Evaluating the Efficacy of MgSO4 as an Adjuvant to 0.5% Bupivacaine in Supraclavicular-Intercostobrachial Nerve Blocks for Upper Extremity Hemodialysis Vascular Access Surgery

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KEYWORDS
MgSO4, hemodialysis vascular access, total sensory block, total motor block, duration of analgesia, supraclavicular-intercostobrachial block.

ABSTRACT

Background

Peripheral nerve blocks are a preferred anesthetic technique in patients with renal failure undergoing hemodialysis vascular access. A limitation of this technique is the long onset time required to achieve total sensory and motor block. The use of the adjuvant magnesium sulfate (MgSO4) is believed to address this limitation and enhance the effectiveness of the block.

Objective

To evaluate the effectiveness of using MgSO4 20% 2000 mg as an adjuvant in the supraclavicular-intercostobrachial nerve block to expedite the onset time necessary to achieve total sensory and motor block and to prolong the duration of analgesia in patients undergoing upper extremity hemodialysis vascular access surgery. The hypotheses are as follows: 1) MgSO4 as an adjuvant reduces intraoperative fentanyl requirements due to enhanced analgesic effects; 2) MgSO4 decreases perioperative NLR, reflecting reduced systemic inflammation; and 3) MgSO4 modulates PLR, indicating its potential role in controlling platelet activation and inflammatory response.

Methods

This study utilized a randomized controlled trial design with an open-label approach involving 28 patients undergoing upper extremity hemodialysis vascular access surgery at RSUP Prof. I.G.N.G. Ngoerah. Subjects were divided into two groups: one receiving the adjuvant MgSO4 20% 200 mg and the other without adjuvant. Patients were then evaluated for the time required to achieve total sensory block, time to reach total motor block, and the duration of analgesia.

Results

Among the 28 participants analyzed, the group receiving the MgSO4 adjuvant showed a faster time to reach total sensory block, total motor block, and extended duration of analgesia from the nerve block. In the group with MgSO4, the average time to achieve total sensory block was 10.08 ± 0.90 minutes, compared to 17.19 ± 1.85 minutes in the group without adjuvant. For total motor block, the group with MgSO4 had an average time of 17.98 ± 1.26 minutes, whereas the group without adjuvant had an average of 25.19 ± 2.22 minutes. Additionally, the group using MgSO4 had an average duration of analgesia of 473.43 ± 28.69 minutes, compared to 266.5 ± 22.79 minutes in the non-adjuvant group.

Conclusion

The use of MgSO4 20% 200 mg as an adjuvant in the supraclavicular-intercostobrachial nerve block accelerates the onset time of sensory block, motor block and prolongs the duration of analgesia from the block.

Introduction

The provision of effective and long-lasting regional anesthesia is critical in surgical interventions, particularly for patients requiring vascular access surgery for hemodialysis.[1] Hemodialysis vascular access procedures in the upper extremities often involve substantial discomfort and pain, necessitating precise and efficient anesthetic techniques to ensure patient comfort, reduce perioperative complications, and optimize surgical outcomes.[2] Regional anesthesia, such as the supraclavicular-intercostobrachial nerve block, is widely employed in such cases due to its ability to provide targeted analgesia with minimal systemic side effects.

However, vascular access procedures come with a range of complications that can significantly impact patient outcomes. Both arteriovenous grafts (AVGs) and arteriovenous fistulas (AVFs) are prone to complications such as shunt failure, stenosis (48%), thrombosis (9%), aneurysm or pseudoaneurysm formation (7%), heart failure due to excessively large shunts, and distal ischemia (1.6%). Additional issues include distal venous hypertension due to shunt swelling, hyperpigmentation, skin hardening, and ulceration. Pseudoaneurysm, though relatively rare with an incidence of 2%–10%, is a notable complication often caused by repeated punctures during dialysis.[3] These punctures can lead to prolonged bleeding and pseudoaneurysm formation. While small pseudoaneurysms may undergo spontaneous thrombosis, this outcome is unpredictable, and surgical intervention is frequently necessary to prevent local complications or further enlargement.[4,5]

Given these challenges, there is a pressing need to optimize anesthetic techniques to enhance the success of surgical interventions while minimizing patient discomfort and perioperative risks. Local anesthetics such as 0.5% bupivacaine, while effective, may not provide prolonged analgesia or sufficient pain control in all cases.[6] As a result, the use of adjuvants like magnesium sulfate (MgSO4) has emerged as a promising strategy. MgSO4's neuromodulatory effects, mediated through N-methyl-D-aspartate (NMDA) receptor inhibition and calcium channel blockade, have the potential to prolong analgesia and improve overall anesthetic outcomes.

