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Comparison of the Effect of Adding Magnesium Sulfate and Low-Dose Dexamethasone to Ropivacaine for Supraclavicular Brachial Plexus (Trunks) Nerve Block in Elective Upper Limb Surgeries: A Prospective Triple-Blind Randomized Clinical Trial

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ABSTRACT

Background & Objective: A supraclavicular brachial plexus block (SCBPB) is a safe alternative to general anesthesia in upper limb surgeries. We compared the effect of adding magnesium sulfate (MS) and low-dose dexamethasone (LDD) to ropivacaine in SCBPB in elective upper limb surgeries.

Materials & Methods: The ultrasound-guided SCBPB was done on 55 candidates for elective upper extremity surgeries in 3 groups by using 200 mg MS + 24 mL ropivacaine 0.5% (MS Group), 4 mg dexamethasone + 24 mL ropivacaine 0.5% (LDD Group), and 1 mL normal saline + 24 mL ropivacaine 0.5% (NS Group). The sample was investigated for the sensory and motor block onset, motor and sensory block duration, analgesia duration, total opioid consumption, and the Visual Analog Scale (VAS) during sensory return.

Results: The onset of motor and sensory block was faster in the MS group compared to the LDD and NS group ($P<0.05$). The sensory block duration was longer in the LDD group compared to the MS and NS groups. The duration of motor block and analgesia in the LDD group was significantly longer than the NS group ($P<0.05$). However, this difference was not significant regarding the MS group ($p>0.05$). The LDD and MS groups were not different in terms of total opioid consumption and VAS at the time of sensory return. However, both groups had significant differences with the NS group ($P<0.05$).

Conclusion: The LDD prolonged the motor and sensory block duration and analgesia compared to MS.

Keywords: Magnesium Sulfate, Dexamethasone, Brachial Plexus Block, Ropivacaine, Nerve Block

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1. Introduction

upraclavicular brachial plexus (trunks) block (SCBPB) is a preferred and efficient regional nerve block analgesia technique for upper limb surgeries (1). This technique provides a rapid onset and dense block due to its limited area of application at the level of the brachial plexus trunks (2). The SCBPB offers several advantages over general anesthesia in upper extremity surgeries, including effective sympathetic block, improved postoperative analgesia, high success rates, and minimal side effects (1). While local anesthetics alone can create suitable conditions for SCBPB, they often result in a short duration of postoperative analgesia. Therefore, various adjuvants are used in combination with local anesthetics to achieve a rapid and prolonged block in brachial plexus blockade (3). Numerous adjuvants have been employed to target different peripheral nerves and improve local block techniques to enhance the quality and duration of local anesthesia (4). These adjuvants encompass a wide range of medications, including clonidine, neostigmine, epinephrine, tramadol, buprenorphine, ketamine, midazolam, and dexamethasone, which are administered alongside local anesthetics. Their purpose is to enhance

the quality, speed of onset, and duration of nerve blocks (5), extend or improve postoperative analgesia (6-9), prolong block duration, and eliminate the need for catheter insertion in continuous local anesthetic infusion (10). Corticosteroids are commonly employed in peripheral nerve blocks to manage acute pain. Dexamethasone, a long-acting corticosteroid with potent analgesic and anti-inflammatory properties, has been the subject of investigation in studies exploring its efficacy as an adjuvant in brachial plexus blocks (11-15). The available literature reports varying values for the duration of analgesia when dexamethasone is used as an adjunct in brachial plexus blocks (1, 16). Magnesium, the body's fourth most abundant cation and the second most prevalent intracellular cation after potassium, can mitigate central sensitization by peripheral pain stimulation. As a result, magnesium sulfate is used as an adjuvant in local anesthetic solutions for various types of regional anesthesia and analgesia, improving quality and extending block duration (17). Clinical studies have demonstrated that the addition of magnesium during general anesthesia reduces the requirement for anesthesia and postoperative analgesia (18, 19). When administered epidurally, magnesium also reduces the need for postoperative opioids (20). Upon reviewing the literature, it becomes evident that dexamethasone and magnesium sulfate have been separately utilized in varying quantities in SCBPB to hasten the onset of local anesthesia, prolong the duration of motor and sensory blocks, and alleviate pain and postoperative nausea. Consequently, this study aimed to compare the effectiveness of adding magnesium sulfate (MS) and low-dose dexamethasone (LDD) to ropivacaine in SCBPBs for elective upper extremity surgery.

