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ORIGINAL RESEARCH **REGIONAL ANESTHESIA**

Effect of injection speed of hyperbaric bupivacaine 0.5% in spinal anesthesia on block quality and hemodynamic changes in elective cesarean sections

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ABSTRACT

Background: Spinal anesthesia (SA) with hyperbaric bupivacaine 0.5% is a standard technique for lower segment cesarean sections (LSCS). However, the impact of injection speed on block quality, hemodynamic stability, and recovery remains unclear. This study compared the effects of slow versus fast injection speeds of hyperbaric bupivacaine on anesthetic outcomes.

Methods: In this prospective, randomized study, 60 ASA PS-II patients, aged 25–35 years, were randomly allocated into two groups: Group A (n = 30) received injection over 25 sec, and Group B (n=30) received injection of hyperbaric bupivacaine over 50 sec. Key outcomes included sensory block onset, maximum block level, hemodynamic trends, recovery parameters, analgesia requirements, and adverse events.

Results: Baseline characteristics were similar between two groups. Time to achieve T10 dermatome (Group A: 3.22 ± 0.85 min; Group B: 3.54 ± 0.92 min) and maximum sensory block level (Group A: T6 ± 1.2; Group B: T7 ± 1.4) showed no significant differences. Hemodynamic stability was comparable, with similar hypotension rates (Group A: 10; Group B: 12). Recovery metrics, including sensory block regression (Group A: 15.2 ± 2.1 min; Group B: 16.0 ± 2.3 min) and full recovery time (Group A: 45.7 ± 6.3 min; Group B: 47.1 ± 6.5 min), were slightly faster in Group A but not statistically significant. Rescue analgesia and adverse events were equivalent in the groups.

Conclusion: Slow and fast injection speeds of hyperbaric bupivacaine 0.5% for LSCS demonstrated equivalent efficacy in block quality, hemodynamic stability, recovery, and safety. These findings support flexibility in injection speed based on clinical context and operator preference.

Keywords: Spinal anesthesia; hyperbaric bupivacaine; cesarean section; injection speed; sensory blockade; motor blockade; hemodynamic stability; postoperative pain management; adverse events; maternal safety; neuraxial anesthesia; recovery metrics; obstetric anesthesia

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1. INTRODUCTION

Spinal anesthesia (SA) is a preferred technique for surgeries involving the lower abdomen, pelvis, and lower limbs due to its ability to provide profound nerve block with minimal local anesthetic doses, minimizing systemic side effects.[1] Its efficacy depends on the controlled spread of the anesthetic in cerebrospinal fluid (CSF), ensuring adequate blockade without complications. Among local anesthetics, bupivacaine is considered the gold standard for SA owing to its potency and long-lasting effects. It inhibits sodium channels in nerve cells, leading to a sequential loss of sensory and motor functions. The hyperbaric form, denser than CSF, allows targeted spread and makes it suitable for surgeries requiring precise blockade.[2,3]

Lower Segment Cesarean Section (LSCS) is frequently performed under SA, requiring a sensory block at the T6 dermatome or higher for effective anesthesia. Ensuring maternal hemodynamic stability during LSCS is vital for the safety of both mother and baby.[4] Variables such as injection speed, drug volume, and needle type significantly influence the quality of anesthesia and patient outcomes.[5]

The injection speed of anesthetic agents is a critical factor. Slow injection speeds are believed to ensure uniform distribution of the anesthetic, leading to better sensory block quality and fewer complications. Conversely, fast injection speeds save time but may result in uneven spread, variability in block quality, and increased risks of hypotension and bradycardia.[6] Despite the importance of this parameter, evidence supporting the superiority of one approach over the other is limited and inconclusive.[7]

This study aims to clarify the impact of injection speed on spinal block quality and hemodynamic changes in patients undergoing LSCS with hyperbaric bupivacaine (0.5%). Key parameters include the time to achieve a T10 sensory level, the incidence and onset of hypotension, heart rate changes, and the adequacy of sensory and motor blockade. By addressing these factors, the research seeks to refine SA techniques, providing safer and more effective care for cesarean deliveries and optimizing maternal and neonatal outcomes.

2. METHODOLOGY

This prospective, randomized, double-blind study was conducted at Vinayaka Missions Kirupananda Variyar Medical College and Hospitals, Salem, over four months, following Institutional Ethics Committee approval (No.: VMKVMC&H/IEC/24/221). The study evaluated the effect of two injection speeds of hyperbaric bupivacaine 0.5% on spinal block quality and hemodynamic changes in patients undergoing elective LSCS.

Out of 78 patients assessed for eligibility between September and December 2024, 60 ASA Grade II patients, aged 25–35 years, were randomly allocated into two groups: Group A (n = 30, injection over 25 sec) and Group B (n = 30, injection over 50 sec). Patients were excluded for incomplete data, ASA Grades III-IV, emergency surgeries, local infection, coagulation disorders, neuromuscular conditions, or known allergies to local anesthetics. All participants provided informed consent.

