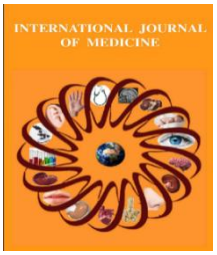

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Original Research

Buprenorphine as an Adjuvant to Bupivacaine in Ultrasound-Guided Supraclavicular Brachial Plexus Block for Upper-Limb Orthopaedic Surgery: A Prospective Randomised Controlled Study

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Abstract

Background and Objectives: Ultrasound-guided supraclavicular brachial plexus block provides reliable anaesthesia for upper-limb surgery, although postoperative analgesia from bupivacaine alone is time-limited. This study compared bupivacaine alone with bupivacaine plus buprenorphine for block characteristics, postoperative analgesia, haemodynamic stability, and adverse effects. **Methods:** This prospective randomised controlled study included 60 adults aged 20-60 years with American Society of Anesthesiologists physical status I or II undergoing elective upper-limb orthopaedic surgery. Participants were allocated equally to receive 25 mL of 0.25% bupivacaine alone or 25 mL of 0.25% bupivacaine with buprenorphine 3 µg/kg through an ultrasound-guided supraclavicular approach. Sensory and motor block characteristics, time to first rescue analgesia, visual analogue scale scores, pulse rate, blood pressure, oxygen saturation, and complications were evaluated. **Results:** Baseline demographic and surgical characteristics were comparable. Sensory block duration was significantly longer with buprenorphine than with bupivacaine alone (722.80 ± 81.42 versus 337.23 ± 26.87 minutes; p<0.001). Time to first rescue analgesia increased from 8.60 ± 2.36 to 18.17 ± 5.53 hours (p<0.001). Pain scores were lower in the buprenorphine group at 240 and 360 minutes. Sensory and motor onset, time to complete blockade, motor block duration, haemodynamic variables, and oxygen saturation remained comparable. Nausea, vomiting, and pruritus were infrequent, with no significant intergroup difference. **Conclusion:** Buprenorphine 3 µg/kg added to 0.25% bupivacaine substantially prolonged sensory blockade and postoperative analgesia without clinically important haemodynamic disturbance or increased adverse effects.

Keywords: *Brachial plexus block; Bupivacaine; Buprenorphine; Postoperative analgesia; Supraclavicular block; Ultrasound guidance.*

Introduction

Regional anaesthesia has become an important component of perioperative care for upper-limb orthopaedic surgery because it can provide surgical anaesthesia, muscle relaxation, and postoperative pain control while reducing exposure to systemic anaesthetic and opioid drugs. The supraclavicular approach targets the brachial plexus where its trunks and divisions are closely grouped, allowing a dense block from the mid-arm to the hand. Ultrasound guidance permits direct identification of the neural cluster, subclavian artery, first rib, pleura, and needle path, while also showing the distribution of injected local anaesthetic. Early clinical investigations demonstrated that ultrasound-guided supraclavicular blockade is technically feasible, accelerates block performance, and improves block quality.1,2 Large clinical series have subsequently reported high surgical success with a low frequency of serious complications when the technique is performed by trained clinicians.3

Bupivacaine is a long-acting amide local anaesthetic frequently selected for brachial plexus blockade. It produces dependable sensory and motor anaesthesia, but a single injection often does not cover the entire period of postoperative pain. Breakthrough pain after block regression can result in early rescue-analgesic use, sleep disturbance, delayed mobilisation, and lower patient satisfaction. Accordingly, several perineural adjuncts have been studied to lengthen analgesia without requiring a continuous catheter. A systematic qualitative review found that buprenorphine, dexamethasone, dexmedetomidine, clonidine, and magnesium were among the adjuncts showing the most consistent block-prolonging effects, although concerns regarding dose, adverse effects, and off-label perineural administration remain.4

Buprenorphine is a highly lipophilic, partial µ-opioid receptor agonist with strong receptor affinity and a prolonged duration of action. Peripheral opioid receptors and local neural effects have been proposed to contribute to analgesia when it is deposited near a nerve plexus. Early comparative work showed prolonged postoperative pain relief when buprenorphine was combined with bupivacaine or other local anaesthetics in brachial plexus blocks.5-8 A later supraclavicular-block trial using buprenorphine 3 µg/kg also reported longer sensory blockade and postoperative analgesia without a clinically important increase in adverse effects.9 Meta-analytic evidence supports a longer duration of analgesia with perineural buprenorphine, while also indicating a higher risk of postoperative nausea and vomiting in some settings.10 Further controlled studies remain useful because results differ with block approach, local-anaesthetic concentration, buprenorphine dose, and outcome definitions.11