2. Materials and Methods

2.1 Research Design and Subjects

The present study was a triple-blind, randomized, parallel-group clinical trial conducted on 55 candidates for elective upper extremity surgery who were referred to Ayatollah Mousavi Hospital in Zanjan, Iran, in 2019. The study has been reported based on the CONSORT checklist (Figure 1).

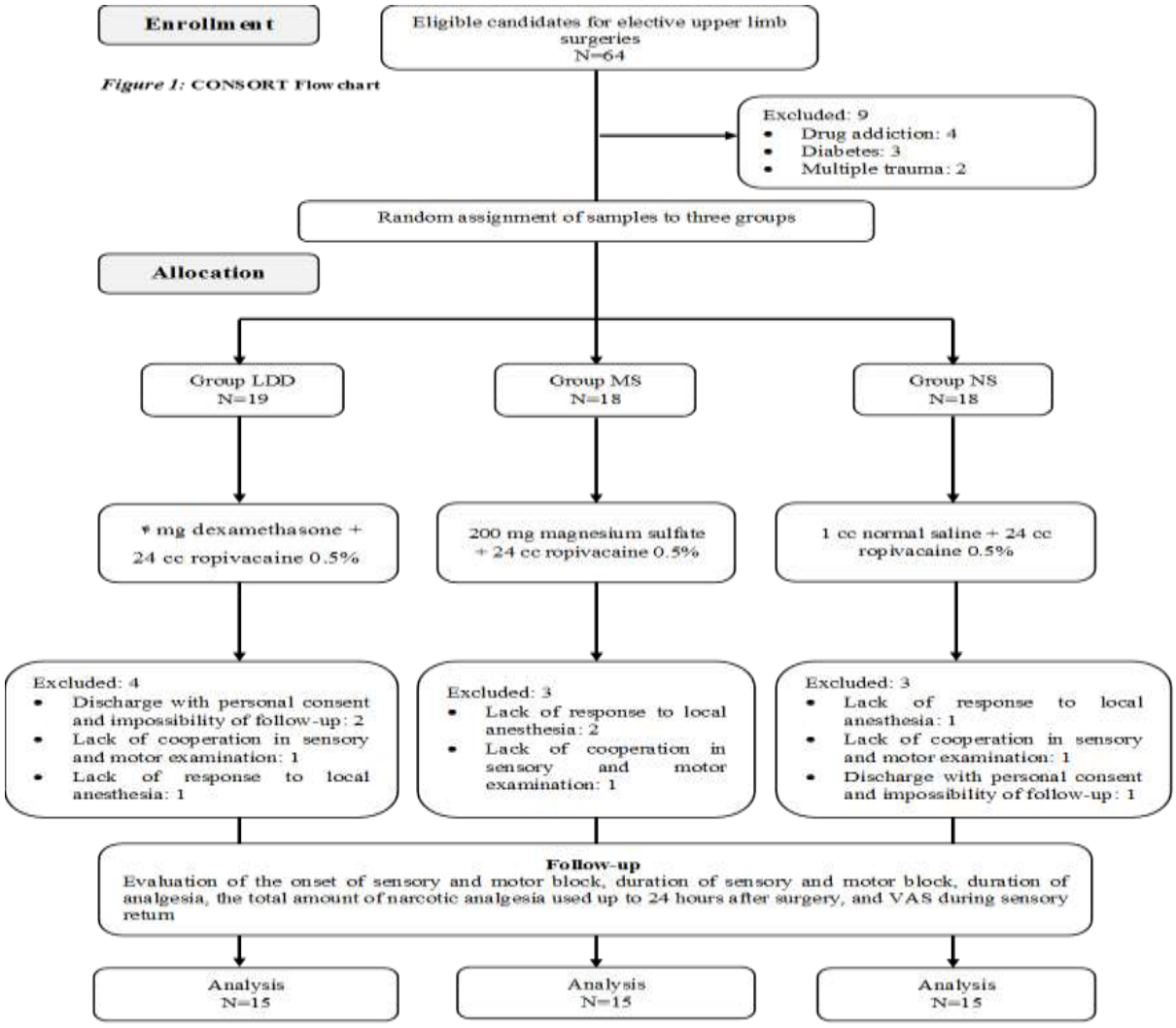


Figure 1: CONSORT Flow chart

Initially, a total of 64 candidates for elective upper extremity surgery, which included surgeries on the distal arm, elbow, forearm, and hand, were referred to Ayatollah Mousavi Hospital, affiliated with Zanjan University of Medical Sciences, during the study period. Subsequently, the participants were categorized into 3 groups (NS, LDD, MS) based on factors such as sex, age, and the type of surgery they required. The dice-rolling method was employed to assign individuals to treatment groups randomly. Numbers 1 and 2 were assigned to the NS group, 3 and 4 to the LDD group, and 5 and 6 to the MS group. The researcher was kept unaware of the medications used, as they were uniformly prepared by an expert to ensure blinding. Additionally, the clinical caregiver remained uninformed about the type of medication administered until data collection was complete. Inclusion criteria for participants comprised being between 18 and 65 years of age, candidacy for elective upper extremity surgery (including procedures on the arm, elbow, forearm, and hand), and having an American Society of Anesthesiologists (ASA) class I or II. The exclusion criteria encompassed multiple trauma, diabetes, neuropathy, decreased levels of consciousness, coagulopathy, bronchopulmonary disease, psychiatric illness, drug addiction, chronic analgesic therapy, a history of corticosteroid use for at least 1 year, and a known allergy to MS. Exclusion criteria were not meeting the appropriate sensory and motor level following the nerve block (nerve block failure), a participants' reluctance to continue their cooperation in the study, and the occurrence of any side effects.

2.2 Intervention Process

In the preoperative unit, vital signs were assessed, and after establishing intravenous (IV) access, a premedication of 4 to 8 mg of midazolam was administered IV for moderate (stimulatory) sedation. Continuous monitoring included blood pressure, pulse oximetry, and electrocardiography (ECG).

