Section: Anaesthesia

Original Research Article

COMPARATIVE ANALYSIS OF BUPIVACAINE VS. ROPIVACAINE IN PERIPHERAL NERVE BLOCKS

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ABSTRACT

Background: The aim is to compare the efficacy, block characteristics, postoperative analgesia, hemodynamic stability, and safety profile of 0.5% Bupivacaine and 0.5% Ropivacaine in ultrasound-guided peripheral nerve blocks for elective limb surgeries. **Materials and Methods:** This prospective, randomized, double-blinded study included 100 adult ASA I/II patients undergoing elective upper limb surgeries under brachial plexus block. Participants were divided into two groups receiving either 0.5% Bupivacaine or 0.5% Ropivacaine. Ultrasound-guided blocks were administered with standardized drug volume, and outcome parameters such as block onset, duration, intraoperative analgesia, VAS scores, hemodynamics, and adverse events were recorded. Data were statistically analyzed using SPSS v26.0, with significance set at $p<0.05$.. **Result:** Group B demonstrated a faster onset of sensory (8.2 ± 1.4 min) and motor block (11.4 ± 1.8 min) than Group R (9.1 ± 1.6 min and 12.2 ± 1.7 min respectively). The duration of sensory and motor blocks was significantly longer in Group B (472.5 ± 60.3 min and 415.3 ± 50.1 min) compared to Group R (390.6 ± 54.2 min and 340.2 ± 45.7 min). VAS scores were comparable at most time points, though slightly higher at 12 hours in Group B. Hemodynamic parameters and adverse event rates were similar in both groups, with no major complications reported. **Conclusion:** Both Bupivacaine and Ropivacaine are effective and safe for peripheral nerve blocks. Bupivacaine offers a quicker onset and longer duration, while Ropivacaine allows earlier recovery and may offer better comfort during the later postoperative period, making it a preferred choice in ambulatory settings.

INTRODUCTION

Regional anesthesia has become an integral component of modern anesthetic practice, offering superior analgesia, reduced opioid requirements, and early postoperative recovery, especially in orthopedic and upper limb surgeries. Among the various regional techniques, the brachial plexus block (BPB) is widely utilized for surgeries involving the upper extremities. It provides effective anesthesia and postoperative analgesia by targeting the network of nerves supplying the arm. Over the years, the supraclavicular approach to BPB has gained prominence due to its high success rate and ability to anesthetize the entire upper limb with a single injection. The efficacy of BPB, however, largely depends on the choice of local anesthetic (LA), volume and concentration used, adjuvants, and the guidance method employed during the block. Traditionally, bupivacaine has been the drug of choice for its prolonged duration of action, but its potential for cardiotoxicity and neurotoxicity has led clinicians to explore safer alternatives like ropivacaine, which offers a favorable safety profile with comparable efficacy.[1-4] The evolution of anesthetic agents in regional blocks has thus spurred a series of comparative studies to establish the most suitable drug for different clinical settings.

Ropivacaine, an S-enantiomer of bupivacaine, was introduced with the aim of reducing the systemic toxicity associated with its racemic counterpart. Numerous studies have shown that ropivacaine produces sensory and motor blockade of a similar magnitude to bupivacaine but with reduced cardiotoxicity, making it particularly suitable for outpatient and day-care surgeries.[2,4,5] Furthermore, its lesser propensity to produce motor block makes it advantageous in procedures where early motor recovery is desirable.[6] In this context, understanding the comparative efficacy and safety profiles of these agents is critical for tailoring anesthesia to individual patient needs and surgical requirements.

Recent research highlights the increasing use of ultrasound guidance in performing nerve blocks. Ultrasound offers real-time visualization of the target nerves and adjacent structures, significantly enhancing the success rate and safety of the

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procedure.[3] The ability to track the spread of the drug and avoid inadvertent intravascular or intraneural injections has redefined the practice of regional anesthesia. Ultrasound-guided BPB not only allows for lower volumes of anesthetics but also increases patient satisfaction and decreases the risk of complications.

