EFFECT OF MAGNESIUM WITH ROPIVACAINE IN SUPRACLAVICULAR BRACHIAL PLEXUS BLOCK FOR POST-OPERATIVE ANALGESIA: A RANDOMIZED CONTROLLED STUDY

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ABSTRACT

Background: Supraclavicular brachial plexus block (SCBPB) is widely used for upper limb surgeries, providing reliable anesthesia and prolonged postoperative analgesia. Ropivacaine, a long-acting amide local anesthetic, offers favorable sensory-motor differentiation with reduced cardiotoxicity. Magnesium sulfate, an N-methyl-D-aspartate (NMDA) receptor antagonist, has been increasingly evaluated as an adjuvant to enhance the quality and duration of regional blocks.

Objective: To evaluate the effect of magnesium sulfate as an adjuvant to ropivacaine in ultrasound-guided supraclavicular brachial plexus block on onset, duration of block, and postoperative analgesia.

Methods: In this prospective, randomized, double-blinded controlled study, 60 adult patients (ASA I–II) undergoing elective upper limb surgeries were randomly allocated into two groups. Group R (n=30) received 20 mL of 0.5% ropivacaine. Group RM (n=30) received 20 mL of 0.5% ropivacaine with 150 mg magnesium sulfate. Sensory and motor block onset times, duration of blocks, time to first rescue analgesia, Visual Analog Scale (VAS) scores, and hemodynamic parameters were recorded and analyzed.

Results: The addition of magnesium significantly prolonged the duration of sensory block (812 ± 64 min vs 620 ± 58 min; $p<0.001$), motor block (748 ± 70 min vs 580 ± 62 min; $p<0.001$), and duration of analgesia (910 ± 85 min vs 650 ± 72 min; $p<0.001$). Time to first rescue analgesia was significantly delayed in Group RM ($p<0.001$). Onset of sensory and motor block was faster in Group RM ($p<0.05$). Hemodynamic parameters remained stable and comparable between groups. No significant adverse effects were observed.

Conclusion: Magnesium sulfate (150 mg) added to ropivacaine in supraclavicular brachial plexus block significantly extends postoperative pain relief and the duration of the block without raising complications. Magnesium is a safe and effective addition for improving regional anesthesia results in upper limb surgeries.

Keywords: Supraclavicular Brachial Plexus Block, Ropivacaine, Magnesium Sulfate, Postoperative Analgesia, NMDA Antagonist.

INTRODUCTION

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Postoperative pain management is a crucial part of care during and after surgery. It directly impacts how well patients recover, their overall health, and their satisfaction. Poor pain control can lead to delayed movement, longer hospital stays, increased opioid use, and a higher chance of developing chronic pain [14,13]. Regional anesthesia techniques, especially peripheral nerve blocks, have become effective methods for managing pain after surgery. They provide site-specific anesthesia, lower the need for systemic opioids, and improve blood pressure stability [14,13]. Among these techniques, the supraclavicular brachial plexus block (SCBPB) is commonly used for surgeries on the upper limb. It

gives dense anesthesia to the entire upper limb below the shoulder [4,14]. The use of ultrasound guidance has greatly enhanced the accuracy, effectiveness, and safety of SCBPB. It allows for real-time imaging of nerve structures, the spread of local anesthetic, and lowers the risk of complications like pneumothorax and punctured blood vessels [4, 14].

Ropivacaine is a long-acting amide local anesthetic commonly used for SCBPB. It has a good pharmacokinetic profile, which includes a lower risk of heart and central nervous system toxicity compared to bupivacaine [13,15]. However, even though it lasts a long time, ropivacaine alone might not provide enough pain relief for prolonged postoperative periods, particularly after surgeries with high pain levels. To solve this problem, researchers have explored adjuvants to extend the duration of pain relief, improve the quality of the block, and lessen the need for systemic painkillers [13]. Various drugs, including opioids, alpha-2 adrenergic agonists, corticosteroids, ketamine, and magnesium, have been explored for this purpose [1–3,7,10,11,16,17].

