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COMPARATIVE EVALUATION OF 0.5% ISOBARIC LEVOBUPIVACAINE AND 0.75% ISOBARIC ROPIVACAINE FOR SEGMENTAL SPINAL ANESTHESIA IN ELECTIVE LAPAROSCOPIC CHOLECYSTECTOMY

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ABSTRACT

Background: General anesthesia remains the standard anesthetic technique for laparoscopic cholecystectomy; however, segmental spinal anesthesia has gained increasing acceptance as an effective alternative because of its advantages, including avoidance of airway manipulation, improved postoperative analgesia, reduced opioid requirement, and enhanced perioperative recovery. Levobupivacaine and ropivacaine are newer long-acting local anesthetics with improved cardiovascular safety compared with racemic bupivacaine, although comparative evidence regarding their effectiveness during segmental spinal anesthesia for laparoscopic cholecystectomy remains limited.

Objectives: To compare the efficacy and safety of 0.5% isobaric levobupivacaine and 0.75% isobaric ropivacaine for segmental spinal anesthesia in patients undergoing elective laparoscopic cholecystectomy, with emphasis on sensory block characteristics, intraoperative hemodynamic stability, postoperative analgesia, recovery profile, and perioperative adverse events.

Methods: This prospective, interventional, double-blind, randomized controlled study was conducted in the Department of Anaesthesiology at a tertiary care teaching hospital. Sixty ASA physical status I–II patients scheduled for elective laparoscopic cholecystectomy were randomly allocated into two equal groups. Group L received 1.5 mL of 0.5% isobaric levobupivacaine with fentanyl 25 µg, while Group R received 1.5 mL of 0.75% isobaric ropivacaine with fentanyl 25 µg intrathecally. Sensory block characteristics, intraoperative hemodynamic parameters, adverse events, postoperative analgesia, recovery profile, and patient satisfaction were evaluated. Statistical analysis was performed using SPSS version 26.0, and a p-value <0.05 was considered statistically significant.

Results: Baseline demographic and clinical characteristics were comparable between the two groups. Patients receiving levobupivacaine demonstrated a significantly faster onset and longer duration of sensory blockade, resulting in prolonged postoperative analgesia and a significantly longer time to first rescue analgesic requirement. Both groups maintained satisfactory intraoperative hemodynamic stability without significant differences in cardiovascular parameters. Levobupivacaine demonstrated superior sensory block characteristics, prolonged postoperative analgesia, and higher patient satisfaction. Recovery parameters were comparable between the two groups, with no clinically significant differences in postoperative ambulation or spontaneous voiding.

Conclusion: Both 0.5% isobaric levobupivacaine and 0.75% isobaric ropivacaine are safe and effective agents for segmental spinal anesthesia during elective laparoscopic cholecystectomy. However, levobupivacaine demonstrated superior overall clinical efficacy by providing faster onset of anesthesia, prolonged sensory blockade, superior postoperative analgesia, higher patient satisfaction, and an excellent safety profile.

KEYWORDS: Segmental spinal anesthesia; Levobupivacaine; Ropivacaine; Laparoscopic cholecystectomy; Thoracic spinal anesthesia; Hemodynamic stability; Postoperative analgesia; Randomized controlled trial.

INTRODUCTION

Laparoscopic cholecystectomy is the gold standard surgical treatment for symptomatic cholelithiasis and other benign gallbladder disorders owing to its minimal invasiveness, reduced postoperative pain, shorter hospital stay, and faster recovery compared with open cholecystectomy.[1] Conventionally, the procedure is performed under general anesthesia because pneumoperitoneum, reverse Trendelenburg positioning, and diaphragmatic irritation can compromise respiratory mechanics and patient comfort. However, general anesthesia is associated with several adverse effects, including airway manipulation, postoperative nausea and vomiting, delayed recovery, increased analgesic requirements, and cardiorespiratory complications, particularly in elderly patients and those with significant comorbidities.[2] Consequently, interest has grown in regional anesthetic techniques that can provide adequate surgical anesthesia while minimizing the physiological disturbances associated with general anesthesia.

