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Original Research Article

COMPARISON OF COMBINED LUMBOSACRAL PLEXUS BLOCK VERSUS SPINAL ANAESTHESIA IN LOWER LIMB ORTHOPAEDIC SURGERIES: A PROSPECTIVE STUDY

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ABSTRACT

Background: Lower limb fractures constitute a significant public health burden, accounting for approximately one-third of all fractures. Effective perioperative pain management is crucial for optimal surgical outcomes. Regional anaesthesia techniques, particularly lumbosacral plexus block (LSPB), have gained popularity for lower limb surgeries due to their favourable safety profile and prolonged postoperative analgesia. **Aim:** To compare the efficacy of combined lumbosacral plexus block using ultrasound guidance (USG) and peripheral nerve stimulator (PNS) versus spinal anaesthesia in patients undergoing lower limb orthopaedic surgeries.

Materials and Methods: This prospective non-randomized study was conducted at a tertiary care centre in Ahmedabad from March 2023 to February 2025, involving 70 patients (35 per group) undergoing lower limb orthopaedic surgeries. Group L received combined LSPB using USG and PNS with 40 mL of solution containing 0.5% bupivacaine, 2% lignocaine with adrenaline, normal saline, and fentanyl 25 mcg. Group S received spinal anaesthesia with 0.5% bupivacaine heavy and fentanyl 25 mcg. Hemodynamic parameters (HR, SBP, DBP, MAP, SpO_2), block characteristics, VAS scores, time to first rescue analgesia, and total analgesic consumption within 24 hours were recorded and analysed.

Results: The mean time to complete block was significantly longer in Group L (22.37±2.25 mins) compared to Group S (6.97±0.85 mins; p<0.0001). Group L demonstrated more stable hemodynamic parameters with fewer fluctuations in heart rate and blood pressure. The time to first rescue analgesia was significantly prolonged in Group L (722.2±54.93 mins) versus Group S (363.9±78.08 mins; p=0.0001). Total analgesic requirement within 24 hours was significantly lower in Group L (1.14±0.35 vs 2.54±0.65; p=0.0001). VAS scores revealed that Group S had superior immediate pain control, while Group L demonstrated better pain control after 12 hours.

Conclusion: Combined lumbosacral plexus block using USG and PNS provides stable haemodynamics, prolonged postoperative analgesia, reduced analgesic requirements, and fewer complications compared to spinal anaesthesia. It may be considered a safe and effective alternative for lower limb orthopaedic surgeries, particularly in high-risk patients.

Keywords: Lumbosacral plexus block, Spinal anaesthesia, Lower limb orthopaedic surgery, Ultrasound guidance, Peripheral nerve stimulator, Postoperative analgesia.

INTRODUCTION

Lower limb fractures account for approximately one-third of all fractures and represent a significant public health concern due to substantial morbidity and mortality they can cause.[1] These injuries can lead to prolonged hospitalization, reduced mobility, and long-term disability, especially in elderly patients or those with comorbidities. Among lower limb fractures, the ankle joint is most frequently affected (22.6%), followed by tibia and fibula fractures (17.3%), hip joint injuries (16.7%), and tarsal/metatarsal fractures (16.7%). Fractures involving the hip, femur, and other lower extremity parts collectively account for approximately 25% of cases, underscoring their clinical relevance.[2]

Rapid urbanization and accelerated ageing of populations in developing countries have significantly contributed to rising lower limb fracture incidence, frequently caused by traffic injuries, architectural injuries, and senile osteoporosis. The growing number of residual injuries and disabilities associated with these fractures further exacerbates their impact, often leading to prolonged recovery times, loss of productivity, and reduced quality of life.[3]

Patients with lower limb fractures experience severe pain, with 30% reporting moderate pain. Inadequate pain control can lead to altered release of hormones including insulin and catecholamines, metabolic disturbances, increased myocardial oxygen demand, agitation, delirium, delayed wound healing, hypoxia/atelectasis, and neuropsychiatric complications such as isolation, anxiety, and PTSD, which can lead to chronic pain.[4,5]

Spinal anaesthesia (SA) is a widely utilized operative anaesthesia technique, particularly for lower limb surgeries, due to its efficacy in providing profound sensory and motor blockade. However, in elderly patients, spinal anaesthesia is often associated with significant hemodynamic changes, including hypotension and bradycardia, which require careful management. The use of SA is contraindicated in certain conditions such as head injuries with neurological deficits, a history of epilepsy, and stenotic valvular diseases.[6]

