

Dexmedetomidine As An Adjuvant To Levobupivacaine In Ultrasound-Guided Supraclavicular Brachial Plexus Block For Upper-Limb Orthopaedic Surgery: A Prospective Randomized Double-Blind Study

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Abstract

Background

Supraclavicular brachial plexus block (SCBPB) is a common regional anaesthesia technique used for upper limb surgeries. This block provides safe and effective anaesthesia with excellent post-operative analgesia. Local anesthetics alone sometimes provide suboptimal analgesia and delayed onset time, prompting the investigation of adjuvants like Dexmedetomidine to enhance these parameters.

Objective

This study aims to compare the efficacy of dexmedetomidine (1µg/kg) as an adjuvant to levobupivacaine in ultrasound-guided supraclavicular brachial plexus block with respect to the onset and duration of blockade, analgesia.

Methods: A randomised controlled study was conducted on patients undergoing upper limb orthopaedic surgeries using ultrasound-guided SCBPB. Patients were divided into two groups: Group I received 19 mL of 0.5% levobupivacaine and 1 mL Normal Saline, and Group II received 19 mL of 0.5% levobupivacaine and 1 µg/kg dexmedetomidine diluted to 1 mL using Normal Saline.

The onset and duration of sensory and motor blockades, duration of analgesia, perioperative hemodynamic stability, and adverse effects were recorded and analysed.

Results

The addition of dexmedetomidine significantly shortened the onset of sensory block (6.03 ± 1.10 vs. 9.60 ± 1.25 minutes; $p < 0.001$) and motor block (12.43 ± 1.72 vs. 16.23 ± 1.70 minutes; $p < 0.001$). Recovery of sensory and motor blockade was prolonged by approximately 184 and 160 minutes, respectively, and postoperative analgesia was significantly extended (800.33 ± 79.48 vs 1076.17 ± 78.02 minutes; $p < 0.001$) without increasing adverse events or causing clinically significant hemodynamic instability.

Conclusion:

Perineural dexmedetomidine significantly improves the quality of ultrasound-guided supraclavicular brachial plexus block by accelerating block onset, prolonging sensory and motor blockade, and extending postoperative analgesia while maintaining acceptable hemodynamic stability.

Keywords: Supraclavicular brachial plexus block (SCBPB), levobupivacaine, Dexmedetomidine, Local anaesthetics, Regional anaesthesia, Ultrasound-guided nerve block, Sensory blockade, Motor blockade.

INTRODUCTION

Supraclavicular brachial plexus block (SCBPB) is a well-established regional anaesthesia technique employed for surgeries involving the upper limb. At the supraclavicular level, the brachial plexus is compactly arranged, allowing effective deposition of local anaesthetic around the neural elements and resulting in reliable sensory and motor blockade of the arm. Because of its consistent block quality, ease of performance, and favourable safety profile, SCBPB is widely utilized for procedures ranging from minor hand surgeries to major orthopaedic interventions^(1,2,3).

Despite its established efficacy, administration of local anaesthetics alone presents certain clinical limitations. The onset of sensory and motor blockade may be delayed, and the duration of postoperative analgesia may be inadequate for sustained pain control. Early regression of block often necessitates supplemental analgesia in the postoperative period. These concerns have stimulated interest in the use of pharmacological adjuvants aimed at accelerating onset and prolonging the duration of analgesia^(4,5)

Accurate localization of the brachial plexus is critical to both the success and safety of SCBPB. Conventional landmark-based or blind techniques may be associated with imprecise nerve identification, multiple needle attempts, and increased risk of vascular puncture or pleural injury. The integration of ultrasound guidance into regional anaesthesia practice has significantly improved block precision. Ultrasound-guided SCBPB enables real-time visualization of neural structures, adjacent vascular anatomy, pleura, and first rib, facilitating accurate needle placement and optimal local anaesthetic deposition while minimizing complications and patient discomfort ^(1,2).