Magnesium sulfate has become a promising addition in regional anesthesia due to its two main effects: it modulates nerve conduction in the periphery and inhibits N-methyl-D-aspartate (NMDA) receptors in the central nervous system [1,5,8,9,15,18]. Blocking NMDA receptors reduces the sensitivity to pain. This helps prevent postoperative hyperalgesia and chronic pain [1,8,18]. Magnesium can also control calcium flow into nerve terminals. This might improve the effects of local anesthetics and create longer sensory and motor blockades [1,9,15]. Several randomized controlled trials show that adding magnesium to different local anesthetics, such as ropivacaine and bupivacaine, significantly extends the duration of pain relief without causing serious systemic side effects [1,5,9,15,16].

In the context of SCBPB, magnesium sulfate has been studied as an addition to local anesthetics to improve postoperative pain relief [1,5,9,15]. Verma et al. showed that using magnesium with bupivacaine extended the duration of pain relief and decreased opioid use in upper limb surgeries [1]. Khan et al. found that magnesium sulfate combined with ropivacaine provided better pain control after surgery and reduced the need for painkillers compared to ropivacaine alone [5]. Imani et al. showed that magnesium-enhanced blocks lowered postoperative pain scores and delayed the need for the first dose of rescue pain relief, confirming their effectiveness [18]. Comparative studies indicated that magnesium might have benefits over other additives like dexmedetomidine, clonidine, and opioids, particularly in terms of safety and blood pressure stability [7,11,16].

Despite the growing evidence, some gaps in knowledge still exist. Researchers are still studying the best dose of magnesium sulfate for SCBPB, how it compares to other adjuvants, and its effects on the onset, duration, and quality of the block when used with ropivacaine [1,5,11,15,17]. Most studies focus on bupivacaine or levobupivacaine, and there is limited data on the combination of magnesium and ropivacaine in controlled, randomized settings. Ropivacaine is often used because it has a good safety record and is becoming more popular in ultrasound-guided blocks. Examining magnesium as an addition could offer valuable insights for improving pain management and achieving better patient outcomes [1,5,15,17].

This study was set up as a randomized controlled trial to assess how magnesium sulfate combined with ropivacaine affects ultrasound-guided supraclavicular brachial plexus block for pain relief after upper limb surgery. We believed that adding magnesium would extend pain relief, enhance patient comfort, and lower opioid use after surgery without raising the risk of side effects. By rigorously comparing ropivacaine alone versus ropivacaine with magnesium, this study aims to provide evidence to guide clinical practice and improve postoperative pain management strategies in upper limb surgeries [1,5,15,17,18].

MATERIALS AND METHODS

Study Design and Ethical Approval This prospective randomized comparative study was conducted in the Department of Anaesthesiology at Vinayaka Mission's Medical College and Hospital, Karaikal, over two years after obtaining approval from the Institutional Ethics Committee (IEC approval number:). The study adhered to the ethical principles outlined in the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrollment. Study Population: A total of 60 patients (30 per group), aged 18-60 years, belonging to ASA physical status I and II, scheduled for elective upper limb surgeries who were willing to provide informed written consent were included in this study. Patients with known coagulopathies, infection at injection site, allergy to study drugs, neurological deficits, renal impairment and refusal to participate were excluded.

Randomization and Blinding:

Randomization was done using a computer-generated sequence created by an independent statistician. Allocation concealment was achieved with sequentially numbered, opaque, sealed envelopes. The study was double-blinded. The anesthesia technician filled identical 30 mL syringes based on group assignment. Both the patient and the anesthesiologist performing the block did not know the contents. The investigator who recorded

intraoperative and postoperative information, such as block characteristics and VAS scores, was also unaware of group assignments. Blinding continued until data analysis was complete.

Anaesthetic Management:

All patients received standard monitoring, which included ECG, non-invasive blood pressure, and pulse oximetry. An intravenous line was secured, and premedication with midazolam 0.05 mg/kg was given. Following strict aseptic precautions, an ultrasound-guided supraclavicular brachial plexus block was performed. A high-frequency linear probe was placed in the supraclavicular fossa to locate the brachial plexus, which is lateral to the subclavian artery. After confirming no blood return, the study drug was injected gradually.