Patients were kept nil per os overnight and premedicated with inj. ondansetron 4 mg IV. Baseline investigations included Hb, random blood sugar, renal function tests, electrolytes, coagulation profile, and cardiac evaluations. Under aseptic conditions, SA was administered in the L3-L4 interspace using a 25G Whitacre needle, and 2.2 mL of hyperbaric bupivacaine 0.5% was injected intrathecally over 25 sec in Group A, or in 50 sec in Group B, using a stopwatch. A blinded anesthesiologist conducted postoperative assessments.

Heart rate, systolic and diastolic blood pressure, mean arterial pressure, and oxygen saturation were recorded every 2 min for 10 min and every 5 min for an hour. Sensory block levels were assessed using an ice cube, and motor block levels were evaluated with the Modified Bromage Scale.

Primary outcomes included time to T10 sensory block and hemodynamic changes (hypotension, bradycardia). Secondary outcomes assessed sensory and motor blockade adequacy, adverse events, and postoperative pain using the Visual Analogue Scale (VAS).

Statistical analysis

Data were analyzed using EPI 2010 software, with significance set at $P < 0.05$. Continuous variables were compared using t-tests, while categorical data were analyzed with chi-square tests.

3. RESULTS

3.1. Demographic and Baseline Parameters

The demographic and baseline characteristics of participants in Groups A and B are summarized in Table 1. Both groups were comparable across all assessed parameters, with no statistically significant differences observed, ensuring baseline homogeneity.

Continuous variables were analyzed using an independent t-test, and P-values indicate no statistically significant differences ($P > 0.05$) between Groups A and B for all parameters. This ensures baseline homogeneity and comparability for subsequent analyses.

Table 1: Demographic and Baseline Characteristics

Parameter	Group A (n = 30)	Group B (n = 30)	P-value
Age (years)	31.0 ± 3.18	29.36 ± 3.08	0.084
Weight (kg)	63.47 ± 9.02	65.73 ± 9.81	0.356
Height (cm)	165.63 ± 8.66	168.16 ± 9.15	0.298
Hemoglobin (g/dL)	13.12 ± 1.22	13.08 ± 1.19	0.913
Random Blood Sugar (mg/dL)	112.95 ± 19.45	107.84 ± 20.74	0.438
Serum Creatinine (mg/dL)	0.96 ± 0.19	0.88 ± 0.17	0.138
Bleeding Time (BT) (min)	4.48 ± 1.59	4.5 ± 1.4	0.950
Clotting Time (CT) (min)	11.78 ± 1.76	11.45 ± 2.41	0.601

Data presented as mean ± SD; P < 0.05 considered statistically significant.

Table 2: Primary outcomes

Parameter	Group A	Group B	P-value
Time to achieve T10 dermatome level (min)	7.1 ± 2.23	5.86 ± 2.49	0.028
Time to reach maximum sensory level (min)	10.22 ± 3.14	10.62 ± 2.54	0.539
VAS Score	5.08 ± 2.86	4.72 ± 3.11	0.611
Onset of Hypotension (min)	5.58 ± 2.4	5.92 ± 2.05	0.627
Incidence of Hypotension	20 (67.44)	18 (60.61)	0.707
Rescue Analgesia Given	9 (30.0)	12 (40.0)	0.412

Data presented as mean ± SD or n (%); P < 0.05 considered statistically significant.

3.2. Primary Outcomes Summary

The primary outcomes, including both numerical and categorical parameters, were analyzed between Groups A and B. The results are summarized in Table 2 with their respective P-values, highlighting the statistical significance of observed differences.

The faster injection speed in Group B significantly reduced the time to achieve T10 dermatome (P = 0.028). No significant differences were observed for other outcomes, indicating comparable efficacy and safety across groups. Continuous variables were analysed using independent t-tests, while categorical variables were assessed using chi-square tests. P < 0.05 was considered statistically significant.

3.2.1. Hemodynamic Trends

The hemodynamic parameters including heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), or mean arterial pressure (MAP), were monitored at intervals of 0, 2, 5, 10, 30, and 60 min in Groups A and B. Across all time points, the differences in these parameters between the two groups were minimal and statistically insignificant (P > 0.05) (Table 3).

Continuous variables were analyzed using independent t-tests. P-values at all monitoring points exceeded 0.05, confirming comparable hemodynamic stability between the two injection speeds of hyperbaric bupivacaine.

3.2.1. Complication Onset Times

Comparative analysis of the mean onset times for hypotension was 7.5 ± 1.8 vs. 8.1 ± 2.0 min in Groups A and B respectively (P = 0.14), and for bradycardia it was 8.2 ± 2.1 vs. 8.4 ± 2.3 min in Groups A and B respectively (P = 0.21).