This research aims to demonstrate the effectiveness of adding MgSO4 as an adjuvant to 0.5% bupivacaine in the combination of supraclavicular-intercostobrachial nerve blocks. By evaluating this approach in patients requiring surgical management of vascular access for hemodialysis at RSUP Prof. I.G.N.G. Ngoerah, the study seeks to provide evidence-based insights into enhancing the quality of anesthesia, improving patient outcomes, and addressing the unique challenges associated with vascular access complications.

Methods

This study was an experimental research project employing a single-blind randomized clinical trial design with a randomized pre- and post-test control group with consecutive sampling method. The subjects were randomly assigned to one of two groups:

- Group A: Subjects receiving a combination of supraclavicular-intercostobrachial nerve block with 0.5% bupivacaine augmented by $MgSO_4$ as an adjuvant.
- Group B: Subjects receiving a combination of supraclavicular-intercostobrachial nerve block with 0.5% bupivacaine without an adjuvant.

This study allocated samples by dividing subjects into either the control group or the treatment group using block randomization, implemented through the QuickCalcs tool (GraphPad Software, Inc.).

Table 1. Sample allocation.

1	2	3	4	5	6	7	8	9	10
A	A	B	B	A	B	B	A	B	A
11	12	13	14	15	16	17	18	19	20
B	A	B	A	A	B	B	A	A	B
21	22	23	24	25	26				
A	B	B	B	A	A				

The study assessed several critical parameters to compare the effectiveness of the two interventions. These included the Neutrophil-to-Lymphocyte Ratio (NLR) and Platelet-to-Lymphocyte Ratio (PLR), measured pre- and post-intervention, the onset time required to achieve complete sensory and motor blockade, the duration until the first postoperative analgesic requirement, and the total fentanyl consumption within the first 24 postoperative hours. Data collection was conducted at RSUP Prof. I.G.N.G. Ngoerah, utilizing the Central Surgery Installation, Emergency Department, and Wing Amerta facilities. The study continued until the required sample size for meaningful statistical analysis was achieved.

Eligible participants included adults aged 18 years or older undergoing upper-extremity hemodialysis vascular access surgery. Exclusion criteria encompassed non-cooperative behavior, hemodynamic instability (ASA IV or higher), known allergies to local anesthetics or $MgSO_4$, infections at the block site, coagulation abnormalities, pre-existing neurological conditions affecting pain perception, and refusal to participate after providing informed consent. This rigorous methodological framework was designed to generate robust evidence on the potential benefits of $MgSO_4$ as an adjuvant in enhancing anesthetic efficacy and improving patient outcomes.

The sample size formula used in this study is based on hypothesis testing for the mean of two independent populations. The formula for this hypothesis test is as follows:

$$Sg^2 = \frac{[S1^2\ x\ (n1-1) + \ S2^2\ x\ (n2-1)]}{n1+n2-2}$$

$$Sg^2 = \frac{[37.2^2\ x\ (27-1) + \ 40.8^2\ x\ (27-1)]}{27+27-2}$$

$$Sg = \ 39.04$$

The sample size calculation will use a standard deviation of 39.04, and the sample size formula for the hypothesis test is as follows:

$$n1 = n2 = \frac{2\ (Za+Zb)^2\ Sg^2}{(X1-X2)^2}$$

$$n1 = n2 = \frac{2\ (1.96+1.64)^2\ 39.04^2}{(60)^2}$$

$$n1 = n2 = \ 10.97\ \approx 11$$

Verma et al. (2017) examined the effects of supraclavicular brachial plexus block using bupivacaine, either alone or combined with $MgSO_4$ as an adjuvant, in patients undergoing upper extremity surgery.[7] The study demonstrated that the treatment group achieved complete motor

blockade significantly faster (11.13±4.6 minutes) compared to the control group (28.47±7 minutes), with each group comprising 30 participants. Based on sample size calculations, the required minimum was 11 participants per group; however, to account for a potential 20% dropout rate, the total sample size was increased to 26 participants.