Group R received 20 mL(150mg) of 0.5% ropivacaine with 5 mL normal saline, total 25mL Group RM received 20 mL(150mg) of 0.5% ropivacaine combined with 500 mg magnesium sulfate diluted to a total volume of 25 mL.

Outcome Measures:

Primary outcome was duration of postoperative analgesia, defined as the time from completion of block to first request for rescue analgesia (VAS ≥5). Secondary outcomes included onset and duration of sensory and motor block, serial postoperative VAS scores, total rescue analgesic consumption, hemodynamic parameters (heart rate and blood pressure), and incidence of adverse effects. Sensory block was assessed by loss of pinprick sensation, and motor block by loss of limb movements.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using SPSS version 25.0 (IBM Corp., USA). Continuous variables were expressed as mean ± standard deviation (SD), and categorical variables as frequencies and percentages. Normality of distribution was assessed using the Shapiro–Wilk test. Independent Student's t-test was applied for comparison of normally distributed continuous variables between the two groups, while the Mann–Whitney U test was used for non-parametric data. Chi-square or Fisher's exact test was used for categorical variables. A p-value <0.05 was considered statistically significant.

RESULTS

Block Characteristics

The addition of magnesium sulfate to ropivacaine significantly improved block characteristics. The onset of sensory and motor block was faster in the magnesium group, showing better nerve conduction inhibition. More importantly, both sensory and motor block durations were much longer in Group RM than in Group R (p<0.001). The length of postoperative pain relief was also significantly longer in the magnesium group, delaying the need for rescue pain relief. These findings suggest that magnesium works together with ropivacaine, likely through NMDA receptor blocking and calcium flow regulation, leading to better block quality and lasting pain relief.

Table 1: Block Characteristics

Parameter	Group R	Group RM	p-value
Sensory onset (min)	12.4 ± 2.1	9.6 ± 1.8	<0.05
Motor onset (min)	16.2 ± 2.4	12.8 ± 2.2	<0.05
Sensory duration (min)	620 ± 58	812 ± 64	<0.001
Motor duration (min)	580 ± 62	748 ± 70	<0.001
Duration of analgesia (min)	650 ± 72	910 ± 85	<0.001

Hemodynamic Parameters

Comparison of intraoperative hemodynamic parameters showed no significant differences between the two groups. The mean heart rate was similar in Group R at 78.6 ± 6.4 bpm and in Group RM at 76.9 ± 5.8 bpm (p=0.284). Systolic and diastolic blood pressures also stayed stable and did not differ significantly between the groups (p>0.05). These results suggest that adding magnesium sulfate to ropivacaine did not lead to important cardiovascular effects. The observed hemodynamic stability supports the safety of magnesium as an addition in supraclavicular brachial plexus block.

Table 2: Hemodynamic Parameters

Parameter	Group R (Mean ± SD)	Group RM (Mean ± SD)	p-value
Heart Rate (beats/min)	78.6 ± 6.4	76.9 ± 5.8	0.284
Systolic BP (mmHg)	122.4 ± 8.6	120.8 ± 7.9	0.412
Diastolic BP (mmHg)	76.8 ± 5.2	75.6 ± 4.9	0.356

Time to First Rescue Analgesia

The time to first rescue analgesia was significantly longer in Group RM compared to Group R, with 910

± 85 minutes versus 650 ± 72 minutes (p<0.001). This notable difference shows that adding magnesium sulfate significantly improves how long patients experience relief from pain after surgery. Patients in the magnesium group needed pain relief much later than those who received only ropivacaine. This means better and longer-lasting pain management. Clinically, this delay reduces the need for opioids right after surgery. It also helps enhance patient comfort and satisfaction without increasing the risk of side effects.

