e-ISSN: 0976-822X, p-ISSN:2961-6042

Available online on http://www.ijcpr.com/

International Journal of Current Pharmaceutical Review and Research 2026; 18(1); 953-959

Original Research Article

A Prospective Observational Study of Unilateral Spinal Anaesthesia Using Low-Dose Hyperbaric Bupivacaine with Buprenorphine in Unilateral Lower Limb Surgeries

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Received: 01-10-2025 / Revised: 15-11-2025 / Accepted: 21-12-2025

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Conflict of interest: Nil

Abstract

Introduction: Spinal anaesthesia is widely used for lower-limb surgeries, conventional bilateral spinal anaesthesia is often associated with adverse effects such as hypotension, bradycardia, postoperative nausea and vomiting, urinary retention, and delayed motor recovery, mainly due to extensive sympathetic blockade. Low-dose hyperbaric local anaesthetic solutions, slow injection techniques, prolonged lateral positioning, and the use of intrathecal opioid adjuvants have been shown to improve the success of unilateral spinal anaesthesia. Objective- To evaluate the success rate, block characteristics, hemodynamic changes, and adverse effects of unilateral spinal anaesthesia using low-dose hyperbaric bupivacaine combined with intrathecal buprenorphine in patients undergoing unilateral lower-limb surgery.

Materials and Methods: This hospital-based prospective observational study was conducted over 18 months in a tertiary care centre in Rajasthan, India. Eighty-eight patients aged 18–65 years, belonging to ASA physical status I and II, undergoing elective unilateral lower-limb surgeries were included. Unilateral spinal anaesthesia was performed using 6 mg of 0.5% hyperbaric bupivacaine combined with 90 µg of buprenorphine, administered intrathecally at a rate of 0.5 ml/min with patients maintained in the lateral decubitus position for 20 minutes. Sensory, motor, and sympathetic blocks were assessed, along with hemodynamic parameters and postoperative adverse events. Data were analysed using appropriate statistical tests.

Results: The mean age of patients was 46.9 ± 14.8 years. Hemodynamic parameters showed statistically significant reductions after spinal anaesthesia ($p < 0.001$), but these changes were clinically acceptable. Dense motor block was achieved predominantly on the dependent side, while most patients showed minimal or no motor and sensory block on the non-dependent side. Postoperative nausea was observed in 3.4% of patients, and no vomiting was reported.

Conclusion: Unilateral spinal anaesthesia using low-dose hyperbaric bupivacaine with intrathecal buprenorphine provides effective surgical anaesthesia with good hemodynamic stability, limited contralateral spread, and a low incidence of adverse effects. It is a safe and effective alternative to conventional bilateral spinal anaesthesia for selected unilateral lower-limb surgeries.

Keywords: Buprenorphine, Hyperbaric Bupivacaine, Low-Dose Spinal Anaesthesia, Spinal Anaesthesia, Unilateral Lower Limb Surgery.

DOI: 10.25258/ijcpr.18.1.158

Introduction

Spinal anaesthesia is one of the most commonly practiced regional anaesthesia techniques for lower-limb surgeries and is associated with effective intraoperative anaesthesia and improved postoperative analgesia compared with general anaesthesia. However, conventional bilateral spinal anaesthesia can produce a wider sympathetic block, resulting in clinically relevant adverse effects such as hypotension, bradycardia, nausea/vomiting, urinary retention, and delayed motor recovery. In a large study evaluating side effects during spinal anaesthesia, these complications are strongly related to the extent (height/spread) of the block, and emphasized that strategies that limit excessive spread can reduce side effects. [1] Unilateral spinal anaesthesia is a modification designed specifically for unilateral lower-limb procedures, where the block is preferentially restricted to the operative limb. This approach offers practical advantages by reducing cardiovascular instability, limiting unnecessary motor block of the non-operative limb, and supporting early mobilisation and discharge. Comparative clinical studies have shown that unilateral spinal techniques can reduce hypotension and improve recovery profiles compared with standard bilateral spinal anaesthesia. Unilateral spinal anaesthesia can provide intra- and postoperative advantages with fewer complications in lower-limb orthopaedic surgery compared with standard spinal anaesthesia. [2]