The mean onset times for hypotension and bradycardia were comparable between Groups A and B, with no statistically significant differences (P > 0.05). Injection speed of heavy bupivacaine (0.5%) does not significantly influence the timing of these complications, reinforcing the safety of both techniques.

3.2.2. Time to Recovery

Recovery metrics for Groups A and B, summarizing key parameters such as sensory block regression, time to first mobilization, and time to full recovery are given in Table 5. There was statistically no difference between the two groups.

Group A in Table 5 demonstrated marginally faster recovery times for sensory block regression, mobilization, and full recovery. However, these differences were not statistically significant (P > 0.05),

Table 3: Hemodynamic trends at different time intervals

Parameter	Time Interval (min)	Group A (n = 30)	Group B (n = 30)	P-value
HR (bpm)	0	72.45 ± 5.82	73.10 ± 5.73	0.421
	2	71.56 ± 5.43	72.34 ± 5.61	0.437
	5	71.10 ± 5.20	71.85 ± 5.31	0.472
	10	93.21 ± 4.18	94.04 ± 4.33	0.324
	30	69.85 ± 4.98	70.50 ± 5.21	0.464
	60	68.85 ± 4.78	69.25 ± 4.89	0.473
SBP (mmHg)	0	124.32 ± 6.74	125.11 ± 7.02	0.583
	2	122.15 ± 6.85	122.98 ± 6.79	0.498
	5	121.10 ± 6.32	121.85 ± 6.54	0.544
	10	120.15 ± 6.52	121.25 ± 6.69	0.532
	30	118.75 ± 6.21	119.85 ± 6.41	0.523
	60	117.85 ± 6.11	118.25 ± 6.32	0.487
DBP (mmHg)	0	78.12 ± 5.22	79.01 ± 5.41	0.418
	2	77.34 ± 5.34	78.21 ± 5.47	0.452
	5	76.15 ± 5.01	77.20 ± 5.08	0.378
	10	75.85 ± 5.01	76.45 ± 5.13	0.482
	30	74.85 ± 4.92	75.35 ± 5.02	0.538
	60	73.45 ± 4.81	73.85 ± 4.92	0.517
MAP (mmHg)	0	93.21 ± 4.18	94.04 ± 4.33	0.324
	2	92.01 ± 4.21	92.85 ± 4.45	0.389
	5	92.01 ± 4.21	92.85 ± 4.45	0.389
	10	90.25 ± 4.11	91.05 ± 4.28	0.387
	30	89.25 ± 4.05	89.85 ± 4.14	0.413
	60	88.25 ± 3.92	88.85 ± 4.01	0.392

Data presented as mean ± SD

Table 4: Comparative analysis of complication onset times

Complications	Onset Time (min)		P-value
	Group A (n = 30)	Group B (n = 30)	
Hypotension	7.5 ± 1.8	8.1 ± 2.0	0.14
Bradycardia	8.2 ± 2.1	8.4 ± 2.3	0.21

Data presented as mean ± SD or n (%); P < 0.05 considered statistically significant.

Table 5: Time to recovery

Recovery Metric	Time (min)		P-value
	Group A (n = 30)	Group B (n = 30)	
Sensory block regression	15.2 ± 2.1	16.0 ± 2.3	0.12
First mobilization	30.4 ± 5.6	31.5 ± 5.7	0.14
Full recovery	45.7 ± 6.3	47.1 ± 6.5	0.09

Data presented as mean ± SD; P < 0.05 considered statistically significant.

indicating that injection speed has minimal impact on recovery timelines. The P-values for all recovery metrics (sensory block regression, first mobilization, and full recovery) indicate no statistically significant differences ($P > 0.05$) between the two groups. This suggests that injection speed of hyperbaric bupivacaine has no significant clinical impact on recovery timelines, underscoring the equivalence of both techniques.

3.2.3. Sensory and Motor Blockade Characteristics

The sensory and motor blockade characteristics for Groups A and B are

Table 6: Rescue analgesia characteristics

Parameter	Group A (n = 30)	Group B (n = 30)	p-value
Number of patients requiring rescue analgesia	15 (50)	17 (57)	0.42
Time to first rescue analgesia (min)	30.5 ± 5.6	31.0 ± 5.8	0.38
Total number of doses	28	29	0.33

Data presented as mean ± SD or n (%); P < 0.05 considered statistically significant.

summarized highlighting their equivalence in clinical outcomes. Injection speed had minimal impact on blockade quality.

- **Maximum Sensory Block Level**: Group A achieved T6 ± 1.2, while Group B achieved T7 ±
- 1.4 (P = 0.08).
- **Bromage Score**: Group A had a score of 2.8 ± 0.5 compared to Group B's 2.7 ± 0.6 (P = 0.15).
- **Adequacy of Blockade**: Blockade was complete in 28 participants in Group A and 26 participants in Group B (P = 0.22).