Among long-acting local anaesthetics, levobupivacaine has gained widespread clinical acceptance. Levobupivacaine is the pure S(-) enantiomer of bupivacaine and belongs to the amino-amide class of local anaesthetics. When administered around mixed peripheral nerves, it produces effective sensory anaesthesia accompanied by motor blockade ^(4,5,6). Compared with racemic bupivacaine, levobupivacaine demonstrates comparable onset and duration of block while offering an improved safety profile, particularly in terms of reduced cardiotoxicity. This advantage is attributed to stereoselective interaction with myocardial sodium channels and favourable protein-binding characteristics^(4,7).

The pharmacological action of levobupivacaine is mediated through reversible blockade of voltage-gated sodium channels on neuronal membranes. By inhibiting sodium influx, it prevents depolarization and propagation of nerve impulses in both sensory and motor fibres^(4,6). Levobupivacaine has a pKa of approximately 8.1 and an elimination half-life of nearly 3 hours, contributing to its long-acting anaesthetic properties^(4,6). Nevertheless, levobupivacaine alone may not consistently provide prolonged postoperative analgesia.

To enhance block characteristics, various adjuvant agents have been evaluated. These include both opioid and non-opioid drugs. Among non-opioid adjuvants, dexmedetomidine has emerged as a promising adjunct in peripheral nerve blocks. Dexmedetomidine is a highly selective α_2 -adrenergic receptor agonist and represents the pharmacologically active dextral isomer of medetomidine^(5,8). It exhibits an $\alpha_2:\alpha_1$ receptor selectivity ratio of approximately 1600:1, which is substantially greater than that of clonidine, thereby minimizing undesirable α_1 -mediated effects⁽⁵⁾.

Dexmedetomidine produces analgesia through activation of α_2 -receptors at both supraspinal and spinal levels, resulting in attenuation of nociceptive transmission and suppression of sympathetic outflow ^(5,8). When used as an adjuvant to local anaesthetics in peripheral nerve blocks, dexmedetomidine has been shown to prolong sensory and motor blockade and extend postoperative analgesia duration ⁽⁹⁾.

Although several randomized controlled trials and systematic reviews have demonstrated the efficacy of dexmedetomidine as a perineural adjuvant, variability persists regarding the magnitude of improvement in onset time, block duration, and postoperative analgesia across different local anaesthetics, doses, and ultrasound-guided techniques, thereby warranting further comparative clinical evaluation.

Hence, the present study was undertaken to evaluate the effect of adding dexmedetomidine to levobupivacaine in ultrasound-guided supraclavicular brachial plexus block, with specific assessment of onset and duration of sensory and motor blockade, duration of postoperative analgesia, and incidence of adverse effects.

Methods

Study Design and Setting

This prospective randomized double-blind study was conducted in the Department of Anaesthesiology at Adichunchanagiri Hospital and Research Centre after obtaining approval from the Institutional Ethics Committee . Written and informed consent was obtained from all participants.

The study was conducted according to CONSORT guidelines for randomised controlled trials.

Patients assessed for eligibility (n=72)

↓

Excluded (n=12)

- Not meeting inclusion criteria (8)

- Declined participation (4)

↓

Randomized (n=60)

↓

Group A (n=30)

Received intervention

Completed follow-up

Analyzed (30)

↓

Group B (n=30)

Received intervention

Completed follow-up

Analyzed (30)

Study Population

Sixty adult patients aged 18–60 years belonging to ASA physical status I–II undergoing elective below-elbow orthopedic surgeries under ultrasound-guided supraclavicular brachial plexus block were included.

Inclusion Criteria

- Age 18–60 years
- ASA physical status I–II
- Elective below-elbow orthopedic surgeries
- Patients willing to provide informed consent

Exclusion Criteria

- Patient refusal
- Allergy to study drugs
- Infection at injection site
- Coagulopathy
- Pre-existing neurological deficits
- Pregnancy
- Severe systemic illness

Sample Size Calculation

The probability of falsely rejecting a true null hypothesis (α) was set at 0.05 ($Z\alpha = 1.96$), and the probability of failing to reject a false null hypothesis (β) was set at 0.20 corresponding to a study power of 80% ($Z\beta = 0.84$).

