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

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

International Journal of Current Pharmaceutical Review and Research 2026; 18(5); 1230-1237

Original Research Article

Ultrasound-Guided Sciatic–Femoral Nerve Block versus Unilateral Spinal Anesthesia for Elective Lower Limb Orthopedic Surgery: A Prospective Randomized Comparative Study

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Received: 01-02-2026 / Revised: 15-03-2026 / Accepted: 21-04-2026
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Conflict of interest: Nil

Abstract

Background: Lower limb orthopedic surgeries demand anesthetic techniques that provide reliable intraoperative conditions, hemodynamic stability, and effective postoperative analgesia. Unilateral spinal anesthesia (ULSA) and ultrasound-guided combined sciatic–femoral nerve block (SFNB) are two established regional techniques for this purpose, yet direct comparative data—particularly in the Indian setting—remain limited.

Methods: A prospective, randomized comparative study was conducted over 15 months (October 2024–December 2025) at the Department of Anaesthesiology, Pacific Institute of Medical Sciences, Udaipur. Seventy patients aged 18–65 years, ASA physical status I–III, scheduled for elective unilateral lower limb orthopedic surgery were randomized into Group A (ULSA, n=35) and Group B (ultrasound-guided SFNB, n=35). Group A received intrathecal 15 mg of 0.75% hyperbaric ropivacaine; Group B received ultrasound-guided femoral nerve block (20 ml of 0.5% ropivacaine) and sciatic nerve block (20 ml of 0.5% ropivacaine). Hemodynamic parameters, block characteristics, Numeric Rating Scale (NRS) pain scores, time to first rescue analgesia, 24-hour analgesic consumption, patient satisfaction, and adverse effects were recorded and compared.

Results: Both groups were demographically comparable at baseline ($p>0.05$). ULSA provided significantly faster onset of sensory block (7.29±1.72 vs 17.74±1.62 min; $p<0.01$) and motor block (8.94±2.14 vs 22.63±1.75 min; $p<0.01$). SFNB provided significantly longer sensory block duration (313.63±65.79 vs 181.37±15.70 min; $p<0.01$) and motor block duration (283.63±65.79 vs 137.94±9.03 min; $p<0.01$). Transient but significant intraoperative hypotension occurred in Group A at 20–30 minutes (DBP: 54.54±5.00 vs 69.63±4.97 mmHg; $p<0.01$). Time to first rescue analgesia was significantly prolonged in Group B (513.63±65.79 vs 210.29±18.20 min; $p<0.01$). NRS scores were significantly higher in Group A from 4 hours onward ($p<0.01$). Urinary retention was more frequent in Group A (5 vs 1 patient); minor hematoma occurred exclusively in Group B (4 patients).

Conclusion: Ultrasound-guided SFNB provides superior hemodynamic stability and significantly prolonged postoperative analgesia compared to ULSA, while ULSA offers faster onset of blockade. SFNB is particularly advantageous in patients with cardiovascular risk or where sustained postoperative analgesia is a clinical priority.

Keywords: unilateral spinal anesthesia, sciatic nerve block, femoral nerve block, peripheral nerve block, lower limb orthopedic surgery, ultrasound guidance, postoperative analgesia, hemodynamic stability.

DOI: 10.25258/ijcpr.18.5.201

Introduction

Lower limb orthopedic procedures, including fracture fixation, ligament reconstruction, arthroscopy, osteotomy, and surgeries of the knee, tibia, ankle, and foot, represent a substantial proportion of elective surgical workload globally. Adequate anesthetic management is central to ensuring optimal surgical conditions, hemodynamic stability, attenuation of the perioperative stress response, and effective postoperative pain control. The choice of anesthetic technique significantly influences recovery profiles, complication rates, duration of hospital stay, and overall patient satisfaction [1]. General anesthesia, despite providing reliable surgical conditions, is associated with the need for airway instrumentation, postoperative nausea and vomiting, delayed cognitive recovery, and systemic drug-related adverse effects [1]. Regional anesthesia circumvents many of these drawbacks by offering superior postoperative analgesia, reduced opioid consumption, preservation of protective airway reflexes, and attenuation of the neuroendocrine stress response [2].

