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CLINICAL RESEARCH

Comparative Study of the Efficacy of Dexmedetomidine and Clonidine as Adjuvant to Ropivacaine in Ultrasound Guided Supraclavicular Brachial Plexus Block in Upper Limb Orthopedic Surgery

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ABSTRACT

This prospective double-blinded comparative study compared the efficacy and safety of dexmedetomidine versus clonidine as adjuvants to ropivacaine in ultrasound-guided supraclavicular brachial plexus block (SCBPB) for upper limb orthopedic surgery. Eighty ASA I-II patients aged 18–65 years were randomly allocated to receive 0.75% ropivacaine 20 ml with either dexmedetomidine 1 μg/kg (Group A, n=40) or clonidine 1 μg/kg (Group B, n=40). Sensory and motor block onset times were significantly faster in Group A (9.43 ± 2.12 and 11.18 ± 1.85 min) compared to Group B (11.65 ± 1.88 and 14.83 ± 2.07 min, p<0.001). Sensory and motor block durations were also significantly longer in Group A (648.05 ± 14.83 and 486.25 ± 8.61 min) than in Group B (435.63 ± 9.34 and 328.85 ± 5.75 min, p<0.001). Group A had prolonged time to first rescue analgesia (840 *vs.* 480 min, p<0.001) and lower 24-hour analgesic requirements. Transient bradycardia was more frequent in Group A (5 *vs.* 0 patients). Dexmedetomidine as an adjuvant provides faster onset, longer duration of sensory-motor blockade, and superior postoperative analgesia compared to clonidine, with manageable side effects.

KEYWORDS

Dexmedetomidine; Clonidine; Ropivacaine; Supraclavicular Brachial Plexus Block; Ultrasound-guided; Regional Anesthesia; Upper Limb Surgery; Adjuvant, Sensory Block; Motor Block; Postoperative Analgesia

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INTRODUCTION

Upper limb orthopedic surgery necessitates anesthesia that ensures both intraoperative immobility and profound postoperative analgesia to promote recovery and early rehabilitation. Brachial plexus block (BPB) is a well-established regional anesthetic technique for such procedures, offering significant advantages over general anesthesia, including superior site-specific pain control, minimized systemic side effects, and a marked reduction in postoperative opioid requirements [1,2].

The supraclavicular approach to the brachial plexus is particularly effective for surgeries of the arm and hand, providing rapid and reliable anesthesia [3]. The landmark-based technique, however, carries inherent risks such as pneumothorax and vascular injury [4]. The advent of ultrasound (USG) guidance has transformed this block, enhancing its safety and efficacy. Real-time visualization allows for precise needle placement, confirms local anesthetic spread around neural structures, reduces the required drug volume, and significantly lowers complication rates [5,6]. Consequently, USG-guided supraclavicular BPB has become a preferred method for upper extremity anesthesia.

Ropivacaine, a long-acting amide local anesthetic, is widely utilized for peripheral nerve blocks due to its favorable neurotoxic and cardiotoxic profile compared to bupivacaine [7]. Despite its efficacy, the duration of analgesia from a single injection of ropivacaine may be insufficient for prolonged postoperative pain management. This limitation has driven the investigation of various adjuvants to extend sensory blockade and improve analgesia [8]. Among these, alpha-2 adrenergic receptor agonists like dexmedetomidine and clonidine have gained prominence.

Dexmedetomidine and clonidine exert their analgesic effects via activation of alpha-2 receptors in the spinal cord and peripheral nerves, leading to hyperpolarization of neurons and inhibition of nociceptive transmission [9,10]. Dexmedetomidine possesses an 8-fold higher selectivity for the alpha-2 receptor compared to clonidine, which may translate to more potent clinical effects [11]. Existing literature suggests both drugs can prolong the duration of local anesthetics when used perineurally [12,13]. However, direct comparative evidence regarding their relative efficacy and safety profiles as adjuvants to ropivacaine in the context of USG-guided supraclavicular BPB for orthopedic surgery is still evolving and warrants further investigation.

This prospective, double-blinded, comparative study was therefore conducted. Its primary objective was to compare the onset and duration of sensory blockade induced by dexmedetomidine versus clonidine when administered as adjuvants to ropivacaine. Secondary objectives included evaluating motor block characteristics, postoperative pain scores, hemodynamic parameters, sedation levels, and the incidence of adverse events. By systematically comparing these two adjuvants, this research aims to provide robust clinical evidence to guide anesthetic practice, with the ultimate goal of optimizing the quality and duration of postoperative analgesia for patients undergoing upper limb orthopedic surgery.

METHODOLOGY

Study Design

A prospective, double-blinded, comparative study.

Sampling

Purposive sampling of 80 consecutive eligible patients. Participants were randomly allocated via computer-generated numbers into two groups of 40 each using sealed opaque envelopes.