The sample size was calculated using the formula:

$$n = 2\sigma^2(Z\alpha/2 + Z\beta)^2 / d^2$$

Where:

- n = sample size per group
- σ = standard deviation
- d = expected clinically significant difference

The calculated minimum sample size was 28 patients per group. To compensate for possible dropouts, 30 patients were included in each group.

Randomization and Blinding

Patients were randomly allocated into two groups using computer-generated randomization. Allocation

concealment was ensured using sequentially numbered opaque sealed envelopes. The study drug was prepared by an anesthesiologist not involved in block administration or outcome assessment. Both the anesthesiologist performing the block and the observer assessing outcomes were blinded to group allocation.

Study Groups

Group A

19 mL of 0.5% levobupivacaine + 1 mL normal saline.

Group B

19 mL of 0.5% levobupivacaine + dexmedetomidine 1 µg/kg diluted to 1 mL with normal saline.

Block Technique

Patients were kept nil per oral for 6 hours before surgery and premedicated according to institutional protocol. Standard monitoring including ECG, non-invasive blood pressure, heart rate, and pulse oximetry was instituted. Intravenous access was secured in the contralateral upper limb.

Patients were positioned supine with the head turned to the opposite side. Under strict aseptic precautions, ultrasound-guided supraclavicular brachial plexus block was performed using a high-frequency linear probe and in-plane needle approach with a 20G 50-mm insulated block needle.

The brachial plexus was visualized lateral to the subclavian artery above the first rib. Following negative aspiration, the study drug was injected incrementally after confirmation of proper needle placement.

Block Assessment

Sensory Block Assessment

Sensory block was assessed using pinprick sensation in the C5–T1 dermatomes.

Grading

- 0 = Sharp pain felt
- 1 = Analgesia (dull sensation)
- 2 = Complete sensory block

Sensory onset time was defined as the time from completion of injection to complete sensory loss.

Duration of sensory block was defined as the time from onset of sensory block to return of normal sensation.

Block failure was defined as inadequate sensory or motor blockade requiring conversion to general anaesthesia or supplemental analgesia.

Motor Block Assessment

Motor block was assessed using modified Bromage scale for upper limb.

Modified Bromage Scale

- 0 – Able to raise arm to 90°
- 1 – Flex elbow and move fingers but cannot raise arm
- 2 – Cannot flex elbow but can move fingers
- 3 – Cannot move arm or fingers

Motor onset time was defined as the time from completion of injection to complete motor blockade.

Duration of motor block was defined as the time from onset of motor blockade to complete recovery of motor function.

Postoperative Assessment

Pain intensity was assessed using Numerical Rating Scale (NRS).

Duration of analgesia was defined as the time from completion of block to first request for rescue analgesia.

Rescue analgesia was administered when NRS ≥4.

Sedation was assessed using the Culebras sedation scale. Mean sedation scores were slightly higher in the

dexmedetomidine group during the early postoperative period; however, no patient developed excessive sedation or respiratory depression.

All adverse effects including bradycardia, hypotension, nausea, vomiting, respiratory depression, and pruritus were recorded.

Statistical Analysis

Data were compiled using Microsoft Excel and analyzed using SPSS version 28.

Continuous variables were expressed as mean $\pm$ standard deviation. Categorical variables were expressed as frequency and percentage.

Student t-test was used for quantitative variables. Chi-square test and Fisher exact test were used for qualitative variables.

A p-value <0.05 was considered statistically significant.

Normality of data distribution was assessed using the Shapiro–Wilk test.

In addition to hypothesis testing, mean differences with corresponding 95% confidence intervals (95% CI) were calculated for the primary outcomes. Standardized effect sizes were estimated using Cohen's *d* to quantify the magnitude of intergroup differences.

Results

A total of 60 patients were enrolled and randomized equally into two groups, with all patients completing the study protocol and included in final analysis.