In the operating room, the ultrasound-guided SCBPB procedure was performed following proper positioning, with strict adherence to aseptic techniques. The subclavian artery's lateral aspect was stimulated in the posterior, inferior, and medial directions using a 1.5-inch, 25 G needle connected to a nerve stimulator device, delivering electrical impulses ranging from 0.5 to 3.3 mA. Once appropriate limb contractions were observed, the drug was injected.

Participants in each of the 3 groups (N: 1 cc normal saline + 24 cc ropivacaine 0.5%, D: 4 mg dexamethasone + 24 cc ropivacaine 0.5%, and MS: 200 mg MS 20% + 24 cc ropivacaine 0.5%) received their respective intended drug. The study employed a German-made eZono AG ultrasound device and a Dutch-made XAVANT (STIMPOD, NMS400) nerve stimulator device.

2.3 Study Instruments

The participants underwent evaluation for several parameters, including the onset time of motor and sensory blocks, the duration of motor and sensory blocks, the duration of analgesia, total opioid consumption within 24 hours after surgery, and Visual Analog Scale (VAS) scores during sensory recovery.

Postoperative sensory block was assessed using the cold sensitivity test, involving the application of cold cotton to the affected area. For motor block evaluation, the patients were instructed to flex and extend their wrists and fingers. Scoring was conducted as follows: 0 represented complete mobility of the wrist and fingers, 1 indicated reduced mobility, and 2 indicated an inability to move the wrist and fingers. The durations of motor and sensory blocks were monitored hourly during the postoperative period. Pain severity was assessed during and after surgery using the VAS, with scores ranging from 0 to 10. Postoperative VAS scores were recorded at hourly intervals until the first request for analgesics and subsequently every 4 hours. The time at which the first analgesic was needed was determined when the VAS score reached or exceeded 4. Total opioid consumption within 24 hours after surgery was calculated for each patient in the 3 study groups.

2.4 Data Analysis

Data analysis was conducted using SPSS v. 22 (IBM Corp., Armonk, NY, USA). A one-way analysis of variance (ANOVA) was employed to compare the mean scores among the 3 groups if the data followed a normal distribution. However, if the data did not exhibit a normal distribution, the Kruskal-Wallis test was used. The significance level was set to $P < 0.05$. Descriptive statistics, including mean and standard deviation (SD), were used for continuous quantitative data, while frequency distribution was utilized for nominal qualitative data.

