar[1], Akhilesh Pahade[1], Vishwadeep Singh[2], Aditi Seal[3]

[1]Associate Professor, Department of Anesthesia, SRMS Institute of Medical Sciences, Bareilly, Uttar Pradesh, India.
[2] Professor, Department of Anesthesia, SRMS Institute of Medical Sciences, Bareilly, Uttar Pradesh, India.
3 Senior Resident, Department of Anesthesia, SRMS Institute of Medical Sciences, Bareilly, Uttar Pradesh, India.

Received : 05/01/2025
Received in revised form : 03/03/2025
Accepted : 18/03/2025

Keywords:
Magnesium sulfate ($MgSO_4$), Brachial plexus block, Postoperative analgesia, Opioid-sparing effect, Opioid free anaesthesia, NMDA receptor antagonis.

Corresponding Author:
Dr. Akhilesh Pahade,
Email: akhileshpahade09@gmail.com

DOI: 10.47009/jamp.2025.7.2.162

Source of Support: Nil,
Conflict of Interest: None declared

Int J Acad Med Pharm
2025; 7 (2); 801-806

Abstract

Background: Postoperative pain following upper extremity orthopedic surgeries remains a significant challenge, often necessitating opioid use with associated side effects. Magnesium sulfate ($MgSO_4$), an NMDA receptor antagonist and calcium channel blocker, has shown potential in enhancing analgesia and reducing opioid consumption. This study evaluates the efficacy of a single-dose intravenous $MgSO_4$ in prolonging postoperative analgesia following brachial plexus block (BPB). **Materials and Methods:** A prospective, randomized, double-blinded, controlled trial was conducted on 60 ASA I-II patients undergoing elective forearm or wrist surgeries under ultrasound-guided supraclavicular BPB. Patients were randomized into two groups: Group M received 50 mg/kg IV $MgSO_4$, and Group C received normal saline. Primary outcomes included postoperative pain scores till first rescue analgesic, effect on hemodynamics and motor/sensory block characteristics at pre-determined end points. Secondary outcomes included adverse events and measurement of serum magnesium levels. **Result:** Baseline characteristics were comparable between groups. The duration of sensory block was significantly prolonged in Group M (256.67 ± 20.32 min) compared to Group C (223.32 ± 16.67 min) ($p < 0.0001$). Time to first analgesic request was significantly longer in Group M (333.67 ± 30.11 min vs. 256.67 ± 30.22 min, $p < 0.0001$), and total opioid consumption was reduced. Serum magnesium levels increased significantly post-administration but remained within safe limits. No significant adverse effects were observed. **Conclusion:** A single-dose IV $MgSO_4$ effectively prolongs postoperative analgesia, reduces opioid consumption, and enhances patient recovery without significant side effects. These findings support its role as an adjunct in multimodal pain management for upper extremity surgeries.

INTRODUCTION

Worldover, surgeries involving upper limb for fractures involving humerus, radius, ulna or bones of hand are a common occurrence, especially among the elderly age group which often suffer from multiple comorbidities. Such patients are also susceptible to excruciating pain in the peri-operative phase. Poorly controlled pain not only exacerbates patient suffering but also elevates the risk of complications, including delayed functional recovery, heightened susceptibility to chronic pain syndromes, prolonged hospital stays and thereby risking the patients to the risk of opioid dependence and addiction.[1] Conventional pain management strategies heavily rely on opioids, but their utility is hampered by dose-limiting side effects such as nausea, sedation, respiratory compromise, and the potential for addiction.[2] Regional nerve blocks prove as a boon for patients undergoing upper limb orthopedic surgeries. However, nerve blocks suffer from the prime limitation of restricted duration, unless nerve block catheters are used. Another method to prolong the duration of nerve block is to use adjuvants either intravenously or along with local anaesthetics. Adjuncts and multimodal pain management strategies synergize with existing protocols to enhance analgesia while minimizing opioid-related risks.

