RESEARCH PAPER

Dexmedetomidine and Fentanyl as an Adjunct to Levobupivacaine 0.5% in Supraclavicular Nerve Block: A Randomized Controlled Trial

Gokul Ram[1], Upakara Selvin Rajan[2], Prasanna Kumar[3], Lokeshwar Vijayakumar[4] ,

[1]*Assistant Professor, Department of Anaesthesiology, Sri Lalithambigai Medical College and Hospital, Chennai, India*
Email id: Gokulram44@gmail.com
[2] *Associate Professor, Department of Anaesthesiology, Sri Lalithambigai Medical College and Hospital, Chennai, India*
Email id: selvin.rajan@gmail.com
[3]*Assistant Professor, Department of Anaesthesiology, Sri Lalithambigai Medical College and Hospital, Chennai, India*
Email id: prasan1092@gmail.com
[4] *Assistant Professor, Department of Anaesthesiology, Sri Lalithambigai Medical College and Hospital, Chennai, India*
Email id: lokeshwarvijayakumaar@gmail.com
Email id: drarivarasan26@gmail.com.

ABSTRACT
Background:Ultrasound-guided supraclavicular brachial plexus block provides effective anesthesia for upper limb surgeries. The use of adjuvants with local anesthetics aims to enhance block characteristics and prolong postoperative analgesia. Comparative data on dexmedetomidine and fentanyl as adjuvants to levobupivacaine remain limited.
Methods:This prospective, randomized, single-blinded controlled study included 60 adult patients (ASA I–II) scheduled for elective upper limb surgeries. Patients were allocated into three equal groups (n = 20 each). Group L received 0.5% levobupivacaine alone, Group LD received levobupivacaine with dexmedetomidine (1 μg/kg), and Group LF received levobupivacaine with fentanyl (1 μg/kg). Onset and duration of sensory and motor blockade, duration of postoperative analgesia, sedation scores, hemodynamic parameters, adverse events, and surgeon satisfaction were assessed.
Results:Baseline demographic variables were comparable among groups (mean age: 34.1 ± 12.6, 33.5 ± 11.8, and 32.7 ± 13.2 years in Groups L, LD, and LF respectively; $p = 0.92$). The onset of sensory block was significantly faster in Group LD (11.2 ± 1.7 min) compared to Group LF (14.9 ± 2.1 min) and Group L (18.6 ± 2.8 min) ($p < 0.001$). Duration of sensory block was longest in Group LD (705 ± 65 min), followed by Group LF (535 ± 60 min) and Group L (420 ± 50 min) ($p < 0.001$). Duration of postoperative analgesia was significantly prolonged in Group LD (725 ± 70 min) compared to Group LF (565 ± 63 min) and Group L (430 ± 52 min). Bradycardia occurred more frequently in Group LD (20%) but was transient and manageable. Surgeon satisfaction rated as good to excellent was highest in Group LD (95%).
Conclusion:Dexmedetomidine is a superior adjuvant to fentanyl when combined with levobupivacaine for supraclavicular brachial plexus block, offering improved block characteristics and prolonged analgesia with an acceptable safety profile..
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INTRODUCTION

Regional anaesthesia has seen significant advances in recent decades, with peripheral nerve blocks becoming fundamental for upper limb procedures. The supraclavicular approach to the brachial plexus is particularly valued as an efficient and consistent method, delivering comprehensive anaesthesia for the arm below the shoulder. Relative to general anaesthesia, this block presents distinct benefits: better postoperative pain control, decreased need for opioids, quicker patient mobilisation, no requirement for airway instrumentation, and enhanced cardiovascular stability, advantages that are especially important for older or comorbid patients [1–3].

Achieving effective peripheral nerve blockade relies on several elements: precise needle positioning, the characteristics of the local anaesthetic agent, and the addition of suitable adjuvants. Earlier, landmark-guided methods often resulted in inconsistent success and risks like vascular injury or pneumothorax. The adoption of nerve stimulators, and subsequently, ultrasound guidance, has transformed the field. Ultrasound enables direct observation of nerves, adjacent anatomy, needle advancement, and drug distribution, which increases block efficacy, accelerates onset, lowers the required anaesthetic volume, and improves safety [4,5].

Local anaesthetics act by reversibly blocking voltage-gated sodium channels, halting nerve signal transmission. For brachial plexus blocks, long-acting amide agents like bupivacaine have been commonly used due to their extended effect. However, potential cardiac and neurological toxicity, especially after accidental vascular injection, has prompted the development of safer options [6,7].