Table 1. Demographic Characteristics

Parameter	Group A	Group B	p-value
Age distribution (20–30 years), n (%)	5 (16.7%)	8 (26.7%)	0.158
Age distribution (31–40 years), n (%)	10 (33.3%)	11 (36.7%)	
Age distribution (41–50 years), n (%)	5 (16.7%)	8 (26.7%)	
Age distribution (51–60 years), n (%)	10 (33.3%)	3 (10.0%)	
Weight (kg)	64.90 $\pm$ 3.83	63.33 $\pm$ 4.83	0.169
Male/Female, n	20/10	20/10	1.000

The addition of dexmedetomidine significantly improved all primary efficacy outcomes. Compared with levobupivacaine alone, patients receiving dexmedetomidine demonstrated a faster onset of sensory and motor blockade, prolonged recovery of both sensory and motor block, and a significantly longer duration of postoperative analgesia (Table 2). All differences were statistically significant ($p < 0.001$).

Table 2. Comparison of Primary Efficacy Outcomes Between the Two Study Groups

Outcome	Group A	Group B	Mean Difference (95% CI)	p-value
Sensory block onset	9.60 $\pm$ 1.25	6.03 $\pm$ 1.10	–3.57 (–4.18 to –2.96)	<0.001
Motor block onset	16.23 $\pm$ 1.70	12.43 $\pm$ 1.72	–3.80 (–4.68 to –2.92)	<0.001

Outcome	Group A	Group B	Mean Difference (95% CI)	p-value
Sensory block duration (min)	450.73 ± 18.02	634.80 ± 32.07	184.07 (170.62 - 197.52)	<0.001
Motor block duration (min)	403.67 ± 17.99	563.20 ± 15.91	159.53 (150.76 - 168.30)	<0.001
Duration of analgesia	800.33 ± 79.48	1076.17 ± 78.02	275.84 (235.14 - 316.54)	<0.001

In the present study, heart rate, systolic blood pressure, diastolic blood pressure, and mean arterial pressure were largely comparable between the two groups during the early intraoperative period, indicating that dexmedetomidine did not produce abrupt or clinically significant cardiovascular depression.

From 90 minutes onward, SBP, DBP, and MAP were consistently lower in the dexmedetomidine group, with statistical significance observed at several time points. Importantly, these reductions were gradual, sustained, and clinically acceptable, without any episodes of severe hypotension requiring intervention. No clinically significant hypotension, bradycardia, oxygen desaturation, or adverse cardiovascular events were observed.

No major complications such as pneumothorax, vascular puncture, respiratory depression, or neurological deficits were observed.

Figure 1. Changes in systolic blood pressure during the study period.