Inclusion Criteria

1. Age 18-65 years.
2. Scheduled for upper limb orthopedic surgery (routine or emergency).
3. American Society of Anesthesiologists (ASA) physical status I or II.

Exclusion Criteria

1. Patient refusal.
2. Contraindications to brachial plexus block (e.g., coagulopathy, local infection).
3. ASA status III or above.
4. Significant cardiac, respiratory, hepatic, renal, or mental disorders.
5. Pregnancy.
6. Known allergy to study medications.

Data Collection

A structured proforma was used to record demographic details, block characteristics (onset/duration), perioperative vitals, Numerical Rating Scale (NRS) pain scores, Richmond Agitation-Sedation Scale (RASS) scores, and adverse events.

Surgical Approach

The study encompassed various upper limb orthopedic surgeries; the specific surgical procedure was not standardized.

Anesthesia Protocol & Preoperative Care

Patients were premedicated with lorazepam and received IV crystalloid preload. Standard monitoring (ECG, NIBP, SpO_2) was applied.

Intraoperative Management

-Group A: Received 20 ml of 0.75% ropivacaine + 1 µg/kg dexmedetomidine (total 21 ml).
-Group B: Received 20 ml of 0.75% ropivacaine + 1 µg/kg clonidine (total 21 ml).

Block Technique

Ultrasound-guided supraclavicular brachial plexus block was performed using a linear probe and a 22-gauge needle. Local anesthetic was deposited caudal and posterolateral to the plexus using a multi-injection technique. Inadequate blocks were excluded, and general anesthesia was administered.

Postoperative Period

Patients were monitored for 2 hours in the Post-Anesthesia Care Unit (PACU) and then in the ward for 24 hours. Pain (NRS), sedation (RASS), and vital signs were recorded. Rescue analgesia (IV ketorolac or tramadol) was provided as per protocol.

Statistical Analysis

Data were analyzed using SPSS version 2.0. Descriptive statistics (mean, SD, median, IQR) and inferential tests (Student's t-test, Chi-square test) were applied. A p-value <0.05 was considered significant.

Ethical Considerations

Approval was obtained from the Institutional Review Committee (IRC). Written informed consent was taken from all participants. The study declared no conflict of interest. Confidentiality was maintained, and participation was voluntary with the right to withdraw.

Results

A total of 80 patients, with a mean age of approximately 41 years, were equally randomized into two groups. Demographic and baseline characteristics were comparable between the groups (Table 1, Figure 1). The distribution of gender (Table 2, Figures 2 & 3), ASA physical status (Table 3, Figure 4), and the mean duration of surgery (Table 4, Figure 5) showed no statistically significant differences.

Table 1: Age distribution.

Variables	Group A	Group B	p value
	Mean ± SD	Mean ± SD	
Age (in years)	42.3 ± 13.5	40.03 ± 12.22	0.432

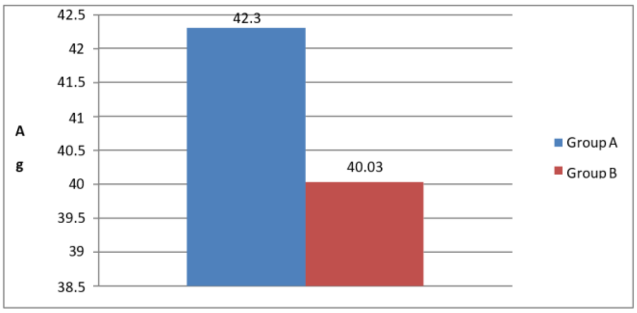

Figure 1: Mean age of patient.

Table 2: Gender distribution.

Variables	Group A	Group B	p value
	Mean	Mean	
Male	20 (55.5%)	16 (44.5%)	0.345
Female	20 (45.5%)	24 (54.5%)	0.369

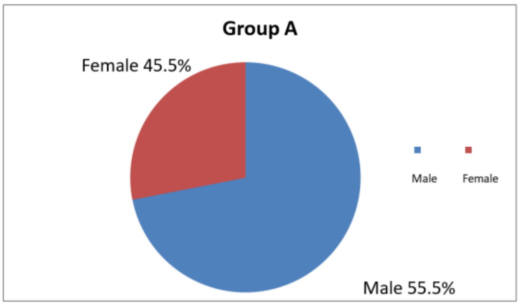

Figure 2: Gender distribution Group A.

Table 3: ASA PS of enrolled patients.

Variables	Group A	Group B	P value
ASA PS I	35	34	0.645
ASA PS II	5	6	0.745

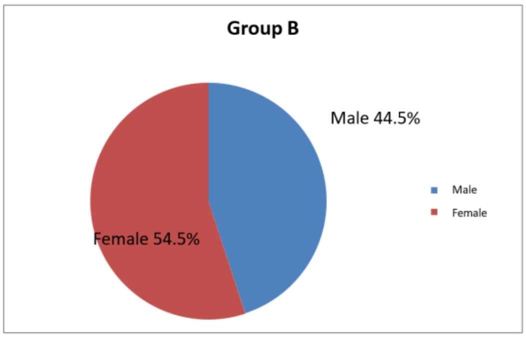

Figure 3: Gender distribution Group B.