ISSN (O): 2687-5365; ISSN (P): 2753-6556

A strong contender for multimodal pain management is magnesium, an endogenous cation having pleiotropic biological effects. Two primary mechanisms are responsible for its antinociceptive effects are: competitive antagonism of NMDA receptors, resulting in decreased wind-up and central sensitisation, and modulation of voltage-gated calcium channels, which reduces neuronal hyperexcitability and nociceptive signalling.[3] In a variety of surgical models, intravenous magnesium sulphate ($MgSO_4$) has been shown to be effective in lowering the requirement for intraoperative anaesthetic and postoperative opioid usage.[4] In significant orthopaedic cases, for example, it has been established that co-administration of epidural and local anaesthetics may prolong the duration of analgesia by up to forty percent.[5] Notwithstanding these results, its potential as a supplement to brachial plexus blocks—a staple in upper limb operations—is still not acknowledged.[6] The integration of a single preoperative intravenous dose of $MgSO_4$ into this regimen may prolong the analgesic window, thus tackling the period between block recovery and the demand for rescue medication, which may have implications on 24 hours opioid requirement. Additionally, its favourable safety profile and low cost make it a practical adjunct in resource-limited environments.

Our study investigated the efficacy of a single intra-operative intravenous magnesium sulphate dose (50 mg/kg) in patients undergoing elective forearm or wrist procedures under peripheral nerve stimulator-guided brachial plexus block(BPB). Primary outcomes include postoperative pain scores (measured via Visual Analog Scale till first rescue analgesic), time to first analgesic request, motor and sensory block characteristics and effect of intravenous magnesium on hemodynamics.

Secondary outcomes encompass incidence of adverse events (e.g., hypotension, bradycardia, sedation) and serum magnesium levels at pre-defined time points. By elucidating impact of a single dose of intravenous magnesium sulphate on analgesia quality, this study aims to redefine perioperative protocols for upper extremity surgeries, potentially reducing opioid reliance and accelerating recovery trajectories.

MATERIALS AND METHODS

This prospective, randomized, parallel-arm, double-blind clinical study, Helsinki protocol compliant, ethical committee approved clinical study was conducted after obtaining written informed consent from all participants. The study included 60 patients aged 18–60 years, of either sex, classified as American Society of Anesthesiologists (ASA) physical status I or II, scheduled for elective upper limb surgeries.

Exclusion criteria comprised patient refusal, known hypersensitivity to the study drugs, pregnancy, significant comorbidities (e.g., active COPD or asthma, congestive heart failure, myocardial infarction within the past six months, heart block, fixed cardiac output lesions, chronic liver or kidney disease), inability to comprehend the postoperative pain assessment scale, intraoperative surgical plan changes, or complications. Patients with failed blocks (defined as absence of anesthesia in two or more peripheral nerve distributions) were administered general anaesthesia and were excluded from the study.

Participants were randomized using a computer-generated randomization method into two groups: Group M (Magnesium sulfate 50mg/kg) and Group C (Control/placebo, 0.9% normal saline). Allocation concealment was achieved using sequentially numbered, sealed, opaque envelopes prepared by an independent volunteer. Study drugs were administered by another volunteer not involved in the trial. Both magnesium sulfate and saline solutions were identical in appearance, ensuring blinding of patients and investigators.

During the preanesthetic visit, patients were familiarized with the 10-point Visual Analog Scale (VAS) and received tablet alprazolam 0.25 mg the night before surgery. Fasting protocols adhered to ASA guidelines. A standardized anesthesia protocol was followed for all participants.

In the operating room, standard monitors were applied, and peripheral venous access was established. A supraclavicular brachial plexus block was performed under peripheral nerve stimulator guidance (Stimuplex® Dig RC, B. Braun, Melsungen, Germany). The target nerve was localized using a 1 mA current at 2 Hz, gradually reduced to <0.5 mA upon eliciting the appropriate motor response. Levo-bupivacaine 0.375% (25 mL, maximum dose 2 mg/kg) was administered as the local anesthetic.

Sensory block was assessed using pinprick testing in the dermatomes of the musculocutaneous (forearm), radial (dorsal 1st and 2nd intermetacarpal area), median (palmar side of the 3rd fingertip), and ulnar (palmar side of the 5th fingertip) nerves. A two-point scale was used (0 = no block, 1 = loss of pinprick sensation). Motor block was evaluated by testing elbow flexion (musculocutaneous nerve), arm extension/supination and finger extension (radial nerve), wrist flexion/pronation and 2nd–3rd finger flexion (median nerve), and 4th–5th finger flexion/thumb adduction (ulnar nerve). Motor block was graded on a three-point scale (0 = no block, 1 = partial block, 2 = complete block).

Group M received a magnesium sulfate bolus (50 mg/kg) infused over 15 minutes following successful block administration, while Group C received an equivalent volume of normal saline. Sensory and motor blocks were assessed every 5 minutes for 30 minutes or until complete blockade was achieved. Surgical anesthesia was defined as sensory block grade 1 and motor block grade 2 in all four nerves.