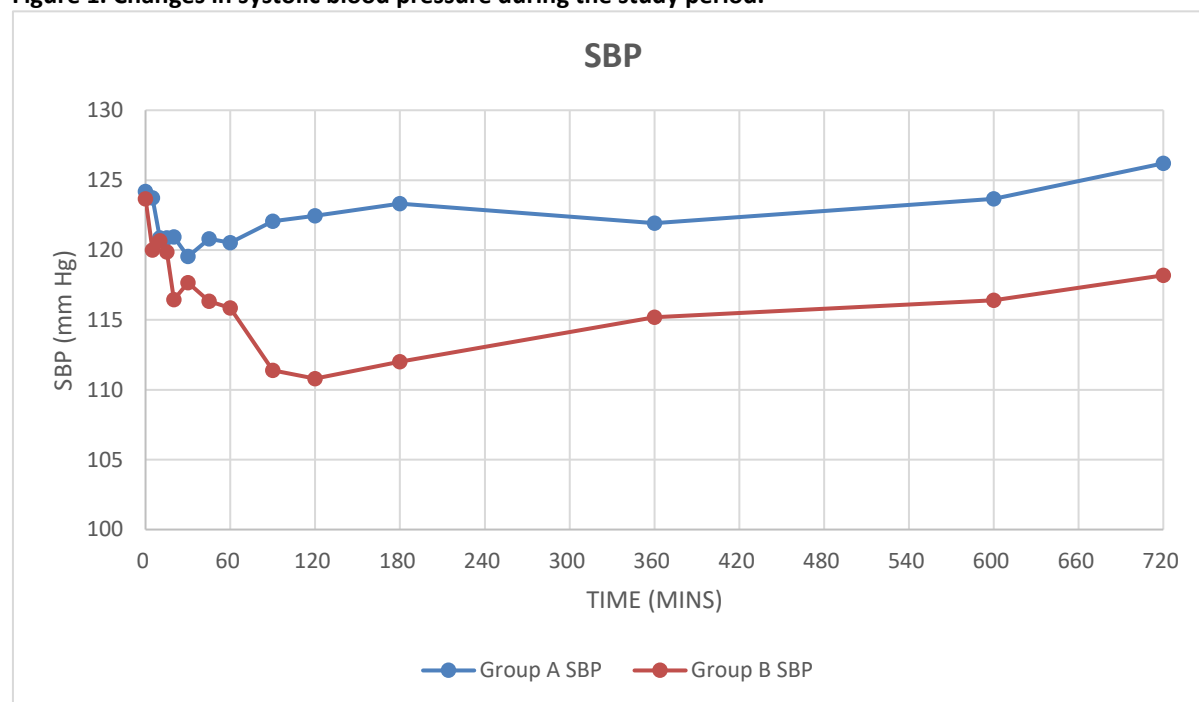


Figure 2. Changes in diastolic blood pressure during the study period.