Among regional techniques, spinal anesthesia has historically been the most widely used method for lower limb orthopedic surgery because of its rapid onset, dense and predictable sensorimotor blockade, and technical simplicity [3,4]. However, conventional bilateral spinal anesthesia produces extensive sympathetic blockade, which may manifest as hypotension, bradycardia, decreased cardiac output, and urinary retention. The clinical severity of these effects is proportional to the height of sympathetic block and is amplified in elderly and high-risk patients, in whom even transient hemodynamic perturbation may be clinically dangerous [5].

To limit these adverse effects, unilateral spinal anesthesia was developed as a modification restricting local anesthetic spread primarily to the operative side. This lateralization is achieved through low-dose hyperbaric agents, slow intrathecal injection, pencil-point needles, and maintenance of the lateral decubitus position for an adequate period following injection [6,7]. Clinical studies have confirmed that ULSA offers adequate surgical anesthesia with lower incidences of hemodynamic instability and faster functional recovery compared to conventional bilateral spinal anesthesia, making it particularly appropriate for ambulatory procedures [6–8].

In parallel, peripheral nerve blocks have gained increasing acceptance as alternatives or adjuncts to neuraxial techniques. For lower limb surgery, combined femoral and sciatic nerve blocks can provide complete anesthesia below the mid-thigh. The femoral nerve supplies the anterior thigh, knee, and medial leg via the saphenous nerve, while the sciatic nerve provides sensation and motor control to the posterior thigh, entire leg, ankle, and foot [9,10]. When performed together, these blocks can functionally replace neuraxial anesthesia for most knee, leg, ankle, and foot procedures. Real-time ultrasound guidance has transformed the practice of peripheral nerve blocks by enabling direct visualization of target nerves, adjacent vascular structures, and the spread of injected local anesthetic [11]. Compared with landmark-based or nerve stimulator techniques, ultrasound guidance offers higher block success rates, faster onset, reduced volumes of local anesthetic, and fewer complications including inadvertent intravascular injection and nerve injury [11].

Prior comparative studies between ULSA and ultrasound-guided SFNB have yielded variable conclusions. Some investigators report that spinal anesthesia provides faster onset and is technically easier to perform, whereas SFNB delivers longer postoperative analgesia and greater hemodynamic stability [12,13]. A clear consensus on optimal technique selection for elective lower limb orthopedic surgery—particularly in Indian practice settings—is lacking. Therefore, this prospective randomized study was designed to systematically compare both techniques with respect to block characteristics, hemodynamic stability, postoperative analgesic duration, pain scores, analgesic consumption, patient satisfaction, and adverse events.

Materials and Methods

Study design and setting: This was a prospective, randomized, comparative study conducted in the Department of Anaesthesiology, Pacific Institute of Medical Sciences, Umarda, Udaipur, Rajasthan, India, over 15 months from October 2024 to December 2025. Institutional Ethics Committee approval was obtained, and all patients provided written informed consent prior to enrolment.

Participants: Seventy patients scheduled for elective unilateral lower limb orthopedic surgery were enrolled. Inclusion criteria were: age 18–65 years, either sex, ASA physical status I–III, and BMI 18.5–30 kg/m². Patients were excluded for emergency or bilateral surgery, coagulopathy or concurrent anticoagulant therapy, infection at the proposed injection site, known allergy to ropivacaine, lidocaine, or diclofenac, and refusal to participate.

Sample size calculation: Sample size was computed using the standard two-group comparison formula ($Z\alpha/2 = 1.96$ at 5% significance level; $Z\beta = 0.84$ at 80% power), based on expected differences in mean duration of postoperative analgesia from prior literature. The calculation yielded a minimum of 33 patients per group; 35 were enrolled per group to account for potential dropout, yielding a total of 70 patients.

Randomization: Participants were allocated to Group A (ULSA, n=35) or Group B (ultrasound-guided SFNB, n=35) using a closed-envelope randomization method.

Pre-anesthetic preparation: All patients underwent detailed pre-anesthetic evaluation the day before surgery, including airway assessment, clinical history, systemic examination, routine investigations, chest X-ray, and ECG where indicated. Patients fasted overnight and received oral alprazolam 0.25 mg the preceding evening. On the operative day, an 18G or 20G intravenous cannula was secured and all patients received 500 ml of Ringer Lactate as preload.

Monitoring: Following transfer to the operating room, standard monitoring was instituted: ECG, NIBP, peripheral SpO_2, and pulse rate. Parameters were recorded at baseline, every 5 minutes for the first 30 minutes, every 15 minutes for the remainder of surgery, and postoperatively at 0, 30 minutes, and 1, 2, 4, 6, 12, and 24 hours.