2.5 Ethical Approval

After obtaining approval from the Ethics Committee of Zanjan University of Medical Sciences (IR.ZUMS.REC.1397.068) and registering the study with the IRCT (Iranian Registry of Clinical Trials) under the code IRCT20180325039148N3, the researcher visited Ayatollah Mousavi Hospital in Zanjan. During this visit, the researcher introduced herself to the research setting, explained the study's objectives, and obtained the necessary permissions from the relevant authorities. The study adhered to ethical principles in accordance with the Declaration of Helsinki. Participants were assured that their information would remain confidential (ensuring anonymity) and were asked to provide informed consent after being informed about the study's objectives. Additionally, they were informed of their right to withdraw from the study at any stage.

3. Results

Initially, 64 candidates for elective upper extremity surgery were considered. In the subsequent stage, 9 patients were excluded based on the inclusion and exclusion criteria (4 due to drug addiction, 3 with diabetes, and 2 due to multiple trauma). Therefore, a

total of 55 individuals were assessed, with 18 participants randomly allocated to the NS group, 18 to the MS group, and 19 to the LDD group. After the exclusion of individuals for various reasons, 15 participants were retained in each of the NS, MS, and LDD groups. Participants were excluded during the follow-up for various reasons, including 4 due to resistance to local anesthesia, 3 due to noncooperation in the evaluation of sensation and movement, and 3 due to voluntary discharge and the impossibility of complete follow-up. The study subjects were homogeneous in terms of demographic information, with no significant differences observed among the groups (P > 0.05). Participant demographic characteristics are presented in Table 1. Statistical analysis revealed a significant difference among the 3 groups in terms of sensory and motor block onset (P <0.001). Comparison of the mean duration of motor and sensory block (in minutes) also showed a statistically significant difference between the groups (P <0.05). Significant differences were observed between the groups in terms of the total amount of postoperative analgesia, duration of analgesia, and VAS during sensory return (P <0.05; Table 2). Table 3 presents the results of pairwise comparisons among the groups concerning the onset of motor and sensory blockade, duration of motor and sensory block, analgesia duration, total amount of postoperative analgesia, and VAS during sensory return using a post-hoc test and Mann-Whitney U test.

Figures 2 to 4 provide a graphical comparison of the studied groups regarding the duration of sensory block, motor block duration, and analgesia duration.

The frequency distribution of side effects, including nausea, vomiting, headache, respiratory depression, central nervous system (CNS) changes, and paresthesia in the study groups, is presented in Table 4.

Table 1. Demographic characteristics of the studied samples

Variable		Frequency (%)			P-Value
		N	MS	D	
Gender	Male	11 (73.3)	12 (80)	10 (66.66)	0.260*
	Female	4 (26.7)	3 (20)	5 (33.33)	
Type of surgery	Distal arm and elbow	5 (33.33)	3 (20)	4 (26.67)	0.459*
	forearm	8 (53.34)	9 (60)	9 (60)	
	Hand	2 (13.33)	3 (20)	2 (13.33)	
		Mean ± SD			
Age		N	MS	D	0.849**
		42.73 ± 12.41	46.73 ± 13.30	40.40 ± 14.22	

Abbreviations: D (Dexamethasone), MS (Magnesium sulfate), N (Normal Saline), SD (Standard Deviation)
* Pearson Chi-Square ** One-way ANOVA

Table 2. Examined variables of patients in the studied groups

Variable	Mean ± SD			P-Value
	NS	MS	LDD	
Onset of sensory block)min (	10.33 ± 3.53	6.00 ± 1.88	9.60 ± 3.08	0.001*
Onset time for motor block)min(	12.26 ± 4.07	7.06 ± 2.21	12.20 ± 3.50	0.001*
Duration of sensory block)min(	494.00 ± 182.08	536.00 ± 198.63	748.00 ± 221.46	0.03*
Duration of motor block)min(	582.00 ± 164.23	606.00 ± 155.55	752.00 ± 223.19	0.031*
Duration of analgesia)min(	738.00 ± 308.20	844.00 ± 471.74	1116 ± 3131.04	0.023*
Total opioid consumption)mg(	26.66 ± 14.84	15.00 ± 18.41	15.00 ± 26.38	0.044**
VAS at the time of sensory return	6.33 ± 2.38	4.33 ± 1.75	4.00 ± 2.44	0.013*

* One Way ANOVA
** Kruskal-Wallis

Table 3. Significance level between each of the two groups in each of the variables

