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Original Research Article

Comparison between Intravenous and Perineural Dexmedetomidine in Enhancing the Block Effect of Ultrasound-Guided Supraclavicular Brachial Plexus Block in Upper Limb Surgeries

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Conflict of interest: Nil

Abstract

Background: Ultrasound-guided supraclavicular brachial plexus block (SCBPB) is widely used for upper limb surgeries because it provides excellent intraoperative anesthesia and postoperative analgesia. Local anesthetics such as bupivacaine are commonly used; however, their duration of action may be limited. Dexmedetomidine, a highly selective α2-adrenergic agonist, has gained popularity as an adjuvant to local anesthetics in peripheral nerve blocks due to its sedative, analgesic, and sympatholytic properties. Dexmedetomidine can be administered either intravenously or perineurally, but the optimal route of administration remains a subject of ongoing research.

Aim: To compare the efficacy of perineural versus intravenous dexmedetomidine as an adjuvant to bupivacaine in ultrasound-guided supraclavicular brachial plexus block in patients undergoing upper limb surgeries.

Materials and Methods: This longitudinal comparative study was conducted at Sri Siddhartha Medical College and Hospital, Tumkur, Karnataka, India, over a period of 24 months. A total of 70 patients scheduled for elective upper limb surgeries under ultrasound-guided supraclavicular brachial plexus block were included in the study. Patients were randomly divided into two equal groups (n = 35 each). Group I (Intravenous group) received Inj. Bupivacaine 0.5% plain 20 mL perineurally with Inj. Dexmedetomidine 1 µg/kg administered intravenously. Group P (Perineural group) received Inj. Bupivacaine 0.5% plain 20 mL with Inj. Dexmedetomidine 1 µg/kg administered perineurally. Parameters assessed included onset and duration of sensory and motor block, duration of analgesia, hemodynamic variables, sedation scores, and adverse effects.

Results: Perineural dexmedetomidine significantly prolonged the duration of sensory and motor blockade compared with intravenous dexmedetomidine ($p<0.001$). The onset time of sensory and motor block was shorter in the perineural group ($p<0.001$). Additionally, the duration of postoperative analgesia was significantly longer in the perineural group ($p<0.001$). Hemodynamic parameters were comparable between the groups, although mild bradycardia and hypotension were more frequently observed in the intravenous group, which was found to be statistically insignificant.

Conclusion: Perineural administration of dexmedetomidine as an adjuvant to bupivacaine in ultrasound-guided supraclavicular brachial plexus block provides faster onset, prolonged sensory and motor block, and longer postoperative analgesia compared with intravenous administration. Therefore, perineural dexmedetomidine appears to be a more effective route for enhancing the quality of brachial plexus block in upper limb surgeries.

Keywords: Dexmedetomidine; Brachial Plexus Block; Supraclavicular Block; Perineural Administration; Intravenous Administration; Regional Anesthesia.

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Introduction

Regional anesthesia has become an integral component of modern anesthetic practice, particularly in upper limb surgeries. Among the various regional anesthesia techniques, the supraclavicular brachial plexus block (SCBPB) is widely preferred due to its ability to provide

reliable anesthesia for surgeries involving the arm, forearm, and hand. This block targets the brachial plexus at the level of the trunks, where the nerve fibers are densely packed, thereby ensuring rapid onset and dense blockade of sensory and motor functions. Recent advances in ultrasound guidance have significantly improved the safety and success rate of brachial plexus blocks by allowing direct visualization of neural structures, surrounding vessels, and needle placement during the procedure. [1]

Local anesthetics such as bupivacaine are commonly used for brachial plexus block due to their long duration of action. However, the duration of analgesia provided by local anesthetics alone may be insufficient for prolonged postoperative pain control. Inadequate postoperative analgesia may lead to increased opioid consumption, delayed recovery, and decreased patient satisfaction. Therefore, various pharmacological adjuvants have been investigated to enhance the quality and duration of nerve blocks. [2]

Among these adjuvants, dexmedetomidine has gained considerable attention in recent years. Dexmedetomidine is a highly selective α2-adrenergic receptor agonist that possesses sedative, analgesic, and anxiolytic properties without causing significant respiratory depression. It exerts its analgesic effect by inhibiting the release of norepinephrine and suppressing neuronal firing in the locus coeruleus and dorsal horn of the spinal cord. These properties make dexmedetomidine an attractive adjunct in regional anesthesia techniques. [3]

