

Comparison of Single-Space Versus Double-Space Combined Spinal–Epidural Anaesthesia in Elective Lower-Limb Orthopedic Surgery: A Prospective Randomized Study

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Abstract:

Background: Combined spinal–epidural anaesthesia (CSEA) combines the rapid onset of spinal anaesthesia with the flexibility of epidural anaesthesia for prolonged surgical procedures and postoperative analgesia. Single-space and double-space techniques are commonly used, but their comparative performance remains uncertain.

Aim and Objective: To compare the single-space and double-space techniques of CSEA in patients undergoing elective lower-limb orthopedic surgery.

Materials and Methods: This prospective randomized comparative study included 80 patients aged 18–75 years with American Society of Anesthesiologists physical status I–II. Patients were randomized into Group A (double-space technique, n=40) and Group B (single-space technique, n=40). Sensory and motor block onset, duration of analgesia, duration of surgery, haemodynamic parameters, and perioperative outcomes were assessed.

Results: The mean age was 35.6 ± 13.7 years in Group A and 40.3 ± 12.1 years in Group B ($p=0.11$). Sensory block onset was faster with the double-space technique (4.85 ± 1.00 vs 5.20 ± 0.99 minutes), representing a 6.7% shorter onset time, although the difference was not significant ($p=0.120$). Motor block onset was also faster in Group A (5.25 ± 1.10 vs 5.75 ± 1.81 minutes; 8.7% difference; $p=0.139$). Analgesia lasted longer with the double-space technique (5.15 ± 0.71 vs 4.82 ± 0.82 hours; 6.8% difference; $p=0.059$). Duration of surgery was comparable (136.15 ± 13.30 vs 138.21 ± 12.95 minutes; $p=0.492$). Heart rate, blood pressure, arterial pressure, and oxygen saturation remained comparable between groups.

Conclusion: Both techniques provide effective and hemodynamically stable CSEA. The double-space technique showed modest numerical advantages in block onset and duration of analgesia, but did not demonstrate statistically significant superiority.

Keywords: Combined Spinal–Epidural Anaesthesia; Single-Space Technique; Double-Space Technique; Sensory Block; Motor Block; Orthopedic Surgery.

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Introduction

Combined spinal–epidural anaesthesia (CSEA) is an established neuraxial technique that combines the rapid onset and dense sensory and motor blockade of spinal anaesthesia with the flexibility of an epidural catheter for prolonging anaesthesia and providing postoperative analgesia [1,2]. This combination is particularly useful in prolonged surgical procedures where reliable intraoperative anaesthesia and continued postoperative pain

control are required. CSEA has therefore been widely used in obstetric, orthopedic, urological, and lower abdominal surgeries [1,2].

Two commonly used approaches are the single-space needle-through-needle technique and the double-space technique. In the single-space method, spinal and epidural components are performed through the same intervertebral space. This technique requires a single puncture and may reduce

procedural time and patient discomfort [2,3]. In contrast, the double-space technique uses separate intervertebral levels for spinal and epidural placement, allowing independent identification of both spaces and potentially improving technical reliability [4,5].

Previous studies have reported variable results regarding the relative advantages of these techniques. Casati et al. observed shorter procedural time and better patient acceptance with the single-space approach, while overall block effectiveness remained comparable [3]. Lyons et al. and Backe et al. reported greater technical success with separate-space techniques in selected populations [4,6]. Puolakka et al., in patients undergoing lower-extremity orthopedic surgery, also demonstrated differences in technical success among CSEA techniques, although successfully established blocks showed generally comparable anaesthetic characteristics [5].

More recent evidence has similarly failed to demonstrate clear superiority of either approach. Chun et al. reported comparable intraoperative block characteristics between single- and double-space techniques, although postoperative sensory blockade and patient satisfaction favoured the double-space method [7]. Basheer et al. found that the single-space technique required fewer punctures and less procedural time, while haemodynamic and anaesthetic outcomes remained comparable [8].

Thus, both techniques offer potential advantages, but evidence in elective lower-limb orthopedic surgery remains limited. The present study therefore aimed to compare single-space and double-space CSEA with respect to sensory and motor block characteristics, anaesthetic onset, haemodynamic stability, duration of analgesia, and perioperative outcomes

Materials and Methods

Study Design and Setting: This prospective, randomized, comparative clinical study was conducted in the Department of Anaesthesiology at SVBP Hospital, associated with L.L.R.M. Medical College, Meerut, Uttar Pradesh. The study was carried out over 18 months, from June 2024 to December 2025. Approval was obtained from the Institutional Ethics Committee (SC-1/2025/2934), and the study was registered with the Clinical Trials Registry–India (CTRI/2026/01/101522).

