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Research Article

Comparative Evaluation of Buprenorphine and Tramadol as Adjuvants to Ropivacaine in Ultrasound-Guided Supraclavicular Brachial Plexus Block for Humeral Procedures

Dr Punyaa Kamal[1], Dr Jayashree Sali[2], Dr Sunita Sankalecha[3], Dr Nakshatra Sali[4], Dr Pranita Gore[5]

[1]Junior Resident, Department of Anaesthesiology, Maharashtra Post Graduate Institute of Medical Education and Research, Nashik, MUHS, Maharashtra, India.
[2]Associate Professor, Department of Anaesthesiology, Maharashtra Post Graduate Institute of Medical Education and Research, Nashik, MUHS, Maharashtra, India.
[3]HOD and Professor; Department of Anaesthesiology, Maharashtra Post Graduate Institute of Medical Education and Research, Nashik, MUHS, Maharashtra, India.
[4]MBBS, SMT. Kashibai Navale Medical College Pune, India.
[5]Junior Resident, Department of Anaesthesiology, Maharashtra Post Graduate Institute of Medical Education and Research, Nashik, MUHS, Maharashtra, India.

Corresponding author addresses: E-mail id/ Social Media Link
Dr. Punyaa Kamal, Junior Resident, Department of Anaesthesiology, Maharashtra Post Graduate Institute of Medical Education and Research, Nashik, MUHS, Maharashtra, India.
Email: punyaakamal2411@gmail.com

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ABSTRACT

Background and Aim: Supraclavicular brachial plexus block is an effective regional anaesthetic technique for upper-extremity surgery. Ropivacaine provides effective blockade, but the duration of a single-injection block may be limited. Adjuvants such as buprenorphine and tramadol have been used to enhance block characteristics and prolong analgesia. This study aimed to compare the effects of buprenorphine and tramadol when added to ropivacaine for ultrasound-guided supraclavicular brachial plexus block in patients undergoing humeral surgery. **Methods:** This prospective, randomized, comparative, double-blind study included 120 patients aged 18–65 years with ASA physical status I–II undergoing humeral surgery. Patients were randomly allocated into two groups of 60 each. Group A received 30 mL of 0.5% ropivacaine with 0.3 mg buprenorphine, while Group B received 30 mL of 0.5% ropivacaine with 100 mg tramadol. Ultrasound-guided supraclavicular brachial plexus block was performed using a standardized technique. The primary outcomes were onset and duration of sensory and motor blockade. Secondary outcomes included postoperative VAS scores, time to first rescue analgesic request, haemodynamic stability, and adverse effects. Statistical analysis was performed using IBM SPSS

Statistics version 28.0, with $p < 0.05$ considered statistically significant. **Results:** Buprenorphine produced a significantly faster onset of sensory and motor blockade than tramadol. The mean onset of sensory blockade was 9.48 ± 1.70 minutes versus 14.88 ± 2.25 minutes, while motor blockade occurred at 13.33 ± 2.05 minutes versus 18.43 ± 2.03 minutes, respectively ($p < 0.001$ for both). Duration of analgesia was significantly longer with buprenorphine than with tramadol (19.77 ± 1.99 vs. 14.05 ± 1.67 hours; $p < 0.001$). Postoperative VAS scores were significantly lower with buprenorphine at 10, 12, and 24 hours. Rescue analgesia was required less frequently in the buprenorphine group than in the tramadol group (18.3% vs. 75.0%; $p < 0.001$). The overall incidence of adverse effects was low and comparable between groups (5% in each group). **Conclusion:** Buprenorphine appears to be a more effective adjuvant than tramadol when combined with 0.5% ropivacaine for ultrasound-guided supraclavicular brachial plexus block in humeral surgery. It provides faster onset of sensory and motor blockade, prolonged analgesia, improved late postoperative pain control, and reduced rescue analgesic requirements, with a comparable adverse-effect profile.

Keywords: Buprenorphine; Tramadol; Ropivacaine; Ultrasound-guided regional anaesthesia; Supraclavicular brachial plexus block; Humeral surgery; Postoperative analgesia.

INTRODUCTION

Effective perioperative analgesia is an integral component of anaesthetic care, as inadequately controlled surgical pain can adversely affect physiological function, delay mobilization and rehabilitation, and contribute to prolonged recovery. Regional anaesthesia, particularly brachial plexus blockade, provides effective surgical anaesthesia and perioperative analgesia for upper-extremity procedures while reducing the need for systemic opioids and their associated adverse effects.

