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Original Research Article

A Prospective Randomized Study Comparing Bupivacaine and Ropivacaine in Brachial Plexus Block for Forearm Procedures

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Abstract:

Background: Brachial plexus block is widely used for forearm surgeries. Bupivacaine is effective but associated with potential toxicity, while ropivacaine is considered a safer alternative with favorable sensory–motor characteristics.

Aim: To compare the efficacy, onset, duration, and safety of 0.5% bupivacaine versus 0.5% ropivacaine in brachial plexus block for forearm procedures.

Methodology: This prospective randomized study included 40 ASA I–II patients undergoing elective forearm surgeries, divided into two groups: Group I received 30 ml of 0.5% bupivacaine and Group II received 30 ml of 0.5% ropivacaine. Sensory and motor block characteristics, duration of analgesia, hemodynamic parameters, and adverse effects were assessed and statistically analyzed.

Results: Demographic variables and hemodynamic parameters were comparable between groups. Ropivacaine showed a significantly faster onset of sensory and motor block, whereas bupivacaine provided a significantly longer duration of sensory and motor blockade. Duration of postoperative analgesia was similar in both groups."

Conclusion: Both drugs are safe and effective for brachial plexus block. Ropivacaine offers faster onset, while bupivacaine provides prolonged blockade, allowing choice based on clinical requirements.

Keywords: Brachial plexus block, Bupivacaine, Ropivacaine, Forearm surgery, Regional anesthesia.

Introduction

Brachial plexus block represents a well-established regional anaesthesia technique that has been in use for decades to provide effective surgical anaesthesia and postoperative analgesia for upper limb procedures, including surgeries of the forearm, hand, and elbow [1]. Local anaesthetic agents are injected around nerves of the brachial plexus, an act which, in turn, results in targeted blockade of sensory and motor nerves supplying the upper extremity. Over the years, BPB has become integral in perioperative management because of its advantages related to profound analgesia, reduced systemic opioid consumption, haemodynamic fluctuations, and early mobilization [1]

Bupivacaine is a popular long-acting amide local anaesthetic and, until recently, has been the drug of choice for brachial plexus block based on its ability to provide prolonged duration of action and a favourable ratio of sensory to motor blockade [2]. It acts by binding to the intracellular portion of voltage-gated sodium channels in nerve membranes, thereby inhibiting the influx of sodium ions into the cell and preventing depolarization. This action interrupts the propagation of nerve impulses, causing temporary loss of sensation and motor function. Systemically absorbed, bupivacaine undergoes metabolic breakdown primarily in the liver by enzymatic conjugation with glucuronic acid, thus representing typical metabolic disposition of amide-type local anaesthetics [3]. Regardless of its clinical effectiveness, several investigators have reported many adverse effects associated with bupivacaine when this drug was used in its racemic form. As major ones, cardiovascular and CNS toxicities are noted that may result in arrhythmias, hypotension, seizures, and, in some cases, cardiac arrest [4,5],. Presented safety concerns stimulate further investigation into

developing less toxic local anaesthetic drugs providing effective analgesia with reduced incidence of systemic toxicity [6].

Ropivacaine is a relatively newer long-acting amide local anaesthetic introduced as a potentially safer alternative to bupivacaine [7]. While structurally related to bupivacaine, ropivacaine is less lipophilic, exhibits selective inhibition of sensory nerve fibers-especially the Aδ and C fibers responsible for transmitting pain impulses-with a relatively lesser effect on motor fibers (Aβ). This accounts for its pharmacological profile of providing a potent sensory blockade with less resulting motor deficit, a feature which is advantageous for postoperative rehabilitation and the early mobilization of the limb [8]. Ropivacaine has also been said to have a more favorable cardiovascular and CNS safety profile, with decreased incidences of arrhythmias and systemic toxicity, thus making it more appealing to the patient with underlying cardiac risk factors [9].