Study Population: Patients aged 18–75 years, of either sex, belonging to American Society of Anesthesiologists (ASA) physical status I or II, and scheduled for elective lower-limb orthopedic surgery expected to last more than 2 hours were eligible. Patients with refusal to participate, infections at the injection site, coagulopathy or bleeding disorders, heart block, peripheral

neuropathy, allergy to local anaesthetic agents, peripheral vascular disease, moderate-to-severe systemic disease, communication difficulty, or any contraindication to regional or epidural anaesthesia were excluded. Written informed consent was obtained from all participants.

Sample Size and Randomization: A total of 80 patients were enrolled, with 40 patients in each group. The sample size was determined based on previous studies, using a 95% confidence level and 80% power. Patients were randomly allocated using a computer-generated random number sequence into: Group A (Double-space CSE technique) and Group B (Single-space CSE technique).

Anaesthetic Procedure: On arrival in the operating theatre, standard monitoring was established and baseline pulse rate, non-invasive blood pressure, respiratory rate, and electrocardiogram were recorded. Intravenous access was secured, and Ringer's lactate infusion was started.

In Group A, the epidural space was identified at the L1–L2 intervertebral space using an 18-G Tuohy needle by the loss-of-resistance technique. An epidural catheter was inserted, and a test dose of 3 mL of 2% lignocaine with adrenaline (1:200,000) was administered. Subarachnoid block was subsequently performed at the L2–L3 interspace using a 25-G Quincke spinal needle, and 3 mL of 0.5% hyperbaric bupivacaine was administered after confirmation of free cerebrospinal fluid flow. The epidural catheter was secured, and the first epidural top-up was given 1 hour after commencement of surgery.

In Group B, the epidural space was identified at the L3–L4 interspace using an 18-G Tuohy needle. A 26-G pencil-point spinal needle was advanced through the epidural needle into the subarachnoid space. After confirming free flow of cerebrospinal fluid, the intrathecal drug was administered. The spinal needle was then removed, and an epidural catheter was passed through the Tuohy needle and secured.

Assessment of Block and Outcomes: Time zero was defined as the completion of the block technique and the removal of the needle. Sensory blockade was assessed using the pin-prick method and graded according to Holmen's scale, while motor blockade was assessed using the Bromage scale. Sensory block was evaluated every 2 minutes for the first 10 minutes, and motor block every 10 minutes for the first 20 minutes, with subsequent assessments at predefined intervals.

The principal outcomes included the onset and level of sensory and motor blockade, procedural time, quality of anaesthesia, duration of analgesia, haemodynamic changes, and intraoperative and postoperative complications. Heart rate, systolic

blood pressure, diastolic blood pressure, mean arterial pressure, and peripheral oxygen saturation were recorded throughout the intraoperative period.

A block was considered successful when adequate sensory and motor blockade were achieved without pain during surgical stimulation and without the need for supplementation or conversion to general anaesthesia. A block requiring supplementation or conversion to general anaesthesia was considered a failure.

Results

A total of 80 patients were included, with 40 (50.0%) in the double-space (Group A) and 40 (50.0%) in the single-space (Group B) groups. Mean age was 35.6

± 13.7 years in Group A and 40.3 ± 12.1 years in Group B ($p=0.110$) (Table 1). The mean onset of sensory block was 4.85 ± 1.00 minutes versus 5.20 ± 0.99 minutes, corresponding to a 0.35-minute (6.7%) faster onset in Group A ($p=0.120$). Motor block onset was 5.25 ± 1.10 versus 5.75 ± 1.81 minutes, a 0.50-minute (8.7%) faster onset in Group A ($p=0.139$). Mean analgesia duration was 5.15 ± 0.71 versus 4.82 ± 0.82 hours, a 0.33-hour (6.8%) longer duration in Group A ($p=0.059$). Mean surgery duration was 136.15 ± 13.30 minutes versus 138.21 ± 12.95 minutes, a 2.06-minute (1.5%) shorter duration in Group A ($p=0.492$). Haemodynamic variables and SpO_2 remained comparable between groups.

