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ORIGINAL RESEARCH ARTICLE

Comparative Efficacy of Dexmedetomidine as an Adjuvant to Intrathecal Hyperbaric Levobupivacaine versus Ropivacaine in Spinal Anaesthesia: A Randomized Controlled Trial

Hari Sankar Prajapati[1] | Rajeev Kumar Dubey[2] | Arun Raj Pandey[3] | Atul Kumar Singh[4*]

Abstract

Background and Aims: This study compared dexmedetomidine as an adjuvant to intrathecal hyperbaric levobupivacaine versus ropivacaine in spinal anaesthesia, focusing on block characteristics, hemodynamic stability, and postoperative analgesia.
Methods: In this prospective randomized single-blind study, 60 patients (ASA I–II) undergoing elective surgery received either levobupivacaine (15 mg) + dexmedetomidine (10 μg) (Group L) or ropivacaine (15 mg) + dexmedetomidine (10 μg) (Group R). Outcomes included onset and duration of sensory/motor block, analgesia duration, and adverse events.
Results: Block onset was comparable in both groups. Group R showed significantly longer sensory block duration and postoperative analgesia, while Group L had prolonged motor block duration. Hemodynamic parameters remained stable with minimal adverse events.
Conclusion: Both combinations are safe and effective. Ropivacaine-dexmedetomidine provides superior analgesia, whereas levobupivacaine-dexmedetomidine offers longer motor blockade. Choice should be based on surgical needs.

Key words: Dexmedetomidine, Levobupivacaine, Ropivacaine, Spinal anaesthesia, Postoperative analgesia, Regional anaesthesia.

1 | INTRODUCTION

Recent evolution in local anaesthetics has witnessed unprecedented growth in procedures requiring safe and effective anaesthesia, particularly in obstetric and lower abdominal interventions. The escalating demand for caesarean deliveries, hernia repairs, and urological procedures necessitates anaesthetic techniques that ensure patient safety while providing optimal surgical conditions. Spinal anaesthesia has emerged as the technique of choice for numerous procedures, offering advantages including reduced respiratory complications, minimal cardiovascular depression, and enhanced postoperative recovery profiles compared to general anaesthesia (1, 2).

The foundation of neuraxial anaesthesia rests upon the selective blockade of neural transmission through voltage-gated sodium channel inhibition. Local anaesthetic agents achieve reversible nerve conduction blockade by preventing action potential generation and propagation, resulting in sensory and motor

[1] Junior Resident, Department of Anaesthesiology, Institute of Medical Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh – 221005, India..
[2] Professor, Department of Anaesthesiology, Institute of Medical Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh – 221005, India..
[3] Associate Professor, Department of Anaesthesiology, Institute of Medical Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh – 221005, India.
[4] Associate Professor, Department of Anaesthesiology, Institute of Medical Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh – 221005, India..
Address correspondence to: Atul Kumar, Singh, Associate Professor, Department of Anaesthesiology, Institute of Medical Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh – 221005, India.,

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blockade. The clinical effectiveness of these agents depends on their pharmacokinetic properties, including onset time, duration of action, and safety profile, which directly influence surgical outcomes and patient satisfaction (3, 4).

Modern local anaesthetic development has prioritized safety improvements while maintaining clinical efficacy. Levobupivacaine, the pure S-enantiomer of racemic bupivacaine, demonstrates reduced cardiovascular toxicity while preserving potent anaesthetic properties. This agent provides reliable neural blockade with decreased risk of cardiac complications, making it particularly suitable for extensive surgical procedures. Conversely, ropivacaine offers unique pharmacological characteristics including preferential sensory blockade and reduced motor impairment, facilitating early postoperative mobilization.

The integration of adjuvant medications represents a significant advancement in spinal anaesthesia optimization. Dexmedetomidine, a highly selective alpha-2 adrenergic agonist, has gained prominence for its ability to enhance local anaesthetic effects without compromising safety. This compound acts through presynaptic alpha-2 receptor binding in the spinal cord, inhibiting pro-nociceptive neurotransmitter release and activating descending inhibitory pathways. The resulting clinical benefits include prolonged sensory blockade, extended postoperative analgesia, and reduced opioid requirements (5, 6).