Group A – Unilateral Spinal Anesthesia: Patients were positioned in the lateral decubitus position with the operative limb dependent. Following aseptic preparation with chlorhexidine 2.5% and ethanol 70%, a 23G or 25G Quincke spinal needle was inserted at the L3–L4 or L4–L5 interspace via a midline approach. After confirming free flow of cerebrospinal fluid, 15 mg of 0.75% hyperbaric ropivacaine was administered intrathecally at a rate of approximately 0.1 ml/second. The lateral position was maintained for 15 minutes to facilitate ipsilateral block consolidation before repositioning supine.

Group B – Ultrasound-Guided SFNB: Femoral nerve block: The patient was positioned supine with the inguinal region prepared aseptically. A high-frequency linear ultrasound probe (6–13 MHz) was placed transversely at the inguinal crease. The femoral artery was identified first, and the femoral nerve was located as a hyperechoic triangular or oval structure lateral to the artery beneath the fascia iliaca.

Using an in-plane technique, a 22G insulated needle was advanced from lateral to medial under real-time ultrasound guidance. Following negative aspiration to exclude intravascular placement, 20 ml of 0.5% ropivacaine was injected incrementally, with sonographic confirmation of circumferential perineural spread.

Sciatic nerve block (Labat technique): The patient was repositioned to the lateral decubitus position with the operative side uppermost and the hip slightly flexed. A low-frequency curvilinear probe (2–5 MHz) was placed over the gluteal region between the greater trochanter and ischial tuberosity. The sciatic nerve was identified as a hyperechoic oval or flattened structure beneath the gluteus maximus. An in-plane needle approach was used; following negative aspiration, 20 ml of 0.5% ropivacaine was injected with continuous visualization of circumferential spread around the nerve. Strict asepsis was maintained throughout, and patients were monitored for signs of local anesthetic systemic toxicity (LAST).

Assessment of block: Sensory block was assessed by loss of pinprick sensation to a 22G needle. Motor block in Group A was graded using the Modified Bromage Scale; in Group B, femoral motor block was assessed by the patient's ability to elevate the limb from the table, and sciatic motor block by ability to dorsiflex and plantarflex the foot against resistance.

Postoperative pain assessment: NRS (0–10) was recorded at 0, 15, 30 minutes and 1, 2, 4, 6, 12, and 24 hours postoperatively by a blinded resident physician.

Rescue analgesia protocol: IV diclofenac 75 mg was administered for NRS >4 (maximum four doses at 6-hour intervals). IV tramadol 1.5 mg/kg was added if NRS exceeded 6. Time to first rescue analgesia and total analgesic consumption over 24 hours were recorded.

Statistical analysis: Data were analyzed using appropriate statistical software. Continuous variables are expressed as mean ± standard deviation. Intergroup comparisons used Student's independent t-test for continuous data and chi-square test for categorical data. A p-value <0.05 was considered statistically significant.

Results

Baseline characteristics: Both groups were well matched at baseline. Mean age was 42.23±7.45 years in Group A versus 41.74±7.48 years in Group B (p=0.84). Mean BMI was 23.63±3.2 kg/m² in Group A versus 26.50±3.2 kg/m² in Group B (p=0.13). Group A comprised 20 males and 15 females; Group B comprised 23 males and 12 females (χ^2=1.14; p=0.28). Age distribution was similar across categories (χ^2=0.883; p=0.82). No statistically significant intergroup differences were identified in any baseline parameter, confirming effective randomization.

Table 1: Comparison of Baseline Demographic Characteristics Between Group A (ULSA) and Group B (SFNB)

Parameter	Group A (ULSA) (n=35)	Group B (SFNB) (n=35)	p-value
Age (years)	42.23 ± 7.45	41.74 ± 7.48	0.847
BMI (kg/m²)	23.63 ± 3.20	26.50 ± 3.20	0.136
Gender (M/F)	20/15	23/12	0.280*

Table 2: Comparison of Block Characteristics between Group A (ULSA) and Group B (SFNB)