Table 1: Baseline characteristics of the study groups

Parameter	Group A: Double-space (n=40)	Group B: Single-space (n=40)	p-value
Participants, n (%)	40 (50.0%)	40 (50.0%)	—
Age, years, mean $\pm$ SD	35.6 ± 13.7	40.3 ± 12.1	0.110
Mean age among males, years	38.8 ± 15.1	42.1 ± 12.5	0.421
Mean age among females, years	30.4 ± 9.2	37.5 ± 11.2	0.064

Data are presented as n (%) or mean $\pm$ SD.

Table 2: Comparison of anaesthetic characteristics

Outcome	Group A: Double-space	Group B: Single-space	Absolute difference	Relative difference*	p-value
Sensory-block onset, min	4.85 ± 1.00	5.20 ± 0.99	0.35 min faster in A	6.7% faster	0.120
Motor-block onset, min	5.25 ± 1.10	5.75 ± 1.81	0.50 min faster in A	8.7% faster	0.139
Duration of analgesia, h	5.15 ± 0.71	4.82 ± 0.82	0.33 h longer in A	6.8% longer	0.059
Duration of surgery, min	136.15 ± 13.30	138.21 ± 12.95	2.06 min shorter in A	1.5% shorter	0.492

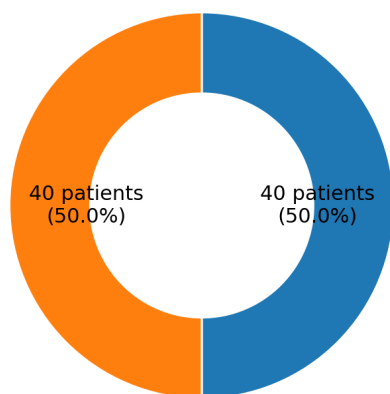
*Relative difference was calculated with Group B as the reference: $(\text{Group B} - \text{Group A}) / \text{Group B} \times 100$

for onset/surgery; $(\text{Group A} - \text{Group B}) / \text{Group B} \times 100$ for analgesia (Table 2).

Table 3: Selected haemodynamic parameters at baseline and 120 minutes

Parameter	Time	Group A	Group B	p-value
Pulse rate, beats/min	Baseline	74.8 ± 8.0	75.7 ± 8.9	0.868
Pulse rate, beats/min	120 min	84.0 ± 4.5	85.0 ± 4.5	0.707
SBP, mmHg	Baseline	119.88 ± 6.18	118.93 ± 5.92	0.485
SBP, mmHg	120 min	126.13 ± 6.41	125.23 ± 6.20	0.530
DBP, mmHg	Baseline	68.75 ± 6.09	68.53 ± 6.50	0.880
DBP, mmHg	120 min	72.13 ± 7.55	74.40 ± 8.07	0.280
MAP, mmHg	Baseline	86.94 ± 4.38	86.55 ± 4.67	>0.05
MAP, mmHg	120 min	88.69 ± 7.03	88.72 ± 7.22	>0.05
SpO_2 , %	Baseline	99.08 ± 0.76	99.00 ± 0.70	0.300
SpO_2 , %	120 min	98.62 ± 0.77	99.20 ± 0.70	0.400

Values are mean $\pm$ SD. No statistically significant between-group difference was reported for the selected haemodynamic variables.



Total N = 80; equal allocation (40 vs 40)
Group A - Double-space Group B - Single-space

Figure 1: Distribution of patients between groups. Of 80 patients, 40 (50.0%) were allocated to the double-space group and 40 (50.0%) to the single-space group.