The success of unilateral spinal anaesthesia depends on multiple technical and pharmacologic factors, including baricity, dose/volume, injection speed, and maintaining the lateral position for adequate "fixation" time. Experimental and clinical data indicated that slower injection speeds improve unilateral distribution. Low-flow injection with hyperbaric bupivacaine, combined with maintaining lateral position, increases the likelihood of unilateral sympathetic blockade. [3]

In a randomized trial, injection flow significantly influences the success of unilateral sensory, motor, and sympathetic block, with slow injection producing better unilateral outcomes. [4] Dose selection is equally important: lower doses can restrict contralateral spread but must still ensure surgical adequacy. Various studies emphasized balancing block adequacy with recovery and hemodynamic stability in unilateral spinal techniques using hyperbaric bupivacaine. [5-7]

Opioid adjuvants are commonly added intrathecally to enhance analgesia and allow lower local anaesthetic doses.

Therefore, the present study evaluates unilateral spinal anaesthesia using a very low dose of 0.5% hyperbaric bupivacaine (6 mg) combined with intrathecal buprenorphine (90 µg) administered with a low-dose slow injection technique and prolonged lateral positioning to assess block characteristics, hemodynamic changes, and adverse events.

Materials and Methods

Study Design and Setting: This hospital-based prospective observational study was conducted in the Department of Anaesthesiology, at a tertiary care facility, Rajasthan, India, over a period of 18 months. The study included patients posted for elective unilateral lower limb surgical procedures performed under subarachnoid block. Patients aged between 18 and 65 years of either sex, classified as American Society of Anesthesiologists (ASA) physical status I and II, were considered eligible for inclusion. Written informed consent was obtained from all participants.

Sample Size: A sample of 80 cases was calculated at confidence level of 95% to verify the expected proportion of 72.5% success rate of unilateral spinal anaesthesia, at an absolute error of 10%.[8] Considering a non-response of 10%, the final sample size was increased to 88 patients.

Inclusion and Exclusion Criteria: Patients aged 18–65 years, of either sex, belonging to ASA physical status I or II, and scheduled for unilateral lower limb surgery under spinal anaesthesia were included in the study. Patients with autonomic neuropathy or peripheral vascular disease, those receiving anticoagulant therapy, patients with spinal deformities such as scoliosis, history of previous spinal surgery, pregnancy, and obese patients with body mass index greater than 35 kg/m² were excluded from the study.

Procedure: All patients were shifted to the operation theatre where standard non-invasive monitoring including heart rate, non-invasive blood pressure, electrocardiography, and pulse oximetry was instituted. The operating room temperature was maintained at 23 ± 0.5°C. A peripheral intravenous line was secured and crystalloid infusion was initiated at a rate of 20 ml/kg/hour. Patients were positioned in the lateral decubitus position with the operative limb kept dependent, while ensuring the operating table remained strictly horizontal. The L3–L4 or L4–L5 intervertebral space was identified using surface anatomical landmarks. Under strict aseptic precautions, lumbar puncture was performed using a 25-gauge Quincke spinal needle. After confirmation of free flow of cerebrospinal fluid, the needle bevel was directed towards the dependent limb.

A total intrathecal volume of 1.5 ml, consisting of 1.2 ml (6 mg) of 0.5% hyperbaric bupivacaine combined with 0.3 ml (90 µg) of buprenorphine, was injected at a controlled rate of 0.5 ml per minute. The lateral decubitus position was maintained for 20 minutes following injection to facilitate unilateral spread and fixation of the local anaesthetic. Thereafter, patients were placed in the supine position.