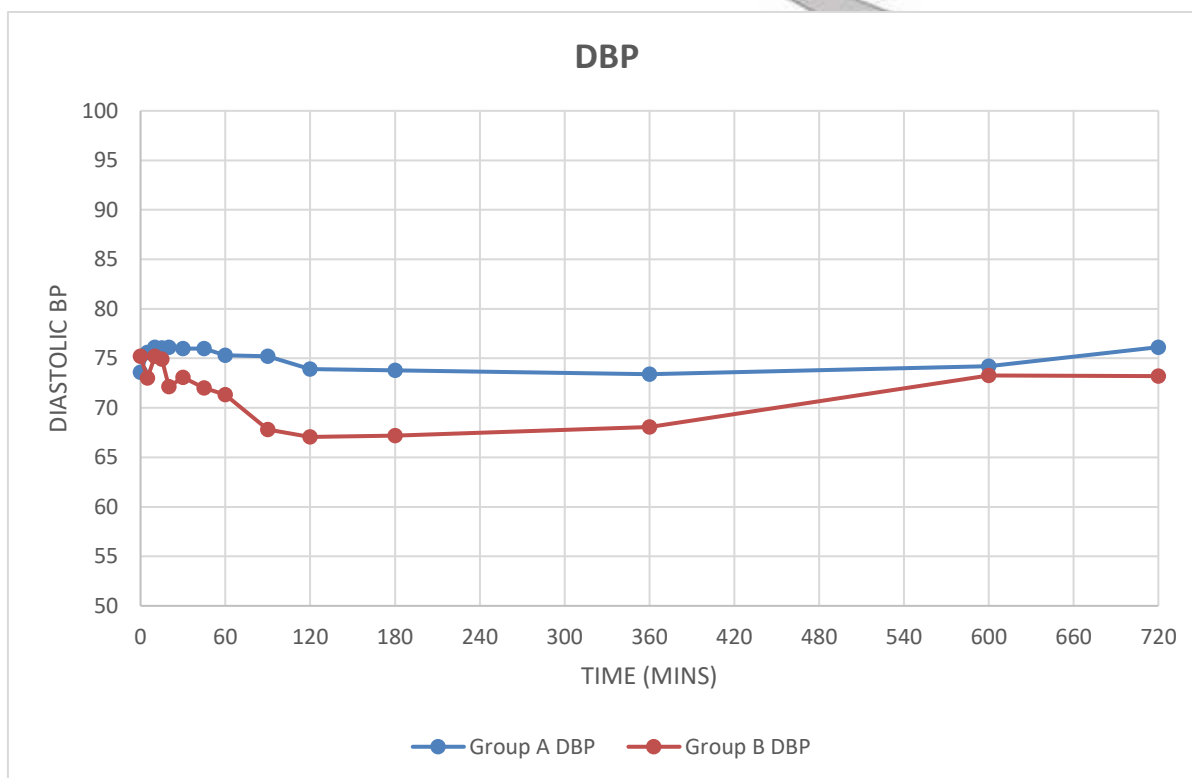
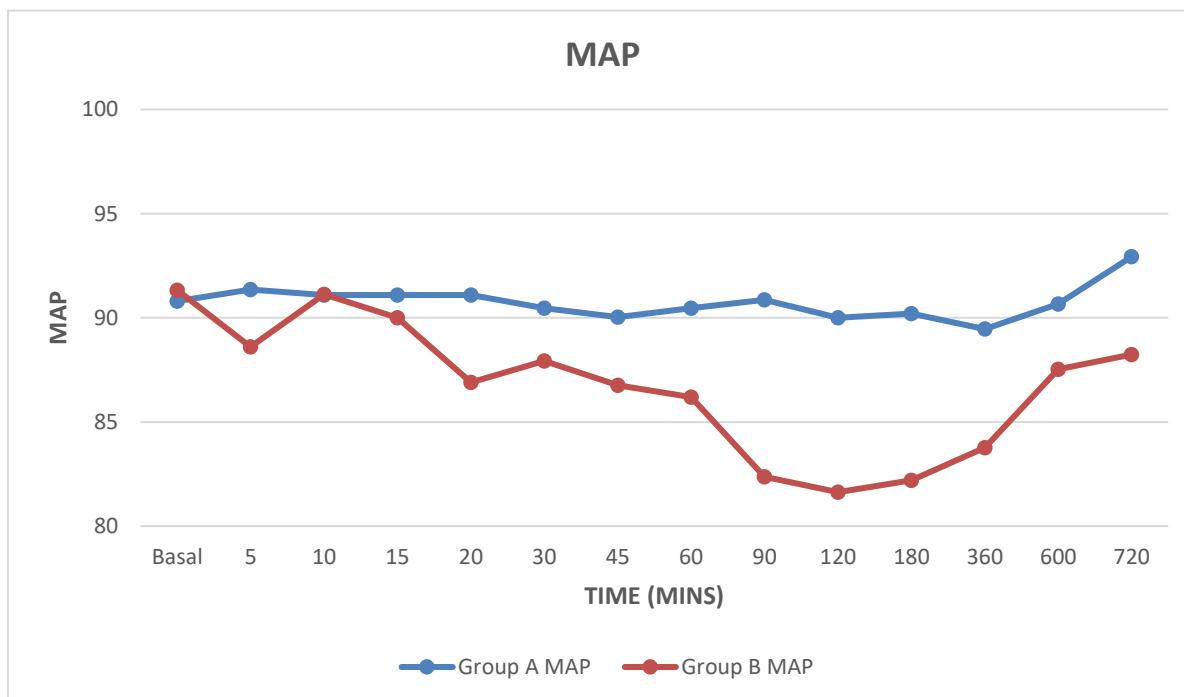


Figure 3. Changes in Mean Arterial Pressure (MAP) during the study period.



DISCUSSION

The present randomized double-blind study demonstrated that the addition of perineural dexmedetomidine (1

µg/kg) to 0.5% levobupivacaine significantly improved the quality of ultrasound-guided supraclavicular brachial plexus block. Patients receiving dexmedetomidine exhibited a faster onset of both sensory and motor blockade, prolonged recovery times, extended postoperative analgesia, and maintained favourable hemodynamic stability without clinically significant adverse events. These findings suggest that dexmedetomidine enhances both the efficacy and duration of regional anaesthesia while preserving an acceptable safety profile.