The supraclavicular approach provides a dense and predictable blockade because the brachial plexus is relatively compact at this level, making it well suited for procedures involving the arm and forearm, including humeral surgery. Ultrasound guidance has further enhanced the precision and safety of peripheral nerve blockade by allowing direct visualization of the neural structures, surrounding anatomy, and spread of local anaesthetic.

Ropivacaine, a long-acting amide local anaesthetic, is widely used for peripheral nerve blocks because of its favourable safety profile and effective sensory blockade. However, the duration of analgesia following a single-injection block may be limited. Consequently, various adjuvants have been investigated to enhance block characteristics and prolong analgesic duration.

Buprenorphine and tramadol are among the opioid-based adjuvants evaluated for peripheral nerve blockade. Buprenorphine, a potent partial μ-opioid receptor agonist with prolonged receptor binding, has been associated with prolongation of sensory blockade and duration of analgesia when combined with local anaesthetics. Tramadol has a multimodal analgesic profile involving weak μ-opioid receptor agonism together with inhibition of norepinephrine and serotonin reuptake, and has also demonstrated potential to prolong the effects of peripheral nerve blocks.

Although both agents have been studied independently as adjuvants to local anaesthetics, direct comparative evidence between buprenorphine and tramadol in supraclavicular brachial plexus blockade remains limited. Humeral procedures can be associated with substantial perioperative

pain, making an effective and prolonged regional anaesthetic technique clinically relevant.

Therefore, the present study was undertaken to comparatively evaluate buprenorphine and tramadol as adjuvants to ropivacaine in ultrasound-guided supraclavicular brachial plexus block for patients undergoing humeral surgery, with assessment of block characteristics, analgesic duration, rescue analgesic requirements, pain scores, and adverse effects.

MATERIALS AND METHODS

Study Design and Participants

This prospective, randomized, comparative, double-blind study was conducted in the Department of Anaesthesiology at a tertiary care centre over 18 months (August 2024–February 2026). After institutional approval and written informed consent, 120 patients aged 18–65 years, classified as ASA physical status I–II and scheduled for elective or emergency humeral surgery, were enrolled.

Patients were excluded if they were pregnant or lactating, had known hypersensitivity to local anaesthetics or study drugs, pre-existing neurological or peripheral neuropathy, hepatic, renal, cardiac or coagulation disorders, were receiving anticoagulant therapy, or had local infection at the block site.

Randomization and Study Groups

Patients were randomly allocated using computer-generated random numbers and sequentially numbered, sealed opaque envelopes into two groups of 60 each. An independent anaesthesiologist prepared the study solutions, while patients, the block-performing anaesthesiologist, surgeon, and outcome assessor remained blinded to allocation.

- **Group A (n=60):** 30 mL of 0.5% ropivacaine + 0.3 mg buprenorphine (1 mL).
- **Group B (n=60):** 30 mL of 0.5% ropivacaine + 100 mg tramadol (2 mL).

The sample size was calculated based on previously reported VAS data, with $\alpha = 0.05$ and 80% power, resulting in 60 patients per group.

Ultrasound-Guided Supraclavicular Brachial Plexus Block

Following standard monitoring and aseptic preparation, the supraclavicular brachial plexus was identified using a high-frequency linear ultrasound probe (6–13 MHz). The subclavian artery, brachial plexus, first rib, and pleura were identified. After local infiltration with 2% lignocaine, a 22-gauge, 50-mm needle was introduced using an in-plane lateral-to-medial approach under continuous ultrasound visualization. Following negative aspiration, the allocated study solution was injected incrementally with intermittent aspiration while observing its spread around the brachial plexus.

Assessment of Block Characteristics

Sensory and motor blockade were assessed at 2-minute intervals following injection. Sensory block was evaluated using cold sensation and pinprick testing in the median, radial, ulnar, and musculocutaneous nerve distributions. Sensory block onset was defined as achievement of analgesia in all four distributions, while duration was measured until complete recovery of normal sensation.

Motor blockade was assessed using the Modified Bromage Scale. Motor block onset was defined as achievement of complete motor blockade, and duration was measured until complete recovery of motor function.