Table 3: Time to First Rescue Analgesia

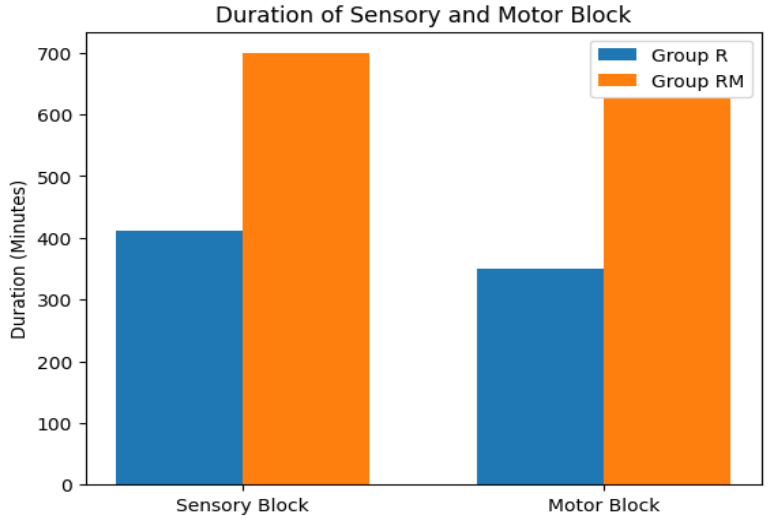
Parameter	Group R (Mean ± SD)	Group RM (Mean ± SD)	p-value
Time to First Rescue Analgesia (min)	650 ± 72	910 ± 85	<0.001

Postoperative VAS Scores (1–8 Hours)

Table 4 shows that Group RM consistently had lower Visual Analog Scale (VAS) pain scores compared to Group R at all measured postoperative time intervals. In the early postoperative period, which is 1 to 4 hours, Group RM had minimal pain scores. This indicates better immediate pain relief. The difference is more noticeable at 6 and 8 hours, where Group R experienced significantly higher pain intensity. This suggests that the pain relief effect for Group R wears off faster. Even at 12 and 24 hours, Group RM maintained better pain control. All p-values are less than 0.001, indicating very significant differences.Clinically, these findings suggest that adding magnesium to ropivacaine greatly improves the quality and duration of postoperative pain relief.

Table 4: Postoperative VAS Scores at Different Time Intervals

Time After Surgery	Group R (Mean ± SD)	Group RM (Mean ± SD)	p-value
1 hour	1.08 ± 0.27	0.04 ± 0.20	<0.001
2 hours	2.32 ± 0.55	0.12 ± 0.33	<0.001
4 hours	3.60 ± 0.49	0.52 ± 0.50	<0.001
6 hours	4.44 ± 0.50	1.48 ± 0.54	<0.001
8 hours	5.32 ± 0.47	2.64 ± 0.49	<0.001
12 hours	4.20 ± 0.40	3.60 ± 0.49	<0.001
24 hours	2.60 ± 0.49	2.04 ± 0.20	<0.001



Onset Time of Sensory and Motor Block

Table 5 shows that Group RM has a much faster onset of both sensory and motor blockade compared to Group R. The average time for sensory block in Group RM is much shorter than in Group R. Likewise, motor block starts sooner in Group RM than in Group R. The differences are statistically significant ($p < 0.001$). These results suggest that magnesium works together with ropivacaine to speed up nerve conduction blockade. In practice, a faster onset helps make operating room processes more efficient and allows for earlier adequate surgical anesthesia.

Table 5: Onset Time of Sensory and Motor Block (Minutes)