Alternatively, peripheral nerve blocks have emerged as an effective option for lower limb surgeries, offering ideal perioperative analgesia without causing hemodynamic instability or impairing pulmonary function. Despite their numerous advantages, including lower morbidity rates and reduced cardiovascular side effects, the adoption of peripheral nerve blocks has remained limited, primarily due to technical challenges such as the need for precise anatomical knowledge and expertise in using ultrasound-guided techniques.[7]

Regional anaesthesia techniques have gained widespread popularity for lower limb surgical interventions due to clinical benefits including effective pain relief, prolonged postoperative analgesia, higher patient satisfaction, reduced reliance on additional resources, and quicker hospital discharge.[8] In elderly patients with comorbidities, regional anaesthesia is frequently preferred over general anaesthesia due to its superior safety profile.[9]

In recent years, the lumbosacral plexus block (LSPB) has gained widespread use in orthopaedic departments, significantly reducing opiate requirements, decreasing acute postoperative pain incidence, facilitating early mobilization, and shortening hospital stays.[10] LSPB effectively blocks main components of the lumbosacral plexus and offers better hemodynamic stability, particularly advantageous in high-risk geriatric patients with comorbidities.[11]

Given the growing popularity of lumbar plexus block in lower limb orthopaedic procedures, this study was conducted to compare the efficacy of combined lumbosacral plexus block using ultrasound guidance (USG) and peripheral nerve stimulator (PNS) assistance versus spinal anaesthesia in patients undergoing lower limb orthopaedic surgeries.

MATERIALS AND METHODS

Study Design and Setting

This prospective non-randomized study was conducted at a tertiary care centre in Ahmedabad from March 2023 to February 2025.

Study Population

The study population included all patients undergoing lower limb orthopaedic surgeries who met the inclusion criteria.

Sample Size

The sample size was calculated using data from Vincent de Visme et al,[6] resulting in 35 patients per group ($n_1 = 35$, $n_2 = 35$) with a type I error (α) of 5% and a power of 80%.

Ethical Considerations

Ethical approval was obtained from the institutional ethics committee before initiating the study. Written informed consent was obtained from all patients for anaesthesia as well as enrolment in the study. Benefits and likely complications of the technique used were explained to patients and their caretakers in understandable language.

Group Allocation

Patients meeting the inclusion criteria were selected, and two groups were formed using a randomized computer sampling method:

- **Group S:** Spinal Anaesthesia (n = 35)
- **Group L:** Combined lumbosacral plexus block (LSPB) using ultrasound guidance (USG) and a peripheral nerve stimulator (PNS) (n = 35)

Inclusion Criteria

- Age between 18 and 80 years
- ASA Grade I, II, or III
- Unilateral lower limb fractures requiring orthopaedic surgery

Exclusion Criteria

- ASA Grade IV or V
- Patient refusal
- Allergy to amide-group local anaesthetics
- Pregnancy or lactation
- Use of anticoagulants or presence of bleeding disorders
- Local site infection
- Neurological or psychiatric disorders
- General Anaesthesia cases
- Bilateral lower limb fractures

Study Protocol

All patients underwent a thorough pre-anaesthetic check-up which included history taking, general examination, systemic examination, and local neurological examination. Routine investigations like CBC, blood sugar, blood urea, serum creatinine, Chest X-Ray, and ECG were carried out for all patients.

Standard monitors like ECG, NIBP, and pulse oximeter were applied and patients' baseline parameters like pulse, blood pressure, and SpO_2 were recorded. Intravenous line was secured and patients were premedicated with:

- Inj. Ondansetron (0.02mg/kg) I.V.
- Inj. Ranitidine (50 mg) I.V.
- Inj. Midazolam (1 mg) I.V.

Conscious sedation was achieved by giving Inj. Dexmedetomidine 0.5µg/kg I.V. over 15 minutes prior to procedure.