Perioperative and Postoperative Assessment

Standard ASA monitoring was continued intraoperatively, with heart rate, blood pressure, and SpO_2 recorded at 5-minute

intervals. Surgery was commenced after adequate sensory and motor blockade was achieved. Postoperatively, pain was assessed using a 0–10 cm Visual Analogue Scale (VAS) at 0, 2, 4, 6, 8, 12, 16, 20, and 24 hours. Time to first rescue analgesic request was recorded, with rescue analgesia administered when VAS was ≥4 or at patient request.

Patients were monitored for haemodynamic changes and adverse effects, including nausea, vomiting, sedation, respiratory depression, bradycardia, hypotension, pruritus, neurological complications, local anaesthetic systemic toxicity, and pneumothorax.

Outcome Measures

Primary outcomes were onset and duration of sensory blockade and onset and duration of motor blockade.

Secondary outcomes included postoperative VAS scores, time to first rescue analgesic request, haemodynamic stability, and incidence of adverse effects.

STATISTICAL ANALYSIS

Statistical analysis was performed using IBM SPSS Statistics version 28.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD) for normally distributed data and median with interquartile range (IQR) for non-normally distributed data, while categorical variables were presented as frequencies and percentages. Normality was assessed using the Shapiro–Wilk test.

For comparison between the two groups, the independent-samples *t* test was used for normally distributed continuous variables and the Mann–Whitney *U* test for non-normally distributed variables. Categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate. Repeated measurements, including VAS scores and haemodynamic parameters, were analysed using repeated-measures analysis of variance (ANOVA), with Bonferroni correction for post hoc pairwise comparisons when applicable.

A two-tailed p value <0.05 was considered statistically significant.

ETHICAL CONSIDERATIONS

The study was conducted after approval from the Institutional Ethics Committee and in accordance with the principles of the Declaration of Helsinki and Good Clinical Practice guidelines. Written informed consent was obtained from all participants after providing information regarding the study procedures, potential benefits, and risks.

Participant confidentiality was maintained throughout the study, with data identified using study-specific codes and access restricted to the research team. Patients were informed of their voluntary participation and their right to withdraw at any time without affecting their clinical care. Appropriate monitoring and emergency equipment, including intralipid for management of local anaesthetic systemic toxicity, were available throughout the study. No financial incentives were provided to participants. Study findings will be disseminated through scientific publication or presentation while maintaining participant anonymity.

RESULTS AND ANALYSIS

This prospective, randomized, comparative, double-blind study included 120 patients undergoing humeral surgery under ultrasound-guided supraclavicular brachial plexus block. Patients were randomly allocated into two equal groups of 60 each: Group A received 0.5% ropivacaine with buprenorphine, while Group B received 0.5% ropivacaine with tramadol.

The study groups were compared with respect to demographic and baseline characteristics, intraoperative parameters,

onset and duration of sensory and motor blockade, postoperative pain scores, rescue analgesic requirements, haemodynamic parameters, and adverse effects. The primary outcomes were the onset and duration of sensory and motor blockade, while postoperative pain scores, time to first rescue analgesic request, haemodynamic stability, and adverse effects were assessed as secondary outcomes.

Table 1: Demographic and Baseline Characteristics

Parameter	Group A (Ropivacaine + Buprenorphine) n=60	Group B (Ropivacaine + Tramadol) n=60	p-value
Age (years) Mean ± SD	37.6 ± 10.6	39.6 ± 10.6	0.316
Weight (kg) Mean ± SD	63.3 ± 9.9	61.0 ± 10.6	0.223
Height (cm) Mean ± SD	162.5 ± 7.8	164.2 ± 7.8	0.234
BMI (kg/m²) Mean ± SD	24.1 ± 4.2	22.8 ± 4.7	0.112
Sex (M/F)	39/21	39/21	1.000
ASA I / II	47/13	33/27	0.012