Several clinical trials have compared ropivacaine and bupivacaine in upper limb surgeries, particularly using the supraclavicular or axillary approaches. In a randomized study, Kaur et al. demonstrated that while both agents are effective in providing surgical anesthesia, ropivacaine showed a faster onset and comparable duration of sensory and motor blocks.[2] Similarly, Badole and Salunke found that both 0.5% ropivacaine and 0.5% bupivacaine provided excellent conditions for surgery, but ropivacaine offered a better hemodynamic profile and quicker recovery.[5]

The choice of concentration also plays a significant role in the quality of the block. Higher concentrations, such as 0.75% ropivacaine, have been shown to enhance the depth and duration of sensory blockade without significantly increasing the risk of toxicity.[6] Chatrath et al. investigated the effect of adding clonidine as an adjuvant to both 0.75% ropivacaine and 0.5% bupivacaine and found that clonidine significantly prolonged the duration of analgesia and enhanced block quality, further supporting the use of ropivacaine in clinical practice.[6]

Moreover, the supraclavicular approach, which is often preferred for its rapid onset and dense block, has been the focus of several comparative studies. Tripathi et al. conducted a double-blinded randomized study comparing ropivacaine and bupivacaine in supraclavicular blocks for upper limb surgeries and concluded that ropivacaine provided effective surgical anesthesia with reduced motor block duration, a factor that contributes to early ambulation and patient satisfaction.[7]

In the Indian clinical setting, where resource constraints often dictate anesthetic choices, it becomes crucial to evaluate the balance between efficacy, safety, and cost-effectiveness. Seth et al. compared ropivacaine, bupivacaine, and lignocaine in femoral nerve blocks and concluded that ropivacaine provides a suitable alternative with prolonged analgesia and fewer hemodynamic fluctuations, suggesting its broader applicability in various nerve blocks.[1] This finding is significant, especially for peripheral nerve blocks in orthopedic trauma cases, where prolonged pain relief is necessary for optimal recovery.

MATERIALS AND METHODS

This prospective, randomized, double-blinded clinical study was conducted at a tertiary care hospital after obtaining approval from the Institutional Ethics Committee. Written informed consent was obtained from all participants prior to enrollment.

A total of 100 adult patients (age 18–65 years), classified as American Society of Anesthesiologists (ASA) physical status I or II, scheduled for elective upper or lower limb surgeries requiring peripheral nerve block, were initially enrolled. However, for uniformity in assessment and standardization of block technique and drug volume, only patients undergoing upper limb surgeries with brachial plexus block were finally included in the analysis. Patients with known hypersensitivity to local anesthetics, coagulopathy, infection at the injection site, severe hepatic or renal dysfunction, or those on chronic pain medications were excluded.

Randomization and Group Allocation

Patients were randomly allocated into two equal groups (n = 50 each) using a computer-generated randomization list:

- **Group B (Bupivacaine Group):** Received 0.5% Bupivacaine.
- **Group R (Ropivacaine Group):** Received 0.5% Ropivacaine.

Randomization codes were kept in sequentially numbered, opaque, sealed envelopes and opened immediately prior to the block procedure.

Procedure

All enrolled patients underwent brachial plexus block appropriate to the site of upper limb surgery, performed under ultrasound guidance by experienced anesthesiologists in a sterile setting. A standardized drug volume of 20 mL was used for each block. The probe used and the exact site of the block (e.g., supraclavicular, infraclavicular, or axillary approach) were selected based on surgical requirement and documented for each case. If lower limb blocks such as femoral or sciatic blocks had been included, it would have been essential to define the exact site (gluteal or popliteal) and probe orientation, as drug volume requirements vary significantly by anatomical location; however, these were excluded to maintain procedural uniformity.

Drug preparation was performed by an independent anesthetist who was not involved in administering the block or assessing outcomes. Both the patient and the outcome assessor were blinded to the drug administered.

Outcome Parameters

The primary outcome parameters included the onset time and duration of both sensory and motor blocks. Sensory block onset time was defined as the interval from drug administration to the complete loss of pinprick sensation in the targeted dermatomes. Motor block onset time was recorded as the time from injection to complete motor paralysis, which was assessed using the Modified Bromage Scale. The duration of the sensory block was measured from the onset of sensory loss to the full return of normal sensation, while the duration of the motor block was determined from the onset of motor impairment until full motor recovery. Intraoperative analgesia requirements were also noted, specifically whether any supplemental analgesics were needed during the

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surgical procedure. Postoperative pain assessment was conducted using the Visual Analog Scale (VAS) at multiple time points—specifically at 2, 4, 8, 12, and 24 hours after surgery—to evaluate the quality and longevity of postoperative analgesia.