The duration of analgesia was defined as the time from block onset to the first request for rescue analgesia. Intraoperative duration and postoperative

ISSN (O): 2687-5365; ISSN (P): 2753-6556

pain (assessed using VAS) were recorded. A VAS score >4 was considered indicative of inadequate analgesia. The time to the first rescue analgesic, incidence of nausea/vomiting, and other side effects were documented over 24 hours. Serum magnesium levels were measured preoperatively, immediately post-administration, and postoperatively. Signs of hypermagnesemia were monitored and managed as needed.

Postoperatively, pulse oximetry, heart rate, mean arterial pressure, and VAS scores were monitored. Pain was assessed immediately upon arrival in the PACU and hourly thereafter. Tramadol (1.5 mg/kg IV) was administered as rescue analgesia for VAS >4. The time to the first rescue analgesic was recorded.

RESULTS

The demographic profile [Table 1] of the two study groups, Group C (Control) and Group M (Magnesium sulfate), revealed no significant differences in baseline characteristics. The mean age of participants in Group C was 36.75±7.296 years, while in Group M, it was 39.54±10.098 years ($p = 0.242$). The BMI was comparable between the two groups, with Group C having a mean BMI of 24.68±3.465 and Group M 25.64±1.929 ($p = 0.204$). The distribution of ASA Physical Status I and II was also similar, with Group C having 12 ASA I and 16 ASA II patients, while Group M had 13 ASA I and 15 ASA II patients ($p = 0.789$). The duration of surgery was almost identical, with Group C averaging 56.39±6.315 minutes and Group M 55.43±6.408 minutes ($p = 0.573$).

Regarding motor block characteristics [Table 2], the onset time of motor blockade was slightly shorter in Group M (15.60 ± 2.77 minutes) compared to Group C (16.50 ± 2.33 minutes), but this difference was not statistically significant ($p = 0.178$). The duration of motor blockade was slightly longer in Group M (271.80 ± 45.36 minutes) than in Group C (252.67 ± 44.84 minutes), though this did not reach statistical significance ($p = 0.105$).

The onset of sensory blockade is similar between the groups, with $p > 0.05$, suggesting no significant difference. However, Group M shows a significantly longer duration of sensory block ($p < 0.0001$) compared to Group C, with a mean duration of 256.67 ± 20.32 minutes versus 223.32 ± 16.67 minutes, respectively. Additionally, the duration of analgesia or the time until the first rescue analgesic is needed is also significantly longer in Group M (333.67 ± 30.11 minutes) compared to Group C (256.67 ± 30.22 minutes), with a p value of < 0.0001. [Figure 2] (heart rate variability) shows that both groups start with similar baseline heart rates (~84.6 bpm). After the block, Group M experiences a greater drop (77.32 bpm) compared to Group C (79.33 bpm). Group C exhibits a transient rise after magnesium administration (82.6 bpm), while Group M remains lower (79.4 bpm). Over time, both groups stabilize, with minimal differences, converging at 80.96 bpm (Group C) and 80.2 bpm (Group M) by the final recorded assessment. While [Figure 3] (mean arterial pressure) indicates that both groups start with similar baseline MAP values (92.43 mmHg for Group C and 92.9 mmHg for Group M). After the block, there is a slight increase in both groups, peaking at 93.1 mmHg (Group C) and 92.73 mmHg (Group M) after magnesium administration. Over time, a gradual decline is observed, with Group M showing slightly lower values than Group C. By the final recorded assessment, MAP decreases to 91.56 mmHg (Group C) and 91.23 mmHg (Group M), suggesting a mild but non-significant reduction in blood pressure over time. Given that magnesium is known for its mild hypotensive and bradycardic effects due to calcium channel antagonism, any significant variations in these parameters should be analyzed to assess safety and tolerability.

Plasma magnesium levels were measured at different time points, showing a significant increase in Group M immediately post-administration. At baseline, magnesium levels were comparable between Group C (2.15 ± 0.21) and Group M (2.11 ± 0.21) ($p > 0.05$). However, immediately after magnesium administration, levels in Group M increased significantly to 2.75 ± 0.17, while Group C remained at 2.16 ± 0.20 ($p < 0.001$). Postoperatively, magnesium levels in Group M were still elevated at 2.30 ± 0.16 compared to 2.13 ± 0.21 in Group C ($p = 0.0008$).

Table 1: Demographic profile.