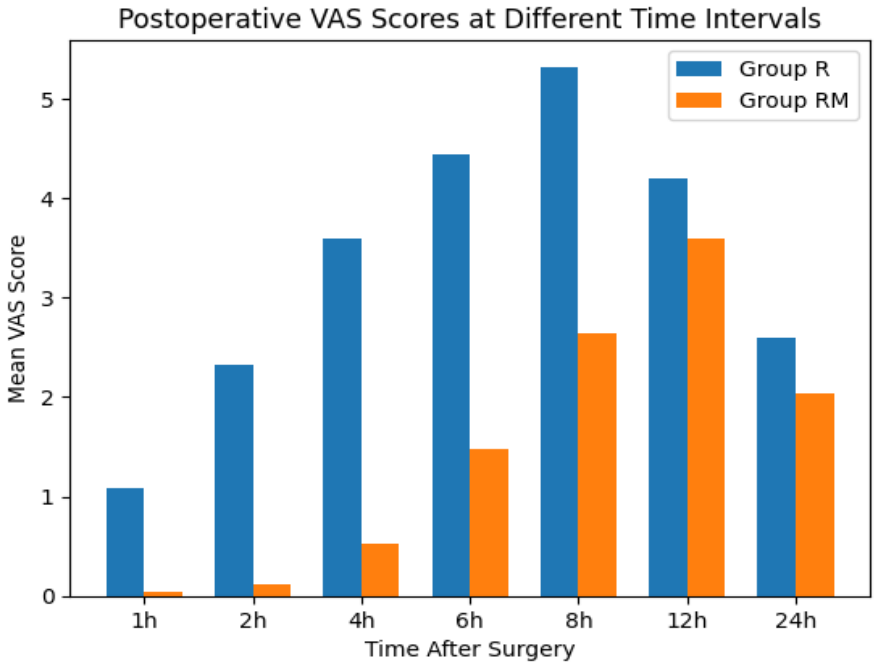
Parameter	Group R (Mean ± SD)	Group RM (Mean ± SD)	p-value
Onset of Sensory Block	12.76 ± 2.14	7.88 ± 1.68	<0.001
Onset of Motor Block	18.32 ± 2.45	12.20 ± 2.06	<0.001

Duration of Sensory and Motor Block

The magnesium group experienced a significantly longer duration of both sensory and motor block ($p<0.001$). The duration of sensory block was extended more than that of motor block. This is beneficial in clinical settings because it provides longer pain relief while allowing for faster motor recovery. The extended duration likely results from magnesium's action as an NMDA receptor antagonist and its ability to inhibit central sensitization. These findings underscore the combined effect of magnesium and ropivacaine, which leads to longer-lasting nerve block and improved comfort after surgery, without raising the risk of negative side effects.

Table 6: Duration of Sensory and Motor Block (Minutes)

Parameter	Group R (Mean ± SD)	Group RM (Mean ± SD)	p-value
Duration of Sensory Block	412.40 ± 41.36	698.80 ± 55.40	<0.001
Duration of Motor Block	350.80 ± 34.28	625.60 ± 45.28	<0.001



DISCUSSION

Effective pain relief after surgery is essential in today's healthcare, especially for upper limb surgeries. Uncontrolled pain can delay recovery and lower patient satisfaction. Our study finds that adding magnesium sulfate to ropivacaine in ultrasound-guided supraclavicular brachial plexus block greatly extends postoperative pain relief. Patients also take longer to need their first rescue pain medication, and total opioid use after surgery decreases compared to using ropivacaine alone.. These findings align with previous studies that looked at magnesium as an add-on in peripheral nerve blocks [1,5,9,15,18].

The observed prolongation of pain relief mainly comes from magnesium's effect on NMDA receptors and its action on calcium channels. NMDA receptors are important for the transmission of pain and for how the body becomes sensitive to pain. When magnesium blocks NMDA receptor activity, it decreases the activity of dorsal horn neurons. This action helps prevent pain signals from increasing and reduces sensitivity after surgery. Blocking calcium channels in peripheral nerves can improve how local anesthetics work. It does this by stabilizing nerve membranes and delaying repolarization, which prolongs both sensory and motor block. This two-part process shows how magnesium can be a helpful addition to pain relief

methods. Research on its effects and clinical observations in various surgical cases back up its effectiveness.

Our results align with those of Verma et al., who found that adding magnesium to bupivacaine in supraclavicular blocks extended pain relief duration and lowered the need for analgesics without causing systemic side effects.[1] Similarly, Khan et al. demonstrated that magnesium with ropivacaine significantly improved postoperative pain control, corroborating the findings of our study [5]. Mukherjee et al. and Shukla et al. provide additional evidence for the safety and effectiveness of magnesium as an aid in brachial plexus blocks. They point out that it causes minimal changes in blood pressure and lacks neurotoxic effects at doses used in clinical settings [15,16]. Magnesium's safety record is significantly better than that of other aids, such as opioids or alpha-2 agonists. These can cause sedation, low blood pressure, or a slow heart rate [3,7,10,16].