Parameter	**Group A (ULSA) (n=35)**	**Group B (SFNB) (n=35)**	**p-value**
Onset of Sensory Block (min)	7.29 ± 1.72	17.74 ± 1.62	**<0.001**
Onset of Motor Block (min)	8.94 ± 2.14	22.63 ± 1.75	**<0.001**
Duration of Sensory Block (min)	181.37 ± 15.70	313.63 ± 65.79	**<0.001**
Duration of Motor Block (min)	137.94 ± 9.03	283.63 ± 65.79	**<0.001**

Table 3: Comparison of Intraoperative Hemodynamic Parameters between Group A (ULSA) and Group B (SFNB)

Time (min)	**Systolic BP (mmHg)**	**Diastolic BP (mmHg)**	**Mean Arterial Pressure (mmHg)**	**Pulse Rate (bpm)**
	Group A	**Group B**	**p-value**	**Group A**
5	122.43 ± 13.04	128.43 ± 8.31	0.210	70.11 ± 6.00
10	127.06 ± 10.34	126.29 ± 8.93	0.360	68.34 ± 5.31
15	121.09 ± 13.44	128.26 ± 7.74	0.140	69.34 ± 6.60
20	**108.69 ± 8.36**	**125.34 ± 8.75**	**<0.001**	**54.54 ± 5.00**
30	**108.80 ± 4.95**	**125.00 ± 10.22**	**<0.001**	**55.60 ± 4.16**
45	116.37 ± 11.63	124.86 ± 7.17	0.300	69.69 ± 6.01
60	119.34 ± 11.76	124.09 ± 8.68	0.450	69.69 ± 5.66

Table 4: Comparison of Postoperative Analgesia and Rescue Analgesia between Group A (ULSA) and Group B (SFNB)

Parameter	**Group A (ULSA) (n=35)**	**Group B (SFNB) (n=35)**	**p-value**
Time to First Rescue Analgesia (min)	210.29 ± 18.20	513.63 ± 65.79	**<0.001**
Total Diclofenac Consumption (mg)	225.00 ± 0.00	41.78 ± 2.30	**<0.001**
Tramadol Requirement (Yes/No)	35/0	0/35	**<0.001***
NRS Score at 4 Hours (0-10)	6.2 ± 1.1	2.1 ± 0.8	**<0.001**
NRS Score at 12 Hours (0-10)	5.8 ± 1.0	1.9 ± 0.7	**<0.001**

Intraoperative hemodynamic parameters: Systolic, diastolic, and mean arterial blood pressure were comparable between groups at most intraoperative time intervals. At 20 and 30 minutes, however, Group A exhibited a significant transient fall in diastolic blood pressure (20 min: 54.54±5.00 vs 69.63±4.97 mmHg; p<0.01 and 30 min: 55.60±4.16 vs 69.23±5.04 mmHg; p<0.01) and mean arterial pressure (20 min: 61.51±7.11 vs 74.09±6.21 mmHg; p<0.01), accompanied by a compensatory rise in pulse rate (20 min: 87.71±9.52 vs 78.83±9.12 bpm; p<0.01; 30 min: 85.66±8.89 vs 75.31±8.26 bpm; p<0.01). These disturbances resolved by 45 minutes, with no significant intergroup differences observed thereafter up to 120 minutes. Group B maintained stable hemodynamics throughout the intraoperative period.

Postoperative hemodynamic parameters: Hemodynamic values were comparable in the early postoperative period (0–2 hours; p>0.05). From 4 hours onward, Group A demonstrated significantly higher SBP (133.74±9.10 vs 127.17±11.66 mmHg at 4 h; p=0.01; 148.51±9.81 vs 126.03±12.56 mmHg at 12 h; p<0.01), DBP, MAP, and pulse rate (84.20±9.53 vs 77.09±9.09 bpm at 4 h; p=0.04; 95.11±6.06 vs 75.74±9.77 bpm at 12 h; p<0.01). Values returned to comparable levels by 24 hours. Group B maintained lower and more stable hemodynamic values postoperatively, consistent with sustained peripheral neural blockade limiting sympathetic reactivation.

Block characteristics: ULSA provided significantly faster onset of sensory block (7.29±1.72 vs 17.74±1.62 min; p<0.01) and motor block (8.94±2.14 vs 22.63±1.75 min; p<0.01). In contrast, SFNB offered significantly longer duration of sensory block (313.63±65.79 vs 181.37±15.70 min; p<0.01) and motor block (283.63±65.79 vs 137.94±9.03 min; p<0.01).