Hemodynamic Monitoring

Hemodynamic parameters, including heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP), were meticulously monitored and recorded at baseline (prior to block administration), and then at 5, 10, 20, 30, 45, and 90 minutes post-block, as well as at the end of the surgical procedure. These measurements were used to assess the cardiovascular stability of patients in response to the local anesthetics administered.

Adverse Events

All patients were closely observed for any adverse events during and after the procedure. Specific complications monitored included hypotension (defined as SBP <90 mmHg or a drop of more than 20% from baseline), bradycardia (HR <50 bpm), nausea, vomiting, and any signs suggestive of local anesthetic systemic toxicity (LAST). Any such adverse effects were promptly managed according to institutional protocols and were systematically documented for comparative analysis between the study groups.

Statistical Analysis

Data analysis was performed using SPSS version 26.0. Continuous variables were expressed as mean ± standard deviation and compared using the Student's t-test or Mann–Whitney U test. Categorical variables were reported as frequency (percentage) and analyzed using the chi-square test or Fisher's exact test, as appropriate. A p-value <0.05 was considered statistically significant.

RESULTS

[Table 1] Demographic Profile of Patients

The demographic characteristics between Group B (Bupivacaine) and Group R (Ropivacaine) were comparable and statistically non-significant. The mean age of patients was 42.3 ± 10.8 years in Group B and 43.7 ± 11.2 years in Group R (p = 0.48). Gender distribution was similar with 28 males and 22 females in Group B, and 30 males and 20 females in Group R (p = 0.68). ASA physical status (I/II) was comparable across both groups (p = 0.65). The mean body weight was also not significantly different between the two groups (69.1 ± 8.7 kg in Group B vs. 70.4 ± 9.3 kg in Group R, p = 0.43). Additionally, the mean duration of surgery was similar in both groups (92.4 ± 18.6 min in Group B vs. 90.1 ± 17.2 min in Group R, p = 0.39). These findings indicate that the two groups were demographically and clinically well-matched.

[Table 2] Block Characteristics

The onset of sensory block was significantly faster in Group B (8.2 ± 1.4 minutes) compared to Group R (9.1 ± 1.6 minutes), with a statistically significant p-value of 0.01. Similarly, the onset of motor block was also quicker in Group B (11.4 ± 1.8 minutes) than in Group R (12.2 ± 1.7 minutes), with a p-value of 0.03, indicating that Bupivacaine produced faster onset of both sensory and motor blocks. In terms of duration, Bupivacaine exhibited a significantly longer sensory block duration (472.5 ± 60.3 minutes) than Ropivacaine (390.6 ± 54.2 minutes), with a highly significant p-value of <0.001. Likewise, the motor block duration was longer in the Bupivacaine group (415.3 ± 50.1 minutes) compared to the Ropivacaine group (340.2 ± 45.7 minutes), again showing statistical significance with a p-value of <0.001. These findings confirm the prolonged action profile of Bupivacaine in regional anesthesia. Regarding the requirement of intraoperative analgesia, 4 patients (8%) in Group B and 6 patients (12%) in Group R needed supplemental analgesia, but this difference was not statistically significant (p = 0.51), suggesting comparable intraoperative analgesic efficacy between the two agents.

[Table 3] Postoperative Pain Scores (VAS)

Postoperative pain scores assessed at various intervals using the Visual Analog Scale (VAS) revealed overall low pain levels in both groups, though some differences emerged over time. At 2, 4, and 8 hours, the differences in VAS scores were not statistically significant (p = 0.41, 0.17, and 0.08, respectively). However, at 12 hours, patients in the Bupivacaine group reported significantly higher pain scores (4.7 ± 1.2) compared to the Ropivacaine group (4.2 ± 1.0), with a p-value of 0.04. At 24 hours, the pain scores again showed no significant difference (2.9 ± 1.1 vs. 2.6 ± 0.9, p = 0.21). These results suggest that although Bupivacaine has a longer block duration, patients experienced slightly more discomfort at 12 hours, possibly due to a steeper offset in analgesic effect.