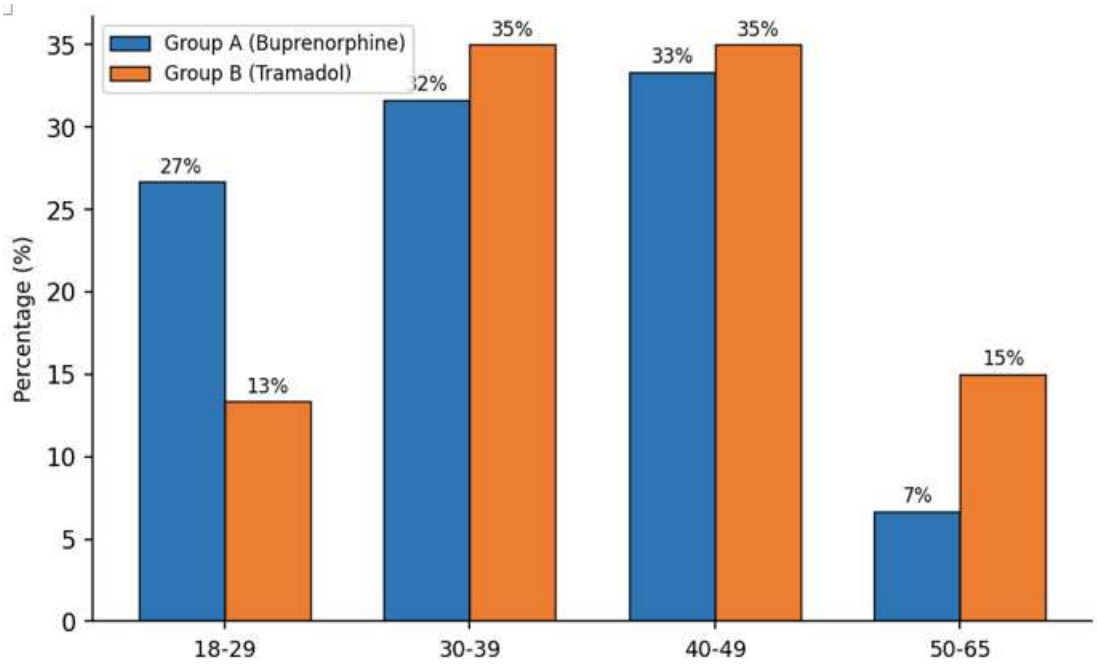

Figure 1: Bar Chart Showing Age Group Distribution Between Group A and Group B

Onset of Sensory Blockade

Table 2: Distribution of Onset of Sensory Blockade

Onset (min)	Group A	Group B

	n (%)	n (%)
6-9 min	32 (53.3%)	1 (1.7%)
10-13 min	26 (43.3%)	12 (20.0%)
14-17 min	2 (3.3%)	40 (66.7%)
18-22 min	0 (0.0%)	7 (11.7%)
Mean ± SD	9.48 ± 1.70	14.88 ± 2.25
p-value	<0.001	

Onset of sensory blockade in minutes

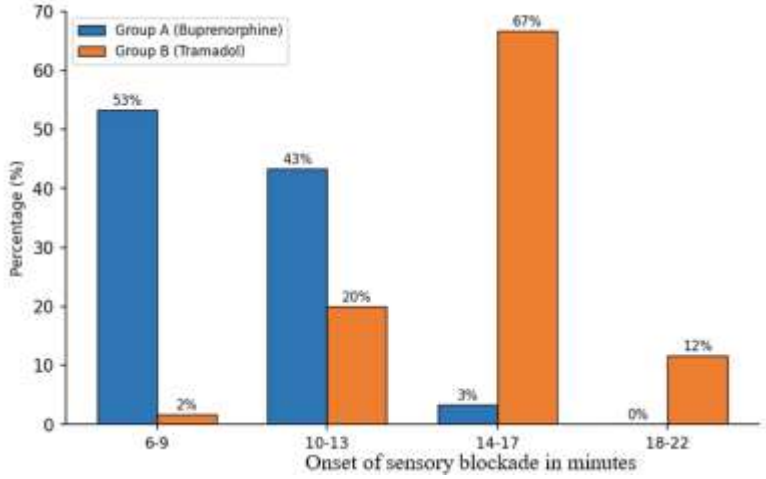

Figure 2: Bar Chart Showing Distribution of Onset of Sensory Blockade in Group A and Group B

Onset of Motor Blockade

Table 3: Distribution of Onset of Motor Blockade

Onset (min)	Group A n (%)	Group B n (%)
8-11 min	9 (15.0%)	0 (0.0%)
12-15 min	44 (73.3%)	4 (6.7%)
16-19 min	6 (10.0%)	38 (63.3%)
20-28 min	1 (1.7%)	18 (30.0%)
Mean ± SD	13.33 ± 2.05	18.43 ± 2.03
p-value	<0.001	