Dexmedetomidine has been shown to enhance the quality of peripheral nerve blocks by shortening the onset time of sensory and motor block, prolonging the duration of anesthesia, and improving postoperative analgesia. When used as an adjuvant with local anesthetics, dexmedetomidine may act by hyperpolarizing nerve membranes and reducing the propagation of pain signals along peripheral nerves. Additionally, its vasoconstrictive effect may decrease systemic absorption of local anesthetics, thereby prolonging their action. [4]

Dexmedetomidine can be administered through different routes during peripheral nerve blocks, including intravenous and perineural administration. Intravenous dexmedetomidine produces systemic analgesic and sedative effects that may enhance the quality of regional anesthesia. On the other hand, perineural administration delivers the drug directly around the nerve structures, potentially resulting in a more localized and prolonged analgesic effect. Several clinical studies have evaluated these two routes of administration; however, the results remain inconclusive regarding which route provides superior analgesic benefits. [5] The use of dexmedetomidine as an adjuvant in supraclavicular brachial plexus block has been associated with improved block characteristics, including faster onset and prolonged duration of sensory and motor blockade. Studies have demonstrated that perineural dexmedetomidine significantly prolongs the duration of analgesia compared with local anesthetic alone. Furthermore, the addition of dexmedetomidine may reduce postoperative analgesic requirements and improve patient comfort during the postoperative period. [6]

Despite these promising findings, concerns remain regarding the optimal route of dexmedetomidine administration. Intravenous administration may lead to systemic effects such as bradycardia, hypotension, and sedation, whereas perineural administration may offer more targeted analgesia with fewer systemic effects. Comparative studies evaluating the efficacy of intravenous versus perineural dexmedetomidine in brachial plexus block are therefore essential to determine the most effective and safe route of administration. [7]

In recent years, the increasing use of ultrasound guidance for peripheral nerve blocks has improved the precision and safety of regional anesthesia techniques. Ultrasound guidance allows accurate deposition of local anesthetic around the brachial plexus, reducing the risk of complications such as pneumothorax, vascular puncture, and nerve injury. When combined with effective adjuvants such as dexmedetomidine, ultrasound-guided brachial plexus block can provide excellent surgical anesthesia and prolonged postoperative analgesia. [8] Several investigators have compared intravenous and perineural dexmedetomidine as adjuvants in brachial plexus block.

Some studies have reported that perineural dexmedetomidine significantly prolongs sensory and motor block duration compared with intravenous administration. Conversely, other studies suggest that systemic administration may provide comparable analgesic effects due to central modulation of pain pathways. [9] Given the growing interest in optimizing regional anesthesia techniques for upper limb surgeries, it is important to determine whether the route of dexmedetomidine administration influences block characteristics and analgesic outcomes. Understanding these differences may help anesthesiologists select the most appropriate technique for enhancing the efficacy of brachial plexus blocks.

Therefore, the present longitudinal comparative study was undertaken to evaluate and compare the efficacy of perineural versus intravenous dexmedetomidine as an adjuvant to bupivacaine in ultrasound-guided supraclavicular brachial plexus block in patients undergoing upper limb surgeries

at Sri Siddhartha Medical College and Hospital, Tumkur, Karnataka, India.

Material and methods

Study design: This study was conducted as a longitudinal comparative study. It was designed to compare the effects of intravenous dexmedetomidine and perineural dexmedetomidine in enhancing the block characteristics.

Study setting: The study was conducted at Sri Siddhartha Medical and Hospital, Tumkur, Karnataka, India. All patients included in the study were selected from this hospital.

Study duration: The study was carried out over a period of 24 months. During this period, patient recruitment, intervention, and follow-up were completed.

Inclusion Criteria

- Patients of ASA Class I and II aged between 18-60 years undergoing upper limb surgery under supraclavicular block.

Exclusion Criteria

- Patients refusing for participation for the study
- Infection at injection site
- History of allergy to Bupivacaine 0.5% Plain and Dexmedetomidine
- Bleeding diathesis.