Variable	NS & MS	NS & LDD	MS & LDD
Onset time for sensory block	0.001	0.772	0.004^
Onset time for motor block	0.001	0.998	0.001^
Duration of sensory block	0.836	0.004	0.017^
Duration of motor block	0.932	0.039	0.087^
Duration of analgesia	0.717	0.022	0.124^
Total opioid consumption	0.049	0.021	0.602+
VAS at the time of sensory return	0.046	0.017	0.911^

+ Mann-Whitney Test

Table 4. Frequency distribution of side effects in the studied samples

Variable		Frequency (%)			P-Value*
		NS	MS	LDD	
Nausea	Yes	1 (6)	3 (20)	0 (0)	0.146
	No	14 (94)	12 (80)	15 (100)	
Vomiting	Yes	1 (6)	1 (6)	0 (0)	0.360
	No	14 (94)	14 (94)	15 (100)	
Headache	Yes	0 (0)	2 (13)	0 (0)	0.123
	No	15 (100)	13 (87)	15 (100)	
Respiratory depression	Yes	0 (0)	0 (0)	0 (0)	———
	No	15 (100)	15 (100)	15 (100)	
CNS changes	Yes	0 (0)	0 (0)	0 (0)	———
	No	15 (100)	15 (100)	15 (100)	
Tingling and burning	Yes	0 (0)	0 (0)	1 (6)	0.118
	No	15 (100)	15 (100)	14 (94)	