Table 4: Duration of surgery

Variables	Group A	Group B	p value
	Mean ± SD	Mean ± SD	
Duration of surgery (mins)	138.63 ± 68.97	125.75 ± 49.19	0.339

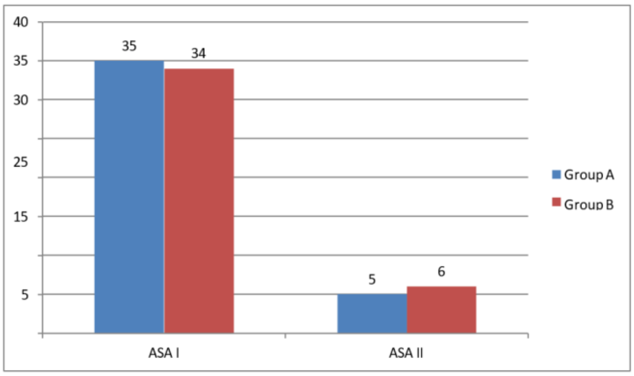

Figure 4: Distribution of ASA PS of enrolled patients within groups.

Table 5: Mean time for sensory, motor onset and sensory, motor duration

Variable(min)	Group A	Group B	p value
	Mean ± SD	Mean ± SD	
Sensory onset	9.43 ± 2.12	11.65 ± 1.88	<0.001
Motor onset	11.18 ± 1.85	14.83 ± 2.07	<0.001
Sensory duration	648.05 ± 14.83	435.63 ± 9.34	<0.001
Motor duration	486.25 ± 2.07	328.85 ± 5.75	<0.001

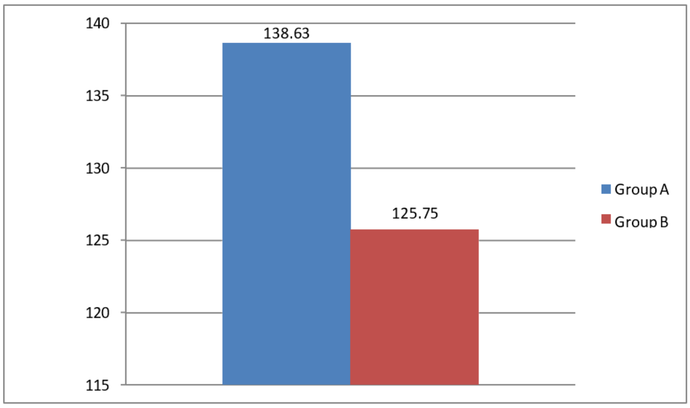

Figure 5: Mean duration of surgery.

Table 6: Baseline and perioperative HR.

Variables (bpm)	Group A	Group B	p value
	Mean ± SD	Mean ± SD	
HR preop	86.73 ± 14.61	85.70 ± 15.00	0.758
HR 30 min	77.93 ± 16.56	75.58 ± 19.24	0.56
HR 60 min	61.90 ± 9.88	79.95 ± 12.68	0.41
HR 90 min	66.00 ± 12.95	82.78 ± 14.32	0.61
HR 120 min	73.04 ± 12.58	79.52 ± 11.42	0.066
HR 10 min postop	84.40 ± 15.25	83.88 ± 15.97	0.881
HR 30 min postop	87.90 ± 11.80	84.78 ± 14.65	0.296
HR 60 min postop	87.80 ± 16.65	84.70 ± 13.87	0.368
HR 120 min postop	83.55 ± 13.50	88.98 ± 13.68	0.078

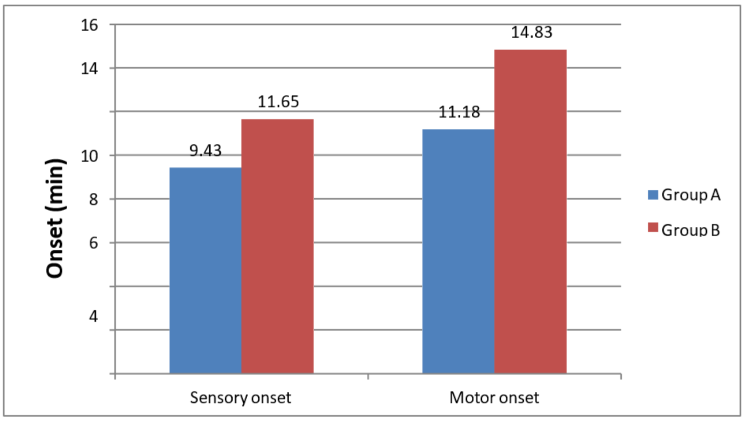

Figure 6: Mean duration of sensory and motor onset.