Demographic profile

The two study groups were comparable with respect to age, gender distribution, and body weight, with no statistically significant differences observed. This demographic homogeneity eliminates confounding influences of age- or weight-related pharmacodynamic variability and ensures that the observed differences in block characteristics and analgesic duration can be attributed to the pharmacological effect of dexmedetomidine rather than baseline patient factors. Similar demographic comparability has been reported in several previous studies evaluating dexmedetomidine as an adjuvant in supraclavicular brachial plexus blocks.^(10-13,15,16)

Onset of sensory and motor block

The approximately 37% reduction in sensory block onset (6.03 ± 1.10 minutes vs 9.60 ± 1.25 minutes, $p < 0.001$) and 23% reduction in motor block onset (12.43 ± 1.72 minutes vs 16.23 ± 1.70 minutes, $p < 0.001$) observed in the present study have important clinical implications. Earlier establishment of surgical anaesthesia reduces the interval between block administration and surgical incision, thereby improving operating room efficiency and minimizing anaesthesia-related delays. The observed improvement is consistent with the proposed peripheral mechanisms of dexmedetomidine, including inhibition of the hyperpolarization-activated cation (I_h) current, peripheral vasoconstriction resulting in reduced vascular absorption of local anaesthetic, and synergistic enhancement of sodium channel blockade.

These findings are consistent with several previous studies that demonstrated a significantly faster onset of sensory and motor block with the addition of dexmedetomidine to levobupivacaine in supraclavicular brachial plexus block. Similar observations have been reported by Reddy et al.⁽¹⁰⁾, Kaur et al.⁽¹²⁾, Nallam et al.⁽¹⁶⁾ and Singh et al.⁽¹⁷⁾, all of whom attributed the faster onset to the synergistic interaction between dexmedetomidine and long-acting local anesthetics. However, some studies have reported variable effects on onset time, which may be related to differences in dexmedetomidine dose, volume of injectate, local anesthetic concentration, and technique used.

Hemodynamic parameters (HR, SBP, DBP, MAP)

Baseline hemodynamic parameters were comparable between the study groups, confirming successful randomization. Although dexmedetomidine produced modest reductions in systolic blood pressure, diastolic blood pressure, and mean arterial pressure during the later intraoperative period, these changes remained within clinically acceptable limits and did not require pharmacological intervention. These findings indicate that perineural dexmedetomidine provides favourable sympatholysis while preserving cardiovascular stability.

Similar hemodynamic trends have been reported by Somsunder et al.⁽¹¹⁾, Nallam et al.⁽¹⁶⁾, and Kaur et al.⁽¹²⁾, who noted mild reductions in heart rate and blood pressure without adverse clinical consequences. El-Boghdadly et al.⁽¹⁴⁾, in their meta-analysis, concluded that perineural dexmedetomidine provides superior block quality with an acceptable hemodynamic safety profile when compared to clonidine.

A more recent meta-analysis by Bajpai et al.⁽¹⁹⁾ further confirmed that dexmedetomidine provides superior prolongation of sensory and motor blockade compared with clonidine while maintaining an acceptable safety profile, supporting its preferential use as a perineural adjuvant.

Oxygen saturation (SpO₂)

Peripheral oxygen saturation remained within normal physiological limits (>98%) throughout the study period in both groups, with no statistically or clinically significant intergroup differences at any time point. This finding confirms that the addition of dexmedetomidine does not compromise respiratory function when used perineurally in supraclavicular brachial plexus block.

Comparable observations have been reported in previous studies, including Reddy et al.⁽¹⁰⁾, Bisui et al.⁽¹⁵⁾, and Singh et al.⁽¹⁷⁾, reinforcing the respiratory safety of dexmedetomidine in regional anesthesia.

Duration and recovery of motor and sensory block

An important finding of the present study was the marked prolongation of both sensory and motor blockade following the addition of dexmedetomidine. Sensory blockade was prolonged by approximately 184 minutes, whereas motor blockade increased by approximately 160 minutes, representing an almost 40% increase compared with levobupivacaine alone. The relatively low variability observed within each study group indicates that the treatment effect was consistent across participants. Clinically, prolonged sensory blockade provides sustained postoperative analgesia, whereas prolonged motor blockade should be interpreted in relation to surgical requirements and anticipated postoperative rehabilitation.