Anaesthesia Technique for Group L

The lumbar plexus block was performed with the patient in the lateral decubitus position (Sim's position), operative side facing up. The skin and ultrasound probe were disinfected. The maximal axis of the low-frequency convex array probe was placed at the L3-4 space and at 4 cm parallel to the posterior midline of the spine. The ultrasound image indicated a trident-shaped structure formed by the transverse processes of three lumbar vertebrae. Out-plane needle insertion was performed at the midpoint of the ultrasound probe until the needle point reached 1.5 cm below the transverse process. The nerve stimulator was connected for nerve stimulation. Following contraction of the quadriceps femoris muscle, the current was adjusted to 0.5 mA. After negative aspiration confirming absence of blood or cerebrospinal fluid, 20 ml of drug mixture was injected.

The sacral plexus block was performed using the parasacral approach based on the bony relationship of the posterior superior iliac spine and the ischial tuberosity. A mark was made 6 cm inferior to the posterior superior iliac spine to define the needle insertion site. A 21-gauge, 10-cm insulated needle was advanced in a sagittal plane until an evoked motor response was elicited, typically at a depth of 5 to 7 cm from the skin. When the needle was properly placed, 20 ml of solution was slowly injected.

Patients in Group L received 40 mL of solution containing 20 mL of 0.5% bupivacaine, 15 mL of 2% lignocaine with adrenaline, and 5 mL of normal saline, along with fentanyl (25 mcg).

Anaesthesia Technique for Group S

Patients were preloaded with Ringer's lactate or normal saline according to patient's condition. Under all aseptic precautions, spinal anaesthesia was performed in the lateral position using a 25-gauge spinal needle at the L3-L4 interspace. The study solution (0.5% bupivacaine heavy according to dose with 25 mcg fentanyl) was administered. Patients were gently placed supine and tested for sensory and motor blockade.

Sensory Block Characteristics

The level of sensory block was evaluated by pinprick test using a 24 G hypodermic needle. Loss of sensation to pin prick was considered as sensory block. Onset time for the sensory block was considered when complete loss of sensation at L1 level was achieved. Time taken to achieve maximum sensory level was assessed. Total duration of sensory block was measured until complete recovery of sensory block in the postoperative period.

Motor Block Characteristics

The onset of motor blockade was assessed using the Modified Bromage scale:

- 0: Free movement of legs, feet, with ability to raise extended legs
- 1: Inability to raise extended leg; hip flexion decreased but full flexion of feet and knee present
- 2: Inability to raise leg or flex knees; flexion of ankle and feet present
- 3: Inability to raise legs, flex knees, ankle, or move toes

Total duration of motor block was evaluated until complete recovery of motor block in the postoperative period.

Hemodynamic Parameters

HR, SBP, DBP, MAP, and SpO_2 were recorded at 5 mins, 10 mins, 15 mins, 20 mins, 30 mins, 2 hours, 4 hours, and 6 hours intraoperatively.

After completion of surgery, patients were transferred to the Post Anaesthesia Care Unit. Postoperative pain was assessed by VAS and hemodynamic parameters till 24 hours.

VAS Score

Pain was assessed using the Visual Analog Scale (VAS), marked on a 10-cm line representing "no pain" to "worst pain" at 5 mins, 10 mins, 15 mins, 20 mins, 30 mins, 2 hours, 4 hours, 6 hours, 8 hours, 12 hours, and 24 hours.

Postoperative Pain Relief

The time to the first IV analgesic requirement was documented and total requirement of postoperative analgesics in 24 hours according to VAS score was recorded.

Complications

Adverse events such as nausea, vomiting, bradycardia, hypotension, and accidental epidural or intrathecal drug administration were observed. The collected data were recorded for further statistical analysis.

Statistical Analysis

Descriptive statistics, including mean and standard deviation (SD) for quantitative data and proportions for qualitative data, were used. Inferential statistics, including Z, T, and chi-square (χ^2) tests, were applied for comparison. A p-value < 0.05 was considered statistically significant.

RESULTS

The age distribution showed a statistically significant difference (p = 0.004). Group L had an older population (mean age 43.74 ± 17.85 years) compared to Group S (33.91 ± 8.34 years).

The gender and ASA distribution showed no statistically significant difference (p = 0.23).

The ASA grade distribution was comparable between groups (p = 0.17).

Table 1: Time to Complete Block

Mean ± SD	Group L	Group S	P-value
Onset of Complete Block (mins)	22.37 ± 2.25	6.97 ± 0.85	<0.0001

Group L had a significantly longer mean time to complete block compared to Group S (p < 0.0001).