Table 7: Systolic BP comparison.

Variables (bpm)	Group A	Group B	p value
	Mean ± SD	Mean ± SD	
SBP preop	129.00 ± 17.65	128.00 ± 16.95	0.797
SBP 30 min	115.73 ± 9.52	116.93 ± 9.82	0.581
SBP 60 min	113.73 ± 8.56	115.18 ± 8.26	0.443
SBP 90 min	116.36 ± 10.68	117.70 ± 9.35	0.578
SBP 120min	116.85 ± 8.61	114.26 ± 8.54	0.297
SBP 10 min postop	126.13 ± 14.85	127.30 ± 16.83	0.741
SBP 30 min postop	123.75 ± 14.41	123.33 ± 14.86	0.897
SBP 60 min postop	126.80 ± 15.95	123.08 ± 14.69	0.281
SBP 120min postop	123.58 ± 14.27	122.55 ± 14.71	0.753

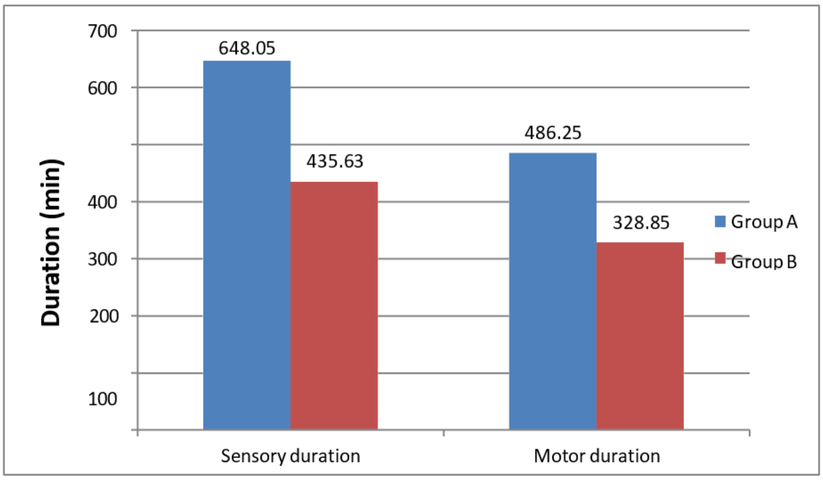

Figure 7: Mean sensory and motor duration.

Table 8: Diastolic BP comparison.

Variables (bpm)	Group A	Group B	p value
	Mean ± SD	Mean ± SD	
DBP preop	84.28 ± 12.92	83.48 ± 15.08	0.8
DBP 30 min	69.80 ± 5.21	71.18 ± 6.12	0.283
DBP 60 min	69.58 ± 6.74	69.63 ± 5.37	0.971
DBP 90 min	72.15 ± 6.22	71.84 ± 5.94	0.83
DBP 120 min	69.23 ± 5.78	68.30 ± 5.94	0.583
DBP 10 min postop	82.58 ± 15.51	85.18 ± 15.97	0.462
DBP 30 min postop	85.78 ± 13.40	89.38 ± 13.32	0.232
DBP 60 min postop	82.58 ± 15.79	88.43 ± 13.16	0.076
DBP 120 min postop	85.85 ± 14.02	87.78 ± 13.36	0.531

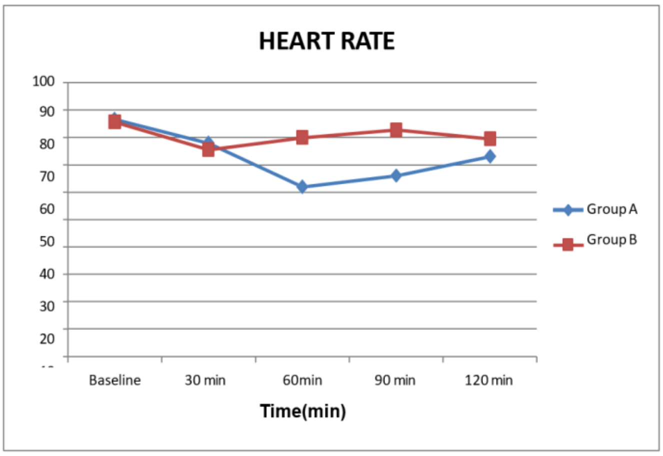

Figure 8: Heart rate comparison among the groups.

Table 9: MAP comparison.