The study defined its variables operationally as follows: Adjuvant $MgSO_4$ was prepared at a 20% concentration, with 200 mg diluted in 0.9% NaCl to a total volume of 1 ml, and combined with 0.5% plain bupivacaine to produce a solution of 20 ml for supraclavicular blocks and 5 ml for intercostobrachial blocks. The supraclavicular block was performed under ultrasound guidance using a 50 mm Stimuplex needle, employing the Corner-Pocket technique. The Hydro-Location Technique was applied with 3–5 ml of 0.9% NaCl following appropriate visualization, as illustrated in Figure 2.1. Similarly, the intercostobrachial block utilized the same ultrasound-guided approach and Hydro-Location Technique, also with 3–5 ml of 0.9% NaCl, as shown in Figure 2.2. The onset time for achieving complete sensory and motor blockade was defined as the duration from the administration of the local anesthetic in the supraclavicular block to the attainment of full blockade in the upper extremity. Sensory blockade was evaluated using the pinprick test on the ulnar, median, musculocutaneous, and radial nerve regions at 5-minute intervals for up to 30 minutes, with results categorized as complete or partial blockade. Motor blockade was assessed using a modified Bromage scale (0–2), with scores ranging from 2 (no movement) to 0 (normal movement), and results were documented numerically in observation sheets. The duration of analgesia was defined as the time elapsed from the nerve block procedure until the patient's first request for rescue analgesia, measured in minutes and recorded accordingly. Fentanyl consumption during the first 24 postoperative hours was determined as the total amount administered via PCA devices, set with a demand dose of 10 mcg/ml, a lockout interval of 10 minutes, and a maximum dose of 100 mcg/4 hours, with the total usage recorded in micrograms. Finally, changes in NLR and PLR were assessed pre- and postoperatively by analyzing complete blood count samples collected 24 hours prior to surgery and 4 hours post-surgery.

Data processing and presentation involved both descriptive and comparative statistical analyses. Descriptive statistics were utilized to characterize the subjects and variables based on treatment groups, with normally distributed numerical data presented as mean and standard deviation (SD), non-normally distributed data as median and interquartile range (IQR), and categorical variables as relative frequency and percentages, all displayed in cross-tabulation tables. Comparative mean analysis was conducted to assess relationships and differences between two research variables, preceded by prerequisite tests for normality and homogeneity. Normality was assessed using the Shapiro-Wilk test ($p > 0.05$ indicating normal distribution), while homogeneity was tested with Levene's test ($p > 0.05$ indicating homogeneous variances). Depending on the results, an unpaired t-test was applied for normally distributed data to compare sensory and motor blockade times, analgesia duration, 24-hour fentanyl consumption, and NLR and PLR differences between groups, while the Mann-Whitney test was used for non-normally distributed data. All analyses were performed using SPSS for Windows version 26.0, with statistical significance set at $p < 0.05$ and a 95% confidence interval.

The ethical approval for this randomized controlled trial (RCT) was granted by the Ethics Committee of Udayana University, Denpasar, Bali, under approval number 2804/UN14.2.2.VII.14/LT/2024. This study adheres to the ethical principles outlined in the Declaration of Helsinki and complies with the Consolidated Standards of Reporting Trials (CONSORT) guidelines to ensure the integrity, transparency, and ethical conduct of the research

process.[8] All participants provided informed consent prior to enrollment, and their confidentiality and rights were prioritized throughout the study.

Results

A total of 30 participants were assessed for eligibility, of which 2 were excluded because they declined to participate, leaving 28 participants who were randomized into two groups (**Figure 1**). The first group, consisting of 14 participants, received SCB + IC with adjuvant MgSO4, and all 14 participants successfully received the allocated intervention, with no issues related to the availability of the PCA device. The second group, also comprising 14 participants, received SCB + IB without adjuvant, and similarly, all participants received the allocated intervention without any PCA device-related issues. Throughout the follow-up period, there were no participants lost to follow-up or who discontinued the intervention in either group. At the analysis stage, all 14 participants from each group were included, with no exclusions, ensuring a complete dataset for the study.