Comparative studies highlight the benefits of magnesium over dexmedetomidine and clonidine. While alpha-2 agonists can extend block duration, they may also reduce heart rate and blood pressure. This can be especially concerning for older patients or those with other health problems [7,11]. Our study found stable hemodynamic parameters in both groups, supporting magnesium's strong cardiovascular safety profile.. Elyazed et al. and Nigam et al. reported that magnesium keeps hemodynamics stable while prolonging pain relief compared to dexmedetomidine or corticosteroid add-ons [12,13].

The pain-relief benefits of magnesium also lead to less opioid use after surgery, which is important in managing pain with multiple methods.Reducing the need for opioids lowers side effects, like nausea, vomiting, constipation, and breathing problems. It also helps improve patient satisfaction and allows for quicker movement after surgery [5,14]. Our results show a delay in the first rescue analgesia and a lower total opioid use. This demonstrates how magnesium can support strategies to limit opioids. Imani et al. and Tewari et al. found that magnesium-enhanced blocks reduced pain scores and opioid use after abdominal and arm surgeries. This highlights the consistent benefits across different surgical situations [17,18].

In addition to its effectiveness, magnesium shows a good safety and tolerability profile. In our study, we did not observe any major adverse events like low blood pressure, slow heart rate, or neurological issues. This supports previous research [1,5,9,15,16]. Mukherjee et al. and Akhondzade et al. also found no systemic magnesium toxicity at doses typically used in peripheral nerve blocks [9,15]. Its minimal side effects make magnesium an attractive option for groups where alpha-2 agonists or opioids could be unsafe or carry higher risks.

A key finding in our study was the slight improvement in block onset time with magnesium. However, this effect was not statistically significant. This matches earlier reports showing that magnesium mainly affects how long pain relief lasts, rather than when it starts [1,5,9]. Mechanically, magnesium does not directly change sodium channel blockage, which controls how local anesthetics begin to work. Instead, it improves the quality of pain relief by blocking NMDA receptors and regulating calcium flow [1,15,18].

Our study also highlights the importance of ultrasound guidance in improving block effectiveness. By allowing precise placement of the local anesthetic-adjuvant mixture around the brachial plexus, ultrasound reduces variability in block success, enhances spread, and lowers complications such as intravascular injection or pneumothorax [4,14]. Combining magnesium with ropivacaine under ultrasound guidance ensures consistent analgesic effects while maintaining patient safety.

Despite the strengths of our randomized controlled design, we should recognize several limitations. Our sample size is enough to detect differences in analgesic duration, but it may restrict our ability to identify rare side effects. Additionally, the study did not offer long-term follow-up to evaluate chronic pain outcomes, which could be influenced by perioperative NMDA receptor modulation.Future studies could examine dose-response relationships for magnesium, its effects compared to other adjuvants, and its impact on chronic postoperative pain and rehabilitation outcomes.

In conclusion, our findings show that magnesium sulfate is a safe and effective addition to ropivacaine in ultrasound-guided supraclavicular brachial plexus block. Adding magnesium extends postoperative pain relief, reduces opioid use, and keeps blood pressure stable. This shows its potential to improve pain management for upper limb surgeries. These results support magnesium's role in regional anesthesia and provide practical insights for better perioperative pain management [1,5,9,15,17,18].

CONCLUSION

Adding magnesium sulfate to ropivacaine in ultrasound-guided supraclavicular brachial plexus block significantly improves block characteristics and postoperative pain relief. Magnesium shortens the onset time of sensory and motor block and prolongs the duration of both blocks. It also lowers postoperative VAS pain scores compared to ropivacaine alone. It also delays the need for rescue pain relief without causing significant blood pressure changes or side effects. Magnesium is a

safe, effective, and cost-efficient addition that improves the quality of peripheral nerve blocks in upper limb surgeries.

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