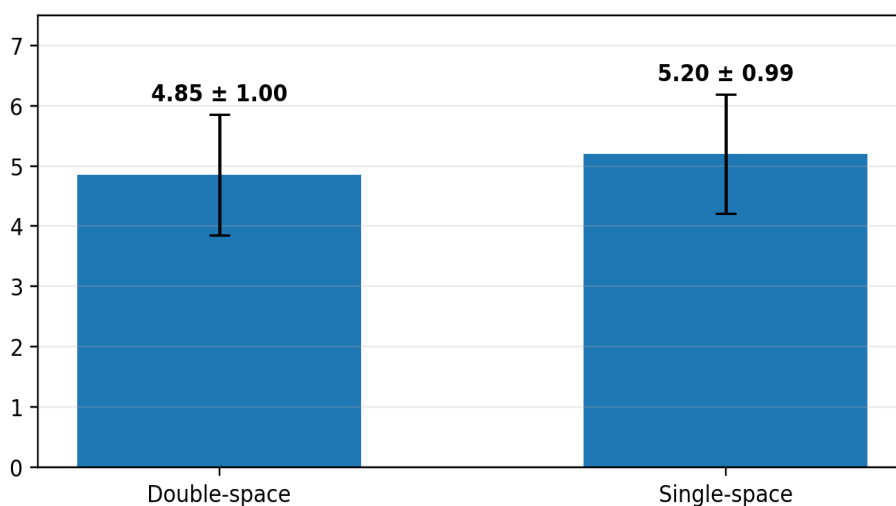


Figure 2. Onset of sensory block. Mean onset was 4.85 ± 1.00 minutes with the double-space technique versus 5.20 ± 0.99 minutes with the single-space

technique. The double-space technique was 0.35 minutes (6.7%) faster; the difference was not statistically significant ($p=0.120$).

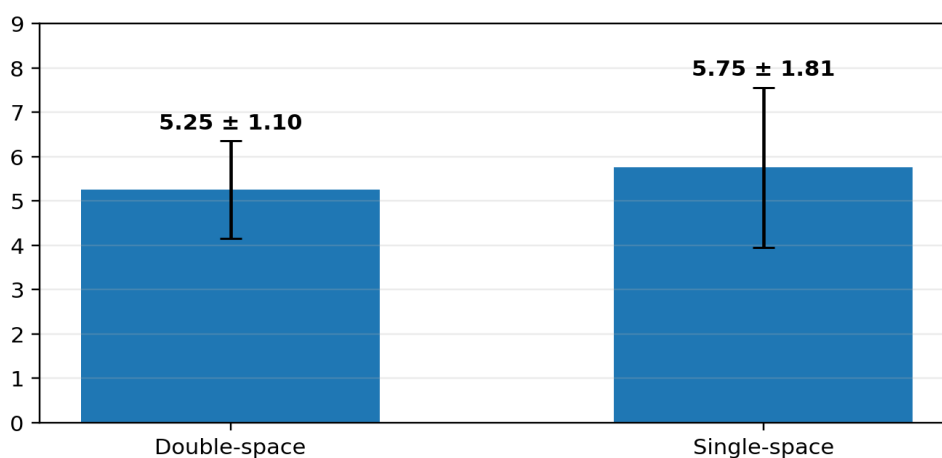


Figure 3. Onset of motor block. Mean onset was 5.25 ± 1.10 minutes with the double-space technique versus 5.75 ± 1.81 minutes with the single-space

technique. The double-space technique was 0.50 minutes (8.7%) faster; the difference was not statistically significant ($p=0.139$).

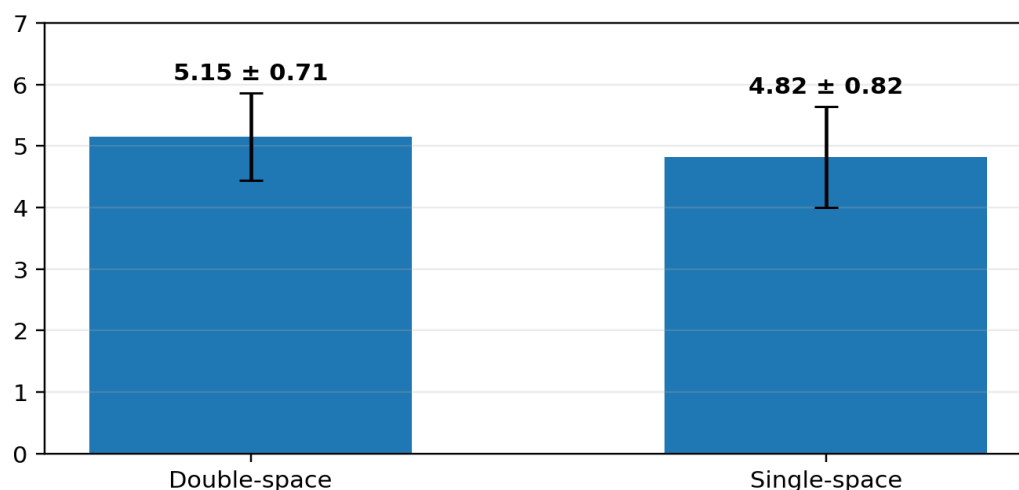


Figure 4. Duration of analgesia. Mean duration was 5.15 ± 0.71 hours with the double-space technique versus 4.82 ± 0.82 hours with the single-space technique. Analgesia was 0.33 hours (6.8%) longer with the double-space technique; the difference was not statistically significant ($p=0.059$).