Clinical investigations have demonstrated that dexmedetomidine significantly enhances the duration and quality of spinal anaesthesia when combined with various local anaesthetics. However, comparative studies evaluating different local anaesthetic-dexmedetomidine combinations remain limited, creating knowledge gaps regarding optimal drug selection for specific clinical scenarios.

The choice between levobupivacaine and ropivacaine as primary local anaesthetics, when combined with dexmedetomidine, may significantly influence clinical outcomes including block characteristics, hemodynamic stability, and patient recovery. Understanding these differences is essential for evidence-based anaesthetic practice and optimal patient care (7, 8).

This investigation aims to provide comprehensive comparative data regarding dexmedetomidine as an adjuvant to intrathecal levobupivacaine versus ropivacaine in spinal anaesthesia. By systematically evaluating onset and duration characteristics, hemodynamic effects, and adverse event profiles, this study seeks to inform clinical decision-making and enhance anaesthetic practice standards. The findings will contribute valuable evidence for selecting appropriate local anaesthetic-adjuvant combinations based on individual patient needs and surgical requirements, ultimately improving perioperative care quality and patient outcomes.

2 | MATERIALS AND METHODS

Study design and setting

The study was a prospective, randomized, single-blind, parallel-group controlled trial in the Department of Anaesthesiology at a tertiary-care teaching hospital. The trial compared intrathecal hyperbaric levobupivacaine plus dexmedetomidine with intrathecal hyperbaric ropivacaine plus dexmedetomidine in adult surgical patients under spinal anaesthesia. Reporting followed CONSORT 2010 recommendations for randomized trials. Participant enrolment, allocation, follow-up, and analysis are depicted in the CONSORT flow diagram Figure 1 .

Participants

Adults aged 18–60 years with American Society of Anaesthesiologists (ASA) physical status I–II scheduled for elective lower-abdominal and lower-limb procedures under spinal anaesthesia were eligible. Exclusion criteria included standard contraindications to neuraxial anaesthesia, hypersensitivity to study drugs, severe systemic or psychiatric disease, prior spinal surgery, anticoagulant therapy, or emergency surgery. Written informed consent was obtained from all participants before enrolment.

Sample size

The sample size targeted the primary endpoint (sensory block duration). Based on the study of Bi YH et al (9) and assuming a 30-minute between-group difference, standard deviation of 35 minutes, α=0.05, and 80% power, 26 participants per arm were required; to offset attrition, 30 per group (n=60) were enrolled.

Randomization and blinding

Participants were assigned 1:1 to the levobupivacaine–dexmedetomidine group (Group L) or the ropivacaine–dexmedetomidine group (Group R) using a computer-generated random sequence. Allocation was concealed with sequentially numbered, opaque, sealed envelopes prepared by staff independent of patient care. The trial was single-blind: participants were blinded to group, the procedural anaesthesiologist knew allocation for safe preparation, and outcome assessors/data analysts remained blinded. Participant disposition is detailed in the CONSORT flow diagram Figure 1.