Levobupivacaine, the S(–) enantiomer of bupivacaine, was introduced to mitigate these risks. It offers similar sensory and motor block but with a notably better cardiovascular

**Author for Correspondence: selvin.rajan@gmail.com*

and central nervous system safety margin, owing to stereoselective binding properties [8–10]. Nevertheless, levobupivacaine by itself may not always ensure fast onset or sufficiently prolonged postoperative pain relief, especially for lengthy surgical cases.

Various adjuvants have been studied to improve block performance and extend analgesia without raising the local anaesthetic dose. These comprise opioids, α2-adrenergic agonists, corticosteroids, and other non-opioid compounds [11,12]. Fentanyl and dexmedetomidine have attracted special interest given their proven analgesic benefits and suitability for peripheral nerve blocks.

Fentanyl, a potent synthetic opioid, acts mainly via μ-opioid receptors. Added to local anaesthetics for brachial plexus blockade, it can enhance block quality and prolong postoperative analgesia; however, its impact on onset time is variable, and opioid-related side effects like pruritus, nausea, bradycardia, and respiratory depression are potential drawbacks.

Dexmedetomidine is a highly selective α2-adrenergic agonist with sedative, anxiolytic, sympatholytic, and analgesic effects. It shows greater α2-selectivity than clonidine and provides sedation without significant respiratory depression [13,14]. As an adjuvant in peripheral nerve blocks, dexmedetomidine has demonstrated faster onset of sensory and motor block, longer block duration, and extended postoperative analgesia [15,16].

Suggested mechanisms involve nerve membrane hyperpolarization, inhibition of norepinephrine release, and reduced pain signal transmission at peripheral and spinal sites. Dexmedetomidine has also been linked to better block quality and higher surgeon satisfaction, although transient bradycardia and hypotension may occur [17].

While multiple studies have separately assessed dexmedetomidine or fentanyl as adjuvants for brachial plexus blocks, head-to-head comparisons of these two agents specifically combined with levobupivacaine in ultrasound-guided blocks are scarce [18–20]. This gap is notable, especially with the growing use of ultrasound-guided supraclavicular blocks and the focus on maximizing block quality safely.

Consequently, this study was designed to directly compare dexmedetomidine and fentanyl as adjuvants to levobupivacaine in ultrasound-guided supraclavicular brachial plexus block for upper limb surgeries. Primary outcomes included onset and duration of sensory and motor blockade, along with postoperative analgesia duration. Secondary measures encompassed surgeon satisfaction and overall block quality.

METHODS

Study Setting and Population

This study included adults scheduled for elective upper limb surgery under supraclavicular brachial plexus block. Eligibility required patients to be 18–60 years old, of American Society of Anesthesiologists (ASA) physical status I or II, and undergoing a procedure anticipated to last under two hours [1]. Exclusion criteria comprised patient refusal, infection at the injection site, pre-existing neurological deficits in the operative limb, known allergy to the study medications, coagulopathy, or significant hepatic/renal impairment. The study was approved by the Institutional Ethics Committee, Government Stanley Medical College (IEC No: STN/IEC/**03/04/2019)** and was registered with the Clinical Trials Registry of India (CTRI/2025/08/092972).

Sample Size and Randomization

Sample size was determined using OpenEpi, Version 3.01, with reference to a prior randomized controlled trial by Kaur et al. comparing an expected difference of approximately **120 minutes in duration of sensory block** between groups, with a standard deviation of **about 130 minutes** among dexmedetomidine and fentanyl as adjuvants to levobupivacaine in this block [21]. To detect a difference in sensory block duration with 95% confidence and 80% power, 60 patients were required. These 60 participants were randomly assigned to one of three equal groups (n=20 each). A computer-generated random number table facilitated randomization, with allocation concealed via sealed opaque envelopes. The design was single-blinded: patients were unaware of their group, while the administering anesthesiologist was not. An independent, blinded observer conducted all block and postoperative assessments to minimize bias. Patient enrolment, allocation, follow-up, and analysis are summarized in the CONSORT flow diagram (Figure 1).