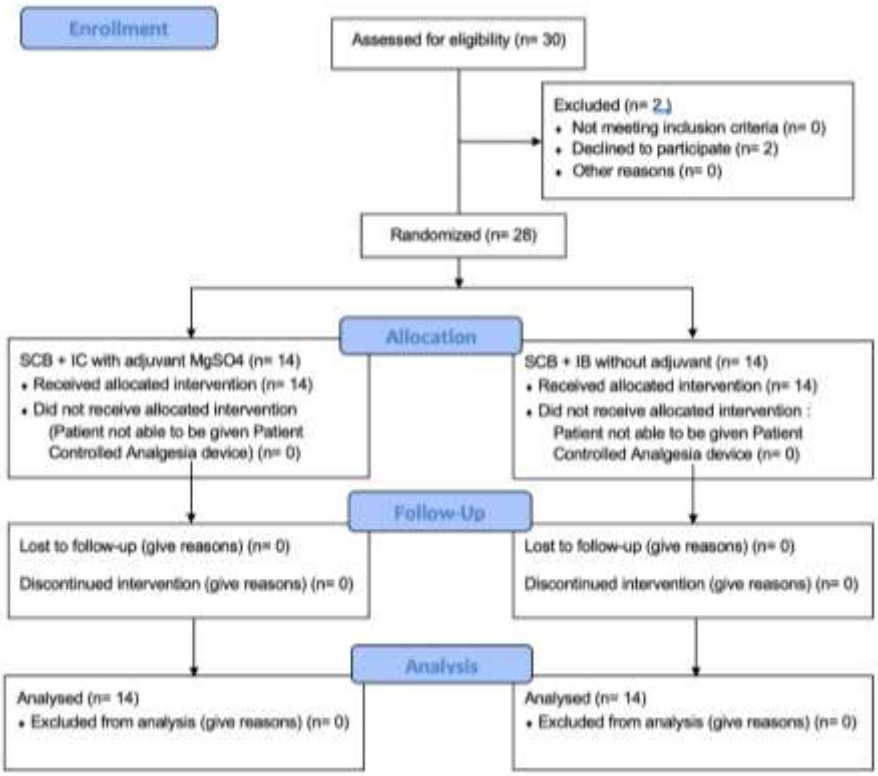

Figure 1. CONSORT 2010 flow diagram.

Table 1 demonstrates the comparability of the two groups, with no dropouts; however, 2 of the 30 eligible patients declined participation after the study was explained. Following randomization, all remaining samples were included. The adjuvant group had a mean age of 52 years (SD 15.16), and the non-adjuvant group had a mean age of 50 years (SD 10.83), with no significant difference ($p = 0.691$) based on an independent t-test. Gender distribution, analyzed using the Chi-square test, was also comparable ($p = 0.127$). In terms of height, the adjuvant group had a mean of 155.14 cm (SD 4.01), while the non-adjuvant group had a mean of 156.5 cm (SD 4.94), showing no significant difference ($p = 0.432$). Weight, analyzed using the Mann-Whitney test, showed a median of 55 kg (IQR 6.00) in the adjuvant group and 54 kg (IQR 9.50) in the non-adjuvant group, with no significant difference ($p = 0.502$). The BMI of the adjuvant group averaged 23.66 kg/m² (SD 2.38) compared to 22.7 kg/m² (SD 2.69) in the non-adjuvant group, with no statistical significance ($p =$

0.328). Additionally, all participants in both groups were classified as ASA Class III, indicating comparable anesthesia risks.