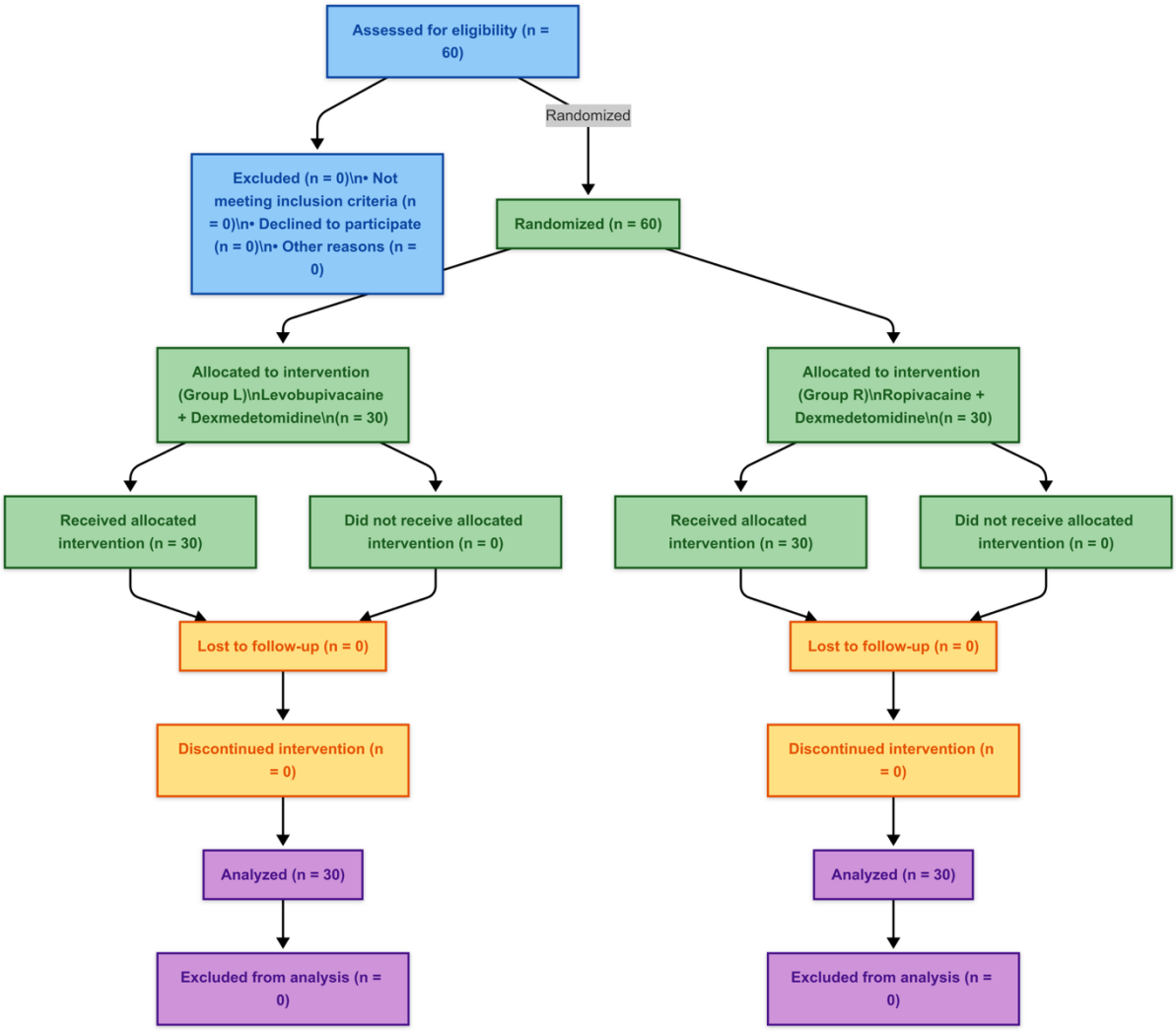

Fig. 1: CONSORT Flow diagram.

Interventions

Study solutions were prepared aseptically immediately before injection to a uniform volume of 3.1 mL. Group L received 3 mL hyperbaric levobupivacaine 0.5% (15 mg) + 0.1 mL dexmedetomidine (10 μg); Group R received 2.0 mL hyperbaric ropivacaine 0.75% (15 mg) + 0.1 mL dexmedetomidine (10 μg) + 1mL of normal saline. Dexmedetomidine was drawn from a 100 μg/mL stock. With standard monitoring and an 18G IV line in place, spinal anaesthesia was performed in the sitting position at L3–L4 or L4–L5 with a 25G Quincke needle; after confirming free cerebrospinal fluid, the study drug was injected over 10–15 s.

Outcomes

Primary outcomes were (1) onset of sensory block, defined as time from injection to loss of pinprick

at T10; (2) duration of sensory block, defined as time to regression to T10; (3) onset of motor block, defined as time to Bromage ≥1; and (4) duration of motor block, defined as time to Bromage 0. Secondary outcomes were time to first rescue analgesia, serial hemodynamic variables [heart rate (HR), systolic/diastolic blood pressure(SBP/DBP), mean arterial pressure(MAP)] recorded at 0, 5, 10, 15, 30, 60, 90, and 120 minutes and then every 30 minutes thereafter, and adverse events. Hypotension was predefined as ≥20% fall in systolic pressure from baseline; bradycardia as heart rate <50 beats/min; nausea, vomiting, respiratory events, failed blocks, and other complications were also recorded.

Safety management

Rescue therapies were prespecified. Hypotension was treated with intravenous crystalloids and mephentermine 6 mg boluses; bradycardia was treated with atropine 0.6 mg IV. Inadequate or failed blocks were converted to general anaesthesia and excluded from per-protocol analyses. Full resuscitation equipment and drugs were available throughout.

