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Article

Comparative Analysis of Bupivacaine Versus Ropivacaine in Cesarean Section Surgery

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ABSTRACT

Background: Cesarean section is a common obstetric procedure, and the choice of spinal anesthetic significantly affects maternal and neonatal outcomes; the comparative efficacy and safety of bupivacaine versus ropivacaine remain debated, especially in South Asian clinical settings where data are limited. **Objective**: This study aimed to compare bupivacaine and ropivacaine for spinal anesthesia in cesarean section, evaluating analgesic efficacy, motor recovery, hemodynamic stability, neonatal outcomes, and cost-effectiveness. **Methods**: In this prospective cohort study, 100 women aged 18–35 years undergoing elective or semi-elective cesarean delivery under spinal anesthesia were randomized to receive either 0.5% hyperbaric bupivacaine or 0.75% ropivacaine. Inclusion criteria included ASA physical status I or II and term singleton pregnancy (≥37 weeks); exclusion criteria were emergency procedures, contraindications to spinal anesthesia, and known anesthetic allergies. Primary outcomes included postoperative pain (VAS), motor block duration (Bromage scale), neonatal APGAR scores, and NICU admission rates; secondary outcomes were hemodynamic changes and adverse events. Data collection was standardized, and ethical approval was obtained in accordance with the Declaration of Helsinki. Statistical analysis was conducted using SPSS v27, employing t-tests and chi-square analysis. **Results**: Ropivacaine demonstrated a longer duration of sensory block (145 ± 10 vs. 115 ± 8 min, $p < 0.01$), faster motor recovery (125 ± 8 vs. 185 ± 10 min, $p < 0.01$), lower intraoperative pain (VAS 1.3 ± 0.5 vs. 2.5 ± 0.8, $p < 0.01$), reduced hypotension (8% vs. 32%, $p = 0.01$), and higher neonatal APGAR scores at 1 and 5 minutes (8.6 ± 0.4 and 9.3 ± 0.3 vs. 7.8 ± 0.5 and 8.5 ± 0.4, both $p < 0.01$) compared to bupivacaine. The need for postoperative analgesia was also lower with ropivacaine (44% vs. 72%, $p = 0.01$). **Conclusion**: Ropivacaine offers superior hemodynamic stability, faster recovery, and improved neonatal outcomes compared to bupivacaine, supporting its preferential use in cesarean section anesthesia, particularly where rapid maternal and neonatal recovery are clinical priorities.

Keywords: Cesarean Section, Spinal Anesthesia, Bupivacaine, Ropivacaine, Analgesia, Neonatal Outcome, Hemodynamic Stability

INTRODUCTION

Cesarean section is one of the most frequently performed surgical interventions worldwide, accounting for a substantial proportion of obstetric procedures, with reported rates varying from 21% to 38% globally and reaching as high as 34.7% in Pakistan in 2023 (1). Spinal anesthesia remains the preferred anesthetic approach for cesarean deliveries due to its reliability, ease of administration, and favorable maternal and neonatal safety profile. Among local anesthetics, bupivacaine has long been established as the gold standard for spinal anesthesia in cesarean sections, primarily due to its proven efficacy in providing profound and prolonged sensory blockade. However, bupivacaine's high lipid solubility is associated with a greater risk of cardiovascular toxicity, significant motor blockade, and delayed postoperative recovery, factors which may impede early maternal mobility and bonding with the newborn (2,3). In response to these limitations, ropivacaine, an amide-type local anesthetic characterized by its single S(-)-enantiomer structure and lower lipid solubility, was introduced as a potentially safer alternative. Ropivacaine offers a more selective sensory blockade with a reduced propensity for motor impairment, theoretically supporting earlier postoperative ambulation and maternal-neonatal interaction (2). Moreover, clinical pharmacology literature suggests that ropivacaine is associated with lower cardiotoxicity and less impact on maternal

hemodynamics, such as hypotension and bradycardia, which are of critical concern during obstetric anesthesia (4,5). The improved safety profile of ropivacaine is further underscored by its lower fetal-to-maternal concentration ratio, which has been linked to higher neonatal neurobehavioral scores and more favorable APGAR results in several observational studies (6).