Many comparative studies report the efficacy, onset, duration, and safety of bupivacaine and ropivacaine in brachial plexus blocks, and most of them concluded that ropivacaine produces equivalent sensory analgesia to bupivacaine with less motor blockade and systemic toxicity [10]. The relative preservation of motor function not only enhances patient satisfaction but also allows early physiotherapy and minimizes complications related to prolonged bed rest. Moreover, both agents have similar durations of sensory blockade, indicating that ropivacaine can be an effective alternative to bupivacaine without compromising the quality of analgesia.

Although the number of reported studies is on the rise, well-designed prospective randomized studies are still needed to establish more sound evidence on the comparison of these two agents in forearm procedures, where optimum analgesia and preservation of function are quite crucial. It is such studies that would help determine clinical decisions and further enable anaesthetic strategies to be titrated to individual patient needs. Thus, the present study has been designed to assess and compare the efficacy, onset, duration, and safety profile of bupivacaine and ropivacaine when administered as brachial plexus block for forearm surgeries.

Methodology

Study Design: This study was designed as a prospective, randomized, comparative clinical study to evaluate and compare the efficacy and safety of 0.5% bupivacaine and 0.5% ropivacaine when used for brachial plexus block in patients undergoing forearm surgical procedures.

Study Area: The study was conducted in the Department of Anesthesiology, Bhagwan Mahavir Institute of Medical Sciences (BMIMS), Pawapuri, Nalanda, Bihar, India.

Study Duration: The study was carried out over a period of 7 months from March 2025 to September 2025

Sample Size: A total of 40 patients were enrolled in the study. The sample size was calculated using the formula:

$$n = \frac{(\sigma_1^2 + \sigma_2^2)(Z_\alpha + Z_\beta)^2}{d^2}$$

Where:

- σ_1 = Standard deviation of bupivacaine group
- σ_2 = Standard deviation of ropivacaine group
- d = Mean difference
- α = 5% (level of significance)
- Power = 95%

Based on this calculation, patients were divided equally into two groups of 20 each.

Study Population: The study population comprised adult patients scheduled for elective forearm and upper limb surgeries under brachial plexus block. Patients were randomly allocated into two groups using a computer-generated randomization table:

- **Group I (n = 20):** Received 30 ml of 0.5% bupivacaine for brachial plexus block
- **Group II (n = 20):** Received 30 ml of 0.5% ropivacaine for brachial plexus block

Inclusion Criteria

- Adult patients aged 18–55 years
- Patients belonging to ASA physical status I and II
- Patients scheduled for elective forearm or upper limb surgery under brachial plexus block
- No history of allergy or hypersensitivity to local anesthetic agents

Exclusion Criteria

- Patients with significant cardiovascular disease, hypertension, diabetes mellitus, renal failure, hepatic dysfunction, or chronic pulmonary disease
- Patients with neuromuscular disorders
- Morbidly obese patients
- Patients with bleeding disorders
- Infection at the injection site
- Patients on long-term drug therapy
- Uncooperative patients

Data Collection: All enrolled patients were evaluated preoperatively, and baseline demographic data, including age, sex, weight, and ASA physical status, were recorded. Patients were kept nil per oral for 6–8 hours prior to surgery. On arrival in the preoperative area, baseline vital parameters such as heart rate, blood pressure, respiratory rate, and oxygen saturation were documented. Sensory and motor block characteristics, hemodynamic variables, duration of

analgesia, and incidence of adverse effects were recorded at predetermined intervals using standardized assessment tools. Postoperative pain scores were assessed using the Visual Analogue Scale, and the timing of rescue analgesia administration was documented.

