Section: Anesthesiology

Original Research Article

A COMPARATIVE EVALUATION OF HYPERBARIC ROPIVACAINE (0.75%) VERSUS HYPERBARIC BUPIVACAINE (0.5%) FOR SPINAL ANESTHESIA IN CESAREAN SECTION: A PROSPECTIVE OBSERVATIONAL STUDY

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Received *: 12/09/2025*
Received in revised form *: 04/11/2025*
Accepted *: 21/11/2025*

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DOI: 10.70034/ijmedph.2025.4.329

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2025; 15 (4); 1838-1843

ABSTRACT

Background: Spinal anesthesia remains the preferred technique for cesarean section due to its safety profile and reliability. While hyperbaric bupivacaine has been the gold standard, ropivacaine offers potential advantages including reduced motor blockade and lower toxicity. This study compared the clinical efficacy and safety profile of hyperbaric ropivacaine (0.75%) with hyperbaric bupivacaine (0.5%) in parturients undergoing cesarean delivery.

Materials and Methods: This prospective, observational, comparative study was conducted at a tertiary care teaching hospital between May 2022 and May 2023. Sixty parturients (ASA II, aged 18-40 years) scheduled for elective cesarean section were allocated into two groups through consecutive sampling: Group B received 2 ml hyperbaric bupivacaine 0.5% (10 mg) and Group R received 2 ml hyperbaric ropivacaine 0.75% (15 mg) intrathecally. Primary outcomes included onset and duration of sensory and motor blockade. Secondary outcomes comprised hemodynamic parameters and adverse effects. Statistical analysis was performed using unpaired t-test and chi-square test, with $p<0.05$ considered significant.

Results: The onset of sensory blockade was significantly faster in Group B compared to Group R (2.77±0.67 vs. 3.63±0.71 minutes, $p<0.0001$). Similarly, motor blockade onset was earlier in Group B (3.57±0.77 vs. 4.1±0.88 minutes, $p=0.016$). However, both sensory (156.53±15.46 vs. 131.9±16.06 minutes, $p<0.0001$) and motor blockade duration (141.40±16.13 vs. 114.76±15.86 minutes, $p<0.0001$) were significantly shorter in Group R. Hemodynamic stability was comparable between groups. Adverse effects were clinically insignificant.

Conclusion: Hyperbaric ropivacaine 0.75% provides effective spinal anesthesia for cesarean section with slightly delayed onset but significantly shorter duration of motor blockade compared to bupivacaine 0.5%, potentially facilitating earlier ambulation and discharge.

Keywords: Spinal anesthesia, Cesarean section, Hyperbaric ropivacaine, Hyperbaric bupivacaine, Motor blockade, Sensory blockade.

INTRODUCTION

Spinal anesthesia, also termed subarachnoid block, represents a cornerstone of regional anesthetic techniques for lower abdominal and pelvic surgical procedures. This technique involves the deliberate injection of local anesthetic agents into the cerebrospinal fluid within the subarachnoid space, producing reversible neural blockade of spinal nerve roots.[1] The widespread acceptance of spinal

anesthesia stems from its numerous advantages over general anesthesia, including preservation of consciousness, maintenance of spontaneous ventilation, reduced perioperative blood loss, decreased thromboembolic complications, and faster return of gastrointestinal function.[2] These attributes make spinal anesthesia particularly advantageous for cesarean delivery, where maternal safety and neonatal outcomes are paramount considerations.[3]

For several decades, hyperbaric bupivacaine has maintained its position as the reference standard local anesthetic for spinal anesthesia in obstetric practice. Bupivacaine, an aminoamide local anesthetic of the pipecoloxylidide class, exists as a racemic mixture containing both S- and R-enantiomers.[4] Its popularity derives from its long duration of action, profound sensory analgesia, and dense motor blockade. However, accumulating evidence has highlighted significant concerns regarding bupivacaine's safety profile, particularly its potential for cardiotoxicity and neurotoxicity when inadvertent intravascular injection occurs.[5] Additionally, the prolonged motor blockade associated with bupivacaine may delay ambulation and increase the duration of postoperative monitoring, which has implications for healthcare resource utilization and patient satisfaction.[6]