[Table 4] Hemodynamic Parameters

Hemodynamic parameters including heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP) were recorded at multiple time points to assess cardiovascular stability. Across all time points—from baseline to the end of surgery—no statistically significant differences were observed between Group B and Group R in any of the measured parameters (all p-values > 0.05). For instance, at baseline, the mean HR was 78.2 ± 6.5 bpm in Group B and 77.5 ± 6.2 bpm in Group R (p = 0.62), and the mean MAP was 93.0 ± 5.8 mmHg in Group B vs. 92.6 ± 5.6 mmHg in Group R (p = 0.60). Similar stability was maintained at 5, 10, 20, 30, 45, and 90 minutes, as well as at the end of the surgical procedure. This demonstrates that both local anesthetics were hemodynamically safe and well-tolerated.

[Table 5] Adverse Events

The incidence of adverse events was low and not significantly different between the two groups. Hypotension occurred in 6% of patients in Group B and 4% in Group R (p = 0.64), while bradycardia was

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reported in 4% vs. 2% of patients respectively (p = 0.56). Minor nausea/vomiting occurred in 4% of Group B patients and 2% of Group R (p = 0.56). Importantly, no cases of local anesthetic systemic toxicity (LAST) were reported in either group. The total incidence of adverse events was slightly higher in the Bupivacaine group (14%) compared to the Ropivacaine group (8%), but this difference was not statistically significant (p = 0.34). These findings indicate a comparable safety profile between the two drugs, with both being associated with minimal and manageable side effects.

Table 1: Demographic Profile of Patients

Parameter	Group B (n = 50)	Group R (n = 50)	p-value
Age (years, mean ± SD)	42.3 ± 10.8	43.7 ± 11.2	0.48
Gender (M/F)	28 / 22	30 / 20	0.68
ASA I/II	34 / 16	32 / 18	0.65
Weight (kg, mean ± SD)	69.1 ± 8.7	70.4 ± 9.3	0.43
Duration of Surgery (min, mean ± SD)	92.4 ± 18.6	90.1 ± 17.2	0.39

Table 2: Block Characteristics

Parameter	Group B (Bupivacaine)	Group R (Ropivacaine)	p-value
Onset of Sensory Block (min)	8.2 ± 1.4	9.1 ± 1.6	0.01*
Onset of Motor Block (min)	11.4 ± 1.8	12.2 ± 1.7	0.03*
Duration of Sensory Block (min)	472.5 ± 60.3	390.6 ± 54.2	<0.001*
Duration of Motor Block (min)	415.3 ± 50.1	340.2 ± 45.7	<0.001*
Intraoperative Analgesia Required	4 (8%)	6 (12%)	0.51

Table 3: Postoperative Pain Scores (VAS)

Time Point (Hours)	Group B (Mean ± SD)	Group R (Mean ± SD)	p-value
2	1.2 ± 0.6	1.3 ± 0.5	0.41
4	2.3 ± 0.7	2.1 ± 0.6	0.17
8	3.5 ± 1.1	3.1 ± 0.9	0.08
12	4.7 ± 1.2	4.2 ± 1.0	0.04*
24	2.9 ± 1.1	2.6 ± 0.9	0.21

Table 4: Hemodynamic Parameters (Comparative Analysis)

Time Point	HR (bpm) B / R	p-value	SBP (mmHg) B / R	p-value	DBP (mmHg) B / R	p-value	MAP (mmHg) B / R	p-value
Baseline	78.2 / 77.5	0.62	122.4 / 121.6	0.55	78.3 / 79.1	0.48	93.0 / 92.6	0.60
5 min	77.4 / 76.8	0.59	121.0 / 120.3	0.47	77.6 / 78.4	0.51	92.0 / 91.7	0.66
10 min	76.1 / 75.9	0.72	119.5 / 118.9	0.63	76.9 / 77.2	0.74	91.1 / 90.7	0.58
20 min	74.6 / 74.2	0.67	117.2 / 116.4	0.46	75.3 / 75.6	0.70	89.2 / 88.7	0.53
30 min	73.5 / 73.1	0.60	116.0 / 115.5	0.52	74.6 / 74.8	0.64	88.4 / 87.9	0.50
45 min	72.8 / 72.3	0.55	114.5 / 113.9	0.49	73.2 / 73.1	0.88	87.1 / 86.7	0.57
90 min	74.2 / 73.9	0.70	115.1 / 114.2	0.45	74.4 / 74.0	0.62	88.0 / 87.4	0.48
End of surgery	75.6 / 75.3	0.66	116.3 / 115.8	0.50	75.8 / 75.6	0.73	89.5 / 89.1	0.59