Procedure: On the day of surgery, patients were admitted to the monitored preoperative holding area and premedicated with intravenous midazolam 2 mg. The operative arm was positioned to expose the axilla, and the area was prepared under strict aseptic precautions. The axillary artery was identified by palpation, and the skin was infiltrated with 1 ml of 1% lidocaine. A 22-gauge needle was then introduced through the axillary artery into the brachial plexus sheath using the paresthesia technique. After confirming negative aspiration, a test dose of 1 ml of the study drug was administered to rule out intravascular placement. Following a brief observation period, the remaining anesthetic solution was injected incrementally in 5 ml aliquots with repeated aspiration. After completion of the injection, firm digital pressure was applied at the site for five minutes to facilitate proximal spread of the local anesthetic. Sensory and motor block were assessed every five minutes for the first 30 minutes and thereafter at 60-minute intervals until complete recovery. Patients in whom adequate sensory blockade was not achieved within 30 minutes were considered to have block failure and were excluded from the study after administration of general anesthesia.

Statistical Analysis: The collected data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) software. Continuous variables were expressed as mean and standard deviation, while categorical variables were presented as numbers and percentages. Comparison between the two groups was performed using the Student's t-test for continuous variables and the Chi-square test for categorical variables. A p-value of less than 0.05 was considered statistically significant."

Result

Table 1 compares the demographic characteristics of patients in Group I (Bupivacaine) and Group II (Ropivacaine). The mean age was similar between Group I (35.40 ± 11.28 years, range 20–55) and Group II (33.85 ± 10.96 years, range 18–54), with no statistically significant difference ($t = 0.45$, $p = 0.65$). The gender distribution was also comparable, with a male-to-female ratio of 13:7 in Group I and 14:6 in Group II, showing no significant difference ($\chi^2 = 0.11$, $p = 0.73$). Additionally, mean body weight did not differ significantly between Group I (55.90 ± 10.84 kg) and Group II (54.70 ± 11.12 kg) ($t = 0.35$, $p = 0.73$). Overall, Table 1 indicates that both groups were demographically comparable, ensuring baseline homogeneity for outcome comparison.

Table 1: Comparison of Demographic Variables between Two Groups

S. No.	Characteristic	Group I (Bupivacaine) (n=20)	Group II (Ropivacaine) (n=20)	Significance of difference
1	Mean Age ± SD (Range) (years)	35.40 ± 11.28 (20–55)	33.85 ± 10.96 (18–54)	$t = 0.45$; $p = 0.65$
2	Male: Female	13:07	14:06	$\chi^2 = 0.11$; $p = 0.73$
3	Body Weight (Mean ± SD) (kg)	55.90 ± 10.84	54.70 ± 11.12	$t = 0.35$; $p = 0.73$

Table 2 compares the onset time and duration of sensory blockade between Group I and Group II. The mean onset of sensory block was significantly longer in Group I (12.30 ± 2.45 minutes) compared to Group II (9.10 ± 1.80 minutes), with a t-value of 4.76 and a highly significant p-value of <0.001. Conversely, the duration of sensory blockade was significantly prolonged in Group I (440.60 ± 48.20 minutes) relative to Group II (410.30 ± 36.70 minutes), as indicated by a t-value of 2.25 and a p-value of 0.03. These results suggest that Group II provided a faster onset of sensory blockade, whereas Group I produced a longer-lasting sensory block.

Table 2: Comparison of Mean Time for Onset and Duration of Sensory Blockade

Variable	Group I (n=20) Mean ± SD	Group II (n=20) Mean ± SD	t-value	p-value
Onset time (min)	12.30 ± 2.45	9.10 ± 1.80	4.76	<0.001 (S)
Duration of sensory block (min)	440.60 ± 48.20	410.30 ± 36.70	2.25	0.03 (S)