Ropivacaine, a newer aminoamide local anesthetic, has emerged as a promising alternative to bupivacaine for neuraxial anesthesia. Structurally similar to bupivacaine but formulated as a pure S-enantiomer, ropivacaine exhibits reduced lipid solubility and lower central nervous system and cardiac toxicity.[7] The stereochemical purity of ropivacaine confers differential blockade characteristics, with preferential inhibition of sensory A-delta and C fibers over motor A-alpha fibers.[8] This sensory-motor dissociation theoretically permits adequate surgical anesthesia while minimizing motor impairment, potentially facilitating earlier mobilization following surgery. Several investigations have demonstrated ropivacaine's efficacy for spinal anesthesia in various surgical contexts,[9,10] however, comparative data specifically addressing its performance against bupivacaine in the cesarean section population remain limited and occasionally contradictory.

Contemporary obstetric anesthetic practice increasingly emphasizes enhanced recovery protocols, which prioritize techniques that facilitate early ambulation, reduce opioid consumption, and minimize maternal-fetal drug transfer.[11] The selection of an optimal local anesthetic agent for spinal anesthesia must therefore balance multiple considerations, including onset time, block quality, duration, hemodynamic stability, and side effect profile. Previous comparative studies have yielded variable conclusions regarding the equipotent doses of ropivacaine and bupivacaine, with some investigators suggesting that ropivacaine requires 50% higher dosing to achieve comparable block characteristics.[12] The baricity of local anesthetic solutions further influences block height and spread, making hyperbaric preparations particularly suitable for predictable, controlled cesarean section anesthesia.[13]

Despite growing interest in ropivacaine for obstetric neuraxial anesthesia, a research gap persists regarding its optimal concentration and dose for cesarean delivery. Furthermore, comprehensive head-to-head comparisons evaluating clinically relevant endpoints such as block characteristics, hemodynamic effects, and safety parameters are needed to inform evidence-based practice. Understanding the comparative performance of these agents may guide anesthetic selection based on individual patient factors, surgical duration, and institutional protocols.

Given this background, we conducted a prospective observational study to systematically compare the clinical efficacy and safety of hyperbaric ropivacaine 0.75% (15 mg) with hyperbaric bupivacaine 0.5% (10 mg) for spinal anesthesia in parturients undergoing elective cesarean section. We hypothesized that ropivacaine would provide adequate surgical anesthesia with shorter motor blockade duration while maintaining comparable hemodynamic stability. The primary objectives were to compare onset times and durations of sensory and motor blockade between the two agents. Secondary objectives included assessment of hemodynamic parameters and documentation of adverse effects.

MATERIALS AND METHODS

Study Design and Setting: This prospective, observational, comparative study was conducted in the Department of Anesthesiology at a tertiary care teaching hospital in Western India over a 12-month period from May 2022 to May 2023. The study protocol received approval from the Institutional Ethics Committee, and written informed consent was obtained from all participants prior to enrollment. The investigation adhered to the principles of the Declaration of Helsinki and Good Clinical Practice guidelines.

Sample Size Calculation: Sample size determination was performed based on pilot data from 10 patients (5 per group). Using diastolic blood pressure at 5 minutes as the reference parameter, with mean values of 76.0 mmHg (SD=7.2) in the ropivacaine group and 70.3 mmHg (SD=8.0) in the bupivacaine group, power calculation yielded a required sample size of 30 patients per group (alpha=0.05, power=80%, delta=-5.7) using STATA version 15 software. Therefore, the total study population comprised 60 participants.

Study Population and Sampling: Participants were recruited through consecutive non-randomized sampling. Allocation to treatment groups was based on clinical practice patterns and consultant preference rather than formal randomization. Eligible participants were parturients scheduled for elective

cesarean section who met the following inclusion criteria: female gender, age 18-40 years, singleton pregnancy at term (≥37 weeks gestation), and American Society of Anesthesiologists (ASA) physical status class II. Exclusion criteria encompassed known hypersensitivity to aminoamide local anesthetics, hepatic or renal dysfunction, cardiopulmonary abnormalities, coagulopathy or bleeding diathesis, infection at the proposed puncture site, history of significant neurological or psychiatric disorders, neuromuscular diseases, and eclampsia.