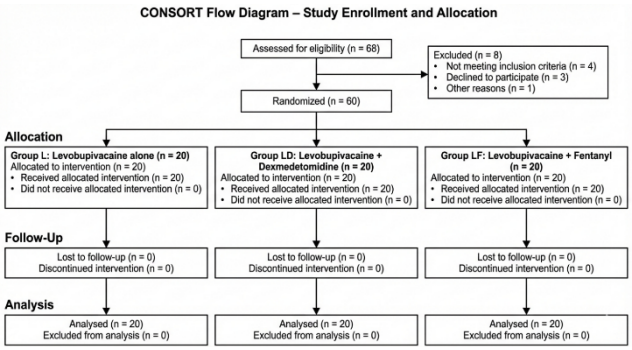

Figure 1: Consort Diagram

Group Allocation and Drug Preparation

Patients were allocated to three groups. **Group L (Control)** received 25 mL of 0.5% levobupivacaine plus 1 mL distilled water. **Group LD** received 25 mL of 0.5% levobupivacaine with dexmedetomidine (1 μg/kg), diluted to 1 mL. **Group LF** received 25 mL of 0.5% levobupivacaine with fentanyl (1 μg/kg), diluted to 1 mL. Adjuvant doses were chosen based on established safety and efficacy data from earlier studies. Solutions were prepared by an anesthesiologist not involved in subsequent evaluations.

Preoperative Evaluation

A comprehensive pre-anesthetic check was performed one day before surgery. This included history, physical and systemic examination, airway assessment (Modified Mallampati classification), and review of baseline investigations—complete blood count, renal and liver function tests, electrocardiogram, and coagulation profile as needed [1]. Baseline heart rate, non-invasive blood

pressure, and peripheral oxygen saturation were documented before block administration.

Ultrasound-Guided Supraclavicular Brachial Plexus Block

All blocks were performed under aseptic technique with ultrasound guidance. Patients were positioned supine, head turned contralaterally, with the ipsilateral arm adducted. A high-frequency linear probe (8–15 MHz) was placed in the supraclavicular fossa to visualize the subclavian artery, first rib, pleura, and the brachial plexus cluster lateral and superficial to the artery [22]. Following skin infiltration with 2–4 mL of 2% lignocaine, a 22-gauge short-bevel needle was advanced using an in-plane lateral-to-medial approach. Under continuous ultrasound visualization, the tip was positioned adjacent to the brachial plexus sheath, avoiding vascular structures. After negative aspiration, the study drug was injected incrementally, observing circumferential spread around the nerves. Injection completion was designated time zero [22,23].

Assessment of Sensory and Motor Block

Sensory blockade was evaluated via pinprick in the musculocutaneous, median, radial, and ulnar nerve distributions using a 3-point scale: 0 (normal sensation), 1 (loss of pinprick), 2 (loss of touch). Onset time was the interval from drug injection to a score of 1 in any nerve. Complete sensory block was defined as a score of 2 in all four territories. Sensory block duration was the time from complete block to full sensory recovery.

Motor block was assessed on a 3-point scale for elbow, wrist, and finger movements: 0 (normal power), 1 (reduced strength), 2 (paralysis). Onset was the time to a score of 1. Motor block duration was measured from complete paralysis (score 2) to full motor recovery.

Postoperative Analgesia, Sedation, and Surgeon Satisfaction

Postoperative analgesia duration was defined as the period from complete sensory block to the first request for rescue analgesia. Rescue analgesia was provided with intravenous paracetamol 1 g when the visual analogue scale (VAS) score exceeded 4, and the time to first rescue analgesic requirement was recorded. Sedation was rated using the Ramsay Sedation Scale at scheduled intraoperative and postoperative times [24]. Block quality was graded by the anesthesiologist as successful, inadequate, or failed. A predefined scoring system based on intraoperative analgesia and muscle relaxation was used to assess surgeon satisfaction [25]. Surgeon satisfaction was assessed using a predefined 3-point scale based on intraoperative surgical conditions and muscle relaxation: 1 = poor, 2 = adequate, and 3 = excellent.

Hemodynamic Monitoring and Adverse Effects

Heart rate, non-invasive blood pressure, oxygen saturation, and sedation scores were recorded at baseline, every five minutes for the first thirty minutes post-block, and at regular intervals for six hours postoperatively. Patients were monitored for adverse events including hypotension, bradycardia, nausea, vomiting, respiratory depression, and local anaesthetic systemic toxicity. Any events were managed per institutional protocols.