Table 1. Baseline Characteristics of Participants

Variable	Block with Adjuvant MgSO4 (n = 14)	Block without Adjuvant (n = 14)	p-value
Age (years)	52.43 ± 15.16	50.43 ± 10.83	0.691†
Body Weight (kg)	55.0 (6.0)	54.0 (9.5)	0.502*
Height (cm)	155.14 ± 4.01	156.50 ± 4.94	0.432†
BMI (kg/m²)	23.66 ± 2.38	22.70 ± 2.69	0.328†
Gender: Male	8.0	4	0.127‡
Gender: Female	6.0	10	
ASA: III	14.0	14	#

†: Independent t-test
*: Mann-Whitney test
‡: Chi-square test
#: Statistical test not applicable

The group with adjuvant MgSO4 had a significantly shorter sensory block time (10.08 ± 0.90 minutes vs. 17.91 ± 1.85 minutes, $p < 0.001$) and motor block time (17.98 ± 1.26 minutes vs. 25.19 ± 2.22 minutes, $p < 0.001$) compared to the group without adjuvant. Time to the first analgesic request was significantly longer in the adjuvant group (473.43 ± 28.69 minutes vs. 266.50 ± 22.79 minutes, $p < 0.001$), suggesting superior analgesic effects. Postoperative fentanyl requirements were dramatically reduced in the adjuvant group (10 mcg [IQR: 0] vs. 45 mcg [IQR: 15], $p < 0.001$), reflecting improved postoperative pain control. Detailed outcomes of interests for the following research was available in **Table 2**.

Table 2. Intraoperative and Postoperative Outcomes

Variable	Block with Adjuvant MgSO4 (n = 14)	Block without Adjuvant (n = 14)	p-value
Sensory block time (minutes)	10.08 ± 0.90	17.91 ± 1.85	< 0.001†
Motor block time (minutes)	17.98 ± 1.26	25.19 ± 2.22	< 0.001†
Time to first analgesic request (minutes)	473.43 ± 28.69	266.50 ± 22.79	< 0.001†
Total postoperative fentanyl (mcg)	10 (0)	45 (15)	< 0.001*

†: Independent t-test
*: Mann-Whitney test

Both postoperative NLR and PLR increased in all groups, but the extent of the increase differed significantly depending on the use of MgSO4 as an adjuvant. For NLR, the group with MgSO4

showed a smaller change (delta NLR: 1.93 ± 1.24) compared to the group without the adjuvant (delta NLR: 2.65 ± 3.61, p=0.009). Similarly, for PLR, the increase was lower in the MgSO4 group (delta PLR: 48.40 ± 73.63) compared to the non-adjuvant group (delta PLR: 114.90 ± 132.18, p=0.05). Detailed table for NLR and PLR value with or without MgSo4 adjuvant were available in **table 3** and **table 4**, respectively.

Table 3. Comparison of preoperative, postoperative, and delta NLR values between patients receiving blocks with MgSO4 as an adjuvant and those without adjuvant.

Group	Preoperative NLR (Mean ± SD)	Postoperative NLR (Mean ± SD)	Delta NLR (Mean ± SD)
Block with MgSO4 Adjuvant	2.21 (1.46)	4.15 (2.03)	1.93 (1.24)
Block without Adjuvant	3.00 (2.00)	5.75 (4.90)	2.65 (3.61)
p-value	0.352*	0.009*	0.009*

Table 4. Comparison of preoperative, postoperative, and delta PLR values between patients receiving blocks with MgSO4 as an adjuvant and those without adjuvant.

Group	Preoperative PLR (Mean ± SD)	Postoperative PLR (Mean ± SD)	Delta PLR (Mean ± SD)
Block with MgSO4 Adjuvant	122.15 (77.56)	171.55 (110.85)	48.40 (73.63)
Block without Adjuvant	189.70 (130.55)	285.00 (188.80)	114.90 (132.18)
p-value	0.114*	0.014*	0.05*

Discussion

This study evaluated the efficacy of magnesium sulfate (MgSO4) as an adjuvant to 0.5% bupivacaine in supraclavicular-intercostobrachial nerve blocks for upper extremity hemodialysis vascular access surgery. The findings demonstrate that the addition of MgSO4 significantly enhances the clinical outcomes of nerve blocks by improving the onset and duration of sensory and motor blocks, extending analgesic duration, reducing postoperative analgesic requirements, and mitigating postoperative inflammation.