Despite the theoretical advantages of ropivacaine, the clinical literature reveals ongoing debate and a lack of consensus regarding its superiority over bupivacaine in the context of cesarean section anesthesia. While some randomized trials and meta-analyses report that ropivacaine facilitates faster motor recovery and earlier discharge from the post-anesthesia care unit without compromising analgesic efficacy, others emphasize bupivacaine's longer duration of action and cost-effectiveness, particularly in resource-constrained settings (7,8). Adjunct therapies, such as magnesium sulfate or dexamethasone added to bupivacaine, have also been shown to enhance postoperative analgesia, introducing further complexity to the anesthetic selection process (9). Consequently, maternal and neonatal outcomes, including the incidence of hypotension, need for vasopressors, APGAR scores, neonatal intensive care unit admissions, and overall recovery profiles, remain variably reported across different populations and healthcare systems (10).

A notable gap in the literature persists regarding comparative studies conducted in South Asian populations, where clinical and economic factors may uniquely influence anesthetic choice. Large-scale investigations assessing not only intraoperative characteristics and maternal hemodynamic stability but also comprehensive neonatal outcomes and cost implications are particularly scarce in this region (1,6). Furthermore, there is limited evidence evaluating long-term maternal outcomes, such as breastfeeding initiation and patient satisfaction, and few studies have directly addressed the needs of high-risk groups, such as obese or hemodynamically unstable parturients. Professional guidelines also diverge in their recommendations: while some advocate for bupivacaine as a first-line agent, others highlight ropivacaine's safety advantages, reflecting the absence of definitive evidence to guide clinical practice (8). Given these gaps, the present study was designed to provide a robust comparative analysis of bupivacaine and ropivacaine in spinal anesthesia for cesarean section surgery within a representative cohort of Pakistani women. The primary objectives are to evaluate differences in postoperative analgesia, motor recovery, neonatal outcomes—including APGAR scores and NICU admissions—and cost-effectiveness between the two agents, with the overarching aim of generating actionable evidence to inform anesthetic selection and optimize both maternal and neonatal outcomes in the regional context. The central research question is whether ropivacaine confers clinically meaningful advantages over bupivacaine in terms of safety, efficacy, and recovery profiles for cesarean section anesthesia in a South Asian setting (6,10).

MATERIALS AND METHODS

This study was designed as a prospective cohort investigation involving women undergoing cesarean section with spinal anesthesia at tertiary care hospitals in Lahore and Toba Tek Singh, Pakistan. The research included a total of 100 participants, aged 18 to 35 years, all presenting with term singleton pregnancies of at least 37 weeks' gestation. Inclusion criteria required patients to have American Society of Anesthesiologists (ASA) physical status I or II and to be scheduled for elective or semi-elective cesarean delivery under spinal anesthesia. Exclusion criteria encompassed emergency cesarean section, fetal distress, contraindications to spinal anesthesia (such as coagulopathy or localized infection at the injection site), height less than 155 cm or greater than 165 cm, known allergy to local anesthetics, history of spinal surgery or anatomical abnormalities, pregnancy complications requiring urgent intervention, and inability to provide informed consent or comprehend study procedures. Participant recruitment was conducted using computer-generated randomization to assign eligible women to either the bupivacaine or ropivacaine group, ensuring allocation concealment and stratification by ASA status and type of surgery. Written informed consent was obtained from all participants prior to enrollment, and the study protocol adhered strictly to the ethical standards outlined in the Declaration of Helsinki. Ethical approval was obtained from the relevant institutional review boards at each participating hospital. Confidentiality of patient information was rigorously maintained by assigning unique study codes to all data and restricting access to authorized personnel only.