Statistical Analysis

Data were compiled in Microsoft Excel and analyzed with suitable statistical software. Continuous variables are presented as mean ± standard deviation or median (interquartile range), based on distribution. Categorical variables are shown as frequencies and percentages. Intergroup comparisons employed ANOVA/Kruskal–Wallis tests for continuous data and chi-square test for categorical data. A p-value <0.05 was considered statistically significant.

RESULTS:

Table 1

Table 1. Sociodemographic and Baseline Clinical Characteristics among the groups (n=60)

Variable	Group L (n=20)	Group LD (n=20)	Group LF (n=20)	p-value*
Age (years), mean ± SD	34.1 ± 12.6	33.5 ± 11.8	32.7 ± 13.2	0.92
Male sex, n (%)	12 (60)	11 (55)	13 (65)	0.81
Weight (kg), mean ± SD	63.4 ± 8.9	64.2 ± 7.8	62.6 ± 9.1	0.76
Height (cm), mean ± SD	166.2 ± 6.5	165.7 ± 7.1	167.1 ± 6.9	0.83
BMI (kg/m²), mean ± SD	22.9 ± 2.4	23.4 ± 2.1	22.5 ± 2.6	0.54
ASA I, n (%)	15 (75)	14 (70)	16 (80)	0.77
ASA II, n (%)	5 (25)	6 (30)	4 (20)	—
Baseline HR (beats/min)	78.4 ± 9.2	76.9 ± 8.7	79.1 ± 9.5	0.68
Baseline MAP (mmHg)	92.6 ± 7.4	91.8 ± 6.9	93.2 ± 7.1	0.79

ANOVA/ Kruskal Wallis test
Chi-square/Fischer Exact Test
***p-value<0.05 is statistically significant**

Interpretation: Groups were comparable at baseline; randomization worked

summarizes the baseline demographic and clinical characteristics of the 60 study participants, with 20 patients in each group. The mean age was comparable across Group L (34.1 ± 12.6 years), Group LD (33.5 ± 11.8 years), and Group LF (32.7 ± 13.2 years) (p = 0.92). Male participants constituted 60% (12/20) in Group L, 55% (11/20) in Group LD, and 65% (13/20) in Group LF (p = 0.81). Most patients belonged to ASA physical status I (75%, 70%, and 80%, respectively). Baseline heart rate and mean arterial pressure were similar between groups, indicating adequate randomization.

Table 2 compares block onset characteristics among the three groups. Group LD demonstrated the fastest onset of

sensory blockade across all nerve distributions, with significantly shorter onset times compared to Group L and Group LF ($p < 0.001$). The time to complete sensory block was lowest in Group LD (11.2 ± 1.7 min), followed by Group LF (14.9 ± 2.1 min) and Group L (18.6 ± 2.8 min). Motor block onset also occurred earlier in Group LD. All patients achieved surgical anesthesia, with no significant difference in block success rates across groups ($p > 0.05$), confirming consistent procedural efficacy.

Table 2. Block Onset Characteristics among the groups (n=60)

Variable (minutes)	Group L	Group LD	Group LF	p-value
Sensory onset – median nerve	14.2 ± 2.1	8.4 ± 1.3	11.1 ± 1.8	<0.001
Sensory onset – ulnar nerve	15.0 ± 2.4	9.1 ± 1.5	11.9 ± 2.0	<0.001
Sensory onset – radial nerve	13.7 ± 2.0	8.0 ± 1.2	10.8 ± 1.6	<0.001
Complete sensory block	18.6 ± 2.8	11.2 ± 1.7	14.9 ± 2.1	<0.001
Motor block onset	19.1 ± 2.6	12.0 ± 1.6	15.8 ± 2.3	<0.001
Time to surgical readiness	22.4 ± 3.1	14.5 ± 2.0	18.2 ± 2.5	<0.001

ANOVA/ Kruskal Wallis test
*p-value<0.05 is statistically significant

Table 3 presents the duration of sensory and motor blockade. The longest duration of sensory blockade was observed in Group LD, with complete sensory recovery at 705 ± 65 minutes, compared to 535 ± 60 minutes in Group LF and 420 ± 50 minutes in Group L ($p < 0.001$). Motor block duration followed a similar trend, being significantly prolonged in Group LD (625 ± 57 minutes). The differential prolongation of sensory over motor block was greater in Group LD (80 ± 18 minutes), suggesting a favorable sensory–motor dissociation. These findings demonstrate a clear advantage of dexmedetomidine as an adjuvant.