There was a statistically significant difference in SBP between Group L and Group S at most time points. Before induction, SBP was significantly higher in Group S than Group L (129.37 ± 7.95 vs. 119.31 ± 5.03 mmHg; p<0.0001). At 5 minutes, Group S continued to show significantly higher SBP (p=0.003). From 10 to 30 minutes and at 2 hours, SBP was significantly higher in Group L than Group S (p<0.0001, except 2 hours p=0.0005). At 4 hours, the difference was not statistically significant (p=0.07). Subsequently, at 6, 8, 12, and 24 hours, SBP was again significantly higher in Group S than Group L (p<0.0001). Overall, the findings demonstrate significant intergroup variation in SBP over the observation period, with Group S generally exhibiting higher SBP during the later postoperative period.

DBP differed significantly between the groups before induction and at 5 minutes, with higher values in Group S (83.48 ± 5.45 vs. 77.94 ± 4.01 mmHg before induction; p<0.0001 and 82.08 ± 4.68 vs. 73.31 ± 4.92 mmHg at 5 minutes; p<0.0001). However, no statistically significant difference was observed between the groups at 10, 15, 20, or 30 minutes (p=0.57, 0.22, 0.97, and 0.10, respectively). From 2 hours onward, DBP was significantly higher in Group S than Group L, with highly significant differences at 2, 4, 6, 8, 12, and 24 hours (p<0.0001 for all). Overall, the DBP findings indicate comparable values between groups during the early intraoperative period, followed by significantly higher DBP in Group S during the later observation period.

There was a statistically significant difference in MAP between Group L and Group S at most time points. Before induction, MAP was significantly higher in Group S than Group L (98.78 ± 5.80 vs. 91.73 ± 4.20 mmHg; p<0.0001). At 5 minutes, MAP remained significantly higher in Group S (p<0.0001). From 10 to 20 minutes, MAP was significantly higher in Group L than Group S (p=0.006, 0.0002, and 0.0004, respectively). At 30 minutes, the difference was not statistically significant (p=0.18). At 2 hours, a statistically significant difference was observed (p=0.03), while from 4 hours onward, MAP was significantly higher in Group S than Group L (p<0.0001 for all time points). Overall, Group S demonstrated higher MAP during the later postoperative period, whereas Group L showed relatively higher MAP during the early period after induction.

Heart rate showed significant intergroup differences at most observation points. Before induction, heart rate was significantly higher in Group S than Group L (85.74 ± 5.63 vs. 74.22 ± 4.62 beats/min; p<0.0001). At 5 minutes, the difference was not statistically significant (p=0.13). From 10 to 30 minutes, heart rate was significantly higher in Group L than Group S (p=0.01, 0.0007, 0.0003, and 0.001, respectively). At 2 hours, no significant difference was observed (p=0.39). From 4 hours through 24 hours, heart rate was significantly higher in Group S than Group L (p=0.0001 at each time point). Overall, the findings indicate a dynamic pattern of heart-rate variation between the groups, with Group L showing higher heart rates during the early period and Group S showing significantly higher heart rates during the later postoperative period.

Table 2: VAS Score Distribution

Mean ± SD	Group L	Group S	P-value
5 min	5.91 ± 1.01	0.25 ± 0.4	0.0001
10 min	3.22 ± 0.77	0 ± 0	-
15 min	1.25 ± 0.65	0 ± 0	-
20 min	0.11 ± 0.32	0 ± 0	-
30 min	0.11 ± 0.32	0 ± 0	-
2 Hours	0 ± 0	0 ± 0	-
4 Hours	0 ± 0	2.08 ± 1.03	-
6 Hours	0 ± 0	2.8 ± 1.16	-

8 Hours	0.11 ± 0.32	3.51 ± 1.4	0.0001
12 Hours	2.94 ± 1.18	3.94 ± 1.13	0.0006
24 Hours	6.51 ± 1.24	4.8 ± 0.86	0.0001

The VAS scores demonstrated a marked difference in postoperative pain intensity between Group L and Group S. At 5 minutes, the mean VAS score was significantly higher in Group L than Group S (5.91 ± 1.01 vs. 0.25 ± 0.40; p=0.0001). In Group L, the VAS score progressively decreased from 5.91 at 5 minutes to near-zero values by 20 minutes and remained minimal up to 8 hours. In contrast, Group S maintained a VAS score of 0 during the early period but showed increasing pain scores from 4 hours onward. At 8, 12, and 24 hours, VAS scores were significantly higher in Group S at 8 and 12 hours, whereas at 24 hours the score was significantly higher in Group L (6.51 ± 1.24 vs. 4.80 ± 0.86; p=0.0001). Overall, Group S provided superior early postoperative analgesia, while pain increased during the later postoperative period, with Group L demonstrating higher pain intensity at 24 hours.