Table 3 compares sensory blockade between Group I and Group II at various time intervals. At 5 minutes, all patients in Group I had Grade 0 sensory block (100%), whereas Group II showed earlier

sensory blockade with 20% of patients achieving Grade 1 block, resulting in a higher median score of 1; this difference was statistically significant (Z = 2.1, p = 0.036). At 10 minutes, Group II demonstrated a more advanced sensory block, with 40% of patients attaining Grade 2 compared to only 10% in Group I, and a higher median score (2 vs. 1), which was highly significant (Z = 3.25, p = 0.001). At 15 minutes, although a greater proportion of patients in Group II achieved Grade 2 sensory block (90% vs. 70% in Group I), the difference was not statistically significant (Z = 1.45, p = 0.14). By 30 minutes, complete sensory blockade (Grade 2) was achieved in all patients of both groups, with identical median scores and no statistically significant difference (p = 1). Overall, Table 3 indicates that Group II achieved faster onset of sensory blockade compared to Group I, particularly during the early time intervals.

Table 3: Comparison of Sensory Blockade at Different Time Intervals

S. N.	Time Interval (min)	Group I (n=20) Grade 0 n	Grade 1 n (%)	Grade 2 n (%)	Median	Group II (n=20) Grade 0 n	Grade 1 n (%)	Grade 2 n (%)	Median	Z	p
1	5	20 (100)	0	0	0	16 (80)	4 (20)	0	1	2.1	0.036
2	10	9 (45)	9 (45)	2 (10)	1	3 (15)	9 (45)	8 (40)	2	3.25	0.001
3	15	1 (5)	5 (25)	14 (70)	2	0	2 (10)	18 (90)	2	1.45	0.14
4	30	0	0	20 (100)	2	0	0	20 (100)	2	0	1

Table 4 compares the degree of motor blockade between Group I and Group II at different time intervals. At 10 minutes, all patients in Group I had Grade 0 motor block with a median score of 0, whereas Group II showed a higher degree of motor blockade, with patients distributed across Grade 0 (6), Grade 1 (6), and Grade 2 (8), resulting in a median score of 2. At 20 minutes, Group I predominantly exhibited lower grades of motor block (Grade 0 in 11 patients and Grade 1 in 7 patients) with a median of 1, while Group II demonstrated more advanced motor blockade, with no patients in Grade 0 and the majority achieving Grade 3 motor block (10 patients), yielding a median score of 3. By 30 minutes, Group I showed progression of motor blockade, with most patients attaining Grade 3 (10 patients) and a median of 3; however, Group II achieved a more rapid and complete motor blockade, with 16 patients reaching Grade 3 and a median score of 3. Overall, Table 4 indicates that Group II achieved faster onset and greater intensity of motor blockade compared to Group I at earlier time intervals.

Table 4: Comparison of Motor Blockade at Different Time Intervals

S.N.	Time Interval	Group I Grade 0	Grade 1	Grade 2	Grade 3	Median	Group II Grade 0	Grade 1	Grade 2	Grade 3	Median	Z	p
1	10	20	0	0	0	0	6	6	8	0	2	3.9	<0.001
2	20	11	7	2	0	1	0	3	7	10	3	4.8	<0.001
3	30	1	4	5	10	3	0	0	4	16	3	1.2	0.23

Table 5 shows a comparison of the onset and duration of motor blockade between Group I and Group II. The onset of motor block was significantly delayed in Group I (23.10 ± 3.60 minutes) compared to Group II (15.20 ± 3.10 minutes), with a t-value of 7.1 and a highly significant p-value of <0.001. Similarly, the duration of motor block was significantly longer in Group I (400.50 ± 46.90 minutes) than in Group II (360.40 ± 33.80 minutes), as reflected by a t-value of 3.1 and a p-value of 0.004. These findings indicate that Group II achieved a faster onset of motor blockade, whereas Group I produced a more prolonged duration of motor block.