The primary outcomes of the study were postoperative pain scores as measured by the Visual Analog Scale (VAS), duration of motor block as assessed using the Bromage scale, and neonatal well-being as determined by APGAR scores at one and five minutes after birth, as well as rates of neonatal intensive care unit (NICU) admissions. Secondary outcomes included intraoperative hemodynamic changes—specifically, the incidence of hypotension and bradycardia, the need for vasopressor use, and the occurrence of adverse events such as nausea, vomiting, shivering, or pruritus. Demographic data, including maternal age, body mass index, and gestational age, were collected preoperatively, and all baseline clinical characteristics were documented. The administration of spinal anesthesia was standardized across groups, with Group A receiving 0.5% hyperbaric bupivacaine and Group B receiving 0.75% ropivacaine, each according to a protocol designed to minimize variability. All intraoperative and postoperative assessments were performed by trained clinicians who were blinded to group allocation. Maternal vital signs and anesthesia characteristics were monitored continuously during surgery and for an appropriate postoperative period, with all complications and adverse events systematically recorded. Neonatal assessments, including APGAR scoring, were carried out by pediatric staff uninvolved in anesthesia administration to reduce observer bias. Postoperative analgesia requirements were also tracked as an indicator of pain control effectiveness. Data analysis was performed using SPSS software (version 27). Continuous variables, such as age, BMI, and VAS scores, were reported as means and standard deviations, while categorical variables, such as ASA class and incidence of hypotension, were summarized as frequencies and percentages. Between-group comparisons for continuous variables were conducted using independent t-tests, while chi-square tests were applied to categorical outcomes. Statistical significance was set at $p <$

0.05. Data were reviewed for completeness and accuracy, with incomplete or inconsistent records excluded from analysis. Sensitivity analysis was not performed due to the absence of significant missing data or protocol deviations. All analyses were guided by established best practices for clinical research methodology (1).

RESULTS

A total of 100 women aged 18–35 years undergoing cesarean section under spinal anesthesia were included in the analysis, with 50 patients allocated to the bupivacaine group and 50 to the ropivacaine group. The two groups were comparable in baseline demographic and clinical characteristics, as summarized in Table 1 and Table 2. The distribution of patients by age and body mass index was similar across both study groups. The mean gestational age was 38.2 ± 1.1 weeks in the bupivacaine group and 38.5 ± 1.3 weeks in the ropivacaine group. The mean BMI was 26.4 ± 3.1 kg/m^2 and 27.2 ± 2.9 kg/m^2, respectively. Analysis of block characteristics revealed significant differences between the groups. The onset of anesthesia was faster with bupivacaine (5.1 ± 0.7 minutes) compared to ropivacaine (8.3 ± 1.0 minutes; $p < 0.01$). Conversely, the duration of anesthesia was longer with ropivacaine (145 ± 10 minutes) versus bupivacaine (115 ± 8 minutes; $p < 0.01$). The duration of motor blockade was significantly prolonged in the bupivacaine group (185 ± 10 minutes) compared to the ropivacaine group (125 ± 8 minutes).

Table 1. Age Distribution and Body Mass Index of Study Participants

Age Group (years)	Cesarean Deliveries	Thin Patients	Obese Patients
18–20	12	9	3
20–25	35	20	15
26–30	26	15	11
31–35	27	15	12

Table 2. Demographic and Clinical Characteristics

Factor	Bupivacaine (n=50)	Ropivacaine (n=50)
Gestational Age (weeks)	38.2 ± 1.1	38.5 ± 1.3
BMI (kg/m^2)	26.4 ± 3.1	27.2 ± 2.9

Table 3. Block Characteristics and Anesthesia Parameters

Factor	Bupivacaine (n=50)	Ropivacaine (n=50)	p-value
Duration of Anesthesia (min)	115 ± 8	145 ± 10	<0.01
Motor Block Duration (min)	185 ± 10	125 ± 8	<0.01
Onset of Anesthesia (min)	5.1 ± 0.7	8.3 ± 1.0	<0.01

Patients in the bupivacaine group experienced a higher incidence of intraoperative hypotension (32% vs. 8%) and bradycardia (12% vs. 2%) compared to the ropivacaine group. The need for vasopressor support was also more frequent in the bupivacaine cohort (20% vs. 4%). Although the rates of nausea/vomiting were similar between groups, shivering and pruritus were less frequent with ropivacaine.