* **Fisher Exact Test**

Figure 2. Comparison of sensory block duration in the studied groups

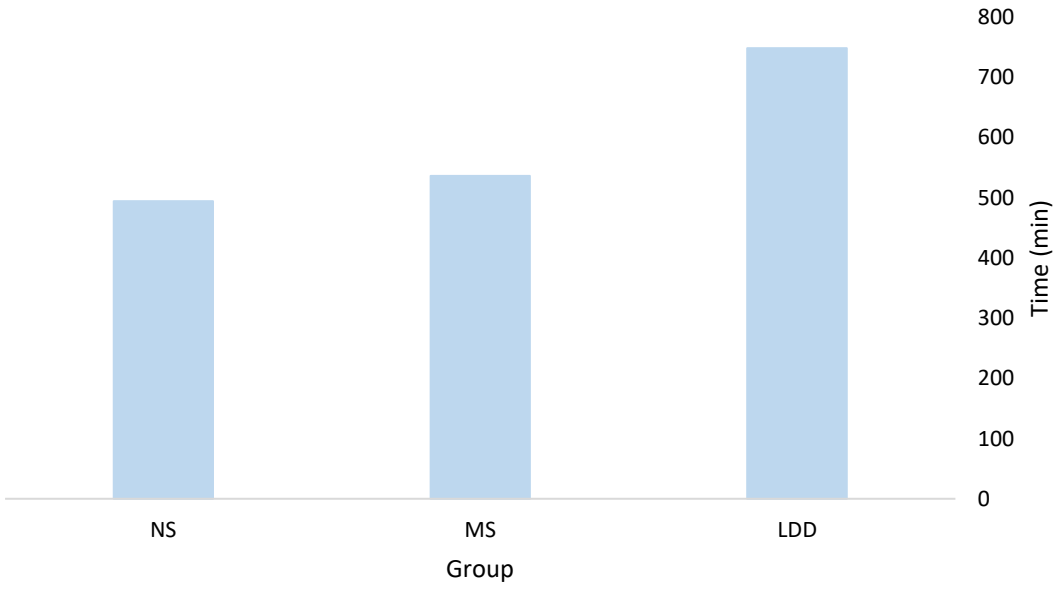


Figure 3. Comparison of motor block duration in the studied groups

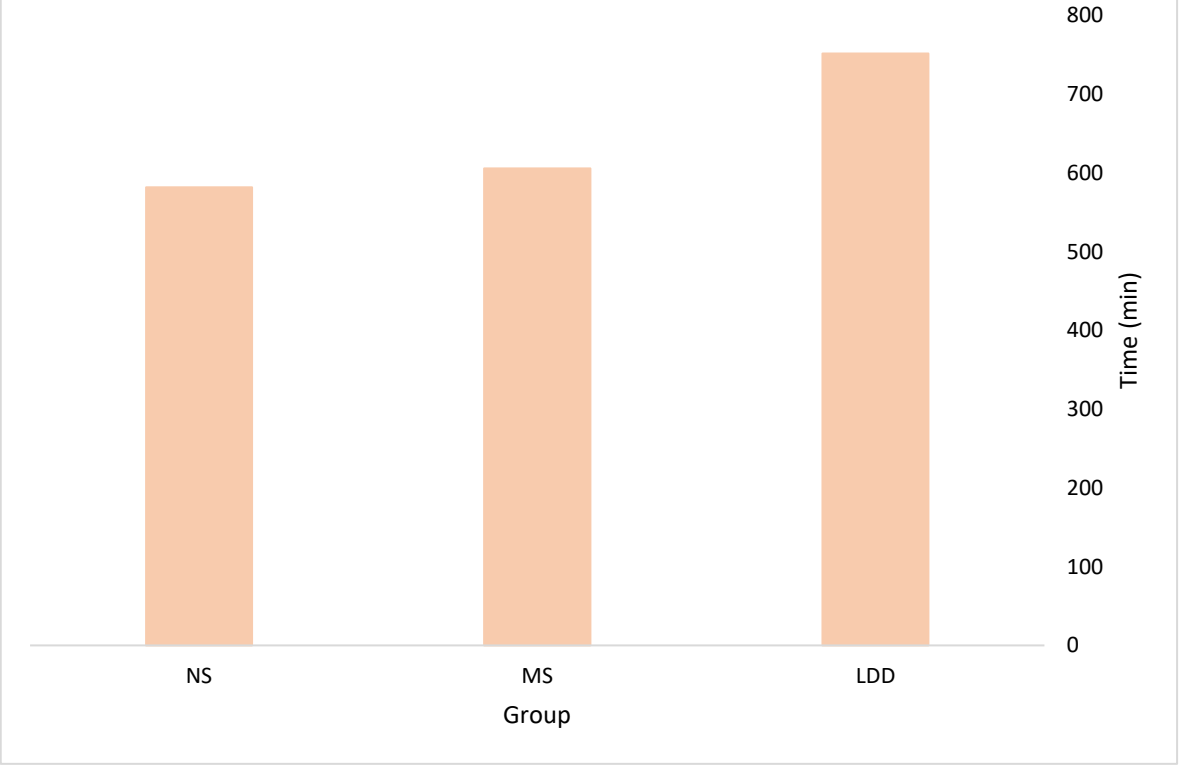
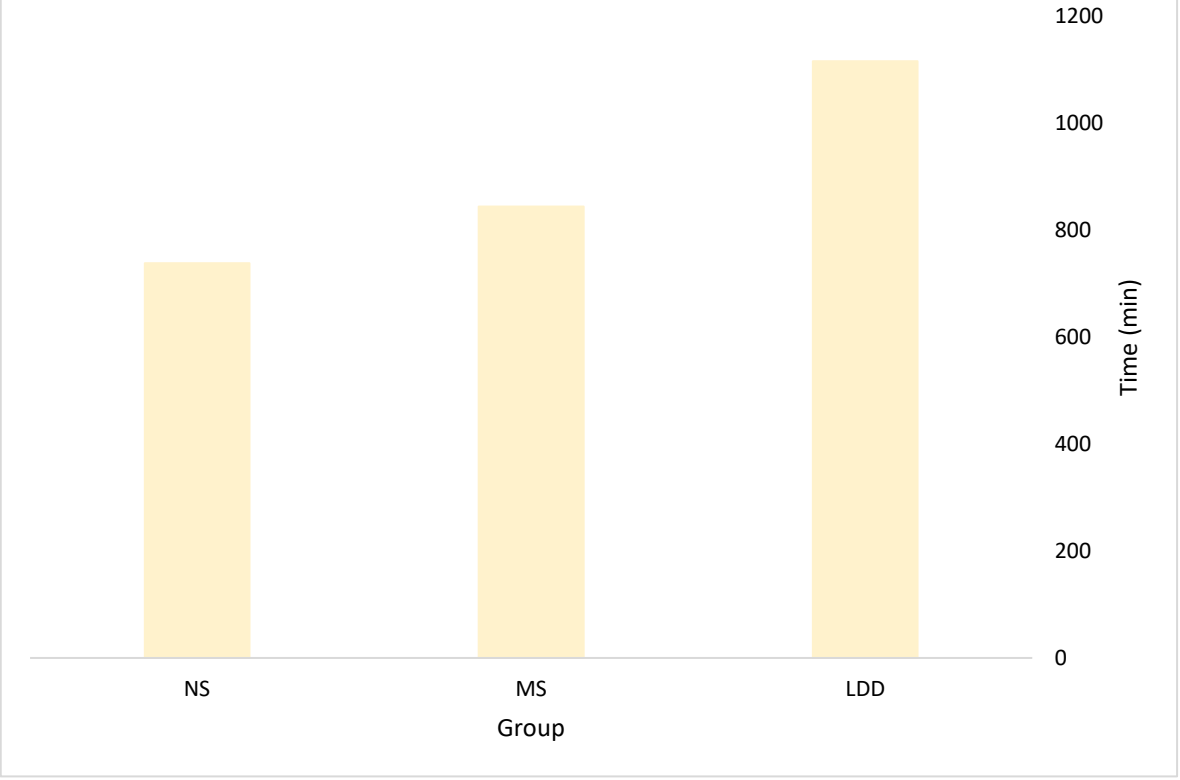