Statistical analysis

Analyses were performed in SPSS version 23 (IBM Corp, Armonk, NY, USA). Normality was checked with the Shapiro–Wilk test. Continuous data were summarized as mean ± standard deviation and compared with unpaired t-tests when normally distributed (or Mann–Whitney U tests otherwise). Categorical data were summarized as counts and percentages and compared with chi-square or Fisher's exact tests. Repeated hemodynamic measures were evaluated with repeated-measures ANOVA and Bonferroni adjustment. Statistical significance was set at $p<0.05$, and 95% confidence intervals were reported for key comparisons.

3 | ETHICAL APPROVAL

The protocol received approval from the Institutional Ethics Committee, Institute of Medical Sciences, Banaras Hindu University, Varanasi, India (Ref no. Dean/2022/EC/3785) on 15 April 2023. All procedures adhered to the Declaration of Helsinki and Good Clinical Practice, and all participants gave written informed consent before enrolment.

4 | RESULTS

Participant Flow and Analysis Set

A total of 60 patients were enrolled in the study and randomized equally into two groups: Group L (levobupivacaine 15 mg + dexmedetomidine 10 μg; n = 30) and Group R (ropivacaine 15 mg + dexmedetomidine 10 μg; n = 30). All participants received the allocated interventions according to protocol. There were no exclusions, protocol deviations, or losses to follow-up, and all 60 patients were analysed for both primary and secondary outcomes. This participant distribution is shown in the CONSORT flow diagram Figure 1 .

Demographic and Baseline Characteristics

The demographic and baseline data of both groups are presented in Table 1. The two groups were comparable in gender distribution, body weight, height, body mass index (BMI), ASA physical status, and comorbidities. Mean age differed significantly between the groups (Group L: 45.07 ± 4.20 years vs Group R: 40.20 ± 4.30 years; p = 0.001), although this difference was not clinically meaningful. The distribution of ASA class I and II patients was balanced, and the frequencies of hypertension, diabetes mellitus, or both conditions were similar. These findings confirm that the randomization process achieved an adequate balance between groups.

Onset of Sensory and Motor Block

The mean onset times for both sensory and motor blocks were similar between the two groups (Table 2). Sensory block onset was 92.27 ± 12.05 s in Group L and 93.57 ± 11.16 s in Group R (p = 0.666). Motor block onset occurred at 326.93 ± 19.03 s in Group L and 327.60 ± 18.68 s in Group R (p = 0.892). These results indicate that dexmedetomidine produced a comparable acceleration of both sensory and motor block onset when combined with either levobupivacaine or ropivacaine.

Table 1. Demographic and Baseline Characteristics

Parameter	Group L (n = 30)	Group R (n = 30)	p-value
Age (years)	45.07 ± 4.20	40.20 ± 4.30	**0.001**
Male : Female	16 : 14	16 : 14	1.000
Weight (kg)	71.23 ± 7.68	69.27 ± 9.42	0.330
Height (cm)	163.43 ± 9.54	162.83 ± 8.69	0.800
BMI (kg/m^2)	26.67 ± 2.87	26.12 ± 3.24	0.480
ASA I / II (%)	60 / 40	66.7 / 33.3	0.752
Comorbidities (HTN / DM / Both)	5 / 3 / 1	6 / 4 / 2	0.679

NS = Not Significant; HTN = Hypertension; DM = Diabetes Mellitus. P-value<0.05 is significant.

Table 2. Onset of Sensory and Motor Block

Parameter	Group L (Mean ± SD)	Group R (Mean ± SD)	p-value
Sensory block onset (seconds)	92.27 ± 12.05	93.57 ± 11.16	0.666
Motor block onset (seconds)	326.93 ± 19.03	327.60 ± 18.68	0.892

P-value<0.05 is significant.

Duration of Sensory and Motor Block

Significant differences were observed in block duration between the two anaesthetic regimens (Table 3). The sensory block lasted considerably longer in Group R (334.83 ± 18.73 min) than in Group L (280.17 ± 14.35 min, $p < 0.05$). Conversely, the motor block lasted longer in Group L (117.33 ± 6.23 min) compared with Group R (111.47 ± 5.88 min, $p < 0.05$). Thus, the combination of ropivacaine and dexmedetomidine offered prolonged sensory anaesthesia with earlier motor recovery, while levobupivacaine maintained a longer motor block duration.