Table 3. Duration of Sensory and Motor Blockade among the groups (n=60)

Variable (minutes)	Group L	Group LD	Group LF	p-value
Sensory block – median nerve	415 ± 48	695 ± 62	528 ± 56	<0.001
Sensory block – ulnar nerve	402 ± 45	682 ± 58	510 ± 52	<0.001
Sensory block – radial nerve	398 ± 43	670 ± 60	502 ± 55	<0.001
Complete sensory recovery	420 ± 50	705 ± 65	535 ± 60	<0.001
Motor block duration	360 ± 42	625 ± 57	470 ± 49	<0.001
Differential sensory–motor gap	60 ± 15	80 ± 18	65 ± 16	0.003

ANOVA/ Kruskal Wallis test
*p-value<0.05 is statistically significant

Table 4 details postoperative analgesic outcomes and sedation scores. The duration of postoperative analgesia was significantly longer in Group LD (725 ± 70 minutes) compared to Group LF (565 ± 63 minutes) and Group L (430 ± 52 minutes) ($p < 0.001$). Fewer rescue analgesic doses were required in Group LD (1.4 ± 0.6) than in Group LF (2.3 ± 0.7) and Group L (3.1 ± 0.8). Mild to moderate sedation (Ramsay score ≥ 3) was more frequent in Group LD, with 15% (3/20) experiencing higher sedation scores, though without respiratory compromise.

Table 4. Postoperative Analgesia and Sedation Profile among the groups (n=60)

Variable	Group L	Group LD	Group LF	p-value
Duration of analgesia (min)	430 ± 52	725 ± 70	565 ± 63	<0.001
Time to first rescue analgesic	445 ± 55	740 ± 75	580 ± 65	<0.001
Total analgesic doses (24 h)	3.1 ± 0.8	1.4 ± 0.6	2.3 ± 0.7	<0.001
Ramsay score at 30 min	2.1 ± 0.4	3.4 ± 0.6	2.6 ± 0.5	<0.001
Excess sedation (RSS ≥4), n (%)	0	3 (15)	1 (5)	0.21
Patient satisfaction (VAS/10)	7.1 ± 0.9	9.0 ± 0.7	8.2 ± 0.8	<0.001

ANOVA/ Kruskal Wallis test
Chi-square/Fischer Exact Test
*p-value<0.05 is statistically significant

Table 5 summarizes hemodynamic effects, adverse events, and surgeon satisfaction. Bradycardia occurred more frequently in Group LD (20%, 4/20) compared to Group LF (5%, 1/20) and Group L (0%), reaching statistical significance ($p = 0.04$). Nausea and vomiting were observed only in Group LF (15%, 3/20). Block failure and conversion to general anesthesia were infrequent and comparable between groups (5% each in Groups L and LF). Surgeon satisfaction rated as good to excellent was highest in Group LD (95%, 19/20), followed by Group LF (85%, 17/20).

Table 5. Hemodynamic Changes, Block Quality, and Adverse Events among the groups (n=60)

Variable	Group L	Group LD	Group LF	p-value
Bradycardia, n (%)	0	4 (20)	1 (5)	0.04
Hypotension, n (%)	1 (5)	3 (15)	1 (5)	0.31
Nausea/vomiting, n (%)	0	0	3 (15)	0.03
Pruritus, n (%)	0	0	2 (10)	0.07
Block failure, n (%)	1 (5)	0	1 (5)	0.60
Conversion to GA	1 (5)	0	1 (5)	0.60
Surgeon satisfaction (Good–Excellent)	14 (70)	19 (95)	17 (85)	0.01

Chi-square/Fischer Exact Test
*p-value<0.05 is statistically significant

DISCUSSION

This randomized controlled trial compared dexmedetomidine and fentanyl as adjuvants to levobupivacaine for ultrasound-guided supraclavicular brachial plexus block. The key results indicate that dexmedetomidine, when added to levobupivacaine, produces a substantially quicker onset of sensory and motor blockade, a longer duration of both blocks, and more extended postoperative analgesia relative to fentanyl or plain levobupivacaine. These outcomes further substantiate existing literature which positions α2-adrenergic agonists as highly effective adjuncts in peripheral regional anesthesia.