Onset of motor blockade in minutes

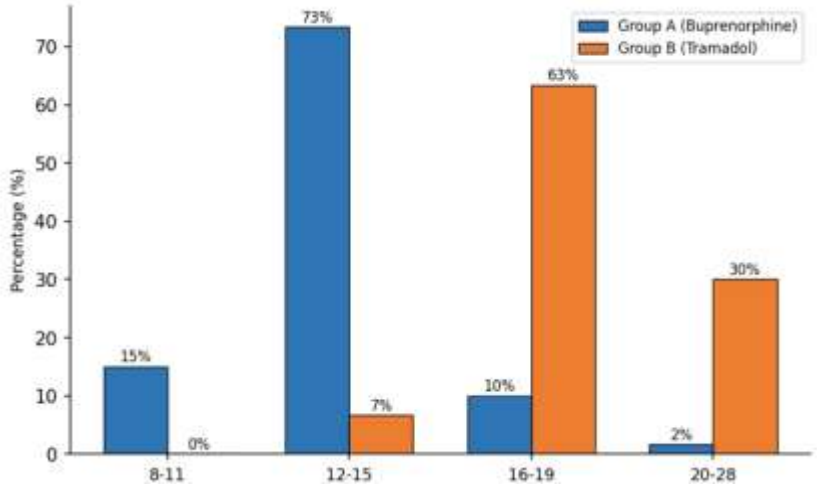

Figure 3: Bar Chart Showing Distribution of Onset of Motor Blockade in Group A and Group B

Postoperative Visual Analogue Scale (VAS) Pain Scores

Table 4: Postoperative VAS Scores at Various Time Intervals

Time Point	Group A Mean ± SD	Group B Mean ± SD	p-value
0 hr	1.23 ± 0.42	1.25 ± 0.43	0.833
2 hr	1.47 ± 0.50	1.40 ± 0.49	0.465
4 hr	1.57 ± 0.50	1.60 ± 0.49	0.714
6 hr	1.50 ± 0.50	1.47 ± 0.50	0.718
8 hr	1.88 ± 0.80	2.02 ± 0.79	0.362
10 hr	2.35 ± 0.73	3.08 ± 0.76	<0.001
12 hr	3.22 ± 0.82	5.67 ± 1.04	<0.001
24 hr	3.00 ± 0.84	4.03 ± 0.82	<0.001

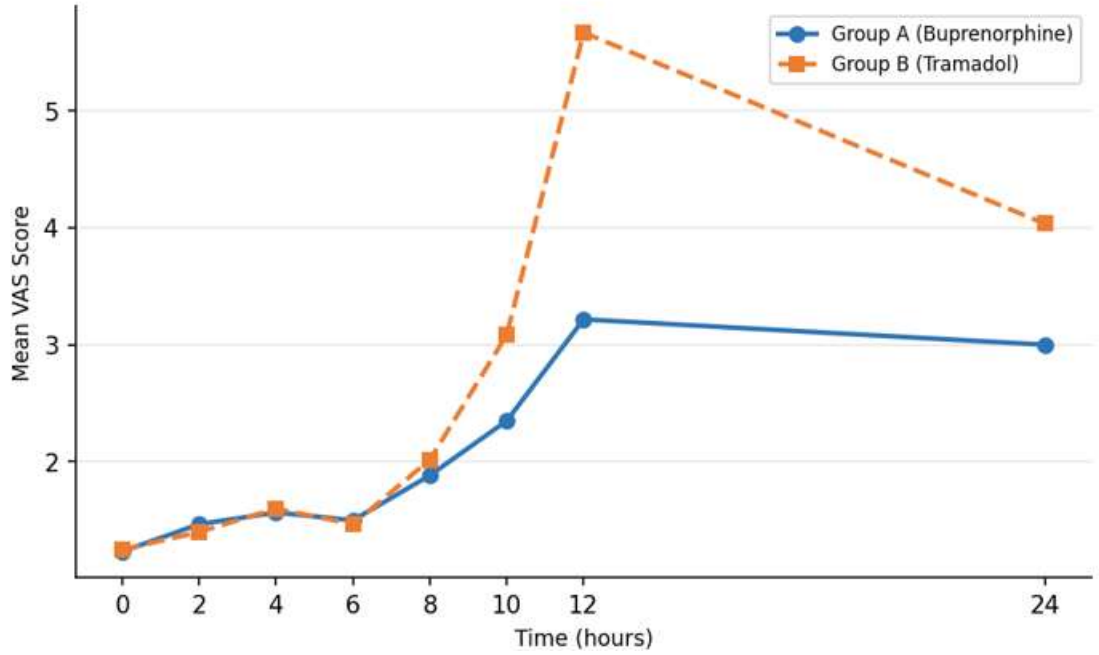

Figure 5: Line Chart Showing Postoperative VAS Score Trends in Group A and Group B