Group Allocation

Participants were allocated to two groups:

- Group B (n=30): Received 2 ml hyperbaric bupivacaine 0.5% (10 mg) for spinal anesthesia
- Group R (n=30): Received 2 ml hyperbaric ropivacaine 0.75% (15 mg) for spinal anesthesia

Preoperative Preparation: All participants underwent comprehensive preanesthetic evaluation including medical history, physical examination, airway assessment, and lumbar spine examination. Baseline investigations included complete blood count, random blood glucose, and electrocardiography. Participants were instructed to fast for 8 hours prior to surgery and received detailed explanation regarding sensory and motor assessment techniques.

Anesthetic Technique: Upon arrival in the operating theater, standard monitoring was established including continuous electrocardiography, non-invasive blood pressure measurement, and pulse oximetry. Baseline vital signs were recorded. Intravenous access was secured using an 20-gauge cannula, and crystalloid preloading (10 ml/kg) was administered over 30 minutes. Premedication consisted of intravenous ranitidine 50 mg and metoclopramide 10 mg.

Spinal anesthesia was performed with participants in the sitting position. Following aseptic skin preparation with povidone-iodine solution and sterile draping, the L3-L4 interspace was identified using the intercristal line as anatomical landmark. A 25-gauge Quincke spinal needle was inserted via midline approach. After confirming free flow of cerebrospinal fluid by aspiration, the assigned study drug was injected slowly over 45 seconds. Participants were immediately positioned supine with 15-degree left lateral tilt to prevent aortocaval compression.

Assessment Parameters:

Sensory Blockade: Assessed using pinprick method with a sterile 23-gauge hypodermic needle. Sensation was graded as: Grade 0 (normal sensation), Grade 1 (blunted sensation), or Grade 2 (complete absence of sensation). Onset of sensory blockade was defined as time from completion of intrathecal injection to loss of pinprick sensation at the T10 dermatome. Duration of sensory blockade was measured from injection to regression of sensory level to L1 dermatome.

Motor Blockade: Evaluated using the modified Bromage scale: Grade 0 (no paralysis, full leg movement), Grade 1 (inability to raise extended leg, able to flex knee), Grade 2 (inability to flex knee, able to flex ankle), and Grade 3 (complete paralysis, no movement). Onset of motor blockade was recorded as time to achieve Bromage Grade 3. Duration of motor blockade was measured from onset of complete motor block to return of free movement (Bromage Grade 0).

Sensory and motor assessments were performed every minute for the first 5 minutes, then every 5 minutes until 20 minutes, and subsequently every 30 minutes postoperatively until complete resolution. Surgery commenced after achieving sensory blockade at T6 dermatome (Grade 2) and complete motor blockade (Bromage Grade 3).

Hemodynamic Monitoring: Heart rate, systolic blood pressure, diastolic blood pressure, mean arterial pressure, and oxygen saturation were recorded at baseline, immediately after spinal injection, then at 5, 10, 15, 20, 25, 30, 45, 60, 90, and 120 minutes. Hypotension was defined as >25% decrease from baseline mean arterial pressure or absolute value <60 mmHg, treated with 6 mg intravenous ephedrine. Bradycardia (heart rate <60 bpm) was managed with 0.6 mg intravenous atropine. Hypoxia (SpO_2 <93%) was treated with supplemental oxygen via face mask.

Adverse Effects: All participants were monitored for complications including hypotension, bradycardia, nausea, vomiting, pruritus, shivering, and respiratory depression.

Statistical Analysis: Data were analyzed using IBM SPSS version 22.0 and Microsoft Office 2019. Qualitative variables were expressed as frequencies and percentages. Quantitative variables were presented as mean ± standard deviation. Comparison of continuous variables between groups was performed using unpaired t-test for normally distributed data and Mann-Whitney U test for non-parametric data. Categorical variables were compared using chi-square test or Fisher's exact test as appropriate. Statistical significance was set at $p<0.05$ (two-tailed).