Study sampling: Purposive sampling method.

Study sample size: The study was powered to detect differences between the two groups, with a target sample size of 70 participants. Given that the two groups (perineural and intravenous) were of equal size, 35 patients were randomly assigned to each group.

- **Group I (Intravenous):** Received Inj. Bupivacaine 0.5% Plain 20 mL perineurally + Inj. Dexmedetomidine 1 µg/kg IV
- **Group P (Perineural):** Received Inj. Bupivacaine 0.5% Plain 20 mL + Inj. Dexmedetomidine at 1 µg/kg both perineurally.

Study procedure: Approval from the Institutional Ethics Committee was obtained prior to commencement of the study (IEC approval number: SSMC/MED/IEC-036/FEB-2024, Dated: 09/02/2024). Eligible patients were enrolled after detailed explanation of the procedure and obtaining written informed consent for anaesthesia and study participation. Pre-anaesthetic assessment was performed for all participants. Standard anaesthesia protocols were followed uniformly. Baseline vital parameters were recorded using ASA-standard multiparameter monitors, including heart rate, mean arterial pressure, oxygen saturation, and electrocardiogram. Under aseptic precautions, an ultrasound-guided supraclavicular brachial plexus block was administered as per standard technique. Upper limb surgery was then performed as planned, with continuous intraoperative monitoring. Postoperatively, patients were observed, and the onset and duration of sensory and motor blockade were recorded. Time to first rescue analgesic requirement was also noted.

Study data collection: Onset of sensory blockade was defined as the time from injection to complete loss of cold sensation. Sensory block was assessed in the musculocutaneous, median, radial, and ulnar nerve distributions using alcohol swab cold testing, graded on a three-point scale, every 5 minutes for 20 minutes. Block was considered failed if anaesthesia was absent in ≥2 nerve territories; such patients were excluded. Duration of sensory block was the time from onset to return of cold sensation, assessed every 4 hours for 24 hours in at least three nerve territories. Onset of motor blockade was the time from injection to complete abolition of upper limb movement, assessed using the Modified Bromage Scale every 5 minutes for 20 minutes.

Block failure was defined as a score 3 with IV tramadol 50 mg slow infusion. After 12 postoperative hours, patients with pain received IV diclofenac 75 mg in 100 ml normal saline over 45 minutes.

Ethical considerations: Ethical approval for the study was obtained from the Institutional Ethical Committee of Sri Siddhartha Medical College and Hospital, Tumkur, Karnataka, India (IEC approval number: SSMC/MED/IEC-036/FEB-2024, Dated: 09/02/2024). Informed consent was obtained from all participants after explaining the study procedure, potential risks, and benefits. Participants were assured that their involvement was voluntary and that they could withdraw at any time without penalty.

All patient information was kept confidential, and data were anonymized to ensure privacy. The study adhered to the principles of good clinical practice and the Declaration of Helsinki, ensuring the protection of participants' rights and welfare

Data analysis: Statistical analysis was carried out using SPSS software version 20. Data were presented as mean ± standard deviation, ranges, numbers, and ratios. Chi-square test, Mann–Whitney test for non-parametric data, and unpaired t-test for parametric data were used for analysis.

A p-value less than 0.05 was considered statistically significant.

Results

The study was powered to detect differences between the two groups, with a target sample size of 70 participants. Given that the two groups

(perineural and intravenous) were of equal size, 35 patients were assigned to each group. Group I (Intravenous): Received Inj. Bupivacaine 0.5% Plain 20 mL perineurally + Inj. Dexmedetomidine 1 µg/kg IV Group P (Perineural): Received Inj. Bupivacaine 0.5% Plain 20 mL + Inj. Dexmedetomidine at 1 µg/kg both perineurally.

Groups were compared and analysed respectively.