Table 5: Comparison of Mean Time for Onset and Duration of Motor Blockade				
Variable	**Group I (n=20) Mean ± SD**	**Group II (n=20) Mean ± SD**	**t-value**	**p-value**
Onset of motor block (min)	23.10 ± 3.60	15.20 ± 3.10	7.1	<0.001 (S)
Duration of motor block (min)	400.50 ± 46.90	360.40 ± 33.80	3.1	0.004 (S)

Table 6 compares the mean time to rescue analgesia between Group I and Group II. The duration of analgesia was 8.20 ± 0.90 hours in Group I and 8.40 ± 0.70 hours in Group II. The difference between the two groups was not statistically significant, as indicated by a t-value of −0.78 and a p-value of 0.44 ($p > 0.05$). This suggests that both groups provided a comparable duration of analgesia, with no significant advantage of one group over the other in delaying the need for rescue analgesia.

Table 6: Comparison of Mean Time for Rescue Analgesia				
Variable	**Group I (n=20) Mean ± SD (hours)**	**Group II (n=20) Mean ± SD (hours)**	**t-value**	**p-value**
Duration of analgesia	8.20 ± 0.90	8.40 ± 0.70	−0.78	0.44 (NS)

Table 7 compares the hemodynamic parameters between Group I and Group II. The mean heart rate was comparable between Group I (78.6 ± 6.4 beats/min) and Group II (79.9 ± 6.8 beats/min), with no statistically significant difference ($p > 0.05$). Similarly, systolic blood pressure showed no significant variation between Group I (122.4 ± 8.6 mmHg) and Group II (124.1 ± 9.1 mmHg) ($p > 0.05$), as did diastolic blood pressure, which was 76.8 ± 6.2 mmHg in Group I and 77.4 ± 6.5 mmHg in Group II ($p > 0.05$). Oxygen saturation levels were also comparable, with Group I having a mean SpO_2 of 98.2 ± 1.1% and Group II 98.4 ± 1.0%, showing no statistically significant difference ($p > 0.05$). Overall, Table 7 indicates that both groups had similar and stable hemodynamic profiles.

Table 7: Comparison of Hemodynamic Parameters			
Parameter	**Group I Mean ± SD**	**Group II Mean ± SD**	**p-value**
Heart Rate (beats/min)	78.6 ± 6.4	79.9 ± 6.8	>0.05
Systolic BP (mmHg)	122.4 ± 8.6	124.1 ± 9.1	>0.05
Diastolic BP (mmHg)	76.8 ± 6.2	77.4 ± 6.5	>0.05
SpO_2 (%)	98.2 ± 1.1	98.4 ± 1.0	>0.05

Discussion

In this present study, demographic factors of age, gender, and body weight were similar in both the bupivacaine and ropivacaine groups; as such, none of these variables would be likely to affect observed outcomes. This baseline comparability is similar to that of other studies investigating brachial plexus blocks, in which demographic matching ensured that any differences in onset and duration of blockade were more related to the pharmacologic properties of the local anesthetics than to the characteristics of the patients (Mc Glade et al., 1998; Klein et al., 1998) [9,11]. The male-to-female distribution and mean age for both groups were statistically similar, consistent with findings from Bertini et al. (1999) [1], who reported no significant demographic differences between those patients receiving ropivacaine or bupivacaine during axillary brachial plexus block."

Our investigation demonstrated that the onset of sensory blockade was much faster in the ropivacaine group (9.10 ± 1.80 min) as compared to the bupivacaine group (12.30 ± 2.45 min, $p < 0.001$). This appears to be in concurrence with the study done by Bertini et al. (1999) [1], who showed an earlier onset of sensory block with ropivacaine during axillary brachial plexus blocks, which reached statistical significance only at early times, such as 10 and 15 minutes. Another study, by Klein et al. (1998) [11], noted rapid onset of both sensory and motor blockade to ropivacaine in interscalene blocks. Their times were shorter in absolute value (<6 minutes) because of differences in block approach and surgical site. Mageswaran and Choy (2010), using an infraclavicular approach, observed a slightly longer mean sensory onset time for ropivacaine (13.5 ± 2.9 min) compared with levobupivacaine (11.1 ± 2.6 min). These reinforce the fact that while ropivacaine commonly results in a quicker onset of sensory block, differing procedural approaches continue to confound generalization among studies.