Figure 4.Comparison of duration of analgesia in the studied groups



4. Discussion

We conducted a comparative study to assess the impact of adding MS and LDD to ropivacaine in SCBPB (trunks) nerve block during elective upper extremity surgeries.

The main findings of our study suggest that the onset of motor and sensory blockade was faster in the MS group compared to the other 2 groups. Additionally, the sensory block duration was extended in the LDD group compared to the other groups.

However, the duration of motor block in the LDD group was significantly longer compared to the MS group. Similarly, the motor block duration in the LDD group was significantly longer compared to the NS group. Moreover, the duration of analgesia in the LDD group was significantly longer compared to the NS group, but there was no significant difference in analgesia duration between the LDD and MS groups. The VAS score during sensory return and total opioid consumption within 24 hours after surgery did not show significant differences between the LDD and MS groups; however, both intervention groups (LDD and MS) had lower VAS scores than the NS group.

The SCBPB enables the provision of dense, rapid, and predictable anesthesia throughout the upper extremity in a highly stable manner. The use of ultrasound guidance enhances the safety of this technique. In some cases, single-shot techniques may appear insufficient to provide postoperative pain relief in peripheral nerve blocks. Perineural catheters, employed to extend the duration of analgesia, can lead to complications such as catheterization difficulties, infections, anesthetic leakage, or pump malfunctions, especially in outpatient surgery settings. These challenges have prompted the exploration of various adjuvants to enhance the duration of analgesia achieved through single-shot techniques, thereby reducing the reliance on continuous perineural infusions (21). Medications like MS and dexamethasone are employed as adjuvants with local anesthetics in brachial plexus blocks to achieve rapid, dense, and prolonged blockade. The results of some studies on the use of dexamethasone and MS as adjuvants in SCBPB are discussed below:

The study conducted by Mukherjee et al. (2014) investigated the effects of adding 150 mg of MS to 30 ccs of ropivacaine 0.5% in supraclavicular brachial plexus block (SCBPB) for elective elbow, forearm, and hand surgeries. The addition of MS to ropivacaine resulted in the prolongation of both motor and sensory block durations and analgesia length while reducing the need for analgesics. Notably, no side effects were reported in their study. Furthermore, their findings revealed that the onset of motor and sensory blockade in the MS group was not statistically different from the control group (normal saline) (3).

In our study, we compared the effect of adding MS to ropivacaine with that of normal saline (1 cc) and dexamethasone (4 mg). Our results align with the aforementioned study regarding motor and sensory block durations, analgesia duration, and the need for analgesics. Additionally, according to our results, the onset of motor and sensory blockade in the MS group was significantly faster than in the normal saline group. Some complications, such as nausea, vomiting, and headache, were observed in the study groups; however, these differences were not statistically significant. In this regard, our findings are consistent with the results of the study mentioned above. However, it is worth noting that our study differs from Mukherjee et al.'s study in terms of the number of study groups and the dosage of drugs used. In our study, we administered 200 mg of MS and 24 ccs of ropivacaine.

Furthermore, the results of Patil et al.'s (2022) study also indicated that the addition of 150 mg of MS to 20 ccs of ropivacaine in the interscalene brachial plexus block led to a quicker onset of motor and sensory block, prolonged durations of motor and sensory block, and reduced postoperative analgesic requirements (22). These findings are in line with the results of our present study.