Variables (bpm)	Group A	Group B	p value
	Mean ± SD	Mean ± SD	
MAP preop	114.09 ± 10.14	113.16 ± 10.95	0.694
MAP 30 min	100.42 ± 6.30	101.68 ± 7.54	0.42
MAP 60 min	99.01 ± 5.82	99.99 ± 5.92	0.456
MAP 90 min	101.63 ± 6.88	102.41 ± 6.44	0.622
MAP 120 min	100.97 ± 5.94	98.94 ± 5.77	0.232
MAP 10 min postop	107.28 ± 10.12	108.08 ± 10.93	0.735
MAP 30 min postop	111.09 ± 10.75	112.0 ± 10.71	0.703
MAP 60 min postop	112.06 ± 11.82	111.53 ± 10.78	0.834
MAP 120 min postop	111.00 ± 10.39	110.96 ± 11.58	0.987

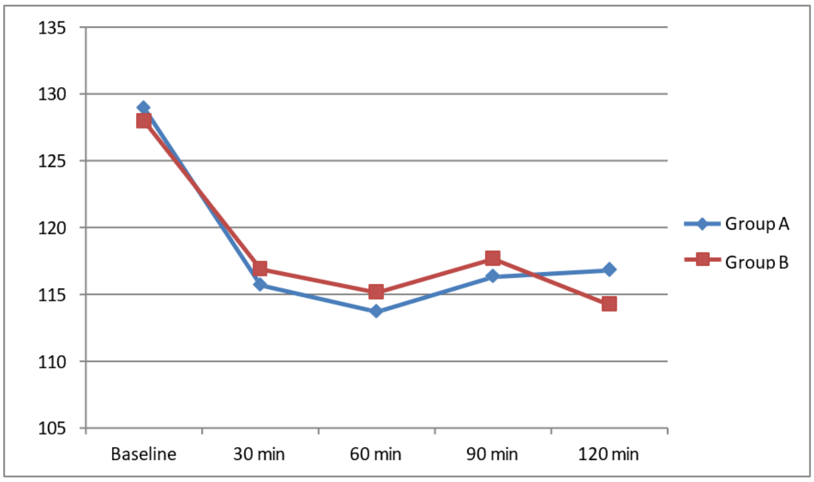

Figure 9: Systolic BP comparison between the groups.

Table 10: NRS score.

Parameters	Group A Median (IQR)	Group B Median (IQR)	p value
NRS 24 hrs	6.5 (5-8)	8(7-9)	<0.001

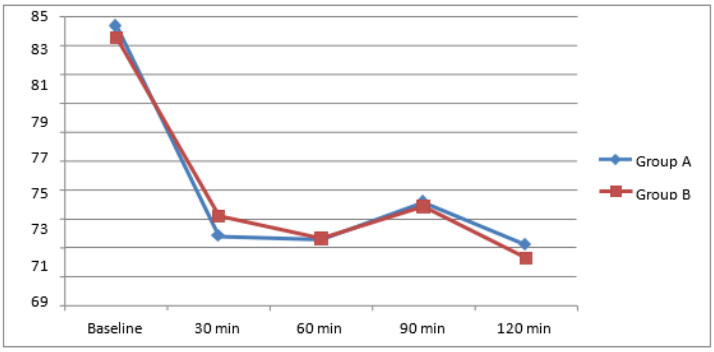

Figure 10: Diastolic BP comparison between the groups.

Table 11: Time of the first rescue analgesia.

Parameters	Group A Median (IQR)	Group B Median (IQR)	p value
Time of the first rescue analgesia (mins)	840 (600-960)	480(370-520)	<0.001

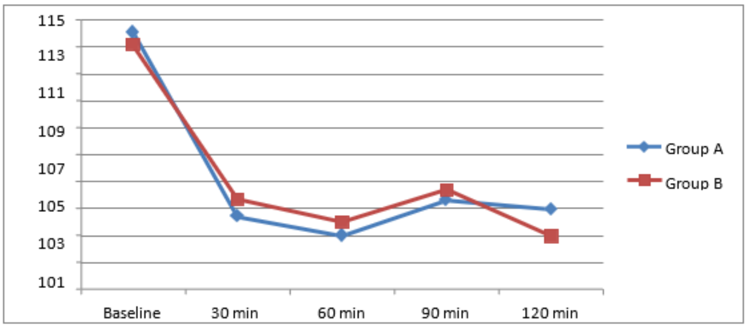

Figure 11: MAP comparison between the groups.

Table 12: Total analgesia required in 24 hrs.

Parameters	Group A	Group B	p value
Ketorolac	4	7	<0.001
Tramadol	2	5	<0.001

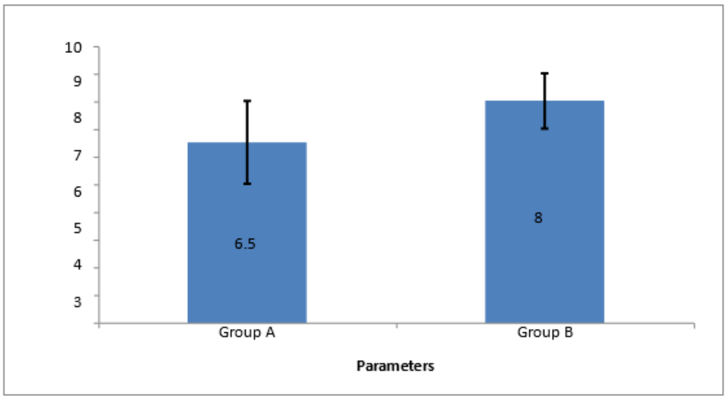

Figure 12: NRS score.