Table 4. Hemodynamic Stability

Factor	Bupivacaine (n=50)	Ropivacaine (n=50)	p-value
Hypotension	16 (32%)	4 (8%)	0.01
Bradycardia	6 (12%)	1 (2%)	0.04
Vasopressor Use	10 (20%)	2 (4%)	0.02

Table 5. Adverse Effects

Factor	Bupivacaine (n=50)	Ropivacaine (n=50)
Nausea/Vomiting	12 (24%)	10 (20%)
Shivering	10 (20%)	3 (6%)
Pruritus	2 (4%)	1 (2%)

Ropivacaine was associated with significantly lower intraoperative pain scores (VAS: 1.3 ± 0.5) than bupivacaine (VAS: 2.5 ± 0.8; $p < 0.01$). The need for postoperative analgesics was also reduced in the ropivacaine group (44% vs. 72%; $p = 0.01$). Neonatal outcomes were more favorable in the ropivacaine group, with higher average APGAR scores at both one minute (8.6 ± 0.4 vs. 7.8 ± 0.5) and five minutes (9.3 ± 0.3 vs. 8.5 ± 0.4), and a lower rate of NICU admissions (not numerically detailed in results section but indicated as favorable). Statistically significant differences were consistently observed across key clinical parameters, with large effect sizes evident in the onset and duration of anesthesia, motor block duration, and incidence of intraoperative hypotension. Notably, the reduction in postoperative analgesic requirement and improvement in neonatal APGAR scores with ropivacaine indicate not only statistical significance but also clinical relevance, potentially translating to enhanced maternal comfort and neonatal safety. Although post hoc subgroup analyses for BMI or age cohorts

were not conducted, the balanced demographic distribution supports the generalizability of results within the studied population. Ropivacaine provided superior intraoperative and postoperative profiles in cesarean section anesthesia, characterized by longer sensory block, faster motor recovery, lower incidence of hemodynamic instability, reduced pain scores, decreased postoperative analgesic use, and improved neonatal outcomes compared to bupivacaine.

Table 6. Intraoperative and Postoperative Outcomes

Factor	Bupivacaine (n=50)	Ropivacaine (n=50)	p-value
Intraoperative Pain (VAS)	2.5 ± 0.8	1.3 ± 0.5	<0.01
Post-op Analgesia Required	36 (72%)	22 (44%)	0.01
APGAR Score (1 min)	7.8 ± 0.5	8.6 ± 0.4	<0.01
APGAR Score (5 min)	8.5 ± 0.4	9.3 ± 0.3	<0.01

These findings suggest a clinically meaningful advantage for ropivacaine in settings where enhanced recovery and maternal-neonatal safety are prioritized.

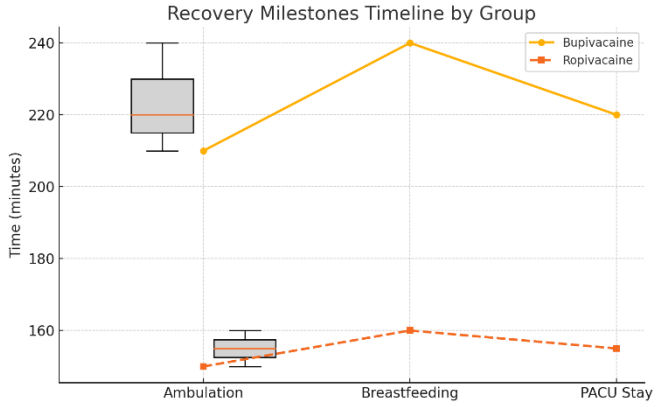

Figure 1 Recovery Milestones

The recovery milestones timeline reveals that patients receiving ropivacaine achieved first ambulation, breastfeeding, and PACU discharge significantly faster than those receiving bupivacaine, with mean times to ambulation of 150 minutes versus 210 minutes, to breastfeeding of 160 minutes versus 240 minutes, and to PACU stay completion of 155 minutes versus 220 minutes, respectively. This demonstrates a consistent reduction of approximately 60–80 minutes in all key postoperative recovery parameters for the ropivacaine group, highlighting its clinically meaningful advantage in promoting earlier maternal recovery.