Assessment of Sensory, Motor, and Sympathetic Block: Sensory block was assessed bilaterally 20 minutes after intrathecal injection using the pin-prick method, progressing from caudal to cephalad direction. The highest sensory dermatome level with reduced sharp sensation was recorded. Motor block was assessed on both dependent and non-dependent limbs 20 minutes after spinal anaesthesia using the Modified Bromage Scale, where grade 0 indicates no motor weakness and grade 3 indicates complete inability to move the lower limb. Sympathetic block was evaluated by measuring skin temperature over the medial aspect of the knee on both limbs before spinal anaesthesia and again at 20 minutes post-injection. An increase in temperature of 0.5°C or more from baseline was considered indicative of sympathetic blockade.

Successful unilateral sensory block was defined as loss of pin-prick sensation up to the L1 dermatome on the dependent limb with intact sensation on the non-dependent limb. Successful unilateral motor block was defined as Modified Bromage grade 3 on the dependent limb with grade 0 on the non-dependent limb. Successful unilateral spinal anaesthesia was defined as the presence of sensory, motor, and sympathetic blockade confined to the dependent limb without significant involvement of the non-dependent limb.

Oxygen saturation was monitored continuously throughout the procedure. Blood pressure and heart rate were recorded at baseline and at 20 minutes after spinal anaesthesia, and the differences were documented. Hypotension was defined as a decrease in systolic blood pressure greater than 30% from baseline or a mean arterial pressure below 60 mmHg and was managed with intravenous fluids and ephedrine 6 mg intravenously. Bradycardia was defined as a heart rate less than 50 beats per minute associated with hypotension and was treated with atropine 0.6 mg intravenously.

In cases where spinal anaesthesia was inadequate or failed to provide surgical anaesthesia, general anaesthesia was administered. Such patients were included for analysis of unilateral block characteristics and hemodynamic changes unless spinal block could not be performed due to anatomical reasons, in which case they were excluded from further analysis.

Statistical analysis

Data were entered into Microsoft Excel and analysed. Continuous variables were assessed for normality using the Shapiro–Wilk test. Normally distributed data were expressed as mean ± standard deviation (SD), while non-normally distributed data were expressed as median with minimum–maximum (range). Categorical variables were summarized as frequency and percentage. Hemodynamic parameters (systolic blood pressure, diastolic blood pressure, and heart rate) recorded before spinal block and at 20 minutes after block were compared using the Wilcoxon signed-rank test (paired non-parametric data), and corresponding p values were reported. Motor block (Modified Bromage scale) and sensory block levels on dependent and non-dependent sides were presented as proportions; where comparison between sides was required, McNemar's test (paired categorical data) was used. The incidence of postoperative nausea and vomiting was expressed as percentages. A two-tailed p value < 0.05 was considered statistically significant.

Results

In this study, a total of 88 patients were included. The mean height of the study population was 165.4 ± 6.5 cm, and the mean body weight was 68.6 ± 13.2 kg. The mean body mass index (BMI) was 23.7 ± 3.1 kg/m². The mean age of the patients was 46.9 ± 14.8 years. Out of 88 patients, 70 were male and 18 were female. 36 patients belonged to ASA grade I, while 52 patients belonged to ASA grade II.

[Table-2] In the present study, hemodynamic parameters were recorded before spinal anaesthesia and 20 minutes after the block. The median systolic blood pressure decreased from 136 mmHg (range 98–188) before block to 127 mmHg (range 82–174) after block, and this change was statistically significant ($p < 0.001$). Similarly, the median diastolic blood pressure reduced from 84 mmHg (range 42–118) before block to 72 mmHg (range 46–98) after block, which was also statistically significant ($p < 0.001$). The median heart rate decreased from 87 beats per minute (range 52–122) before block to 75 beats per minute (range 58–118) after block, and this difference was found to be statistically significant ($p < 0.001$).