Spinal anesthesia has long been recognized as a safe, reliable, and cost-effective regional anesthetic technique for lower abdominal and lower limb surgeries. Compared with general anesthesia, spinal anesthesia offers superior intraoperative analgesia, reduced stress response, lower incidence of thromboembolic complications, decreased postoperative opioid consumption, and early postoperative recovery.[3] Advances in surgical and anesthetic techniques have expanded the application of spinal anesthesia to selected upper abdominal laparoscopic procedures, including laparoscopic cholecystectomy. Recent evidence suggests that spinal anesthesia can be successfully employed in appropriately selected patients while maintaining satisfactory surgical conditions and patient comfort.[4]

The concept of segmental spinal anesthesia has further refined the use of neuraxial blockade for upper abdominal surgery. Segmental spinal anesthesia involves administering a low dose of local anesthetic at a thoracic or high lumbar level to selectively block only the dermatomes required for the surgical procedure, thereby limiting unnecessary sympathetic and motor blockade.[5] This targeted approach preserves lower limb motor function, facilitates early ambulation, minimizes urinary retention, and improves hemodynamic stability. Furthermore, the use of low-dose local anesthetics in combination with intrathecal opioids has been shown to provide adequate sensory anesthesia with minimal respiratory compromise and reduced incidence of hypotension.[6]

Selection of an appropriate local anesthetic is crucial for achieving an optimal balance between surgical anesthesia, postoperative analgesia, recovery profile, and safety. Levobupivacaine and ropivacaine, the newer long-acting amide local anesthetics, have largely replaced racemic bupivacaine in many clinical settings because of their lower cardiotoxicity and neurotoxicity.[7] Levobupivacaine, the pure S(-)-enantiomer of bupivacaine, provides effective sensory anesthesia with a relatively shorter duration of motor blockade while maintaining excellent cardiovascular safety. Ropivacaine, another pure S-enantiomer, exhibits greater sensory–motor differentiation, producing less intense motor blockade and facilitating earlier postoperative mobilization, characteristics that are particularly advantageous in ambulatory and minimally invasive surgeries.[8]

The use of isobaric formulations of levobupivacaine and ropivacaine offers additional advantages during segmental spinal anesthesia. Unlike hyperbaric solutions, isobaric local anesthetics are less influenced by patient positioning, resulting in a more predictable spread of intrathecal drug and a lower risk of excessively high spinal block.[9] Previous comparative studies evaluating intrathecal levobupivacaine and ropivacaine have demonstrated favorable safety profiles for both agents; however, differences have been reported in onset of sensory block, duration of analgesia, motor blockade characteristics, and hemodynamic effects. Most available evidence has been derived from lower abdominal or lower limb surgeries, while high-quality comparative data specifically evaluating their role in segmental spinal anesthesia for laparoscopic cholecystectomy remain limited.[3,8,10]

In India, laparoscopic cholecystectomy is increasingly performed as a day-care or short-stay procedure, highlighting the importance of anesthetic techniques that promote rapid recovery, early ambulation, minimal postoperative discomfort, and reduced healthcare costs. Although segmental spinal anesthesia appears to be a promising alternative to general anesthesia, the optimal local anesthetic for achieving effective sensory blockade with favorable hemodynamic stability and rapid postoperative recovery has not been conclusively established. Comparative evidence between 0.5% isobaric levobupivacaine and 0.75% isobaric ropivacaine for this specific indication remains scarce, particularly in tertiary care settings in northern India.

Therefore, the present prospective, interventional, double-blind randomized controlled study was undertaken to compare the efficacy and safety of 0.5% isobaric levobupivacaine and 0.75% isobaric ropivacaine for segmental spinal anesthesia in patients undergoing laparoscopic cholecystectomy. The primary objective was to compare intraoperative hemodynamic variations between the two groups, while the secondary objectives were to evaluate the onset, duration, and maximum level of sensory blockade.

METHODOLOGY

Study Design: This study was designed as a prospective, interventional, double-blind, randomized controlled trial.

Study Setting: The study was conducted in the Department of Anaesthesiology, Dr. Susheela Tiwari Government Hospital, Government Medical College, Haldwani, Uttarakhand.

Study Duration: The study was conducted over a period of 12 months from the date of approval by the Institutional Ethics Committee until completion of patient recruitment and follow-up.

Study Population: The study population comprised adult patients scheduled for elective laparoscopic cholecystectomy under segmental spinal anesthesia. Eligible patients belonged to American Society of Anesthesiologists (ASA) physical status I or II and fulfilled the predefined eligibility criteria.

Inclusion Criteria
• Patients aged 18 years or older of either sex.
• Patients scheduled for elective laparoscopic cholecystectomy.
• ASA physical status I or II.
• Patients willing to participate and providing written informed consent.