Table 3: Time to First Rescue Analgesia

Mean ± SD	Group L	Group S	P-value
Time to first rescue analgesia (mins)	722.2 ± 54.93	363.9 ± 78.08	0.0001

The mean time to first rescue analgesia was significantly longer in Group L compared with Group S (722.2 ± 54.93 vs. 363.9 ± 78.08 minutes; p=0.0001). This indicates that patients in Group L experienced a significantly prolonged duration of postoperative analgesia, requiring rescue analgesia approximately 6 hours earlier in Group S. Thus, Group L demonstrated a substantially longer analgesic duration.

Table 4: Total Analgesia Required in 24 Hours

Mean ± SD	Group L	Group S	P-value
Total number of analgesia required in 24 hours	1.14 ± 0.35	2.54 ± 0.65	0.0001

The total number of rescue analgesic doses required during the first 24 hours was significantly lower in Group L than in Group S (1.14 ± 0.35 vs. 2.54 ± 0.65 doses; p=0.0001). This represents a substantially reduced requirement for rescue analgesia in Group L. Overall, the findings indicate that Group L provided better sustained postoperative analgesia and reduced the need for supplemental analgesics during the first 24 hours.

DISCUSSION

The comparison between combined lumbosacral plexus block (LSPB) and spinal anaesthesia for lower limb orthopaedic surgeries highlights key differences in efficacy, safety, and patient outcomes. LSPB provides longer-lasting pain relief, fewer hemodynamic changes, and greater motor function preservation, making it ideal for extended surgeries and patients with cardiovascular concerns. However, it is technically more complex and may require conversion to general anaesthesia if the block is incomplete. Spinal anaesthesia, in contrast, offers rapid onset, predictable blockade, and ease of administration, but may lead to hypotension, bradycardia, and post-dural puncture headaches, along with a shorter duration of action.

Age Distribution

The age distribution demonstrated a statistically significant difference (p = 0.004). Group L had a higher mean age (43.74 ± 17.85 years) compared to Group S (33.91 ± 8.34 years). Group L had 20% patients in the 61-80 age range, while Group S had no patients aged 61 years or above. This is consistent with findings from Horasanli E et al,[14] (mean age 54.0 ± 16.9 years in EA group and 51.3 ± 14.9 years in LPSB group, P > 0.05), Gandhi A et al,[17] (57 ± 17.8 years in Group I and 56.2 ± 16.41 years in Group II, P = 0.86), and Bhojani A et al,[24] (mean age 68.37 ± 13.57 years). However, our study showed a significant age difference, possibly due to selection bias, as older patients may have been preferentially assigned to the LSPB group due to its favourable hemodynamic profile.

Gender Distribution

The gender distribution showed no statistically significant difference (p = 0.23). Group L had 57.14% males and 42.86% females, while Group S had 42.86% males and 57.14% females. This is comparable to previous studies. Horasanli E et al,[14] reported 69.2% males in EA group and 64.9% males in LPSB group (P > 0.05). Gandhi A et al,[17] found 32% females in Group I and 36% in Group II. Bhojani A et al,[24] reported 53.7% males and 46.3% females. Patel S H et al,[20] noted 48% males in SAB group and 44% in LSPB group.

ASA Grade Distribution

The ASA grade distribution was comparable between groups (p = 0.17). Group L had 17.14% ASA 1, 60% ASA 2, and 22.86% ASA 3 patients, while Group S had 37.14% ASA 1, 45.71% ASA 2, and 17.14% ASA 3 patients. This is similar to Horasanli E et al,[14] who found nearly identical ASA distributions between groups (35.9% ASA I in EA and 37.8% in LPSB). Bhojani A et al,[24] found most patients were ASA III (61%), followed by

ASA IV (20.7%). Kacmaz M et al,[21] reported a significant difference in ASA distribution (P = 0.039) between groups.