Table 3. Duration of Sensory and Motor Block

Parameter	Group L (Mean ± SD)	Group R (Mean ± SD)	p-value
Sensory block duration (min)	280.17 ± 14.35	334.83 ± 18.73	**<0.05**
Motor block duration (min)	117.33 ± 6.23	111.47 ± 5.88	**<0.05**

P-value<0.05 is significant.

Hemodynamic Parameters

Hemodynamic stability was maintained throughout the perioperative period. Heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP) showed minor fluctuations during the initial 10–15 minutes after spinal administration but remained within safe clinical limits. The transient decreases in blood pressure and increases in heart rate were comparable between groups and did not require pharmacological correction. Overall, both local anaesthetic–dexmedetomidine combinations provided stable cardiovascular profiles.

Postoperative Analgesia

The postoperative analgesia was evaluated using Visual Analogue Scale (VAS). Patients having VAS score equal to or more than 4 received rescue analgesic as tramadol intravenously. The duration of postoperative analgesia was significantly longer in Group R compared to Group L (Table 4). The mean time to the first request for rescue analgesia was 513.67 ± 35.04 minutes in Group R and 416.50 ± 37.65 minutes in Group L ($p < 0.05$). These findings demonstrate that the addition of dexmedetomidine to ropivacaine produces longer-lasting postoperative analgesia, reflecting the superior sensory selectivity of ropivacaine.

Table 4. Duration to First Rescue Analgesia

Metric	Group L (mean ± SD)	Group R (mean ± SD)	p-value
Time to the first analgesic requirement (min)	416.50 ± 37.65	513.67 ± 35.04	<0.05
Median (min)	410	512	—
Range (min)	350–480	450–580	—

P-value<0.05 is significant.

Adverse Events

Adverse events were minimal, self-limiting, and similar across both study arms (Table 5). Hypotension occurred in 5 patients (16.7%) in Group L and 6 patients (20%) in Group R (p = 0.739). No episodes of bradycardia, nausea, vomiting, or respiratory depression were observed in either group. Overall, 81.7% of all participants experienced an entirely uneventful perioperative course. No rescue interventions beyond standard intravenous fluids and occasional vasopressor boluses were necessary. Both local anaesthetic–dexmedetomidine combinations were thus well tolerated and clinically safe.

Table 5. Adverse Events

Adverse Events	Group L (n = 30)	Group R (n = 30)	Total (n = 60)	p-value
Hypotension	5 (16.7 %)	6 (20.0 %)	11 (18.3 %)	0.739
Bradycardia	0 (0 %)	0 (0 %)	0 (0 %)	—
Nausea/Vomiting	0 (0 %)	0 (0 %)	0 (0 %)	—
Any adverse event	5 (16.7 %)	6 (20.0 %)	11 (18.3 %)	0.739
Patients without event	25 (83.3 %)	24 (80.0 %)	49 (81.7 %)	—

P-value<0.05 is significant.

Both levobupivacaine-dexmedetomidine and ropivacaine-dexmedetomidine combinations provided effective and hemodynamically stable spinal anaesthesia with minimal side effects. Onset times were comparable; however, ropivacaine-dexmedetomidine offered a longer sensory block and extended postoperative analgesia, making it suitable for prolonged surgical and recovery periods. Levobupivacaine-dexmedetomidine maintained a longer motor block, which may be beneficial for surgeries requiring sustained immobility. No serious adverse effects were observed, confirming the safety and clinical feasibility of dexmedetomidine as an intrathecal adjuvant.

5 | DISCUSSION

This study provides a comprehensive comparison of dexmedetomidine as an adjuvant to intrathecal hyperbaric levobupivacaine and ropivacaine for spinal anaesthesia, focusing on clinical efficacy and safety in adult surgical patients. Both combinations were effective in producing rapid and predictable onset of sensory and motor blocks, with no significant differences in initial induction profiles. The demographic and baseline characteristics were well balanced between groups, allowing for unbiased interpretation of outcomes (8).