Exclusion Criteria
• Contraindications to spinal anesthesia (coagulopathy, bleeding disorders, local infection at puncture site, raised intracranial pressure, or severe spinal deformity).
• Known hypersensitivity to amide local anesthetics or fentanyl.
• Severe chronic obstructive pulmonary disease or significant respiratory insufficiency.
• Pregnancy.
• Refusal to undergo spinal anesthesia.
• Patients requiring emergency surgery.

Sample Size Calculation: The sample size was calculated using the formula for comparison of two independent means:

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

where:
• Zα/2 = 1.96 (95% confidence level)
• Zβ = 0.84 (80% power)
• σ = 2.7 (standard deviation derived from previous published studies)
• Allocation ratio = 1:1

The calculated minimum sample size was **30 participants per group**, resulting in a **total sample size of 60 patients**.

Sampling Technique: Eligible patients satisfying the inclusion criteria were recruited using consecutive sampling. Participants were randomly allocated in a 1:1 ratio into two study groups using a computer-generated randomization sequence. Allocation concealment was maintained using sequentially numbered, opaque, sealed envelopes prepared by an independent investigator. Both the patient and the investigator responsible for intraoperative assessment were blinded to group allocation throughout the study.
• **Group L (n = 30):** Received 1.5 mL of 0.5% isobaric levobupivacaine with fentanyl 25 µg intrathecally.
• **Group R (n = 30):** Received 1.5 mL of 0.75% isobaric ropivacaine with fentanyl 25 µg intrathecally.

Data Collection Tools and Procedure: Following pre-anesthetic evaluation, baseline demographic characteristics and clinical parameters were recorded. Standard fasting guidelines were followed, and routine monitoring, including electrocardiography (ECG), non-invasive blood pressure (NIBP), pulse rate, peripheral oxygen saturation (SpO_2), and mean arterial pressure (MAP), was instituted before administration of anesthesia. Intravenous access was secured, and patients received standard premedication according to institutional protocol. With the patient in the sitting position, thoracic subarachnoid puncture was performed at the T9–T10 intervertebral space under strict aseptic precautions using a spinal needle. According to randomized allocation, patients received either 1.5 mL of 0.5% isobaric levobupivacaine with fentanyl 25 µg (Group L) or 1.5 mL of 0.75% isobaric ropivacaine with fentanyl 25 µg (Group R). Patients were immediately placed supine after intrathecal injection. Adequacy of sensory block was assessed using loss of cold sensation, while surgery commenced after achieving the desired block level. Hemodynamic parameters were recorded preoperatively and at predefined intraoperative intervals (0, 1, 3, 5, 10, 20, 40, 60, 80, and 120 minutes). Rescue intravenous fentanyl (50 µg) was administered if additional analgesia was required during surgery. All patients were monitored throughout the intraoperative and immediate postoperative periods for adverse events and recovery characteristics.

Study Variables: The independent variable was the type of intrathecal local anesthetic administered (0.5% isobaric levobupivacaine or 0.75% isobaric ropivacaine). The primary dependent outcome was intraoperative hemodynamic stability, assessed using heart rate, systolic blood pressure, diastolic blood pressure, mean arterial pressure, and oxygen saturation. Secondary outcome variables included onset time of sensory block, duration of sensory block, highest sensory dermatome achieved, requirement of supplemental analgesia, intraoperative adverse events (hypotension, bradycardia, nausea, vomiting, shoulder pain), and postoperative recovery profile.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) software version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ±standard deviation (SD) or median (interquartile range) depending on data distribution, while categorical variables were presented as frequencies and percentages. Normality of data distribution was assessed using the Shapiro–Wilk test. Continuous variables were compared using the independent samples Student's t-test for normally distributed data and the

Mann–Whitney U test for non-normally distributed variables. Categorical variables were analyzed using the Chi-square test or Fisher's exact test, as appropriate. A two-tailed p-value <0.05 was considered statistically significant.

Ethical Considerations: The study was conducted after obtaining approval from the Institutional Ethics Committee of Government Medical College, Haldwani, before commencement of patient recruitment. Written informed consent was obtained from all participants after explaining the objectives, procedures, potential benefits, and possible risks of the study in their preferred language. Participation was entirely voluntary, and participants were free to withdraw from the study at any stage without affecting their standard medical care. Confidentiality of patient information was strictly maintained by anonymizing all study data. The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki (2013 revision), the ICMR National Ethical Guidelines for Biomedical and Health Research involving Human Participants, and Good Clinical Practice (GCP) guidelines.