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The objective of this study was to compare ultrasound-guided supraclavicular brachial plexus block using 0.25% bupivacaine alone with 0.25% bupivacaine plus buprenorphine 3 µg/kg in adults undergoing elective upper-limb orthopaedic surgery. The primary objectives were to compare sensory block duration, postoperative pain scores, and perioperative haemodynamic stability. Secondary objectives were to compare motor block characteristics, time to first rescue analgesia, oxygen saturation, and treatment-related complications.

Materials and Methods

Study design and setting

This prospective, parallel-group randomised controlled study was conducted from March 2024 to February 2025 in the Department of Anaesthesiology at Government Medical College and Government General Hospital, Nalgonda, Telangana, India. The tertiary-care teaching hospital provides emergency, inpatient, orthopaedic, anaesthesia, and operative services. Trial reporting followed CONSORT guidance.12

Participants

Adults aged 20-60 years of either sex, classified as American Society of Anesthesiologists physical status I or II, and scheduled for elective upper-limb orthopaedic surgery were eligible. Participants required acceptable haematological and biochemical findings and absence of local infection. Exclusion criteria were refusal of consent, allergy to local anaesthetics, cardiovascular or respiratory disease, bleeding disorder, local bony deformity, and extreme obesity.

Sample size, randomisation, and masking

The approved protocol specified 60 participants, with 30 in each group. This allocation provides approximately 80% power to detect a standardised between-group difference of 0.75 using a two-sided alpha level of 0.05. Eligible participants received sequential identification numbers enclosed in opaque sealed envelopes. Odd-numbered assignments formed Group A and even-numbered assignments formed Group B. Participants and the statistician were blinded to group codes; the anaesthesiologist performing the block was not blinded.

Intervention and block procedure

Standard monitoring included pulse rate, non-invasive blood pressure, and peripheral oxygen saturation. An 18-gauge intravenous cannula was placed in the contralateral arm, and intramuscular diazepam 10 mg was administered 30 minutes before the block. With the participant supine and the head rotated 45° away from the operative side, a 12-MHz linear ultrasound probe was positioned in the supraclavicular fossa. The brachial plexus, subclavian artery, first rib, and pleura were identified. A 22-gauge, 50-mm Teflon-coated needle was advanced in-plane from lateral to medial, with continuous visualisation of the tip and injectate spread, consistent with established ultrasound-guided practice.13 Group A received 25 mL of 0.25% bupivacaine. Group B received the same solution with buprenorphine 3 µg/kg.

Outcome assessment

Sensory and motor block onset, time to complete block, block duration, and time to first rescue analgesia were recorded. Pain was assessed using a 10-cm visual analogue scale, a standard measure of pain intensity.14 Pulse rate, systolic and diastolic blood pressure, oxygen saturation, and pain scores were documented at 5, 15, 30, 60, 120, 240, 360, and 480 minutes. Nausea, vomiting, pruritus, bradycardia, respiratory depression, and other complications were monitored.

Statistical analysis

Data were analysed using IBM SPSS Statistics version 20. Continuous variables were expressed as mean ± standard deviation and compared using the independent-samples t-test after assessment of normality with the Kolmogorov-Smirnov test. Categorical variables were summarised as frequencies and percentages and compared using the chi-square test, with exact testing considered for sparse cells. All tests were two-sided, and $p<0.05$ indicated statistical significance.

Ethical approval and consent

Institutional Ethics Committee, Government Medical College, Nalgonda, approved the protocol on 14 February 2024 (approval No. GMC/NLG/2024/08). Written informed consent was obtained from every participant after explanation of procedures, benefits, and risks in their preferred language. Confidentiality was maintained throughout data collection and analysis.