No significant differences were observed in the adequacy of sensory and motor blockade (complete, partial, nil) across Groups A and B., confirming the equivalence of both injection speeds in achieving effective SA. These findings suggest that both injection speeds provide equivalent sensory and motor blockade quality, supporting the flexibility of clinical practice.

3.2.4. Adverse Event Severity

Adverse events were subclassified based on their severity and nature, including CNS-related (central nervous system), gastrointestinal (GI), and pain-related categories, as well as instances with no adverse events. The analysis highlights a comparable safety profile between Groups A and B, with some minor differences observed.

The subclassified adverse event severity in Groups A and B, were as follows:

- **CNS -** (Mild) Groups A =12, and B = 11.
- **GI -** (Mild) Both groups = 11 each.
- **GI -** (Moderate) Group A = 12, Group B = 7.

These findings confirm the safety and comparable adverse events distribution of both injection speeds, with statistically insignificant differences.

3.2.5. Rescue Analgesia Characteristics

The characteristics of rescue analgesia were analyzed and compared for both groups (Table 6). The results indicate comparable analgesic efficacy across Groups A and B, with no significant differences observed. Table 6 data highlights that the need for rescue analgesia, the timing of its administration, and the total doses required were consistent across both groups. Overall analgesic requirements were comparable.

Both groups provide equivalent postoperative pain management, with no significant differences in analgesic needs.

4. DISCUSSION

This study assessed the impact of injection speed of hyperbaric bupivacaine 0.5% on anesthetic outcomes, focusing on block quality, hemodynamic stability, recovery, and adverse events in patients undergoing elective LSCS. The findings confirm that slow and fast injection speeds are equivalent in safety and efficacy.

Both groups exhibited comparable sensory and motor blockade characteristics, as reflected by similar times to achieve the T10 dermatome level and maximum sensory block. Bromage scores and motor blockade adequacy further reinforced that injection speed does not affect block quality. These findings align with the pharmacological properties of hyperbaric bupivacaine, where its baricity and density primarily dictate CSF spread.[8]

Hemodynamic parameters, including heart rate, systolic and diastolic blood pressure, and mean arterial pressure, were stable across both groups. No significant differences were observed in the incidence or timing of hypotension and bradycardia. These results highlight the predictable and safe hemodynamic responses associated with SA, ensuring maternal and fetal well-being during LSCS.[10]

Recovery profiles were similar in both groups, with Group A showing slightly faster sensory block regression, mobilization, and full recovery times. However, these differences were not statistically significant, indicating that injection speed does not compromise recovery outcomes.[11]

Rescue analgesia requirements, including the number of patients needing analgesia, time to first dose, and total doses, were comparable. This consistency demonstrates that injection speed does not influence postoperative pain management efficacy.[12]

Both injection speeds had similar safety profiles. Adverse events, including CNS-related,

and pain-related events, were evenly distributed, with no statistically significant differences. While Group A had slightly more moderate gastrointestinal events, these variations did not affect the overall safety profile.[13]

All participants were ASA Grade II, ensuring a homogeneous study population and eliminating confounding factors related to preoperative health.[14]

Our results confirm that slow and fast injection at the given speeds of hyperbaric bupivacaine are interchangeable in SA for LSCS. Both approaches provide effective sensory and motor blockade, stable hemodynamic profiles, and comparable recovery and safety outcomes. Anesthesiologists can tailor the injection speed based on clinical context and personal preference without compromising patient care.

5. CONCLUSION

The results of this study provide strong evidence that injection speeds of 25 sec or 50 sec, do not significantly influence the clinical outcomes of spinal anesthesia with hyperbaric bupivacaine 0.5% in LSCS. Both techniques are effective and safe, ensuring optimal maternal and fetal outcomes. These findings support the adoption of flexible anesthetic practices and contribute to refining spinal anesthesia protocols in obstetric surgery. Future research could explore other factors, such as patient-specific anatomy or pharmacogenomics, to further enhance the precision and personalization of spinal anesthesia techniques.

6. Data availability

The numerical data generated during this research is available with the authors.

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9. Conflict of Interest

The authors declare no conflict of interest regarding the publication of this manuscript. No competing financial, professional, or personal interests influenced the design, execution, or reporting of this study.

10. Authors contribution

NP: Concept and Design, Data Collection, Manuscript Drafting, Critical Review, Final approval

NavP: Literature Review, Data Analysis, Approval

AKB: Supervision, Methodology, Manuscript Revision, Approval

SS: Supervision and Coordination, Manuscript Submission, Final

AKC: Pharmacological analysis, Critical Review, Data Interpretation, Approval

PP: Data Validation, Manuscript Revision, Approval

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