Discussion

The present prospective randomized comparative study evaluated the clinical performance of the double-space and single-space techniques of combined spinal-epidural anaesthesia (CSEA) in patients undergoing elective lower-limb orthopedic surgery. A total of 80 patients were equally allocated between the two groups. Overall, both techniques provided satisfactory neuraxial anaesthesia with comparable haemodynamic stability. The double-space technique showed a modest numerical advantage in sensory and motor block onset and duration of analgesia, although none of these differences reached statistical significance. CSEA is particularly useful in major orthopedic procedures because it combines the rapid and dense block of spinal anaesthesia with the flexibility of an epidural catheter for extending anaesthesia and providing postoperative analgesia [1].

The demographic characteristics of the study groups were comparable. Mean age was 35.6 ± 13.7 years in the double-space group and 40.3 ± 12.1 years in the single-space group ($p=0.11$), while sex-specific age comparisons also showed no significant differences. Baseline comparability is important because patient characteristics, spinal anatomy, and body habits may influence the technical difficulty and duration of CSEA. Slavković et al. demonstrated that the time required for single-space CSEA was significantly associated with body habitus and the quality of spinal anatomical landmarks [5].

An important finding of the present study was the slightly faster development of sensory blockades with the double-space technique. Mean time to Holmen Grade 4 sensory block was 4.85 ± 1.00 minutes in the double-space group compared with 5.20 ± 0.99 minutes in the single-space group, equivalent to an approximately 6.7% shorter onset time. However, the difference was not statistically significant ($p = 0.120$). Similarly, Bromage Grade 4 motor blockade occurred at 5.25 ± 1.10 minutes and 5.75 ± 1.81 minutes, respectively, representing an approximately 8.7% faster onset with the double-space technique ($p=0.139$). Thus, the numerical advantage seen with double-space CSEA cannot be interpreted as evidence of statistical superiority.

Previous comparative studies have reported differing findings regarding block performance. Casati et al. randomized 120 patients to needle-through-needle or double-segment CSEA and found that overall readiness for surgery was achieved significantly earlier with the single-space technique (22.7 ± 8.2 vs. 29.8 ± 8.31 minutes; $p<0.001$). Patient acceptance was also higher with the single-space technique, while the incidence of hypotension, post-dural puncture headache, and back pain was comparable [3]. The difference in our results may relate to outcome definitions, as Casati et al. assessed the total time from skin preparation to readiness for surgery, whereas our study assessed sensory and motor block onset after completion of the neuraxial procedure.

Puolakka et al. provided particularly relevant evidence because their randomized study involved 90 patients undergoing lower-extremity orthopedic surgery. They compared two single-space CSE systems with a traditional double-segment technique. Successful CSEA was achieved in all patients receiving the double-segment technique, whereas technical success varied with the single-space devices. Among patients in whom CSEA was

successfully performed, however, block characteristics were largely comparable [8]. These observations support our finding that both methods can produce satisfactory clinical anaesthesia despite technical differences between the approaches.

Earlier studies have also suggested that performing spinal and epidural components separately may improve technical reliability. Lyons et al. reported failure in 16% of needle-through-needle procedures compared with 4% when spinal and epidural blocks were performed at separate interspaces.[9] Similarly, Backe et al. compared the needle-through-needle approach with double-space CSEA in 200 patients undergoing caesarean section and found a higher successful surgical block rate with the double-space approach [4]. These findings suggest that independent identification of the epidural and subarachnoid spaces may provide a technical advantage in some patients.

However, single-space CSEA has the practical advantage of requiring only one intervertebral puncture. Basheer et al. studied patients undergoing elective lower abdominal and lower-limb procedures and found that the single-space technique required less procedural time and fewer spinal punctures, while intraoperative variables and adverse effects remained comparable between the groups [7]. Thus, single-space CSEA may be preferable when procedural efficiency and reduction in the number of punctures are considered important.

Slavković et al. compared single-space with double distant-space CSEA in 156 patients and found no significant difference in procedural duration or patient preference. Approximately 90% of patients receiving the double-space technique and 87% receiving the single-space technique indicated that they would choose CSEA again. Procedural discomfort was also comparable [5]. These findings reinforce the concept that differences between the two techniques may be relatively small when both are performed by experienced anesthesiologists.