Rescue Analgesia Requirements

Table 5: Rescue Analgesia Requirements

Parameter	Group A n (%)	Group B n (%)	p-value
Rescue Analgesia Required	11 (18.3%)	45 (75.0%)	<0.001

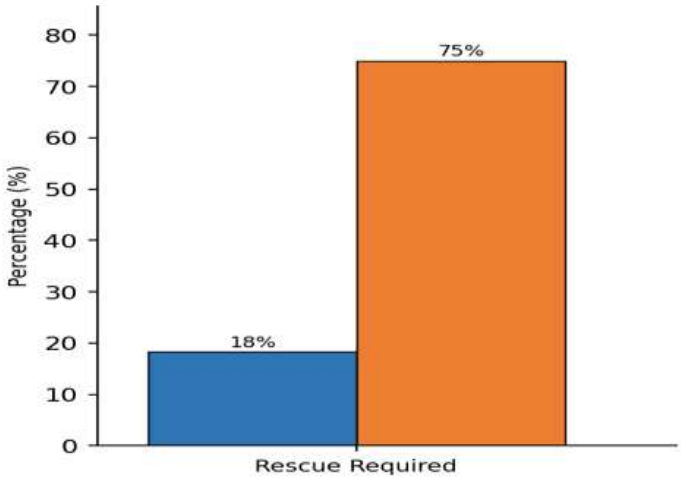

Figure 6: Bar Chart Showing Rescue Analgesia Requirements in Group A and Group B

Adverse Effects

Table 6: Adverse Effects Observed in Both Groups

Parameter	Group A	Group B	p-value

	n (%)	n (%)	
Adverse Effects Present	3 (5.0%)	3 (5.0%)	1.000
Nausea	2 (3.3%)	1 (1.7%)	-
Pruritus	0 (0.0%)	1 (1.7%)	-
Mild Sedation	1 (1.7%)	1 (1.7%)	-

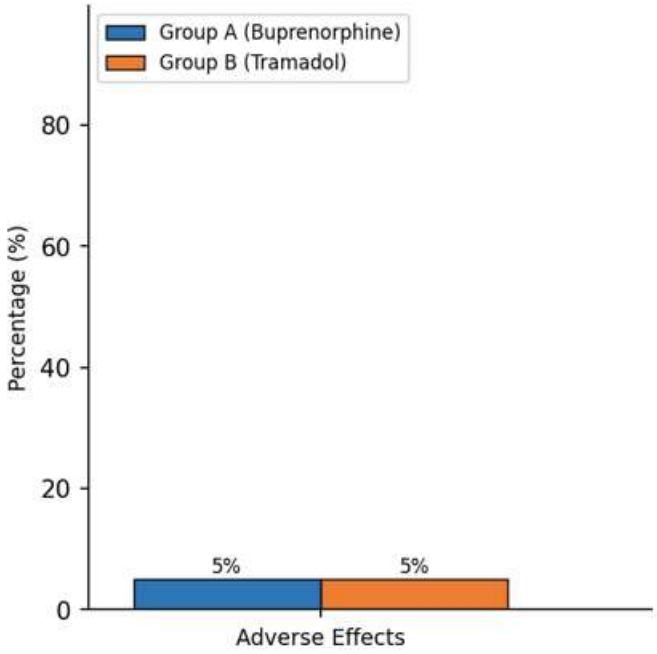

Figure 7: Bar Chart Showing Adverse Effects in Group A and Group B

DISCUSSION

The present study compared 0.5% ropivacaine with buprenorphine versus tramadol for ultrasound-guided supraclavicular brachial plexus block in patients undergoing humeral surgery. The two groups were comparable with respect to age, weight, height, BMI, and sex distribution.

Buprenorphine was associated with a significantly faster onset of both sensory and motor blockade compared with tramadol. The mean onset of sensory block was 9.48 ± 1.70 minutes with buprenorphine versus 14.88 ± 2.25 minutes with tramadol, while motor block occurred at 13.33 ± 2.05 versus 18.43 ± 2.03 minutes, respectively ($p < 0.001$ for both). These findings suggest that buprenorphine may potentiate the onset of ropivacaine-induced neural blockade. Similar faster onset of sensory and motor blockade with buprenorphine has been reported in previous studies evaluating its use as an adjuvant in supraclavicular brachial plexus block.