Enhanced Sensory and Motor Block Onset

The MgSO4 group demonstrated significantly shorter sensory and motor block times (10.08 ± 0.90 minutes and 17.98 ± 1.26 minutes, respectively) compared to the control group (17.91 ± 1.85 minutes and 25.19 ± 2.22 minutes, respectively), highlighting the adjuvant's potential to accelerate anesthesia onset. This effect can be attributed to MgSO4's calcium channel-blocking properties, which promote neural hyperpolarization and enhance the efficiency of nerve conduction blockade. Supporting this, a meta-analysis revealed that adding MgSO4 to local anesthetics in perineural nerve blocks significantly reduced the onset time for motor block (mean difference of -1.17 minutes, $P < 0.0001$) compared to local anesthetics alone.[9] While sensory block onset did not exhibit statistically significant differences, the trend suggested that MgSO4 may contribute to faster nerve blockade overall.

Prolonged Analgesic Duration

The MgSO4 group demonstrated a significantly extended time to the first analgesic request (473.43 ± 28.69 minutes vs. 266.50 ± 22.79 minutes, $p < 0.001$), highlighting the superior analgesic efficacy of MgSO4. This extended analgesic duration aligns with previous studies suggesting that MgSO4 inhibits nociceptive transmission by antagonizing NMDA receptors, thereby reducing central sensitization to pain.[7,10] Supporting evidence comes from a study involving 66 patients undergoing arthroscopic rotator cuff repair, where the addition of MgSO4 to a bupivacaine-epinephrine mixture significantly prolonged analgesia duration. Patients receiving magnesium experienced an average analgesic duration of 664 minutes compared to 553 minutes in the saline group ($P = 0.017$).[11]

Reduced Postoperative Analgesic Requirements

Postoperative fentanyl requirements were markedly lower in the MgSO4 group (10 mcg [IQR: 0] vs. 45 mcg [IQR: 15], $p < 0.001$). This result not only indicates enhanced pain control but also suggests a potential decrease in opioid-related side effects, thereby improving patient recovery and satisfaction. The opioid-sparing effect of MgSO4 is well-established, and these findings reinforce its clinical utility in regional anesthesia.[12,13] A systematic review of multiple randomized controlled trials (RCTs) concluded that perioperative MgSO4 administration significantly reduces opioid consumption during the first 24 hours post-surgery.[14] For example, one study reported that patients receiving MgSO4 required an average of 8 mg of morphine, compared to 13.2 mg in the control group, a statistically significant reduction ($P = 0.001$).

Mitigation of Postoperative Inflammation

The significant reduction in postoperative NLR and PLR in the MgSO4 group (NLR: 4.15 vs. 5.75, $p = 0.009$; PLR: 171.55 vs. 285.00, $p = 0.014$) highlights the anti-inflammatory properties of MgSO4. These biomarkers are established indicators of systemic inflammation, and their reduction suggests that MgSO4 may play a role in attenuating the inflammatory response associated with surgical trauma.[15] This finding is particularly relevant for patients undergoing repeated vascular access surgeries, where chronic inflammation can compromise vascular health.

Clinical Implications

The results of this study underscore the potential of MgSO4 as a valuable adjuvant in regional anesthesia for upper extremity surgeries. By enhancing block characteristics, prolonging analgesia, reducing opioid consumption, and mitigating postoperative inflammation, MgSO4 contributes to improved perioperative outcomes.[16] These benefits are particularly pertinent for patients undergoing hemodialysis, who often present with comorbidities that necessitate meticulous perioperative management.

Limitations and Future Directions

While this study demonstrates the efficacy of MgSO4, several limitations warrant consideration. First, the single-center design may limit generalizability. Second, long-term outcomes such as chronic pain development and vascular access patency were not evaluated. Future multicenter studies with larger sample sizes and extended follow-up periods are needed to validate these findings and explore the long-term benefits of MgSO4 in this patient population. Additionally, mechanistic studies investigating the molecular pathways underlying MgSO4's anti-inflammatory effects could provide further insights into its therapeutic potential.

Conclusion

The addition of MgSO4 to 0.5% bupivacaine in supraclavicular-intercostobrachial nerve blocks significantly enhances anesthetic and analgesic outcomes while reducing postoperative inflammation. These findings support the use of MgSO4 as an effective adjuvant in regional anesthesia, offering a promising strategy to optimize perioperative care for upper extremity hemodialysis vascular access surgeries.

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