Parameter	Group C	Group M	P
Age	36.75±7.296	39.54±10.098	0.242
BMI	24.68±3.465	25.64±1.929	0.204
ASA-I ASA-II	12 16	13 15	0.789
Duration of surgery	56.39±6.315	55.43±6.408	0.573

Table 2: Motor block characteristics

Motor blockade (minutes)	Group C Mean ± SD	Group M Mean ± SD	p Value
Onset	16.50 ± 2.33	15.60 ± 2.77	0.178
Duration	252.67 ± 44.84	271.80 ± 45.36	0.105

ISSN (O): 2687-5365; ISSN (P): 2753-6556

Table 3: Sensory block characteristics

Sensory Blockade (min)	Group C (Mean ± SD)	Group M (Mean ± SD)	p Value
Onset	12.1 ± 2.67	12.2 ± 2.94	>0.05
Duration of sensory block	223.32 ± 16.67	256.67 ± 20.32	<0.0001
Duration of analgesia/first rescue analgesic	256.67 ± 30.22	333.67 ± 30.11	<0.0001

Table 4: Mean plasma magnesium levels

Time	Group C Mean ± SD	Group M Mean ± SD	p Value
Baseline	2.15 ± 0.21	2.11 ± 0.21	>0.05
Imm post Mg	2.16 ± 0.20	2.75 ± 0.17	<0.001
Imm Post Op.	2.13 ± 0.21	2.30 ± 0.16	0.0008

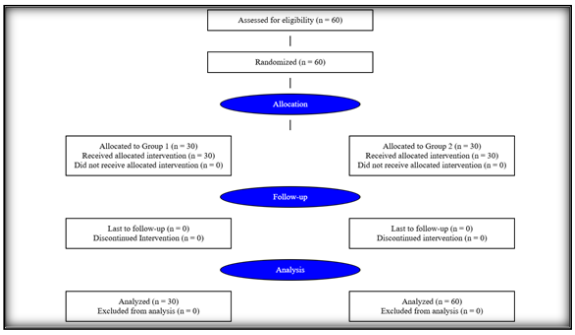

Figure 1: CONSORT Diagram

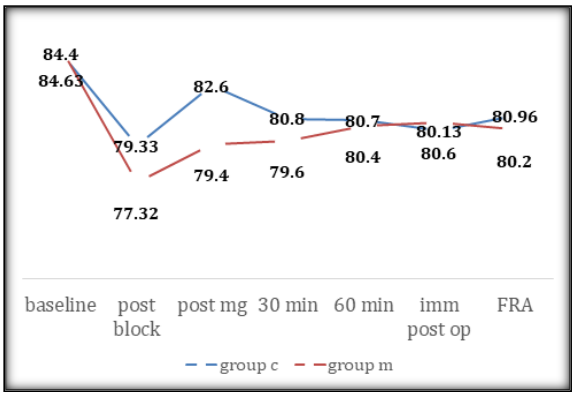

Figure 2: Heart rate variability

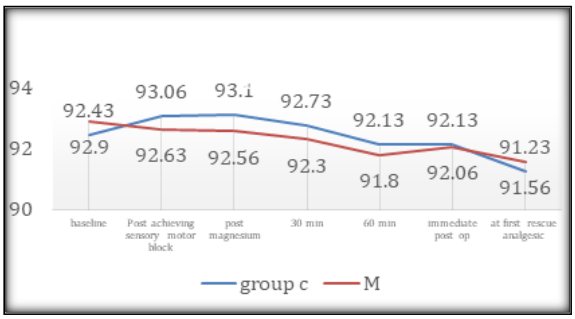

Figure 3: Mean arterial pressure variability

DISCUSSION

Peri-operative pain management following upper limb orthopedic surgeries is a major challenge for anaesthesiologist world-over. Regional nerve blocks and brachial plexus block (BPB) as employed by us in our study is effective technique in the armamentarium of anaesthesiologists for perioperative anesthesia and analgesia. However, nerve blocks face the problem of their effects wearing off unless adjuvants or catheters are employed. This shortcoming translates into the need for frequent rescue analgesics particularly opioids. Among the commonly used adjuvants used is magnesium sulfate ($MgSO_4$) which has generated interest due to its distinct NMDA-receptor antagonism and calcium channel-blocking properties, helping in pain modulation and nullifying central sensitization.

Our research aimed to assess the efficacy of a single preoperative intravenous dose of $MgSO_4$ and explore its potential to enhance postoperative analgesia in patients undergoing upper limb orthopedic surgeries with regional nerve block (Supraclavicular brachial plexus block (BPB)).

Both study groups were comparable in terms of baseline demographics, thereby ensuring that any differences in pain outcomes were attributable to the intervention itself.