This prolongation is attributed to the predominantly peripheral action of dexmedetomidine on nerve fibers, particularly its effect on C-fiber transmission and sodium channel modulation. The extended block duration contributes to improved postoperative comfort and reduced need for rescue analgesics.

These findings align closely with those of Nallam et al.⁽¹⁶⁾, Kaur et al.⁽¹²⁾, Singh et al.⁽¹⁷⁾ and the randomized controlled trial by Aydın et al.⁽¹⁸⁾ all of whom reported significantly prolonged sensory and motor block durations with dexmedetomidine. The systematic review and meta-analysis by El-Boghdadly et al.⁽¹⁴⁾ further supports these observations, concluding that dexmedetomidine is superior to clonidine in prolonging block duration when used as a perineural adjuvant.

Duration of analgesia

Perhaps the most clinically relevant finding of the present study was the significant prolongation of postoperative analgesia observed with dexmedetomidine. Patients experienced approximately 4.6 hours of additional postoperative analgesia, which has important implications for multimodal analgesic strategies. Prolonged analgesia may reduce early postoperative opioid requirements, delay the need for rescue analgesics, improve patient comfort, and potentially facilitate enhanced recovery protocols following upper-limb orthopaedic surgery.

The prolonged analgesic effect observed in the present study is likely multifactorial. Proposed mechanisms include inhibition of peripheral nerve hyperpolarization-activated cation currents, suppression of substance P release, attenuation of nociceptive transmission, and local vasoconstriction, which delays vascular absorption of levobupivacaine.

Comparable prolongation of analgesia has been reported by Reddy et al.⁽¹⁰⁾, Kaur et al.⁽¹²⁾, Sinha et al.⁽¹³⁾ and Singh et al.⁽¹⁷⁾, confirming the reproducibility of this effect across different study designs and populations.

Recent evidence synthesized by Feng and Chen⁽²⁰⁾ further demonstrated that perineural administration of dexmedetomidine provides longer postoperative analgesia than intravenous administration while also shortening motor block onset, supporting the peripheral mechanism proposed in the present study.

Clinical implications

The present findings have important clinical implications for contemporary regional anaesthesia practice. By facilitating earlier establishment of surgical anaesthesia and extending postoperative analgesia by approximately 4–5 hours, dexmedetomidine may reduce perioperative opioid requirements, improve patient comfort, and contribute to enhanced recovery protocols following upper-limb orthopaedic surgery. The favourable safety profile observed further supports its routine consideration as a perineural adjuvant in appropriately selected patients.

Strengths of the Study

The strengths of the present study include its prospective randomized double-blind design, standardized ultrasound-guided block technique, homogeneous patient population, and comprehensive evaluation of both efficacy and safety outcomes. The use of ultrasound guidance minimized procedural variability and enhanced the internal validity of the observed treatment effects.

Limitations

The present study has certain limitations. First, it was conducted at a single tertiary care centre with a relatively small sample size, which may limit the generalisability of the findings to broader patient populations. Second, only ASA physical status I and II patients undergoing elective upper-limb orthopaedic surgeries were included; therefore, the results may not be directly applicable to high-risk patients or emergency surgical settings. Third,

postoperative opioid consumption, patient satisfaction scores, and long-term neurological outcomes were not assessed, which could have provided additional information regarding the overall clinical benefits of dexmedetomidine. Finally, although statistically significant improvements were observed in block characteristics, future multicentre studies with larger sample sizes are warranted to further validate these findings and establish optimal dosing strategies for perineural dexmedetomidine.

CONCLUSION

In conclusion, perineural dexmedetomidine (1 µg/kg) added to 0.5% levobupivacaine significantly accelerated the onset of sensory and motor blockade while prolonging block duration and postoperative analgesia without compromising hemodynamic stability. These findings support dexmedetomidine as an effective and safe adjuvant for ultrasound-guided supraclavicular brachial plexus block in elective upper-limb orthopaedic surgery.

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