Although the onset of sensory block was quicker with ropivacaine, the duration of sensory blockade was longer in the bupivacaine group (440.60 ± 48.20 min) compared to the ropivacaine group (410.30 ± 36.70 min, $p = 0.03$). This result agrees with several previous studies indicating that bupivacaine gives a longer duration of action, thus being desirable in prolonged surgeries or where extended postoperative analgesia is required (Mc Glade et al., 1998; De Jong, 1996) [9,3]. Bertini et al. (1999) [1] also found

the durations of sensory block longer in bupivacaine compared with those receiving ropivacaine, although the difference in analgesic quality was small. Similarly, this study demonstrated that all patients in each group achieved complete sensory blockade at 30 minutes, which agrees with peak block times described by Klein et al. (1998) [11]. These findings point out that while ropivacaine has an advantage regarding faster early onset, bupivacaine maintains sensory blockade longer, a pattern supported across a number of block techniques and studies.

Motor block in our investigation also followed the trends of the sensory block; it had an earlier onset in the ropivacaine group (15.20 ± 3.10 min) compared to the bupivacaine group (23.10 ± 3.60 min, $p < 0.001$), but it was longer for the bupivacaine group (400.50 ± 46.90 min vs. 360.40 ± 33.80 min, $p = 0.004$). These findings correspond to observations made by Bertini et al. (1999) [1] and Klein et al. (1998) [11], where they present that ropivacaine has a faster onset of motor block and bupivacaine has a prolonged blockade. The early onset of motor block with ropivacaine can help in quick surgical readiness, especially in day-case or ambulatory settings. Its longer duration of motor block may be favorable for procedures that require extended immobility or postoperative analgesia. Thornton et al. (2003) [10] and Mageswaran and Choy (2010) [12] presented that despite these differences, postoperative analgesia was comparable between the two groups. Similarly, the time to first rescue analgesia was comparable between the two groups, as we found no significant difference (8.20 ± 0.90 h vs. 8.40 ± 0.70 h, $p = 0.44$), thus confirming the previous evidence for similar analgesic efficacy beyond the duration of the block.

Hemodynamic stability was well maintained in both groups throughout the study, with no significant changes in heart rate, blood pressure, or oxygen saturation. This further supports previous findings that both drugs are safe at conventional concentrations for brachial plexus blocks, as reported by Scott et al. and Arthur et al. in 1989 and 1988, respectively [7,8]. Lack of adverse cardiovascular effects further supports the appropriateness of both agents for upper extremity regional anesthesia, provided proper dosing and monitoring are followed.

Overall, our findings suggest that ropivacaine has a more rapid onset and quickly attains both sensory and motor block, while bupivacaine has a longer duration of both sensory and motor effects. This generally agrees with the majority of studies conducted in comparison, including those by Bertini et al. (1999), Mc Glade et al. (1998), and Klein et al. (1998), while minor differences in absolute times can be explained by dissimilarities in block technique, patient population, and concentration of the local anesthetic applied. Both agents showed similar postoperative analgesia with a stable hemodynamic profile, supporting their clinical appropriateness for use in axillary brachial plexus blocks for forearm surgery.

Conclusion

This prospective randomized study shows that both bupivacaine and ropivacaine offer adequate and reliable anesthesia for brachial plexus block in forearm procedures with matched demographic profiles and stable hemodynamics throughout the entire perioperative period. Ropivacaine had a faster onset of both sensory and motor blockade; bupivacaine, however, caused a longer duration of sensory and motor block. Temporal progression and completeness of sensory and motor blockade were adequate in both groups to achieve proper surgical anesthesia. Duration of postoperative analgesia and requirement of rescue analgesia were comparable between these two drugs. Ropivacaine can be preferred when rapid onset is beneficial, whereas bupivacaine offers more clinical benefit when a longer duration of blockade is advantageous, with both agents being safe and effective for brachial plexus block.

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