Patient discomfort and paranesthesia represent additional considerations when choosing the CSEA technique. Ahn et al. randomized 116 patients and reported that the overall frequency of paranesthesia was significantly higher with the needle-through-needle technique than with the double-segment technique (56.9% vs. 31.6%; $p=0.011$). Paranesthesia during both spinal needle and epidural catheter insertion was more frequent with the single-space approach [10]. Although our study was not designed primarily to quantify paranesthesia, this evidence indicates that technical convenience with a single puncture does not necessarily translate into less procedural sensory disturbance.

Another clinically relevant finding of the present study was the duration of analgesia. Mean analgesia

duration was 5.15 ± 0.71 hours in the double-space group compared with 4.82 ± 0.82 hours in the single-space group, representing an approximately 6.8% longer duration with the double-space approach. The difference approached but did not achieve statistical significance ($p=0.059$). Therefore, this finding should be regarded as a trend toward prolonged analgesia rather than definitive evidence of superiority.

Chun et al. reported findings that support a potential postoperative advantage of double-spacing CSEA. In their randomized double-blind study, intraoperative sensory block and adverse effects were comparable between the two techniques. However, postoperative sensory block was maintained at a significantly higher level with the double-space technique at 1 and 6 hours, and postoperative patient satisfaction was also greater [6]. This is directionally consistent with the longer mean analgesia duration seen in the double-space group in our study.

The reliability of the epidural component is also important, particularly when prolonged surgery or postoperative analgesia is anticipated. Cook described a separate-needle CSEA technique in 201 consecutive procedures and reported successful placement of both needles in 200 of 201 cases (99.5%). Epidural catheter failure occurred in only 1.1% of cases in which the catheter was used, and no neurological complications were reported [11,2]. These findings demonstrate that a carefully performed separate-needle technique can provide high technical success with a low complication rate.

Failures of neuraxial techniques are clinically important because they may require catheter manipulation, replacement, supplementation, or conversion to another anaesthetic technique. Pan et al., in a large analysis of 19,259 deliveries, reported an overall neuraxial failure rate of 12%, with 6.8% of patients developing inadequate analgesia after initially satisfactory placement that required epidural catheter replacement [12]. Although this population differs from the present orthopedic cohort, these findings emphasize the importance of reliable epidural catheter placement and continued assessment after apparently successful neuraxial blockade.

Haemodynamic parameters were well maintained with both techniques in the present study. Pulse rate, systolic blood pressure, diastolic blood pressure, and mean arterial pressure showed comparable patterns throughout surgery, with no statistically significant intergroup difference at the recorded intervals. Peripheral oxygen saturation also remained approximately 98–99% in both groups. These findings are consistent with previous comparative studies reporting similar intraoperative

haemodynamic profiles between the two approaches [3,7,8].

Duration of surgery was also comparable, averaging 136.15 ± 13.30 minutes in the double-space group and 138.21 ± 12.95 minutes in the single-space group ($p=0.492$). Similar surgical duration is relevant because it reduces the possibility that differences in block duration, haemodynamic changes or analgesic requirements resulted simply from unequal operative exposure.

Taken together, the findings indicate that both double-space and single-space CSEA are effective and hemodynamically stable approaches for elective lower-limb orthopedic surgery. Double-space CSEA showed approximately 6.7% faster sensory-block onset, 8.7% faster motor-block onset, and 6.8% longer analgesia, although these differences were not statistically significant. Existing evidence indicates that the single-space technique may reduce procedural time and the number of punctures, whereas the double-space approach may offer greater technical reliability and, in some studies, better maintenance of postoperative blockade [3-11]. Therefore, the selection of techniques should be individualized according to patient anatomy, operator experience, equipment availability, surgical duration, and the anticipated need for postoperative epidural analgesia.

Conclusion

Both the single-space and double-space combined spinal-epidural anaesthesia techniques were effective and provided comparable haemodynamic stability in patients undergoing elective lower-limb orthopedic surgery. The double-space technique showed a slightly faster onset of sensory block and motor block and a longer mean duration of analgesia, although these differences were not statistically significant. The duration of surgery was also similar between the groups. Overall, neither technique demonstrated clear statistical superiority. Therefore, the choice between single-space and double-space CSEA may be based on patient characteristics, technical feasibility, operator experience, and the anticipated need for prolonged epidural analgesia.

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