Duration of sensory block and total duration of analgesia were our primary outcome measures. Our findings showed that patients who received IV $MgSO_4$ experienced significantly lower pain scores evaluated using Visual analogue scale postoperatively compared to the control group. Both duration of sensory block and total analgesic duration were higher in patients who were administered intravenous MagSO4. These results are in line with previous studies. Peng et al., observed reduced postoperative pain across different orthopedic procedures following intravenous administration of $MgSO_4$.[7] Alternately, Akhondzadeh et al. also reported prolonged sensory blockade and improved pain relief when $MgSO_4$ was combined with lidocaine in supraclavicular BPB.[8] The possible reasons for this observations by Peng et al and Akhondzadeh et al can be attributed to $MgSO_4$'s ability to avert central sensitization and wind-up phenomena, which are typically activated by surgical insults.

Our results also were in line with those reported by Verma et al., who inferred that $MgSO_4$ as an adjuvant extended postoperative analgesia. However, supremacy of $MgSO_4$ was questioned by Olapour et al. The investigators reported that sufentanil; an opioid provided superior pain relief compared to $MgSO_4$.[9,10] We presume that these discrepancies might be due to differences in surgical type, $MgSO_4$ dosage or the route of administration.

We also analysed an important outcome measure i.e time for first rescue analgesic or analgesic duration as provided by the initial bolus of MgSO4. The time to the first analgesic request was also significantly

ISSN (O): 2687-5365; ISSN (P): 2753-6556

prolonged in the $MgSO_4$ group over control population. These results align with a systematic review by Peng et al., who highlighted the opioid-sparing effects of IV $MgSO_4$.[7] Also, Khanal et al. conferred the efficacy of both intravenous and perineural $MgSO_4$ administration in providing post-operative pain relief, although the IV route was more effective in reducing opioid consumption.[11] A few authors viz., Abdelrahman et al. agreed to the opioid reduction with perioperative $MgSO_4$ use, its efficacy in prolonging postoperative analgesia was comparable to dexamethasone.[12]

Regarding block characteristics, our study revealed a modest increase in sensory and motor blockade duration in the $MgSO_4$ group over the control population. While $MgSO_4$ only slightly extend motor blockade, its effect was not significant. Akhondzadeh et al. and Verma et al. also reported a trend similar to ours.[8,9] However, a meta-analysis done by Peng et al. pointed out that while $MgSO_4$ reliably reduces pain scores and opioid requirements, its effect on block duration varied and were non-consistent.[7]

Excellent safety profile of IV $MgSO_4$ in our study bolstered its usability in patients requiring perioperative pain relief. There were no episodes of hypotension, bradycardia, or excessive sedation. This is consistent with findings by Abdelrahman et al., who reported that a single IV dose of $MgSO_4$ did not cause significant cardiovascular instability.[12] However, patients with cardiac or renal dysfunction may be at a higher risk of magnesium-related complications, and caution should be exercised in such cases. We also observed that patients of magnesium group exhibited lower incidence of postoperative nausea and vomiting (PONV) which can be attributed to reduced use of peri-operative opioids. Akhondi and Sarkoohi reported similar findings in patients undergoing laparoscopic cholecystectomy, where $MgSO_4$ administration significantly reduced PONV and improved overall recovery.[16]

Serum magnesium levels were monitored and they increased significantly in the $MgSO_4$ group commencing immediately post-administration. However, they were confined in the normal physiologically levels. While serum magnesium levels declined over the perioperative period the levels were still elevated in the study group. Normal serum magnesium levels typically range between 1.7 and 2.3 mg/dL, and none of our study subjects overshot the permissible physiological levels, thereby allaying the anxiety of hypermagnesemia related side effects.[13] Prior researches also concluded IV $MgSO_4$ administration result into transient rise in serum magnesium levels, with levels of magnesium correlating with degree and duration of postoperative pain-free periods.[14,15]

Limitations

No study is free of any limitations and so was ours. The relatively small sample size may have impact over its generalizability, and more trials with larger sample size and possibly on populations of different demographic profiles are needed to revalidate these results. Additionally, while we assessed postoperative pain till first rescue analgesic requirement and a longer follow-up would be beneficial to explore $MgSO_4$'s potential role in chronic pain management and patients with history of opioid use/abuse.