A significant difference was also observed in the duration of analgesia. The mean duration was 19.77 ± 1.99 hours in the buprenorphine group compared with 14.05 ± 1.67 hours in the tramadol group ($p < 0.001$). In the buprenorphine group, 83.3% of patients experienced analgesia lasting ≥18 hours, whereas all patients in the tramadol group had analgesia lasting less than 18 hours. The

prolonged duration observed with buprenorphine is consistent with its high affinity for μ-opioid receptors and prolonged receptor binding, which may contribute to sustained analgesic activity when used as a peripheral nerve block adjuvant.

The postoperative pain profile further supported this finding. VAS scores were comparable during the early postoperative period but became significantly lower with buprenorphine from 10 hours onwards, with the greatest difference observed at 12 hours. Correspondingly, rescue analgesia was required in only 18.3% of patients in the buprenorphine group compared with 75% in the tramadol group ($p < 0.001$). These findings indicate that the prolonged analgesic effect of buprenorphine translated into a clinically meaningful reduction in postoperative pain and rescue analgesic requirements.

Although tramadol has demonstrated efficacy as an adjuvant to local anaesthetics, the present findings suggest that buprenorphine provides more sustained analgesia and more favourable block characteristics when combined with 0.5% ropivacaine for supraclavicular block. The overall incidence of adverse effects was low and identical between groups (5%), with nausea, pruritus, and mild sedation occurring infrequently. Thus, the greater analgesic efficacy of buprenorphine was not accompanied by an apparent increase in adverse effects.

Overall, buprenorphine, when added to 0.5% ropivacaine for ultrasound-guided supraclavicular brachial plexus block, produced faster onset of sensory and motor blockade, significantly prolonged analgesia, lower postoperative pain scores at later time points, and reduced rescue analgesic requirements compared with tramadol, with a comparable adverse-effect profile. These findings support buprenorphine as a potentially more effective adjuvant to ropivacaine for regional anaesthesia in patients undergoing humeral surgery.

STRENGTHS OF THE PRESENT STUDY

The present study has several strengths, including an adequate sample size of 120 patients, a prospective randomized double-blind design, concealed allocation, and a standardized ultrasound-guided supraclavicular brachial plexus block technique. Restricting the study population to patients undergoing humeral surgery provided a relatively homogeneous surgical population and allowed focused assessment of block characteristics and postoperative analgesia.

LIMITATIONS OF THE PRESENT STUDY

The single-centre design may limit the generalizability of the findings to other institutions and patient populations. The absence of a ropivacaine-only control group precluded assessment of the individual contribution of buprenorphine and tramadol compared with ropivacaine alone. Follow-up was limited to 24 hours, preventing assessment of longer-term analgesic outcomes and late adverse effects. Routine prophylactic ondansetron may also have influenced the observed incidence of nausea and vomiting.

CLINICAL IMPLICATIONS

The findings suggest that buprenorphine 0.3 mg may be a more effective adjuvant than tramadol 100 mg when combined with 0.5% ropivacaine for ultrasound-guided supraclavicular brachial plexus block in humeral surgery. Its association with faster block onset, prolonged analgesia, lower late postoperative pain scores, and reduced rescue analgesic requirements, without an apparent increase in adverse effects, supports its potential use for prolonged perioperative analgesia. Further multicentre studies with larger sample sizes, appropriate control

groups, and longer follow-up are warranted to confirm these findings.

SUMMARY AND CONCLUSION

This prospective, randomized, double-blind study compared buprenorphine and tramadol as adjuvants to ropivacaine in ultrasound-guided supraclavicular brachial plexus block for humeral surgery.

Buprenorphine demonstrated a significantly faster onset of sensory and motor blockade, prolonged analgesic duration, better late postoperative pain control, and reduced requirement for rescue analgesia compared with tramadol. Both adjuvant regimens demonstrated a comparable and favourable safety profile.

In conclusion, buprenorphine appears to be a more effective adjuvant than tramadol when combined with ropivacaine for ultrasound-guided supraclavicular brachial plexus block, providing improved block characteristics and more sustained postoperative analgesia without an apparent increase in adverse effects.

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