Table 13: Sedation score.

Parameters	Group A	Group B	p value
Excessive Sedation(RAAS>-2)	5	4	0.243
No sedation(RAAS<-2	35	36	0.243

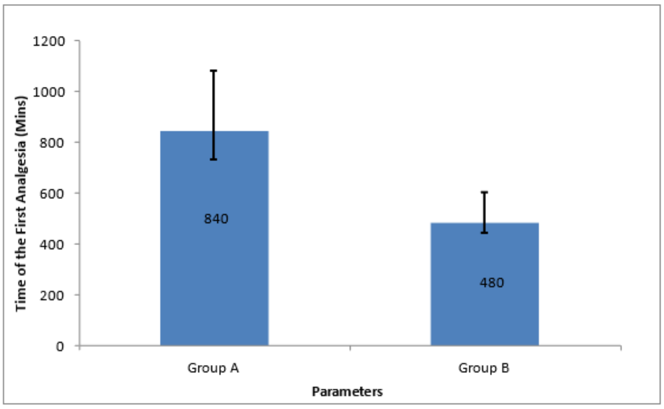

Figure 13: Time of the first rescue analgesia.

Table 14: Bradycardia.

Parameters	Group A	Group B	p value
Bradycardia	5	0	<0.001
No bradycardia	35	40	<0.004

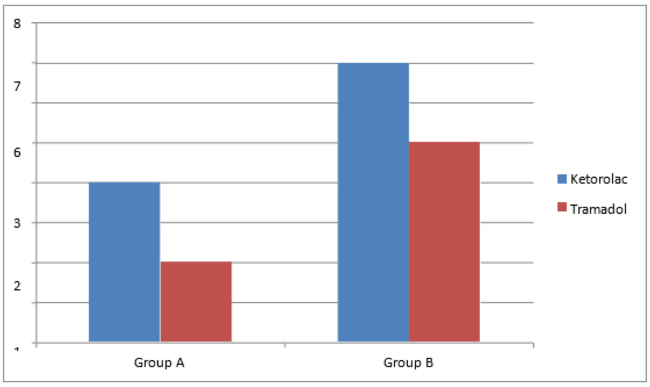

Figure 14: 24 hrs analgesic requirements.

Table 15: Hypotension.

Parameters	Group A	Group B	p value
Hypotension	10	4	<0.001
No	30	36	<0.001

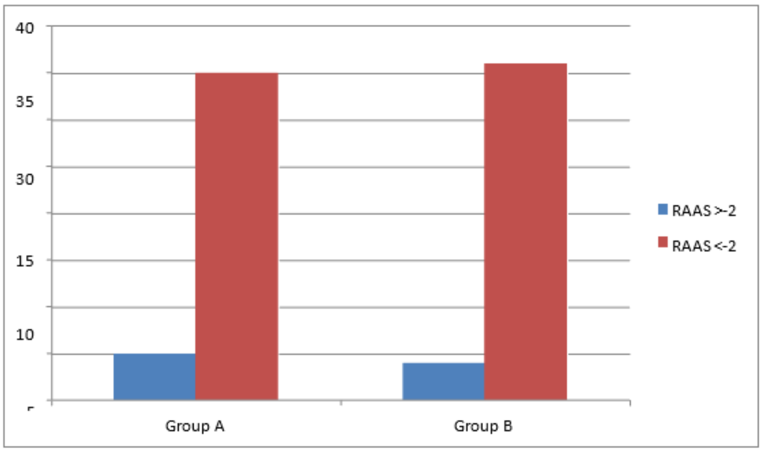

Figure 15: Sedation score.

Table 16: Comparison of incidence of nausea and vomiting.

Variables	Group A	Group B	p value
Nausea vomiting (yes)	5	2	0.245
No	35	38	0.235

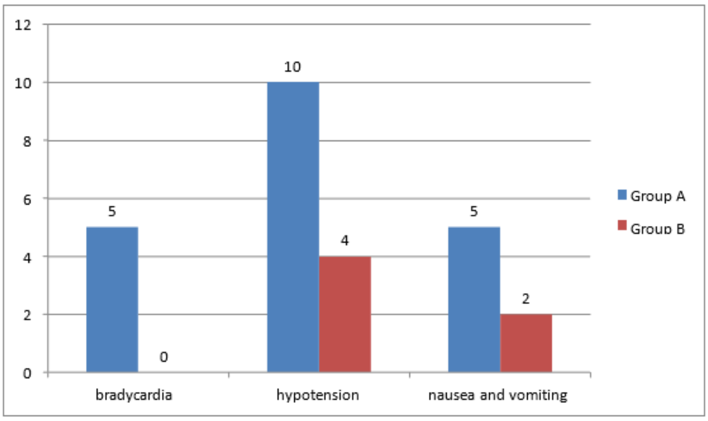

Figure 16: Adverse effects.