[Table -3] On the dependent side, the majority of patients achieved higher grades of motor block, with 54 patients (61.4%) having Bromage grade 3 and 30 patients (34.1%) having grade 2. Only 2 patients (2.3%) each had Bromage grades 0 and 1.On the non-dependent side, most patients (70 patients; 79.5%) showed no motor block (Bromage grade 0). Minimal motor block was observed in a small proportion of patients, with 3 patients (3.4%) having grade 1, 10 patients (11.4%) having grade 2, and 5 patients (5.7%) having grade 3.

[Table-4] On the dependent side, sensory block was observed in all patients, with the upper level of sensory block ranging from T6 to L3. The most commonly achieved sensory levels were L1 (29.5%), T12 (25.0%), and T10 (20.5%). On the non-dependent side, 70 patients (79.5%) showed no sensory block, indicating preservation of sensation. In the remaining patients, sensory block was limited, most commonly observed at T10 (10.2%) and T11 (8.0%), with no patient showing sensory block above T10.

[Figure-1] Post-operative nausea was observed in 3 patients (3.4%), while 85 patients (96.6%) did not experience nausea. None of the patients experienced post-operative vomiting.

Table 1: Demographic Data of Patients Studied (n = 88)

Variable	Mean ± SD
Height (cm)	165.4 ± 6.5
Weight (kg)	68.6 ± 13.2
BMI (kg/m²)	23.7 ± 3.1
Age (years)	46.9 ± 14.8

Table 2: Hemodynamic Variables Before and After Spinal Block (n = 88)

Variable	Time	Median (Min–Max)	p value vs Baseline
SBP (mm Hg)	Before block	136 (98–188)	<0.001
	After block	127 (82–174)	
DBP (mm Hg)	Before block	84 (42–118)	<0.001
	After block	72 (46–98)	
Heart rate (bpm)	Before block	87 (52–122)	<0.001
	After block	75 (58–118)	

Table 3: Motor Block on Dependent and Non-Dependent Side (Modified Bromage Scale) (n = 88)

Bromage Grade	Dependent Side n (%)	Non-Dependent Side n (%)
0	2 (2.3%)	70 (79.5%)
1	2 (2.3%)	3 (3.4%)
2	30 (34.1%)	10 (11.4%)
3	54 (61.4%)	5 (5.7%)

Table 4: Upper Level of Sensory Block on Dependent and Non-Dependent Side (n = 88)

Sensory Level	Dependent Side n (%)	Non-Dependent Side n (%)
Nil	0 (0%)	70 (79.5%)
T6	2 (2.3%)	0 (0%)
T8	9 (10.2%)	0 (0%)
T9	0 (0%)	0 (0%)
T10	18 (20.5%)	9 (10.2%)
T11	5 (5.7%)	7 (8.0%)
T12	22 (25.0%)	2 (2.3%)
L1	26 (29.5%)	0 (0%)
L3	6 (6.8%)	0 (0%)