Table 5: Adverse Events

Adverse Event	Group B (n = 50)	Group R (n = 50)	p-value
Hypotension	3 (6%)	2 (4%)	0.64
Bradycardia	2 (4%)	1 (2%)	0.56
Nausea/Vomiting	2 (4%)	1 (2%)	0.56
Signs of LAST	0 (0%)	0 (0%)	—
Total Adverse Events	7 (14%)	4 (8%)	0.34

DISCUSSION

The demographic data demonstrate that both groups—Bupivacaine (Group B) and Ropivacaine (Group R)—were comparable in terms of age, gender, ASA classification, weight, and surgery duration, with no statistically significant differences. This uniformity indicates a balanced study design, minimizing confounding variables and enhancing the validity of the subsequent comparisons. Similar demographic matching has been emphasized as crucial in comparative studies of local anesthetics to ensure that outcomes are attributable to the drugs rather than patient-related factors (Sehgal et al., 2019).[8]

The findings clearly show that Bupivacaine had a faster onset of both sensory and motor blocks compared to Ropivacaine. However, the duration of action was significantly longer with Bupivacaine, which aligns with previous research demonstrating its prolonged effect profile (Singh et al., 2017).[9] Ropivacaine, while slightly slower in onset, provided a shorter duration of block, which might be advantageous for shorter procedures or cases where early postoperative mobility is desired (Gonuguntla, 2016).[10] According to Singelyn (2001),[11] the slower onset and shorter duration of Ropivacaine are balanced by its favorable safety and reduced cardiotoxicity profile. Additionally, a meta-analysis by Li et al. (2017),[12] supports the use of Ropivacaine

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for peripheral nerve blocks due to its lower potency but better differential blockade, which often results in faster motor recovery.

Pain assessment revealed no significant difference between the groups at earlier postoperative time points (2–8 hours). However, at 12 hours, Group B showed significantly higher VAS scores than Group R. This slightly increased pain perception could result from the abrupt decline of Bupivacaine's prolonged block, potentially leaving a period of heightened sensitivity before systemic analgesics fully compensate. Similar findings were noted by Sejpal et al. (2019),[13] who reported higher pain scores with Bupivacaine as the block wore off. Ropivacaine's more gradual regression might result in a smoother transition to postoperative pain management, thus showing slightly better pain control at later time points despite its shorter block duration.

Throughout the intraoperative period, there were no significant differences in heart rate, systolic or diastolic blood pressure, or mean arterial pressure between the two groups, demonstrating that both drugs maintained hemodynamic stability. This observation supports existing literature emphasizing that both Bupivacaine and Ropivacaine are hemodynamically safe when used for peripheral nerve blocks (Lew et al., 2001).[14] Moreover, Ropivacaine, being less lipophilic than Bupivacaine, has a lower potential for cardiovascular and CNS toxicity, which is particularly advantageous in high-risk patients (Li et al., 2017).[12] Honnannavar and Mudakanagoudar (2017),[15] also reported similar hemodynamic stability in supraclavicular blocks using either agent.

The incidence of adverse events such as hypotension, bradycardia, and nausea/vomiting was slightly higher in the Bupivacaine group but not statistically significant. Importantly, there were no cases of local anesthetic systemic toxicity (LAST) in either group. This supports findings from Gupta et al. (2014),[16] who concluded that both Bupivacaine and Ropivacaine are associated with low rates of complications when used properly. Ropivacaine's reduced lipid solubility limits its penetration into cardiac and central nervous tissues, which contributes to its better safety profile (Lew et al., 2001).[14] These characteristics make Ropivacaine a suitable alternative to Bupivacaine, particularly when patient safety is a concern, such as in ambulatory settings or in elderly populations.

CONCLUSION

This study concludes that both Bupivacaine and Ropivacaine are effective and safe for use in supraclavicular brachial plexus blocks, with comparable hemodynamic stability and low incidence of adverse events. Bupivacaine offers a faster onset and longer duration of sensory and motor blockade, making it suitable for longer procedures. In contrast, Ropivacaine, with its shorter block duration and smoother regression, may be preferable when early postoperative recovery is desired. Pain control was similar in both groups, though Ropivacaine showed slightly better comfort at later time points. Overall, Ropivacaine presents a favorable safety profile, particularly in outpatient or high-risk patients.

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