Results

All 60 enrolled participants received the allocated intervention and were included in the final analysis, with 30 participants in each group. No post-randomisation loss or exclusion was recorded in the study dataset. The groups were comparable in age, sex, height, weight, body mass index, and duration of surgery. Mean age was 38.03 ± 11.22 years in Group A and 37.80 ± 11.60 years in Group B. Men constituted 63.3% and 70.0% of the respective groups. The mean duration of surgery was approximately 145 minutes in both groups (Table 1).

Table 1. Baseline demographic, anthropometric, and surgical characteristics

Variable	Group A Bupivacaine	Group B Bupivacaine + buprenorphine	p-value
Age (years)	38.03 ± 11.22	37.80 ± 11.60	0.937
Male sex, n (%)	19 (63.3)	21 (70.0)	0.392
Female sex, n (%)	11 (36.7)	9 (30.0)	
Height (cm)	151.23 ± 5.32	151.30 ± 6.08	0.964
Weight (kg)	58.93 ± 5.13	61.20 ± 6.12	0.125
Body mass index (kg/m²)	25.83 ± 2.44	26.63 ± 2.39	0.204
Duration of surgery (minutes)	144.67 ± 29.69	145.17 ± 26.59	0.945

Values are mean ± standard deviation unless stated otherwise. Group A and Group B each included 30 participants. Independent-samples t-test was used for continuous variables; chi-square test was used for sex distribution.

The onset of sensory block, time to complete sensory block, onset of motor block, and time to complete motor block did not differ significantly between groups. Addition of buprenorphine produced a pronounced increase in sensory block duration, from 337.23 ± 26.87 minutes with bupivacaine alone to 722.80 ± 81.42 minutes with the combination ($p<0.001$). Motor block duration remained comparable. The mean time to first rescue analgesia was more than doubled in Group B, increasing from 8.60 ± 2.36 hours to 18.17 ± 5.53 hours ($p<0.001$) (Table 2).

Table 2. Sensory block, motor block, and rescue-analgesia outcomes

Outcome	Group A	Group B	p-value
Onset of sensory block (minutes)	4.30 ± 0.92	4.13 ± 1.20	0.547
Time to complete sensory block (minutes)	21.93 ± 1.82	23.00 ± 3.11	0.110
Duration of sensory block (minutes)	337.23 ± 26.87	722.80 ± 81.42	<0.001
Onset of motor block (minutes)	3.97 ± 0.72	3.57 ± 1.14	0.108
Time to complete motor block (minutes)	18.43 ± 2.58	19.50 ± 2.92	0.139
Duration of motor block (minutes)	322.83 ± 20.80	330.20 ± 22.21	0.190
Time to first rescue analgesia (hours)	8.60 ± 2.36	18.17 ± 5.53	<0.001

Values are mean ± standard deviation. Between-group comparisons used the independent-samples t-test. A p-value <0.05 was considered statistically significant.

Pulse rate and systolic blood pressure remained comparable at every recorded time point. Diastolic blood pressure also showed no statistically significant intergroup difference. Peripheral oxygen saturation was stable in both groups throughout follow-up. No sustained clinically important haemodynamic or respiratory deterioration was documented (Table 3).

Table 3. Haemodynamic variables and peripheral oxygen saturation during follow-up