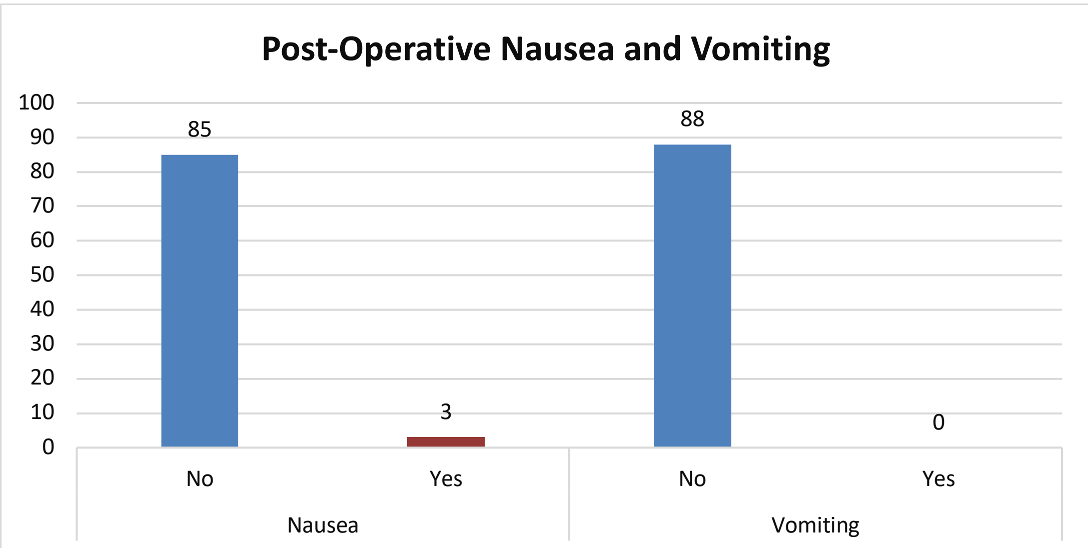

Figure 1: Post-Operative Nausea and Vomiting (n = 88)

Discussion

In the present study, unilateral spinal anaesthesia using 6 mg of 0.5% hyperbaric bupivacaine with 90 µg buprenorphine was evaluated in 88 ASA I–II adults undergoing unilateral lower-limb surgery. Participants had a mean age of 46.9 ± 14.8 years with a predominance of males (70/88). Mean BMI was 23.7 ± 3.1 kg/m², suggesting that most patients were in a non-obese range, which is relevant because technical difficulty, CSF volume variation, and intrathecal spread may be more variable in obesity. Overall, the demographic profile is comparable to unilateral spinal anaesthesia trials that largely included ASA I–II adults scheduled for unilateral lower-limb procedures (often arthroscopy), supporting reasonable external comparability. [9]

In the present study, SBP, DBP, and heart rate showed a statistically significant reduction 20 minutes after spinal block (p<0.001). Even when statistically significant, the key clinical point is that the reduction remained within a range that is typically manageable, reflecting the expected physiology of spinal anaesthesia—sympathetic blockade (arterial and venous vasodilatation) with possible reduction in venous return and reflex changes in heart rate. A central rationale for unilateral spinal anaesthesia is to reduce the extent of sympathetic blockade by limiting spread to the non-dependent side. Low-dose hyperbaric bupivacaine with maintained lateral position is a known strategy to reduce hemodynamic instability compared with conventional bilateral spinal techniques. Kuusniemi et al [10] (2000) using 6 mg hyperbaric bupivacaine with 20-minute lateral positioning reported minimal hemodynamic changes, with hypotension in ~5% and bradycardia in ~1.7%. Fanelli et al [11] (2000) also found that unilateral technique produced less cardiovascular effect and lower vasopressor requirement compared with bilateral block. The overall direction of hemodynamic change in our study matches the general unilateral spinal literature, where lower doses and lateral fixation reduce clinically important hypotension compared with higher-dose bilateral techniques. [12]

Esmaoğlu et al [9] showed that with higher intrathecal dose (e.g., 2.5 mL of 0.5%, i.e., 12.5 mg), non-dependent spread increased and hypotension incidence rose (10–20%), while lower/mid doses were more favorable. This supports why our low-dose regimen likely contributed to acceptable hemodynamic profile even though a statistically significant decline was seen.

In the present study, the dependent limb achieved a dense motor block more frequently (Bromage grade 3 in 61.4%, grade 2 in 34.1%). On the non-dependent side, most patients (79.5%) had no motor block (grade 0), indicating substantial contralateral sparing.

Hyperbaric solutions tend to settle in the dependent regions of the subarachnoid space under gravity. Maintaining the lateral position for a fixation period (20 minutes in your protocol) allows greater "unilateralization." This is consistent with Kuusniemi et al. (6 mg hyperbaric) where hyperbaric solution produced more unilateral distribution than plain bupivacaine when lateral positioning was maintained. [2]

Borghi et al5 (dose-finding) reported complete unilateral motor block in 93% of patients receiving 6 mg hyperbaric bupivacaine (Whitacre needle, lateral 15 min). Esmaoğlu et al [9] demonstrated greater non-dependent block progression with larger volumes (e.g., 2.5 mL), supporting why strict unilateral motor block becomes less likely as dose increases. A literature review and recommendations paper emphasized slow injection and ~20 min lateral position as key determinants for achieving unilateral blocks with hyperbaric bupivacaine. [13]