The primary outcomes revealed significant advantages for the dexmedetomidine group. The mean onset time for sensory block was significantly faster in Group A (9.43 ± 2.12 min) compared to Group B (11.65 ± 1.88 min) ($p<0.001$). Similarly, the duration of complete sensory block was substantially longer in Group A (648.05 ± 14.83 min) than in Group B (435.63 ± 9.34 min) ($p<0.001$) (Table 5, Figure 6 & Figure 7).

The secondary outcomes for motor blockade followed the same pattern. Motor block onset was quicker in Group A (11.18 ± 1.85 min) versus Group B (14.83 ± 2.07 min), and its duration was prolonged in Group A (486.25 ± 8.61 min) compared to Group B (328.85 ± 5.75 min) ($p<0.001$ for both) (Table 5, Figure 6 & Figure 7).

Hemodynamic parameters are detailed in Tables 6-9 and Figures 8 - Figure 11. While baseline and most intraoperative readings were comparable, Group A exhibited a predictable, transient decrease in heart rate at 60-90 minutes, with five patients (12.5%) requiring treatment for bradycardia (Table 14). Hypotension, though treatable, was also more frequent in Group A (10 patients *vs.* 4 in Group B) (Table 15).

Postoperative pain management outcomes strongly favoured dexmedetomidine. The median 24-hour NRS pain score was lower in Group A (6.5) than in Group B (8) ($p<0.001$) (Table 10, Figure 12). The time to first request for rescue analgesia was significantly delayed in Group A (median 840 min) compared to Group B (median 480 min) ($p<0.001$) (Table 11, Figure 13). Consequently, the total 24-hour analgesic consumption was significantly lower in Group A for both ketorolac and tramadol ($p<0.001$) (Table 12, Figure 14).

Sedation scores (RASS > -2) were comparable between groups, with no statistically significant difference (5 patients in Group A *vs.* 4 in Group B) (Table 13, Figure 15). The incidence of postoperative nausea and vomiting was low and similar in both groups (Table 16, Figure 16). All reported adverse events, including bradycardia and hypotension, were transient and effectively managed.

DISCUSSION

This prospective, double-blinded comparative study demonstrates that perineural dexmedetomidine is a superior adjuvant to clonidine when combined with ropivacaine for ultrasound-guided supraclavicular brachial plexus block (SCBPB) in upper limb orthopedic surgery. Our findings reveal that dexmedetomidine provides a significantly faster onset and a substantially longer duration of both sensory and motor blockade, translating into prolonged postoperative analgesia and reduced analgesic requirements. These benefits, however, are accompanied by a higher incidence of transient, treatable bradycardia.

The demographic and surgical variables between the two groups were comparable, indicating successful randomization and validating the subsequent comparative analyses. The significantly faster onset of sensory (9.43 *vs.* 11.65 minutes) and motor (11.18 *vs.* 14.83 minutes) blockade with dexmedetomidine aligns with the findings of prior systematic reviews and meta-analyses [14,15]. This accelerated onset can be attributed to dexmedetomidine's higher receptor specificity. With an alpha-2 to alpha-1 adrenoceptor selectivity ratio approximately eight times greater than that of clonidine, dexmedetomidine exerts a more potent inhibitory effect on the hyperpolarization-activated cation current (Ih) in peripheral nerves, leading to faster conduction blockade [11,16]. This pharmacodynamic superiority provides a practical clinical advantage by reducing the waiting time for surgical readiness.

The most compelling finding of our study is the marked prolongation of sensory and motor block duration with dexmedetomidine. The sensory block lasted over 210 minutes longer, and the motor block over 150 minutes longer, in the dexmedetomidine group compared to the clonidine group. This result is consistent with and strengthens the evidence from recent high-level syntheses. El-Boghdadly et al. and Vorobeichik et al., in their respective meta-analyses, concluded that dexmedetomidine prolongs sensory block duration by an estimated 20-60% more than clonidine [14,15]. The mechanism extends beyond mere vasoconstriction and reduced systemic absorption. Alpha-2 agonists act on receptors in the spinal cord and peripheral nerve terminals, inhibiting the release of pro-nociceptive neurotransmitters like substance P and glutamate, and causing hyperpolarization of interneurons [10]. Dexmedetomidine's greater affinity for these receptors, particularly the α2A subtype responsible for analgesia and sedation, likely underlies its enhanced prolongation effect [17].

Furthermore, our study observed a differential blockade, where the prolongation of sensory analgesia was more pronounced than that of motor function. This desirable characteristic, also noted in other studies [15,18] suggests that dexmedetomidine may have a more selective inhibitory action on pain-transmitting Aδ and C fibers compared to motor fibers. This differential effect is a distinct clinical advantage over adjuvants like dexamethasone, which non-selectively prolong both sensory and motor block. It facilitates earlier postoperative physiotherapy and mobilization, which are crucial for functional recovery after orthopedic procedures.