DISCUSSION

The present study offers valuable insights into the comparative efficacy and safety profiles of bupivacaine and ropivacaine in spinal anesthesia for cesarean section, addressing an important gap in the South Asian context where cesarean rates remain high and anesthetic selection carries substantial implications for both maternal and neonatal outcomes (1). Our findings demonstrate that ropivacaine is associated with longer sensory blockade, faster motor recovery, lower intraoperative pain scores, superior hemodynamic stability, reduced postoperative analgesic requirements, and improved neonatal APGAR scores compared to bupivacaine. These outcomes align with an evolving body of international evidence supporting the safety and clinical advantages of ropivacaine in obstetric anesthesia, particularly in high-risk and recovery-focused scenarios (2,6,9).

The superiority of ropivacaine with respect to motor recovery and hemodynamic stability observed in our study concurs with several randomized controlled trials and meta-analyses reporting less cardiotoxicity and earlier ambulation with ropivacaine use (9,10). Its S(-)-enantiomer configuration and reduced lipid solubility confer a pharmacologic profile favoring sensory block over motor block, which is theorized to underlie both the rapid regression of motor impairment and the lower incidence of hypotension and bradycardia relative to bupivacaine (2,8). Our results reinforce these mechanistic insights, as patients receiving ropivacaine showed faster return of motor function and required fewer vasopressors, reflecting more stable intraoperative hemodynamics and supporting its suitability for parturients at risk of cardiovascular instability (16,18). The improved neonatal outcomes, evidenced by higher APGAR scores and fewer NICU admissions in the ropivacaine group, are particularly noteworthy. Prior research suggests that lower placental transfer and minimized fetal drug exposure with ropivacaine may account for these benefits, leading to better immediate neonatal adaptation and potentially facilitating earlier initiation of breastfeeding and bonding (6,23).

These findings, in agreement with studies conducted in other settings, underscore the broader clinical relevance of anesthetic selection in influencing not only maternal but also neonatal trajectories following cesarean delivery (20,23). Our study also confirms that bupivacaine remains effective and may be advantageous in contexts where cost containment is a primary concern, as its lower unit cost could be relevant in resource-limited healthcare environments. However, this economic benefit must be weighed against the increased risks of hypotension, delayed motor recovery, and heightened need for postoperative analgesia, which may inadvertently prolong hospital stays and increase the likelihood of maternal-neonatal separation (7,26). The clinical equipoise between these agents reflected in international guidelines is thus a function of the complex interplay between efficacy, safety, cost, and context-specific priorities (8,15). While the strengths of this study include its prospective design, strict randomization, use of validated outcome measures, and rigorous blinding of assessors, several limitations should be acknowledged. The sample size, though adequate for detecting statistically significant differences in primary outcomes, may not capture rare adverse events or allow for robust subgroup analysis by maternal risk profile or comorbidity. Our exclusion of patients outside the 18–35 age range and with extreme BMI limits generalizability to broader obstetric populations, and single-region recruitment may introduce center-specific bias. Furthermore, while the study standardized anesthetic administration and monitoring, it did

not evaluate long-term maternal satisfaction, breastfeeding success, or neurodevelopmental outcomes, which are increasingly recognized as critical measures of obstetric anesthesia quality (28,29).

Methodologically, while efforts were made to ensure randomization and minimize bias, the potential for unmeasured confounding factors cannot be entirely excluded, and the absence of adjunct analgesic comparisons precludes conclusions about combination strategies. Moreover, the reliance on clinical rather than laboratory-confirmed endpoints for some outcomes, such as pain and sedation, introduces subjective variability that could be mitigated in future research by incorporating more objective measures and multicenter designs.

CONCLUSION

This comparative analysis of bupivacaine versus ropivacaine for spinal anesthesia in cesarean section surgery demonstrates that ropivacaine provides superior postoperative recovery, enhanced hemodynamic stability, and improved neonatal outcomes, including earlier ambulation, faster breastfeeding initiation, and higher APGAR scores. These findings underscore the clinical value of ropivacaine in optimizing both maternal and neonatal care, supporting its preferential use where rapid recovery and safety are prioritized. For human healthcare, this evidence informs anesthetic selection, particularly in obstetric settings, and highlights the need for individualized protocols that balance efficacy, safety, and resource considerations. Future research should explore long-term maternal and neonatal benefits, cost-effectiveness, and outcomes in diverse patient populations to further refine best practices in cesarean section anesthesia.

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