CONCLUSION

Our findings suggest that a single-dose IV $MgSO_4$ is an effective adjunct for upper limb surgeries performed under BPB. It enhances postoperative analgesia, reduces opioid use, and delays the need for rescue analgesics without causing significant adverse effects. While some inconsistencies exist in the literature, our study supports the opioid-sparing benefits of IV $MgSO_4$. Given its low cost, favorable safety profile, and ease of administration, $MgSO_4$ could become a valuable component of multimodal analgesia protocols. Future research should focus on optimizing dosing strategies, evaluating long-term pain outcomes, and exploring interactions with other adjuvants.

REFERENCES

1. Kehlet H, Jensen TS. Persistent postsurgical pain: risk factors and prevention. Lancet. 2006;367(9522):1618-25.
2. Benyamin R, Trescot AM, Datta S, et al. Opioid complications and side effects. Pain Physician. 2008;11(2 Suppl):S105-20.
3. Fawcett WJ, Haxby EJ, Male DA. Magnesium: physiology and pharmacology. Br J Anaesth. 1999;83(2):302-20.
4. Dabbagh A, Elyasi H, Razavi SS, et al. Intravenous magnesium sulfate for post-operative pain in patients undergoing lower limb orthopedic surgery. Acta Anaesthesiol Scand. 2009;53(8):1088-91.
5. Arcioni R, Palmisani S, Tigano S, et al. Combined intrathecal and epidural magnesium sulfate supplementation of spinal anesthesia to reduce post-operative analgesic requirements: a prospective, randomized, double-blind, controlled trial in patients undergoing major orthopedic surgery. Acta Anaesthesiol Scand. 2007;51(4):482-9.
6. Albrecht E, Kirkham KR, Liu SS, Brull R. Peri-operative intravenous administration of magnesium sulphate and postoperative pain: a meta-analysis. Anaesthesia. 2013;68(1):79-90.
7. Peng YN, Sung FC, Huang ML, Lin CL, Kao CH. The use of intravenous magnesium sulfate on postoperative analgesia in orthopedic surgery: A systematic review of randomized controlled trials. Medicine. 2018;97(50):e13583.
8. Akhondzadeh R, Nesioonpour S, Gousheh M, Soltani F, Davarimoghadam M. The effect of magnesium sulfate on postoperative pain in upper limb surgeries by supraclavicular block under ultrasound guidance. Anesth Pain Med. 2017;7(3):e14232.
9. Verma V, Rana S, Chaudhary SK, Singh J, Verma RK, Sood S. A dose-finding randomized controlled trial of magnesium sulphate as an adjuvant in ultrasound-guided supraclavicular brachial plexus block. Indian J Anaesth. 2017;61(3):250-5.
10. Olapour AR, Mohtadi AR, Soltanzadeh M, Ghomeishi A, Akhondzadeh R, Jafari M. The effect of intravenous magnesium sulfate versus intravenous sufentanil on the duration of analgesia and postoperative pain in patients with tibia fracture. Anesth Pain Med. 2017;7(3):e44035.
11. Khanal D, Sah BP, Bhattarai B, Prasad J, Subedi A, Khatiwada K, et al. The effectiveness of magnesium sulphate intravenous bolus or added as an adjunct to ropivacaine for brachial plexus block in upper limb orthopedic surgeries. IJISRT. 2023;8(6):1340-41.

ISSN (O): 2687-5365; ISSN (P): 2753-6556

12. Abdelrahman TN, Abu-Sinna RG. Comparing intravenous single low doses of magnesium sulphate versus dexamethasone as adjuvants to ultrasound-guided transversus abdominis plane (TAP) block for prolongation of postcesarean analgesia. Open Anesthesia J. 2021;15:22-9.
13. Fawcett WJ, Haxby EJ, Male DA. Magnesium: Physiology and pharmacology. Br J Anaesth. 1999;83(2):302–20
14. Khosravi MB, Madani SH, Banihashem N, Seyed Siamdoust SA. The effect of intravenous magnesium sulfate on spinal anesthesia with bupivacaine in lower limb orthopedic surgery. Anesth Pain Med. 2020;10(4):e101815.
15. Telci L, Esen F, Akcora D, Erden T, Canbolat AT, Akpir K. Evaluation of effects of magnesium sulphate in reducing intraoperative anesthetic requirements. Br J Anaesth. 2002;89(4):594–8
16. Akhondi M, Sarkoohi A. Effect of intravenous injection of magnesium sulphate on intraoperative end-tidal CO2 level and postoperative pain in laparoscopic cholecystectomy. Anesth Pain Med. 2023;13(6):e135189.

ISSN (O): 2687-5365; ISSN (P): 2753-6556