The superior block characteristics directly translated into enhanced postoperative pain outcomes. Patients receiving dexmedetomidine experienced significantly lower pain scores over 24 hours, a nearly doubled time to first analgesic request (840 *vs.* 480 minutes), and a reduced total consumption of rescue analgesics. This aligns with the findings of Das et al. and Tripathi et al., who reported similar extensions in analgesic duration with dexmedetomidine in brachial plexus blocks [18,19]. Despite having an elimination half-life of only 2-3 hours, dexmedetomidine's effects persist due to its profound supraspinal and spinal modulatory actions on pain pathways, along with its anxiolytic and thymoleptic properties which alter pain perception [20,21]. This prolonged analgesia reduces opioid exposure, thereby minimizing associated side effects like nausea, vomiting, and respiratory depression - a key goal in enhanced recovery protocols [6].

Regarding hemodynamics, our study confirms the known sympatholytic profile of alpha-2 agonists. While intraoperative blood pressure (SBP, DBP, MAP) remained stable and comparable between groups—likely due to adequate preloading - a predictable decrease in heart rate was observed in the dexmedetomidine group at 60-90 minutes. This resulted in a significantly higher incidence of transient bradycardia (12.5% *vs.* 0%), a finding consistent with the meta-analysis by Kariem et al.[14] This bradycardia is mediated by the central inhibition of sympathetic outflow from the locus coeruleus and potentiation of vagal activity [16,22]. All episodes were readily managed with atropine, underscoring the importance of vigilant monitoring, especially during the first hour post-administration. The incidence of hypotension was also higher in the dexmedetomidine group but was similarly treatable.

Sedation, assessed using the Richmond Agitation-Sedation Scale (RASS), was comparable between the groups in our study, which contrasts with some previous reports that found greater sedation with dexmedetomidine [14,15]. This discrepancy may be due to the perineural route of administration, which leads to lower systemic plasma concentrations compared to intravenous use, or differences in the dosing or formulation of the drug. The similar, minimal sedation levels observed are advantageous, as excessive sedation can delay recovery room discharge and ambulation. The incidence of postoperative nausea and vomiting was low and statistically similar between groups, which is an expected benefit of effective regional analgesia reducing systemic opioid need.

LIMITATIONS

Our study has certain limitations. First, we did not include a control group receiving only ropivacaine, which limits our ability to quantify the absolute prolongation effect of each adjuvant over the base local anesthetic. Second, we employed a fixed dose (1 µg/kg) of both adjuvants; a dose-response evaluation could have identified an optimal dose that maximizes benefit while minimizing side effects like bradycardia. Third, we did not assess long-term outcomes such as chronic pain development or functional recovery, nor did we evaluate potential neurotoxic effects of perineural alpha-2 agonists, though current evidence suggests their safety [15]. Finally, the study drugs were not standardized from a single manufacturer, which may introduce variability.

In conclusion, this study provides robust evidence that dexmedetomidine, at a dose of 1 µg/kg, is a more effective perineural adjuvant than clonidine for ultrasound-guided supraclavicular brachial plexus block with ropivacaine. It offers a faster onset, a significantly longer duration of sensory-motor blockade with a favorable differential profile, and superior postoperative analgesia with reduced opioid consumption. These benefits come at the cost of an increased, but manageable, risk of transient bradycardia. Therefore, for patients undergoing upper limb orthopedic surgery where prolonged analgesia is desired, dexmedetomidine should be considered the preferred alpha-2 agonist adjuvant, provided appropriate hemodynamic monitoring is in place.

CONCLUSION

Compared to clonidine, perineural dexmedetomidine as an adjuvant to ropivacaine in ultrasound-guided supraclavicular brachial plexus block provides a significantly faster onset and longer duration of sensory and motor blockade, resulting in superior and prolonged postoperative analgesia with reduced rescue analgesic requirements. While associated with a higher incidence of transient, treatable bradycardia, its overall efficacy and manageable side-effect profile make dexmedetomidine the preferable alpha-2 agonist for enhancing single-injection brachial plexus blocks in upper limb orthopedic surgery, facilitating better pain control and potentially improved recovery outcomes.

AUTHOR’S CONTRIBUTIONS

Conceptualization: Pran Shrestha, Rahul Kumar Chaudhary, Satish Thakur

Data Curation: Pran Shrestha, Rahul Kumar Chaudhary

Writing-original draft: Rahul Kumar Chaudhary, Pran Shrestha

Writing-review and editing: Rahul Kumar Chaudhary

Conflict of Interest

No conflict of interest between co-authors.

Data Availability Statement

Datasets generated/analyzed during this study are available from the corresponding author on reasonable request.

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