RESULTS

A total of 60 parturients were enrolled and completed the study, with 30 participants allocated to each group. All participants received the intended intervention, and no case required conversion to general anesthesia due to inadequate spinal blockade.

Demographic and Clinical Characteristics:

[Table 1] presents the baseline demographic and anthropometric characteristics of study participants. The groups were comparable regarding age distribution, with mean ages of 26.57±4.43 years in Group B and 26.76±4.09 years in Group R (p=0.864). Similarly, no statistically significant differences were observed between groups for height (164.53±6.79 vs. 163.4±8.07 cm, p=0.560), weight (69.57±5.90 vs. 67.7±7.96 kg, p=0.306), or body mass index (25.94±1.63 vs. 25.40±2.18 kg/m², p=0.282). The mean duration of surgery was nearly identical

between groups (36.17±4.49 vs. 36.67±5.92 minutes, p=0.714), indicating comparable surgical complexity and operative time.

Table 1: Demographic and Clinical Characteristics

Parameter	Group B (n=30)	Group R (n=30)	P-value
Age (years)	26.57 ± 4.43	26.76 ± 4.09	0.864
Height (cm)	164.53 ± 6.79	163.4 ± 8.07	0.560
Weight (kg)	69.57 ± 5.90	67.7 ± 7.96	0.306
BMI (kg/m²)	25.94 ± 1.63	25.40 ± 2.18	0.282
Duration of surgery (min)	36.17 ± 4.49	36.67 ± 5.92	0.714

Values expressed as mean ± standard deviation; BMI = body mass index

Block Characteristics

[Table 2] summarizes the comparative block characteristics between the two groups. The onset of sensory blockade was significantly faster in Group B compared to Group R (2.77±0.67 vs. 3.63±0.71 minutes, p<0.0001), representing approximately a 30% longer onset time with ropivacaine. Similarly, motor blockade onset occurred significantly earlier in the bupivacaine group (3.57±0.77 vs. 4.1±0.88 minutes, p=0.016).

Conversely, both the duration of sensory blockade and motor blockade were significantly prolonged in Group B compared to Group R. Mean sensory blockade duration was 156.53±15.46 minutes in the bupivacaine group versus 131.9±16.06 minutes in the ropivacaine group (p<0.0001), representing approximately 18% shorter duration with ropivacaine. The difference in motor blockade duration was even more pronounced, with Group B demonstrating 141.40±16.13 minutes compared to 114.76±15.86 minutes in Group R (p<0.0001), corresponding to approximately 23% reduction in motor block duration with ropivacaine.

Table 2: Comparison of Block Characteristics

Parameter	Group B (n=30)	Group R (n=30)	P-value
Onset of sensory blockade (min)	2.77 ± 0.67	3.63 ± 0.71	<0.0001
Onset of motor blockade (min)	3.57 ± 0.77	4.1 ± 0.88	0.016
Duration of sensory blockade (min)	156.53 ± 15.46	131.9 ± 16.06	<0.0001
Duration of motor blockade (min)	141.40 ± 16.13	114.76 ± 15.86	<0.0001

Values expressed as mean ± standard deviation

Hemodynamic Parameters and Adverse Effects:

Hemodynamic stability was well maintained in both groups throughout the perioperative period. Heart rate demonstrated no statistically significant differences between groups at any measured timepoint from baseline through 120 minutes postoperatively (all p>0.05). Similarly, systolic blood pressure, diastolic blood pressure, mean arterial pressure, and oxygen saturation remained comparable between groups across all measurement intervals, with no significant intergroup differences observed.