In the present study, the dependent limb developed sensory block in all patients, with cephalad spread T6 to L3, most commonly around L1 (29.5%), T12 (25.0%), and T10 (20.5%). On the non-dependent side, 79.5% had no sensory block, while the remaining showed limited spread, most commonly up to T10 and T11. The absence of non-dependent sensory block in ~80% indicates good unilateralization but not complete exclusion of contralateral spread in all patients.

Even with hyperbaric solutions, some degree of mixing and redistribution can occur due to CSF pulsations, subtle patient/table tilt, and speed of injection, needle type/orientation, and inter-individual CSF volume differences. These factors can explain why a proportion of patients develop partial contralateral sensory block despite adherence to a unilateral technique. [9,13]

Kuusniemi et al. reported unilateral motor + sensory block in 83% with 6 mg hyperbaric bupivacaine and 20-minute lateral position. Your non-dependent "no sensory block" rate of 79.5% is close in magnitude, suggesting broadly similar unilateralization.

Borghi et al [5] reported strictly unilateral sensory block in 93% of patients receiving 6 mg (lateral 15 min, outpatient arthroscopy setting). The somewhat lower contralateral sparing could relate to differences in surgery type (and duration), patient positioning maintenance, needle type (Quincke vs pencil-point), and operational factors. In the same Borghi dose-finding study, 8 mg showed lower strictly unilateral sensory block (77%), supporting the known dose–spread effect. Atef et al [6] similarly reported that lower doses (e.g., 5–7.5 mg) were associated with higher unilateral sensory/motor block rates than higher doses. The systematic review by Nair et al [12] concluded that with unilateral positioning, 4–5 mg can often be sufficient for knee arthroscopy, and higher doses delay recovery—again reinforcing why your low-dose approach is mechanistically sound for minimizing extensive spread.

In the present study, nausea occurred in 3.4% and vomiting in 0%. This low incidence is clinically favorable. Possible contributors include limited sympathetic blockade (less hypotension-related nausea), lower systemic opioid exposure, and relatively localized neuraxial spread. Unilateral spinal approaches are generally associated with fewer systemic adverse effects due to reduced hemodynamic instability, which can indirectly reduce nausea. Also, dose-finding unilateral studies report low rates of nausea/vomiting across low-dose groups. [6] Regarding intrathecal buprenorphine, published evidence supports that it can prolong analgesia when used as an adjuvant. While adjuvants can sometimes increase nausea/pruritus depending on drug and dose, observed PONV rates remain low, suggesting acceptable tolerability in this regimen. [14,15]

Conclusion

In the present study, unilateral spinal anaesthesia using low-dose 0.5% hyperbaric bupivacaine (6 mg) combined with intrathecal buprenorphine (90 µg), administered by a slow injection technique with maintenance of lateral decubitus position for 20 minutes, was found to be an effective anaesthetic technique for unilateral lower limb surgeries.

The technique produced a predominantly unilateral distribution of sensory and motor block on the dependent limb, with minimal involvement of the non-dependent limb in the majority of patients.

Hemodynamic parameters showed statistically significant reductions after spinal anaesthesia; however, these changes were clinically acceptable and easily manageable, indicating relative hemodynamic stability with this low-dose unilateral approach. The incidence of adverse effects, including postoperative nausea and vomiting, was low, and no serious complications were observed.

Unilateral spinal anaesthesia using low-dose hyperbaric bupivacaine with buprenorphine offers the advantages of adequate surgical anaesthesia, improved hemodynamic stability, limited contralateral spread, and good postoperative tolerability. This technique can be considered a safe and effective alternative to conventional bilateral spinal anaesthesia for selected patients undergoing unilateral lower limb surgical procedures.

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