RESULTS

A total of 60 patients undergoing elective laparoscopic cholecystectomy were enrolled and randomized equally into two groups: Group L (0.5% isobaric levobupivacaine, n = 30) and Group R (0.75% isobaric ropivacaine, n = 30). All randomized patients completed the study and were included in the final analysis.

The baseline demographic and clinical characteristics of the study participants were comparable between the two groups, with no statistically significant differences observed in age, sex distribution, body weight, body mass index, or ASA physical status (Table 1).

Table 1. Baseline demographic and clinical characteristics of study participants

Variable	Group L (Levobupivacaine) (n=30)	Group R (Ropivacaine) (n=30)	p-value
Age (years), Mean ± SD	42.8 ± 10.1	44.3 ± 9.5	0.56
Male, n (%)	9 (30.0)	10 (33.3)	0.78
Female, n (%)	21 (70.0)	20 (66.7)	
Weight (kg), Mean ± SD	64.7 ± 8.2	66.2 ± 7.9	0.48
BMI (kg/m²), Mean ± SD	25.1 ± 2.8	25.6 ± 3.0	0.52
ASA Grade I, n (%)	18 (60.0)	17 (56.7)	0.79
ASA Grade II, n (%)	12 (40.0)	13 (43.3)	

Independent samples t-test and Chi-square test were applied as appropriate.

Sensory block characteristics were compared between the two study groups. Patients receiving levobupivacaine demonstrated a significantly faster onset of sensory blockade and a significantly longer duration of sensory block compared with those receiving ropivacaine. The maximum sensory block level achieved was comparable between the groups (Table 2).

Table 2. Comparison of sensory block characteristics

Parameter	Group L (n=30)	Group R (n=30)	p-value
Onset of sensory block (min), Mean ± SD	4.2 ± 0.7	5.1 ± 0.9	<0.001
Time to T4 block (min), Mean ± SD	5.9 ± 0.8	6.8 ± 0.9	<0.001
Duration of sensory block (min), Mean ± SD	182 ± 18	156 ± 17	<0.001
Highest sensory level T2, n (%)	10 (33.3)	6 (20.0)	0.39
Highest sensory level T3, n (%)	17 (56.7)	18 (60.0)	
Highest sensory level T4, n (%)	3 (10.0)	6 (20.0)	

Independent samples t-test and Chi-square test were applied.

Both groups maintained comparable intraoperative hemodynamic stability, with no statistically significant differences in heart rate, mean arterial pressure, oxygen saturation, hypotension, or bradycardia (Table 3).

Table 3. Intraoperative hemodynamic profile

Variable	Group L (n=30)	Group R (n=30)	p-value
Lowest Heart Rate (beats/min), Mean ± SD	70 ± 7	68 ± 8	0.31
Lowest MAP (mmHg), Mean ± SD	79 ± 6	77 ± 7	0.24
Lowest SpO_2 (%), Mean ± SD	98.4 ± 0.8	98.2 ± 0.9	0.37
Hypotension requiring vasopressor, n (%)	2 (6.7)	5 (16.7)	0.22
Bradycardia requiring atropine, n (%)	1 (3.3)	3 (10.0)	0.30

Independent samples t-test and Fisher's exact test were applied.

The incidence of intraoperative and postoperative adverse events was low in both groups. Patients receiving levobupivacaine demonstrated numerically fewer adverse events and a lower requirement for supplemental intraoperative analgesia, although these differences were not statistically significant (Table 4).

Table 4. Intraoperative and postoperative adverse events

Adverse Event	Group L (n=30)	Group R (n=30)	p-value
Shoulder pain	2 (6.7)	5 (16.7)	0.23
Nausea	1 (3.3)	4 (13.3)	0.16
Vomiting	1 (3.3)	3 (10.0)	0.30
Supplemental IV fentanyl required	2 (6.7)	6 (20.0)	0.12
Conversion to general anesthesia	0 (0.0)	1 (3.3)	0.31

Fisher's exact test was applied.

Recovery parameters, including ambulation and spontaneous voiding, were comparable between the two groups. However, levobupivacaine provided significantly prolonged postoperative analgesia and higher patient satisfaction (Table 5).

Table 5. Postoperative recovery characteristics

Parameter	Group L (n=30)	Group R (n=30)	p-value
Time to first rescue analgesia (min), Mean ± SD	248 ± 30	205 ± 26	<0.001
Duration of effective analgesia (hours), Mean ± SD	4.1 ± 0.5	3.4 ± 0.4	<0.001
Time to ambulation (hours), Mean ± SD	4.5 ± 0.6	4.3 ± 0.5	0.14
Time to spontaneous voiding (hours), Mean ± SD	5.3 ± 0.7	5.1 ± 0.6	0.18
Patient satisfaction score (0–10), Mean ± SD	9.5 ± 0.5	9.0 ± 0.7	0.003

Independent samples t-test was applied.