Table 3: Comparison of Adverse Effects

Adverse Effect	Group B (n=30)	Group R (n=30)	P-value
Hypotension	3 (10.0%)	1 (3.3%)	0.301
Bradycardia	1 (3.3%)	1 (3.3%)	1.000
Nausea/Vomiting	2 (6.7%)	0 (0%)	0.553
Total complications	6 (20.0%)	2 (6.7%)	0.254

Values expressed as number (percentage)

The incidence of adverse effects was low in both groups and did not differ significantly [Table 3]. Hypotension occurred in three participants (10%) in Group B compared to one participant (3.3%) in Group R, though this difference was not statistically significant (p=0.301). Bradycardia was observed in one participant in each group (3.3%, p=1.000). Two participants in Group B experienced nausea and vomiting, while none in Group R reported these symptoms (p=0.553). All adverse effects were promptly managed with standard interventions and resolved without sequelae. No cases of respiratory depression, high spinal, total spinal anesthesia, or neurological complications were observed in either group.

DISCUSSION

The present study provides comparative evidence regarding the clinical performance of hyperbaric ropivacaine 0.75% and hyperbaric bupivacaine 0.5% for spinal anesthesia in cesarean section. Our principal findings demonstrate that while bupivacaine exhibits faster onset of both sensory and motor blockade, ropivacaine produces significantly shorter duration of motor blockade with comparable hemodynamic stability and safety profile. These results have important implications for clinical

practice, particularly in the context of enhanced recovery protocols that prioritize early ambulation.

The faster onset of sensory and motor blockade observed with bupivacaine aligns with findings from previous comparative investigations.[14,15] Our observed mean sensory block onset times of 2.77 minutes for bupivacaine versus 3.63 minutes for ropivacaine closely parallel those reported by Chung and colleagues, who documented onset times of 2.5 and 3.2 minutes respectively using similar doses in parturients undergoing cesarean delivery.[12] The differential onset kinetics may be attributed to the slightly higher lipid solubility of the racemic bupivacaine mixture compared to the pure S-enantiomer formulation of ropivacaine, facilitating more rapid neural membrane penetration.[7] From a clinical perspective, the approximately 1-minute difference in onset time, while statistically significant, represents a minimal delay that is unlikely to impact surgical workflow or patient satisfaction substantially.

The significantly shorter duration of motor blockade with ropivacaine represents perhaps the most clinically relevant finding of our investigation. The 26.6-minute reduction in motor block duration (114.76 vs. 141.40 minutes) offers substantial practical advantages in the postoperative period. Early recovery of motor function facilitates earlier ambulation, which is associated with reduced risk of venous thromboembolism, faster return of bladder function, and enhanced patient autonomy.[2,16] These benefits are particularly salient in contemporary obstetric practice, where enhanced recovery after cesarean delivery (ERAC) protocols emphasize interventions that accelerate functional recovery and hospital discharge.[11] Our findings corroborate those of Kulkarni and associates, who reported motor block durations of 102.75 minutes with ropivacaine compared to 146 minutes with bupivacaine, demonstrating approximately 30% reduction similar to our results.[9]

The differential motor-sensory blockade characteristics observed with ropivacaine derive from its unique pharmacological properties. As a pure S-enantiomer with reduced lipophilicity, ropivacaine demonstrates preferential blockade of small-diameter sensory A-delta and C fibers over large-diameter motor A-alpha fibers.[8] This sensory-motor dissociation permits adequate surgical anesthesia while minimizing motor impairment. Experimental evidence from Rosenberg and Heinonen demonstrated that ropivacaine exhibits greater differential sensitivity between sensory C fibers and motor A fibers compared to bupivacaine,[17] providing mechanistic support for our clinical observations.

Regarding the duration of sensory blockade, our study documented significantly longer duration with bupivacaine (156.53 vs. 131.9 minutes). This 24.6-minute difference, while statistically significant, warrants careful interpretation. Both agents provided sensory anesthesia exceeding the mean surgical duration by substantial margins (approximately 120 and 95 minutes respectively), ensuring adequate coverage for the cesarean procedure and immediate postoperative period. The shorter sensory block duration with ropivacaine may actually represent an advantage in some clinical contexts, potentially reducing the interval before patients can ambulate and facilitating earlier transition to oral analgesics.