Table 1: Baseline Demographic and Clinical Characteristics of Study Participants

Variable	Category	Group I (Intravenous) n=35	Group P (Perineural) n=35	χ^2 value	p-value
Age (years)	18–25	4 (11.4%)	2 (5.7%)	4.40	0.354
	26–35	8 (22.9%)	10 (28.6%)		
	36–45	14 (40.0%)	9 (25.7%)		
	46–55	9 (25.7%)	12 (34.3%)		
	56–60	0 (0%)	2 (5.7%)		
Gender	Male	24 (68.6%)	22 (62.9%)	0.063	0.801
	Female	11 (31.4%)	13 (37.1%)		
ASA Status	ASA I	23 (65.7%)	23 (65.7%)		
	ASA II	12 (34.3%)	12 (34.3%)	0.000	1.000

Table 1 presents the baseline demographic and clinical characteristics of patients in both study groups. The majority of patients in the perineural group (Group P) were in the 46–55 years age group (34.3%), while the intravenous group (Group I) had the highest proportion of patients in the 36–45 years age group (40.0%).

However, statistical analysis using the Chi-square test showed no significant difference in age distribution between the groups ($\chi^2 = 4.40$, $p = 0.354$). With respect to gender distribution, male predominance was observed in both groups, with 60.0% males in Group I and 62.9% males in Group P. The difference was not statistically significant ($\chi^2 = 0.063$, $p = 0.801$).

Similarly, the American Society of Anesthesiologists (ASA) physical status classification was equally distributed between the two groups, with 54.3% of patients classified as ASA I and 45.7% as ASA II in both groups, and the difference was not statistically significant ($p > 0.05$).

Table 2: Block Characteristics and Postoperative Pain Scores in Both Study Groups

Parameter	Group I (Intravenous) n=35	Group P (Perineural) n=35	p-value
Onset of sensory block (minutes)	19.21 ± 1.59	10.54 ± 1.20	**<0.001**
Onset of motor block (minutes)	22.43 ± 1.21	15.13 ± 1.30	**<0.001**
Duration of sensory block (minutes)	472.83 ± 46.54 (7.88 hrs)	798.17 ± 53.10 (13.30 hrs)	**<0.001**
Duration of motor block (minutes)	403.11 ± 41.10 (6.72 hrs)	721.03 ± 45.80 (12.02 hrs)	**<0.001**
VAS score – 4 hours	2.57 ± 0.50	0.51 ± 0.51	**<0.001**
VAS score – 8 hours	4.14 ± 0.85	1.17 ± 0.66	**<0.001**
VAS score – 12 hours	5.11 ± 0.83	1.94 ± 0.80	**<0.001**
VAS score – 16 hours	6.03 ± 0.82	3.23 ± 0.81	**<0.001**

The table compares block characteristics and postoperative pain scores between the intravenous dexmedetomidine group (Group I) and the perineural dexmedetomidine group (Group P).

The onset of sensory and motor block was significantly faster in the perineural group, with sensory block beginning at 10.54 ± 1.20 minutes and motor block at 15.13 ± 1.30 minutes, compared with 19.21 ± 1.59 minutes and 22.43 ± 1.21 minutes, respectively, in the intravenous group ($p < 0.001$). Furthermore, the duration of both sensory and motor blockade was markedly prolonged in Group P, with sensory block lasting 798.17 ± 53.10 minutes (13.30 hours) and motor block lasting 721.03 ± 45.80 minutes (12.02 hours), compared with 472.83 ± 46.54 minutes (7.88 hours) and 403.11 ± 41.10 minutes (6.72 hours) in Group I ($p < 0.001$).

Postoperative pain assessment using the Visual Analogue Scale (VAS) showed that Group P consistently demonstrated lower pain scores at all time intervals (4, 8, 12, and 16 hours) compared with Group I, indicating better postoperative analgesia.

Overall, these findings demonstrate that perineural dexmedetomidine provides faster onset of block, significantly prolonged sensory and motor blockade, and superior postoperative pain control compared with intravenous administration, achieving high statistical significance ($p < 0.001$).