Postoperative analgesia: Time to first rescue analgesia was significantly prolonged in Group B (513.63±65.79 min) compared to Group A (210.29±18.20 min; p<0.01)—approximately 2.5 times longer. NRS scores were comparable in the immediate postoperative period (0–2 hours; p>0.05) but diverged significantly from 4 hours onward, with Group A exhibiting markedly higher pain scores at 4, 6, 12, and 24 hours (all p<0.01). Mean diclofenac consumption over 24 hours was substantially lower in Group B (41.78±2.3 mg vs 225±0.00 mg). No patient in Group B required tramadol, whereas the ULSA group needed both diclofenac and tramadol supplementation.

Patient satisfaction and adverse effects: Overall satisfaction ratings (excellent, good, satisfactory) were statistically comparable between groups (χ^2=2.334; p=0.31). Willingness to undergo the same technique again was higher in Group A

(100% vs 85.7%; p=0.01). Urinary retention requiring catheterization occurred in 5 patients in Group A versus 1 in Group B (p<0.05). Localized, self-limiting hematoma at the injection site occurred in 4 patients in Group B and none in Group A (p<0.01). No major systemic or neurological adverse events were recorded in either group.

Discussion

This study compared ULSA and ultrasound-guided SFNB in 70 patients undergoing elective unilateral lower limb orthopedic surgery at a single tertiary center. The central findings were that ULSA affords significantly faster sensorimotor block onset, while SFNB delivers superior hemodynamic stability, markedly prolonged postoperative analgesia, lower rescue analgesic consumption, and a reduced incidence of urinary retention.

Baseline equivalence: The absence of statistically significant intergroup differences in age, BMI, gender, and ASA status confirms effective randomization and validates that observed outcome differences are attributable to the anesthetic technique rather than patient-level confounders. This is consistent with prior RCTs including Hussien et al. [37], Spasiano et al. [38], and Indian studies by Pattajoshi et al. [39], Shah et al. [40], and Arakkal et al. [41], all of which demonstrated comparable baseline demographics when these two techniques were compared.

Intraoperative hemodynamics: The transient hypotension and compensatory tachycardia observed in Group A at 20–30 minutes reflect sympathetic blockade consequent to intrathecal local anesthetic spread, even with the low-dose lateralized approach used in ULSA. Despite optimal technique—including slow injection, hyperbaric agent, and maintained lateral positioning—some degree of contralateral sympathetic block appears inevitable in the early phase. This is well supported in the literature. Coviello et al. (2025), in a triple-blind RCT comparing multi-nerve peripheral nerve block with selective spinal anesthesia in hip fracture surgery, reported a significantly lower incidence of intraoperative hypotension (16.7% vs 43.4%; p=0.048) and bradycardia (10% vs 33.3%; p=0.028) in the PNB group [42]. Shokri and Kasem (2020) similarly demonstrated significantly lower intraoperative hypotension with the sciatic-obturator-femoral technique compared to spinal anesthesia (p=0.001) [43]. Davarci et al. (2013) also reported superior intraoperative hemodynamic stability with ultrasound-guided SFNB [47]. The single dissenting study, Hussien et al. (2020), found no significant intraoperative hemodynamic differences between ULSA and SFNB, a discrepancy plausibly explained by their higher-risk patient population (predominantly ASA III–IV) and differences in management protocol [37].

Postoperative elevations of blood pressure and pulse rate in Group A from 4 hours onward most likely represent rebound sympathetic activation following regression of spinal block, compounded by inadequately treated breakthrough pain—a mechanism described by Tekye and Alipour (2014) [46] and Boujan and Hussein (2020) [45]. The comparatively lower and stable postoperative hemodynamic values in Group B reflect sustained peripheral analgesia limiting sympathetic reactivation.