Overall, the findings of the present study indicate that 0.5% isobaric levobupivacaine provided superior overall clinical performance compared with 0.75% isobaric ropivacaine for segmental spinal anesthesia in elective laparoscopic cholecystectomy, while maintaining an excellent safety profile and satisfactory intraoperative hemodynamic stability.

DISCUSSION

The present prospective, double-blind randomized controlled trial compared the efficacy and safety of 0.5% isobaric levobupivacaine and 0.75% isobaric ropivacaine for segmental spinal anesthesia in patients undergoing elective laparoscopic cholecystectomy. The findings demonstrated that both anesthetic agents provided effective surgical anesthesia with satisfactory intraoperative hemodynamic stability and a low incidence of perioperative complications. However, levobupivacaine consistently demonstrated superior overall clinical performance, characterized by a significantly faster onset of sensory blockade, prolonged duration of sensory anesthesia, extended postoperative analgesia,

higher patient satisfaction, numerically lower requirement for supplemental intraoperative analgesia and fewer perioperative adverse events, although these differences were not statistically significant.

Laparoscopic cholecystectomy is conventionally performed under general anesthesia because pneumoperitoneum and upper abdominal surgical manipulation may compromise respiratory mechanics and patient comfort. Nevertheless, increasing evidence has demonstrated that thoracic segmental spinal anesthesia is a safe and effective alternative in appropriately selected patients, providing adequate surgical anesthesia while avoiding airway instrumentation and minimizing the physiological stress response associated with general anesthesia.[4,5] In addition to excellent intraoperative analgesia, segmental spinal anesthesia has been associated with reduced postoperative pain, lower opioid consumption, decreased postoperative nausea and vomiting, early oral intake, and shorter hospital stay.[6] The findings of the present study further strengthen the evidence supporting the use of thoracic segmental spinal anesthesia for elective laparoscopic cholecystectomy.

One of the principal observations of the present study was the significantly faster onset of sensory blockade achieved with levobupivacaine. Rapid establishment of an adequate sensory block is advantageous because it shortens anesthetic preparation time, improves operating room efficiency, and facilitates timely surgical commencement. Similar findings have been reported in previous comparative studies evaluating intrathecal levobupivacaine, where its favorable physicochemical properties resulted in faster onset and reliable sensory anesthesia while maintaining an improved safety profile compared with racemic bupivacaine.[3,7] The earlier onset observed with levobupivacaine is likely related to its greater lipid solubility and intrinsic anesthetic potency, allowing more rapid penetration into neural tissues.

The present study also demonstrated a significantly longer duration of sensory blockade and postoperative analgesia in the levobupivacaine group. These findings are consistent with those reported by Glaser et al., who observed prolonged sensory anesthesia and sustained postoperative analgesia with intrathecal levobupivacaine while maintaining cardiovascular stability.[3] Prolonged postoperative analgesia is clinically beneficial because it delays the need for rescue analgesics, improves patient comfort, reduces postoperative opioid requirements, and contributes to enhanced recovery. The significantly longer time to first rescue analgesia observed in the present study further supports the superior analgesic efficacy of levobupivacaine.

Both groups demonstrated comparable intraoperative hemodynamic stability. Although fewer patients in the levobupivacaine group required vasopressors or atropine, these differences were not statistically significant. These observations are consistent with previous reports demonstrating that low-dose thoracic spinal anesthesia effectively limits sympathetic blockade while preserving cardiovascular function.[5,6,11] Furthermore, the addition of intrathecal fentanyl in both study groups probably enhanced sensory analgesia without increasing the incidence of significant hemodynamic disturbances.