Table 3: Postoperative Analgesia, Hemodynamic Parameters, and Adverse Effects in Both Study Groups

Parameter	Group I (Intravenous) n=35	Group P (Perineural) n=35	p-value
Time to first rescue analgesia (minutes)	482.00 ± 42.84 (8.03 ± 0.71 hrs)	833.57 ± 36.74 (13.89 ± 0.61 hrs)	<0.001
Mean Arterial Pressure (MAP)	Progressive decline after block with lowest value at 1 hour, gradually returning toward baseline by 12 hours	Similar trend observed	>0.05 (between groups)
Heart Rate (HR)	Decrease from baseline with maximum reduction at 1 hour, gradually returning toward baseline by 12 hours	Similar pattern observed	>0.05 (between groups)
Hypotension	5 (14.3%)	3 (8.6%)	0.294
Bradycardia	6 (17.1%)	3 (8.6%)	0.145

The table summarizes postoperative analgesia requirements, hemodynamic parameters, and adverse effects in both study groups. The time to first rescue analgesia was significantly prolonged in the perineural group, with patients requiring analgesia at 833.57 ± 36.74 minutes (13.89 hours) compared with 482.00 ± 42.84 minutes (8.03 hours) in the intravenous group ($p < 0.001$), indicating superior postoperative analgesia with perineural dexmedetomidine.

Hemodynamic parameters such as mean arterial pressure (MAP) and heart rate (HR) showed a progressive decline after block placement in both groups, reaching the lowest levels at approximately 1 hour post-procedure, followed by gradual return toward baseline by 12 hours. Although within-group variations over time were statistically significant ($p < 0.001$), no statistically significant differences were observed between the two groups ($p > 0.05$), indicating comparable hemodynamic stability.

Regarding adverse effects, hypotension and bradycardia occurred more frequently in the intravenous group, but the differences were not statistically significant ($p = 0.294$ for hypotension and $p = 0.145$ for bradycardia).

Discussion

The present longitudinal comparative study evaluated the efficacy of perineural versus intravenous dexmedetomidine as an adjuvant to bupivacaine in ultrasound-guided supraclavicular brachial plexus block for upper limb surgeries. The study demonstrated that perineural dexmedetomidine significantly improved block characteristics, including faster onset of sensory and motor blockade, prolonged duration of anesthesia, delayed requirement of rescue analgesia, and improved postoperative pain control compared with intravenous administration.

Demographic Characteristics: Baseline demographic variables such as age, gender, and ASA physical status were comparable between the two study groups. The age distribution did not differ significantly between groups ($\chi^2 = 4.40$, $p = 0.354$), indicating adequate randomization and comparable baseline characteristics. Similar demographic balance was reported by Abdallah et al. who found no significant difference in baseline characteristics while comparing dexmedetomidine routes in peripheral nerve blocks. [1]

Male predominance observed in the present study is consistent with the epidemiological pattern of upper limb trauma and orthopedic procedures, which are more common among males. Similar gender distribution patterns were reported in studies by Gandhi et al. and Swami et al., which also investigated dexmedetomidine as an adjuvant in brachial plexus block. [2,3]

Additionally, the ASA classification distribution was identical between the groups, indicating that both groups were comparable with respect to preoperative physical status. This homogeneity minimized confounding variables related to systemic health and strengthened the internal validity of the study findings.

Onset of Sensory and Motor Block: One of the key findings of this study was the significantly faster onset of sensory block in the perineural group (10.54 ± 1.20 minutes) compared with the intravenous group (19.21 ± 1.59 minutes) ($p < 0.001$). Similarly, the onset of motor block occurred earlier in the perineural group (15.13 ± 1.30 minutes) compared with the intravenous group (22.43 ± 1.21 minutes) ($p < 0.001$).

These findings are consistent with the study by Rancourt et al., who reported that perineural dexmedetomidine accelerates the onset of both sensory and motor block in brachial plexus anesthesia. [4] The faster onset may be explained by the direct action of dexmedetomidine on peripheral nerve fibers, which enhances local anesthetic diffusion and increases neuronal hyperpolarization.

Similarly, Abdallah and Brull reported that dexmedetomidine shortens the onset time of nerve blocks through α2-receptor mediated inhibition of

nerve conduction and enhancement of local anesthetic action. [5]

Duration of Sensory and Motor Block: The present study also demonstrated a significantly prolonged duration of sensory and motor block in the perineural group. Sensory blockade lasted 798.17 ± 53.10 minutes (13.30 hours) in Group P compared with 472.83 ± 46.54 minutes (7.88 hours) in Group I. Similarly, motor blockade lasted 721.03 ± 45.80 minutes (12.02 hours) in the perineural group compared with 403.11 ± 41.10 minutes (6.72 hours) in the intravenous group ($p < 0.001$).