Demographic and clinical parameters were similar across all groups, confirming effective randomization and reducing the potential for confounding factors to affect block outcomes. The consistency in age, gender, ASA classification, and preoperative hemodynamics aligns with prior research on adjuvants for brachial plexus blockade [21,26], reinforcing the internal validity of the comparative results obtained.

A particularly notable result was the significantly faster onset of sensory and motor blockade in the dexmedetomidine group. This is consistent with previous reports where dexmedetomidine hastened onset times with long-acting local anesthetics [21,22,26]. Mechanistically, this may be attributed to nerve membrane hyperpolarization via inhibition of hyperpolarization-activated cation (Ih) currents, reduced norepinephrine release, and improved neural uptake of local anesthetic. In contrast, fentanyl demonstrated variable and less pronounced effects on onset, a pattern corroborated by earlier studies [20,27].

Both sensory and motor block durations were significantly longer with dexmedetomidine compared to fentanyl and control. Notably, sensory blockade was prolonged more than motor block, creating a clinically advantageous sensory-motor dissociation. This allows for extended analgesia alongside earlier motor recovery, a finding also reported by Kaur et al. and Singh et al. [20,26]. While fentanyl prolonged block duration compared to levobupivacaine alone, its effect was consistently less than that of dexmedetomidine, supporting the view that α2 agonists outperform opioid adjuvants in peripheral nerve blocks [19-21].

Postoperative analgesia was significantly longer in the dexmedetomidine group, reflected in a delayed time to first rescue analgesic and lower 24-hour analgesic consumption. This aligns with earlier studies highlighting dexmedetomidine's analgesic benefits in brachial plexus blocks [19-21]. The extended analgesia likely stems from combined peripheral α2 receptor activation and systemic effects mediated at spinal and supraspinal sites. Fentanyl provided moderate analgesic extension but was linked to a higher rate of typical opioid side-effects like nausea and vomiting, as seen in prior reports [20].

Sedation scores were elevated in the dexmedetomidine group, consistent with its central α2-mediated sedative action. However, sedation remained within a clinically acceptable, "arousable" range without respiratory depression, which can enhance patient comfort during regional anesthesia [28]. Fentanyl produced less sedation but a greater incidence of postoperative nausea and vomiting.

Hemodynamically, dexmedetomidine was associated with more frequent, though transient and easily managed, bradycardia. Similar findings are documented elsewhere [26,29]. No episodes of severe hypotension or need for advanced intervention occurred, supporting its cautious use in selected patients.

Surgeon satisfaction was highest in the dexmedetomidine group, indicating better intraoperative conditions, muscle relaxation, and reduced supplemental analgesic requirements. This parameter serves as a practical indicator of block quality and procedural ease.

This study has several limitations. Although statistically adequate, the sample size was modest and may affect generalizability. Only a single dose of each adjuvant was tested, precluding dose-response evaluation. The absence of serum drug level measurements makes it challenging to distinguish peripheral from systemic drug effects. Long-term neurological outcomes were not assessed, and the inclusion of only ASA I-II patients limits applicability to higher-risk cohorts. The study employed a single-blinded design, as the anesthesiologist administering the block was not blinded to group allocation. This may have introduced performance bias, particularly in subjective assessments such as block onset timing and surgeon satisfaction, despite outcome assessment being performed by an independent observer. Only a single fixed dose of dexmedetomidine and fentanyl was evaluated, and dose–response relationships were not explored, which may limit optimization of adjuvant dosing.

The results suggest dexmedetomidine is a more effective adjuvant than fentanyl for enhancing ultrasound-guided supraclavicular block with levobupivacaine. It improves block quality, prolongs analgesia, and increases satisfaction, with a manageable safety profile. Future research should involve larger populations, dose-ranging

designs, inclusion of higher-risk patients, comparisons with other adjuvants, and evaluation of long-term outcomes.

CONCLUSION

In conclusion, dexmedetomidine proved superior to fentanyl as an adjuvant to levobupivacaine in this setting. It accelerated block onset, extended sensory and motor blockade duration, and prolonged postoperative analgesia while reducing rescue analgesic needs. Although associated with a higher incidence of mild bradycardia and sedation, these effects were transient and manageable without respiratory compromise. Fentanyl provided moderate benefits over plain levobupivacaine but was less efficacious than dexmedetomidine and carried opioid-related side effects. Dexmedetomidine thereby enhanced overall block quality, patient comfort, and surgeon satisfaction, establishing it as a more reliable and effective adjunct for supraclavicular brachial plexus blockade...

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