A critical consideration in comparing ropivacaine and bupivacaine involves dose equivalency. We employed 15 mg of ropivacaine 0.75% compared to 10 mg of bupivacaine 0.5%, representing a 50% dose differential. This dosing strategy reflects the consensus emerging from multiple investigations suggesting that ropivacaine requires approximately 40-50% higher doses to achieve block intensity comparable to bupivacaine.[12,18] Gautier and colleagues specifically recommended a 50% dose increment for ropivacaine based on their ambulatory surgery data.[18] Our choice of concentrations (0.75% ropivacaine vs. 0.5% bupivacaine) aligns with recommendations from comparative potency studies and appears to have produced clinically equivalent surgical conditions based on successful completion of all procedures without supplementation or conversion to general anesthesia.

Hemodynamic stability represents a crucial consideration in obstetric anesthesia, where maintenance of uteroplacental perfusion is paramount. Our study demonstrated comparable hemodynamic profiles between groups, with no significant differences in heart rate, blood pressure parameters, or oxygen saturation throughout the perioperative period. The incidence of hypotension, the most common complication of spinal anesthesia, occurred in 10% of bupivacaine patients versus 3.3% of ropivacaine patients, though this difference did not achieve statistical significance. These rates are notably lower than the 20-27.5% incidence reported by Kulkarni et al,[9] possibly reflecting our standardized preloading protocol and proactive vasopressor use. The comparable hemodynamic effects suggest that both agents produce similar degrees of sympathetic blockade at the doses employed, and that ropivacaine's reduced motor blockade does not compromise hemodynamic stability.

The safety profile observed in our study was excellent for both agents, with low overall complication rates and no serious adverse events. The absence of cardiotoxicity, neurotoxicity, or persistent neurological sequelae is reassuring, though the relatively small sample size limits definitive safety comparisons. Ropivacaine's theoretical safety advantages related to reduced cardiac and central nervous system toxicity,[5,7] become most relevant in scenarios involving inadvertent intravascular injection or systemic absorption from large-volume peripheral nerve blocks, situations less likely in carefully performed single-shot spinal anesthesia.

Several limitations of our study merit acknowledgment. The non-randomized allocation

method introduces potential selection bias, though the comparable baseline characteristics between groups suggest successful matching. The consecutive sampling approach and single-center design may limit generalizability to other populations or practice settings. Our study was powered to detect differences in hemodynamic parameters rather than block characteristics, potentially leading to type II error for some outcomes. Additionally, we did not assess postoperative analgesia requirements, patient satisfaction, or time to hospital discharge—outcomes increasingly valued in enhanced recovery protocols. Future investigations employing randomized controlled designs with larger sample sizes and assessment of patient-centered outcomes would strengthen the evidence base.

The clinical implications of our findings support the use of hyperbaric ropivacaine 0.75% as a viable alternative to hyperbaric bupivacaine 0.5% for cesarean section spinal anesthesia, particularly when early ambulation is prioritized. The modest delay in onset is clinically acceptable and offset by the substantial reduction in motor blockade duration. For institutions implementing enhanced recovery protocols or managing high patient volumes requiring rapid bed turnover, ropivacaine may offer meaningful advantages. Conversely, in settings where prolonged postoperative motor blockade is not problematic or where faster onset is prioritized, bupivacaine remains an appropriate choice. Ultimately, anesthetic selection should be individualized based on patient factors, surgical context, and institutional resources.

CONCLUSION

This prospective observational study demonstrates that hyperbaric ropivacaine 0.75% (15 mg) provides effective and safe spinal anesthesia for elective cesarean section with clinically relevant differences compared to hyperbaric bupivacaine 0.5% (10 mg). While bupivacaine exhibits marginally faster onset of sensory and motor blockade, ropivacaine produces significantly shorter duration of motor blockade while maintaining comparable hemodynamic stability and low adverse effect rates. The approximately 27-minute reduction in motor block duration with ropivacaine facilitates earlier ambulation and aligns well with contemporary enhanced recovery protocols. Both agents demonstrated excellent safety profiles with minimal complications. Based on these findings, hyperbaric ropivacaine 0.75% represents a valuable alternative to bupivacaine for cesarean section anesthesia, particularly when prioritizing early postoperative mobilization and functional recovery. The choice between these agents should be guided by individual patient characteristics, institutional protocols, and specific clinical priorities.

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