Parameter and time	Group A	Group B	p-value
Pulse rate (beats/min), 5 min	76.77 ± 9.68	73.17 ± 7.49	0.113
Pulse rate (beats/min), 15 min	76.67 ± 9.58	75.97 ± 9.80	0.781
Pulse rate (beats/min), 30 min	77.83 ± 9.50	78.87 ± 10.60	0.692
Pulse rate (beats/min), 60 min	75.00 ± 10.07	78.93 ± 9.93	0.133
Pulse rate (beats/min), 120 min	74.67 ± 9.78	75.37 ± 5.86	0.738
Pulse rate (beats/min), 240 min	75.87 ± 8.06	78.90 ± 8.51	0.161
Pulse rate (beats/min), 360 min	75.00 ± 6.32	76.90 ± 5.29	0.212
Pulse rate (beats/min), 480 min	75.20 ± 6.50	77.70 ± 6.52	0.143
Systolic blood pressure (mmHg), 5 min	121.67 ± 10.86	123.07 ± 13.19	0.655
Systolic blood pressure (mmHg), 15 min	123.37 ± 12.22	120.67 ± 13.63	0.422
Systolic blood pressure (mmHg), 30 min	122.23 ± 8.23	121.23 ± 9.72	0.669
Systolic blood pressure (mmHg), 60 min	122.33 ± 10.93	123.47 ± 10.97	0.690
Systolic blood pressure (mmHg), 120 min	120.67 ± 8.52	121.63 ± 13.19	0.737
Systolic blood pressure (mmHg), 240 min	121.00 ± 8.99	117.40 ± 11.10	0.173
Systolic blood pressure (mmHg), 360 min	120.60 ± 6.13	119.23 ± 8.81	0.488
Systolic blood pressure (mmHg), 480 min	120.53 ± 7.03	118.07 ± 9.00	0.241
Diastolic blood pressure (mmHg), 5 min	78.03 ± 6.77	78.97 ± 7.45	0.613
Diastolic blood pressure (mmHg), 15 min	79.33 ± 8.19	81.60 ± 7.36	0.264
Diastolic blood pressure (mmHg), 30 min	79.27 ± 8.39	79.20 ± 8.66	0.976
Diastolic blood pressure (mmHg), 60 min	81.90 ± 6.90	78.73 ± 6.60	0.074
Diastolic blood pressure (mmHg), 120 min	80.00 ± 6.28	76.30 ± 8.38	0.058
Diastolic blood pressure (mmHg), 240 min	81.33 ± 7.01	83.13 ± 6.83	0.591
Diastolic blood pressure (mmHg), 360 min	78.87 ± 5.10	79.47 ± 4.22	0.621
Diastolic blood pressure (mmHg), 480 min	80.33 ± 5.67	81.07 ± 4.68	0.496
SpO_2 (%), 5 min	98.33 ± 1.09	97.80 ± 0.93	0.146
SpO_2 (%), 15 min	98.00 ± 0.95	97.80 ± 0.89	0.402
SpO_2 (%), 30 min	98.00 ± 0.91	98.07 ± 1.14	0.803
SpO_2 (%), 60 min	97.97 ± 0.93	98.17 ± 0.99	0.422
SpO_2 (%), 120 min	97.77 ± 1.10	97.87 ± 1.14	0.731
SpO_2 (%), 240 min	98.00 ± 1.23	98.10 ± 1.16	0.747

Parameter and time	Group A	Group B	p-value
SpO_2 (%), 360 min	97.63 ± 0.81	97.70 ± 0.70	0.734
SpO_2 (%), 480 min	97.53 ± 0.90	97.70 ± 0.92	0.480

Values are mean ± standard deviation. SpO_2, peripheral oxygen saturation. Comparisons used the independent-samples t-test; all reported p-values were >0.05.

Pain scores were zero in both groups through 120 minutes. At 240 minutes, Group A had a mean visual analogue scale score of 0.87 ± 1.17, whereas Group B remained pain-free (p<0.001). At 360 minutes, the corresponding scores were 0.77 ± 1.28 and 0 (p<0.001). By 480 minutes, both groups recorded a mean score of 0.77 ± 1.28, with no between-group difference (Table 4).

Table 4. Visual analogue scale pain scores during follow-up

Time	Group A	Group B	p-value
5 minutes	0	0	Not applicable
15 minutes	0	0	Not applicable
30 minutes	0	0	Not applicable
60 minutes	0	0	Not applicable
120 minutes	0	0	Not applicable
240 minutes	0.87 ± 1.17	0	<0.001
360 minutes	0.77 ± 1.28	0	<0.001
480 minutes	0.77 ± 1.28	0.77 ± 1.28	1.000

Values are mean ± standard deviation. Statistical testing was not applicable when both groups had zero variance.

Adverse effects were infrequent. In Group A, nausea and vomiting each occurred in 2 participants (6.7%). In Group B, nausea occurred in 1 participant (3.3%), while pruritus and vomiting each occurred in 2 participants (6.7%). The overall distribution of recorded complications did not differ significantly between groups (p=0.502). No respiratory depression, severe haemodynamic instability, local anaesthetic systemic toxicity, pneumothorax, or persistent neurological deficit was reported in the supplied study records (Table 5).