Time to Complete Block

Group L had a significantly longer mean time to complete block (22.37 ± 2.25 minutes) compared to Group S (6.97 ± 0.85 minutes, p < 0.0001). This slower onset is consistent with findings from Gandhi A et al,[17] who reported time required for sensory blockade was more in LPB group (17.32 ± 2.61) compared to SA group (3.76 ± 0.91, p < 0.05). Karthikeyan R et al,[26] also noted delayed onset in patients receiving lumbar plexus and sciatic nerve blocks. This delayed onset is a trade-off for the prolonged duration of action and better hemodynamic stability offered by LSPB.

Hemodynamic Parameters

The study revealed distinct SBP, DBP, MAP, and heart rate trends between the groups. Group S had significantly higher baseline values but experienced more pronounced fluctuations. This is consistent with findings from Patel S H et al,[20] who reported higher baseline SBP in SAB group (128.24 ± 5.5 mmHg) than in LSPB group (121.13 ± 4.3 mmHg, p = 0.001), with SAB patients showing greater intraoperative SBP drops. Kacmaz M et al,[21] observed that MAP was notably higher in the LPSNB group (85.3 ± 11.5 mmHg) compared to the SA group (82.4 ± 9.4 mmHg, p = 0.046). The stable hemodynamic profile in Group L is advantageous, especially in elderly patients with cardiovascular comorbidities.

VAS Score

Group S showed superior immediate pain control, with scores dropping to 0 by 10 minutes. However, Group L demonstrated better pain control after 12 hours. At 24 hours, Group L reported higher pain (6.51 ± 1.24) compared to Group S (4.8 ± 0.86, p = 0.0001). This pattern is consistent with Gandhi A et al,[17] who found VAS score at 30 minutes was significantly higher in SA group (3.16 ± 1.11) compared to LPB group (1.5 ± 0.51). Karaduman Y et al,[19] reported VAS scores in the SFBN group were significantly lower at 1, 6, 12, and 24 hours, with especially large differences at 6 hours (4.93 vs 1.78) and 12 hours (5.62 vs 2.07), p < 0.001.

Time to First Rescue Analgesia

Group L had a significantly longer time to first rescue analgesia (722.2 ± 54.93 minutes) compared to Group S (363.9 ± 78.08 minutes, p = 0.0001). This is consistent with Horasanli E et al,[14] who found the median time to first analgesic request was significantly extended in the LPSB group (360 minutes, range 240-720) compared to the EA group (240 minutes, range 150-560, P < 0.05). Karaduman Y et al,[19] found time to first analgesic requirement was much longer in the SFBN group (412.22 ± 62.21 minutes vs 195.55 ± 25.36 minutes, p < 0.001). Patel S H et al,[20] reported a mean time of 689.0 ± 107.4 minutes in LSPB group compared to 263.6 ± 25.8 minutes in SAB group (p = 0.002).

Total Analgesia Required in 24 Hours

Group L required significantly fewer analgesic doses (1.14 ± 0.35) within 24 hours compared to Group S (2.54 ± 0.65, p = 0.0001). This is consistent with Karaduman Y et al,[19] who observed fewer patients in the SFBN group required rescue analgesia within 24 hours (46.66% vs 90%, p < 0.001). Awad S S et al,[18] reported total analgesic consumption was significantly lower in the FSNB group (4.9 ± 1.58 mg) compared to the ULSA group (10.1 ± 1.62 mg, P < 0.001).

CONCLUSION

In this prospective non-randomized study, the efficacy of combined lumbosacral plexus block using ultrasound guidance (USG) and peripheral nerve stimulator (PNS) was compared with spinal anaesthesia in lower limb orthopaedic surgeries at a tertiary care centre. The findings suggest that the lumbosacral plexus block provided stable hemodynamic parameters with fewer fluctuations in heart rate and blood pressure compared to spinal anaesthesia. Additionally, it was associated with a delayed need for the first rescue analgesic and a reduced total requirement of postoperative analgesics within 24 hours. The incidence of postoperative complications and adverse effects was also lower in the block group.

Overall, the combined lumbosacral plexus block demonstrated favourable outcomes and may be considered a safer and effective alternative to spinal anaesthesia in select lower limb orthopaedic procedures, particularly in elderly patients or those with cardiovascular comorbidities where hemodynamic stability is crucial.

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