Kore et al. (2022) proposed that the addition of dexamethasone (8 mg) as an adjuvant in SCBPB accelerates the onset of motor and sensory blocks and prolongs their duration, as well as the duration of analgesia when compared to fentanyl and normal saline (23). Our study's results are in line with Kore et al.'s findings, as we observed that dexamethasone (4 mg), compared to normal saline, extended the duration of motor and sensory blocks and analgesia. However, it is worth noting that the onset of motor and sensory blocks in the dexamethasone group was faster than in the normal saline group, but this difference was not statistically significant, which contrasts with the above study. The difference in dexamethasone dosage (8 mg in Kore et al. vs. 4 mg in our study) and the addition of 2% lidocaine in Kore et al.'s study may account for these discrepancies.

Yousef et al. (2021) assessed the effects of dexamethasone (8 mg) or MS (200 mg) in combination with bupivacaine for supraclavicular nerve block in 36 candidates undergoing upper extremity surgery. They reported a shortened onset of motor and sensory blockade in the dexamethasone group compared to the MS and normal saline groups. Furthermore, the duration of motor and sensory blockade and analgesia was prolonged in the dexamethasone group compared to the other 2 groups (1). While our findings align with Yousef et al.'s study regarding the prolonged duration of motor and sensory blockade and analgesia in the dexamethasone group, they differ in terms of the onset of sensory and motor blockade. This variance could be attributed to the use of a lower dose of dexamethasone in our study. In our research, the onset of sensory and motor blockade was shorter in the MS group compared to the dexamethasone and normal saline groups.

The results of a systematic review indicate that the combination of dexamethasone and local anesthetics leads to a prolonged peripheral nerve block (24), which corroborates the outcomes of our study.

Rai et al. (2018) reported in their study that the addition of dexamethasone (8 mg) to bupivacaine in

supraclavicular nerve block for upper extremity surgery accelerated the onset and prolonged the duration of sensory and motor block (25). Their findings were in line with our study regarding the duration of sensory and motor block but differed concerning the onset of motor and sensory blockade. This variation could be attributed to the lower dose of dexamethasone used in our study.

Thomas et al. (2021) conducted a comparative study of dexamethasone (8 mg) and MS (500 mg) as adjuvants in SCBPB. Their results indicated that sensory block onset was significantly faster with dexamethasone than with MS. Furthermore, motor block and analgesia duration were longer in the supraclavicular block with dexamethasone than with MS. The duration of analgesia was 533 minutes with dexamethasone and 415 minutes with MS. Dexamethasone and MS showed no significant difference in terms of the onset of motor block and sensory block duration (2). Our findings diverged from Thomas's study in some aspects. In our research, the onset of motor and sensory block was faster with MS than with LDD. The sensory block duration was longer in the LDD group. Although the analgesia duration was longer in the LDD group compared to the MS group in our research, this difference was not statistically significant. In our research, the duration of analgesia was 1 116 minutes with LDD and 844 minutes with MS. The variation in findings may be attributed to the differences in drug dosages.

Based on the findings of the present study, the study groups exhibited no differences in terms of side effects, including nausea, vomiting, headache, respiratory depression, central nervous system changes, and paresthesia.

One of the strengths of our study was the use of low doses of adjuvant drugs, which resulted in fewer side effects among patients. However, it is important to note that the sample size in the present study was small. Therefore, for more robust conclusions regarding the use of LDD in nerve blocks, it is recommended that future studies be conducted with larger sample sizes.

5. Conclusion

Dexamethasone extended the duration of motor and sensory block, as well as analgesia, when compared to MS. Conversely, MS resulted in a quicker onset of sensory and motor blockade. Both medications showed similar total opioid consumption per patient and similar VAS scores at the time of sensory return. Given the minimal side effects associated with adding dexamethasone to the ropivacaine anesthetic in SCBPBs for upper limb surgeries, dexamethasone is considered a suitable adjuvant in nerve blocks.

6. Declaration

6.1 Acknowledgments

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6.2 Authors' Contribution

Authors DK and SJ designed the study. DK collected the data, and SJ analysed it. All authors were involved in the final interpretation of the data. FGH prepared the manuscript. All authors critically reviewed the manuscript and approved the final version for publication.

6.3 Conflict of Interest

The authors declare that they have no conflict of interest.

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