Table 5. Recorded adverse effects

Adverse effect	Group A	Group B	p-value
Nausea, n (%)	2 (6.7)	1 (3.3)	
Pruritus, n (%)	0	2 (6.7)	
Vomiting, n (%)	2 (6.7)	2 (6.7)	
Overall comparison			0.502

Data are number (percentage). The source analysis reported an overall chi-square p-value of 0.502.

Discussion

The principal finding was that buprenorphine 3 µg/kg added to 0.25% bupivacaine markedly extended sensory blockade and delayed postoperative analgesic requirement. Sensory block duration increased by approximately 386 minutes, and the interval to first rescue analgesia increased by nearly 10 hours. These gains occurred without a significant change in sensory or motor onset, time to complete blockade, or motor block duration. The analgesic effect was also reflected by lower pain scores at four and six hours after the block.

The findings are consistent with earlier evidence that buprenorphine has a clinically meaningful block-prolonging effect. Viel and colleagues reported extended postoperative analgesia after brachial plexus administration of buprenorphine.5 Candido et al. subsequently observed an approximately threefold increase in postoperative analgesic duration when buprenorphine was added to local anaesthetic for upper-limb blocks.6,7 Behr et al. also demonstrated prolonged analgesia with epineural buprenorphine in interscalene blockade.8 In the supraclavicular setting, Patil et al. used the same weight-based dose of 3 µg/kg and found prolonged sensory block and analgesia without an important increase in side effects.9 The magnitude of benefit in the present study therefore aligns with the direction of effect reported across different brachial plexus approaches.

Buprenorphine's high lipid solubility, strong µ-opioid receptor affinity, slow receptor dissociation, and potential action at peripheral opioid receptors provide a plausible explanation for the prolonged analgesic response. Meta-analysis has confirmed longer analgesia with perineural buprenorphine, although postoperative nausea and vomiting can increase in some populations.10 In the current study, nausea, vomiting, and pruritus were uncommon and statistically comparable. Differences between studies can reflect local-anaesthetic choice, concentration, block location, perioperative antiemetic practice, and the definition of rescue analgesia. The absence of a significant extension of motor blockade is clinically useful because prolonged analgesia without additional motor impairment can support earlier limb assessment and rehabilitation.

Haemodynamic variables and oxygen saturation remained stable across eight hours of observation. This supports the tolerability of the selected dose and is consistent with controlled studies of buprenorphine-containing brachial plexus blocks.9,11 Ultrasound guidance also contributed to precise needle placement and visual confirmation of local-anaesthetic spread; prior trials and large clinical series have shown improved technical performance and high success with this approach.1-3,13 Nevertheless, perineural buprenorphine requires careful patient selection, monitoring, and institutional governance because dosing practices and regulatory status differ across settings.

Generalizability

Generalizability is strongest for adults with American Society of Anesthesiologists physical status I or II undergoing elective upper-limb orthopaedic procedures in tertiary-care hospitals where ultrasound-guided regional anaesthesia is routinely available. The findings are less directly applicable to children, older frail adults, emergency surgery, severe cardiopulmonary disease, pregnancy, or centres without experienced ultrasound practitioners. Differences in rescue-analgesic protocols and local-anaesthetic concentrations should also be

considered when applying the observed duration of benefit.

Limitations

This study was conducted at one institution with 60 participants, limiting external validity and precision for rare adverse events. The block-performing anaesthesiologist was not blinded, creating potential performance and assessment bias. Follow-up covered the early postoperative period only. A single bupivacaine concentration and buprenorphine dose were evaluated, and patient satisfaction, total postoperative analgesic consumption, and longer-term neurological outcomes were not measured.

Conclusion

In adults undergoing elective upper-limb orthopaedic surgery, adding buprenorphine 3 µg/kg to 25 mL of 0.25% bupivacaine for ultrasound-guided supraclavicular brachial plexus block produced longer sensory blockade and postoperative analgesia than bupivacaine alone. The combination more than doubled the interval to first rescue analgesia and reduced pain scores during the intermediate postoperative period. Sensory and motor onset, completion of blockade, motor block duration, pulse rate, blood pressure, and oxygen saturation were comparable between groups. Minor adverse effects were uncommon and did not increase significantly. The bupivacaine-buprenorphine combination therefore offers an effective option for extending single-injection regional analgesia when appropriately selected, monitored, and used under an approved institutional protocol in practice.

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