These results are in agreement with the findings of Al-Mustafa et al., who reported that dexmedetomidine significantly prolongs the duration of sensory and motor blockade when used as an adjuvant with bupivacaine in brachial plexus blocks. [6] The mechanism may involve local vasoconstriction, reduced systemic absorption of local anesthetic, and inhibition of hyperpolarization-activated cation currents in nerve cells.

A meta-analysis by Vorobeichik et al. further confirmed that perineural dexmedetomidine prolongs analgesia duration by several hours compared with systemic administration. [7]

Postoperative Analgesia and Pain Scores: Postoperative pain assessment using the Visual Analogue Scale (VAS) demonstrated significantly lower pain scores in the perineural group at all time points (4, 8, 12, and 16 hours). This indicates superior postoperative analgesia when dexmedetomidine is administered perineurally.

The time to first rescue analgesia was significantly longer in the perineural group (833.57 ± 36.74 minutes) compared with 482.00 ± 42.84 minutes in the intravenous group, representing a delay of approximately 351 minutes (5.9 hours) ($p < 0.001$).

These findings are consistent with studies by Esmaoglu et al. and Rancourt et al., which reported significantly prolonged analgesia duration with perineural dexmedetomidine. [4,8]

The analgesic effect of dexmedetomidine is believed to be mediated through activation of α2-adrenergic receptors in the peripheral and central nervous system, resulting in reduced neurotransmitter release and decreased nociceptive transmission. [9]

Hemodynamic Parameters: In the present study, mean arterial pressure (MAP) and heart rate (HR) showed a similar pattern in both groups, with a mild decline after block administration followed by gradual return toward baseline. Although within-group variations were statistically significant ($p < 0.001$), there were no significant differences between the two groups ($p > 0.05$).

These findings suggest that both intravenous and perineural dexmedetomidine provide comparable hemodynamic stability. Similar results were reported by Gandhi et al., who observed stable hemodynamic parameters during brachial plexus block with dexmedetomidine as an adjuvant. [2]

Dexmedetomidine is known to produce sympatholytic effects, which may cause mild reductions in heart rate and blood pressure. However, these effects are generally well tolerated in clinical practice. [10]

Adverse Effects: The present study observed hypotension and bradycardia in both groups, with a slightly higher incidence in the intravenous group. However, the differences were not statistically significant.

This observation is consistent with previous studies indicating that systemic administration of dexmedetomidine may produce more pronounced cardiovascular effects due to its central sympatholytic action. [11]

Nevertheless, the incidence of adverse effects in the present study remained low and manageable, indicating that both routes of administration are relatively safe when used in appropriate doses.

Clinical Implications: The findings of this study have important clinical implications for anesthetic practice. Perineural dexmedetomidine was associated with a faster onset of sensory and motor block, prolonged duration of anesthesia, extended postoperative analgesia, and lower postoperative pain scores. These advantages suggest that perineural dexmedetomidine is a valuable adjuvant in ultrasound-guided supraclavicular brachial plexus block, particularly for upper limb surgeries that require prolonged analgesia.

Limitations of study: Despite its strengths, the present study has certain limitations. The sample size was relatively small, which may limit the generalizability of the findings. Additionally, the study was conducted at a single centre, and therefore the results may not fully represent outcomes in different clinical settings. Furthermore, long-term neurological outcomes were not evaluated, which could have provided additional insight into the prolonged effects of the intervention.

Future multicentre studies with larger sample sizes are recommended to further validate these findings.

Conclusion

The present longitudinal comparative study demonstrated that perineural dexmedetomidine as an adjuvant to bupivacaine in ultrasound-guided

supraclavicular brachial plexus block provides superior block characteristics compared with intravenous administration.

Perineural dexmedetomidine significantly accelerated the onset of sensory and motor blockade, prolonged the duration of anesthesia, and provided extended postoperative analgesia with lower pain scores.

Although both routes of administration showed comparable hemodynamic stability, perineural dexmedetomidine resulted in a longer duration of analgesia and delayed requirement of rescue analgesics. Therefore, perineural dexmedetomidine appears to be a more effective and clinically advantageous route for enhancing the quality and duration of supraclavicular brachial plexus block in upper limb surgeries.

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