Block characteristics: The faster onset with ULSA is a well-established pharmacodynamic property of intrathecal administration, attributed to direct contact of local anesthetic with thin-walled cauda equina nerve roots. The prolonged duration of SFNB reflects the slower diffusion kinetics of 0.5% ropivacaine deposited circumferentially around thick peripheral nerve trunks under ultrasound guidance. This pattern—faster onset with spinal anesthesia, longer duration with peripheral nerve blocks—is consistently reported across the literature. Hussien et al. (2020) documented significantly shorter ULSA onset times (sensory: 3.90±1.10 vs 10.60±2.22 min; p<0.001; motor: 4.70±0.95 vs 15.00±1.15 min; p<0.001) and longer SFNB recovery duration (sensory recovery: 6.00±2.75 vs 2.18±0.79 h; p<0.001) [37]. Coviello et al. (2025) similarly documented faster onset but shorter duration with selective spinal anesthesia, versus slower onset with prolonged blockade with PNBs [42]. Pattajoshi et al. (2022) confirmed significantly longer sensory and motor blockade with combined sciatic–femoral nerve block versus spinal anesthesia in below-knee surgery (p<0.05) [39]. Oberndorfer et al. (2007) further highlighted that ultrasound guidance improves nerve localization precision and may enhance block consistency and duration [49].

Postoperative analgesia: The approximately 2.5-fold extension of time to first rescue analgesia in Group B (513.63 vs 210.29 min; p<0.01) represents a clinically substantial advantage, enabling patients to remain pain-free through the most painful early postoperative hours while minimizing systemic opioid use. This finding is closely mirrored by Bhardwaj et al. (2023), who reported significantly longer time to readiness for discharge—a surrogate analgesic endpoint—in the SFNB group versus ULSA in arthroscopic knee surgery (595.4±195.7 vs 351.9±129.5 min; p<0.001) [50]. Davarci et al. (2013) demonstrated shorter time to first analgesic request in the spinal group, reinforcing the peripheral block's analgesic superiority [47]. Deshpande et al. (2023) similarly confirmed prolonged block duration and reduced rescue requirements with ultrasound-guided femoral and sciatic blocks [51]. Bansal et al. (2016) documented 12–13 hours of postoperative analgesia with combined femoral–sciatic block using ropivacaine without significant hemodynamic changes [53].

The significantly higher NRS scores from 4 hours onward in Group A are a direct consequence of intrathecal block regression. Bhardwaj et al. (2023) reported significantly lower VAS scores at 2, 4, 12, and 24 hours in the nerve block group ($p<0.05$ at all time points) [50], mirroring the temporal pattern of our data. Hussien et al. (2020) and Coviello et al. (2025) observed the same directional advantage of peripheral blockade for postoperative pain scores [37,42].

Adverse effects: The higher incidence of urinary retention in Group A (5 vs 1 patient; $p<0.05$) is consistent with the recognized sacral autonomic sequelae of intrathecal local anesthetics, which impair detrusor contractility and promote urinary bladder retention [47]. Hussien et al. (2020) reported significantly prolonged time to first voiding in the ULSA group and earlier discharge in the SFNB group [37]; Spasiano et al. (2007) documented earlier return of bladder function in peripheral nerve block patients (~200 vs 269 min; $p<0.05$) [38]. Indian studies by Pattajoshi et al. (2022) and Shah et al. (2023) similarly reported higher urinary retention rates with spinal anesthesia compared to SFNB [39,40].

The four cases of localized hematoma confined to Group B, while self-limiting, underscore that ultrasound guidance reduces but does not eliminate the risk of inadvertent vascular puncture. The incidence in this study (11.4%) is higher than the 0.82% reported by Joubert et al. (2019) in a systematic review of bleeding complications in regional anesthesia [54]; this discrepancy may reflect closer perioperative surveillance, smaller sample size, or reporting differences. The higher willingness to repeat ULSA (100% vs 85.7%; $p=0.01$) may reflect patient perception of procedural simplicity—a single injection versus multiple injection sites—rather than a difference in analgesic outcomes.

Conclusion

Both unilateral spinal anesthesia and ultrasound-guided combined sciatic–femoral nerve block provide effective and safe anesthesia for elective lower limb orthopedic surgery. ULSA offers a significantly faster onset of sensorimotor blockade, which is advantageous when rapid surgical readiness is required. Ultrasound-guided SFNB, however, provides superior intraoperative and postoperative hemodynamic stability, markedly prolonged postoperative analgesia, substantially reduced rescue analgesic requirements, and a lower incidence of urinary retention. These attributes make SFNB the preferable technique in patients with cardiovascular comorbidities or when sustained postoperative pain control is the priority. Future multicenter randomized trials with larger sample sizes, standardized blinding protocols, and assessment of long-term functional and patient-reported outcomes are warranted to consolidate these findings and guide broader clinical adoption.

Declaration

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