The mean onset times for sensory and motor blockade did not differ significantly between groups, confirming that dexmedetomidine enhances the initiation kinetics of both local anaesthetics at similar rates. However, the duration profiles revealed notable differences: Group R (ropivacaine-dexmedetomidine) achieved a substantially longer sensory blockade and extended postoperative analgesia, whereas Group L (levobupivacaine-dexmedetomidine) produced a more prolonged motor block. These pharmacodynamic characteristics have critical implications for clinical practice; ropivacaine-dexmedetomidine is preferable when extended pain relief is desired, while levobupivacaine-dexmedetomidine suits procedures requiring sustained immobility (10, 11).

Group R demonstrated superior postoperative analgesia, with patients remaining pain-free for nearly 100 minutes longer on average. This shift indicates better management of postoperative pain and reduced reliance on supplementary opioid therapy, which is highly advantageous in the context of enhanced recovery protocols and opioid-sparing approaches (9, 12–14).

Both groups maintained stable cardiovascular parameters throughout the perioperative period. Initial mild hypotension was observed with similar frequency across regimens and was effectively managed without clinical sequelae. Bradycardia, nausea, and vomiting were notably absent in all subjects. Slight differences in mean arterial pressure at some intervals were noted in Group R, but these did not translate into clinical instability. The consistency of these results reassures practitioners of the safety and tolerability of both anaesthetic combinations when dexmedetomidine is used as an adjuvant (15, 16).

Adverse events were rare and mild, confined to manageable episodes of hypotension. More than 80% of participants in each group experienced no side effects. No serious complications or persistent adverse events were observed, reinforcing the safety of dexmedetomidine in spinal anaesthesia (17, 18). The low incidence and mild nature of side effects across both groups suggest that dexmedetomidine is a well-tolerated adjunct, suitable for a range of surgical patient populations.

Clinical Implications and Recommendations

The findings of this comparative study suggest that the choice between levobupivacaine and ropivacaine as a primary local anaesthetic can be tailored based on individual surgical needs:

Both regimens maintain stable hemodynamic and present minimal risk of adverse events. These results support the flexible use of dexmedetomidine with different local anaesthetic to optimize patient outcomes and enhance perioperative care (19) (20) .

6 | LIMITATIONS AND FUTURE RESEARCH

The study's limitations include a modest sample size, single-centre design, and lack of stratification by age or surgical subgroup. Future research should enroll larger, more diverse populations, evaluate long-term patient outcomes, and investigate optimal dosing strategies for dexmedetomidine. Comparative trials involving other adjuvants such as clonidine or fentanyl may also help refine spinal anaesthesia protocols.

7 | CONCLUSION

This comparative study demonstrated that both levobupivacaine and ropivacaine, when combined with intrathecal dexmedetomidine, provide effective and dependable spinal anaesthesia with favorable safety profiles. The onset times for sensory and motor blocks were comparable, ensuring rapid and reliable anaesthesia induction across both groups. However, ropivacaine-dexmedetomidine offered significantly longer sensory block duration and postoperative analgesia, translating into extended pain relief and reduced analgesic requirements postoperatively. Conversely, levobupivacaine-dexmedetomidine exhibited a longer motor block duration, which may benefit surgical procedures demanding prolonged immobility.

Hemodynamic stability was maintained in both groups, with only minimal, transient hypotensive episodes effectively managed during the perioperative period. No cases of bradycardia or other serious adverse events were observed, reaffirming dexmedetomidine's suitability as a safe adjuvant. Overall side-effect incidences were low and comparable between groups, highlighting the safety of these anaesthetic combinations.

Therefore, ropivacaine combined with dexmedetomidine is particularly advantageous when extended postoperative analgesia and early motor recovery are priority in patients undergoing lower limb surgeries. In contrast, levobupivacaine with dexmedetomidine may be preferred for surgeries requiring longer motor block durations as in patients undergoing lower abdominal surgeries for better muscle relaxation intraoperatively. These findings support tailored anaesthetic plans based on surgical demands and patient recovery objectives, optimizing clinical outcomes and enhancing patient comfort.

Author Contributions

• **Concept and design:** Rajeev Kumar Dubey, Atul Kumar Singh

• **Data acquisition and analysis:** Hari Sankar Prajapati, Arun Raj Pandey

• **Manuscript drafting:** Hari Sankar Prajapati

• **Critical revision and final approval:** Atul Kumar Singh

All authors approved the final version of the manuscript and agree to be accountable for all aspects of the work.

8 | FUNDING AND CONFLICT OF INTEREST

No funding was received from any external or commercial agency.The authors declare **no conflicts of interest** related to this study.

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