The incidence of intraoperative and postoperative adverse events remained low in both groups, confirming the safety of both anesthetic agents. Although the incidence of shoulder pain, nausea, vomiting, and supplemental fentanyl requirement was numerically lower in the levobupivacaine group, these differences were not statistically significant. Furthermore, no patient receiving levobupivacaine required conversion to general anesthesia, whereas one patient in the ropivacaine group required conversion because of inadequate surgical anesthesia. These findings are comparable with previous studies evaluating thoracic spinal anesthesia for laparoscopic procedures, which have reported excellent safety profiles when appropriate patient selection, meticulous monitoring, and low-pressure pneumoperitoneum are employed.[4,6]

Patient satisfaction is an important indicator of the overall quality of perioperative care. In the present study, satisfaction scores were high in both groups but were significantly higher among patients receiving levobupivacaine. This finding is likely attributable to the combination of rapid onset of anesthesia, prolonged postoperative pain relief, lower requirement for supplemental analgesia, and fewer perioperative discomforts. Improved patient satisfaction further supports the clinical usefulness of levobupivacaine in minimally invasive upper abdominal surgery.

Postoperative recovery parameters, including ambulation and spontaneous voiding, were comparable between the two groups. Therefore, the superior sensory block characteristics, prolonged postoperative analgesia, and higher patient satisfaction observed with levobupivacaine support its overall clinical advantage.[11,12]

From a clinical standpoint, the findings of the present study suggest that 0.5% isobaric levobupivacaine represents the more effective intrathecal local anesthetic for segmental spinal anesthesia during elective laparoscopic cholecystectomy. Its ability to provide rapid onset, prolonged sensory blockade, superior postoperative analgesia, higher patient satisfaction, and an excellent safety profile makes it a valuable option for routine clinical practice. Although ropivacaine remains a safe alternative, its comparatively shorter duration of analgesia and greater requirement for supplemental analgesia may limit its overall clinical utility in procedures where sustained postoperative pain control is desirable.

The strengths of the present study include its prospective randomized double-blind design, standardized anesthetic protocol, equal allocation of participants, and comprehensive assessment of intraoperative hemodynamic variables, block characteristics, postoperative analgesia, adverse events, and patient satisfaction. These methodological strengths reduce the risk of selection and observer bias while enhancing the internal validity of the findings.

However, certain limitations should be acknowledged. The study was conducted at a single tertiary care center with a relatively modest sample size, which may limit the generalizability of the findings. Postoperative follow-up was confined to the early recovery period, precluding assessment of long-term outcomes and quality-of-recovery measures. Motor blockade was assessed indirectly through clinical recovery parameters rather than by a validated scoring system such as the Modified Bromage Scale. Finally, the study included only ASA physical status I and II patients undergoing elective

laparoscopic cholecystectomy; therefore, the findings should be interpreted cautiously in elderly patients, high-risk populations, or individuals with significant systemic comorbidities.

CONCLUSION

The present randomized controlled trial demonstrated that both 0.5% isobaric levobupivacaine and 0.75% isobaric ropivacaine are safe and effective agents for segmental spinal anesthesia in patients undergoing elective laparoscopic cholecystectomy, providing satisfactory intraoperative hemodynamic stability with a low incidence of perioperative complications. However, levobupivacaine demonstrated superior overall clinical efficacy, characterized by a significantly faster onset of sensory blockade, longer duration of sensory anesthesia, prolonged postoperative analgesia, higher patient satisfaction, and an excellent safety profile. Although postoperative recovery parameters were comparable between the two groups, the enhanced anesthetic profile and sustained analgesic effect observed with levobupivacaine make it the more favorable intrathecal local anesthetic for segmental spinal anesthesia in laparoscopic cholecystectomy. Therefore, 0.5% isobaric levobupivacaine appears to be the preferred intrathecal local anesthetic for achieving effective surgical anesthesia while ensuring prolonged postoperative pain relief and excellent patient comfort. Further multicenter randomized studies with larger sample sizes and extended follow-up are warranted to validate these findings and establish definitive recommendations for routine clinical practice.

DECLARATIONS

Funding: The authors received no external funding for this study.

Conflict of Interest: The authors declare no conflict of interest.

Ethical Approval: The study protocol was approved by the Institutional Ethics Committee, Government Medical College, Haldwani, Uttarakhand, before commencement of patient recruitment. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki (2013 revision), the ICMR National Ethical Guidelines for Biomedical and Health Research Involving Human Participants, and Good Clinical Practice (GCP) guidelines.

Informed Consent: Written informed consent was obtained from all participants prior to enrollment after explaining the nature, objectives, potential benefits, and possible risks of the study. Participant confidentiality and privacy were maintained throughout the study.

Data Availability: The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

Acknowledgements: The authors express their sincere gratitude to the faculty and staff of the Department of Anaesthesiology, Dr. Susheela Tiwari Government Hospital, Government Medical College, Haldwani, for their guidance and support throughout the study. The authors also thank all study participants for their voluntary participation and cooperation.

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