INTERNATIONAL JOURNAL OF CLINICAL, MEDICAL AND HEALTH SCIENCES

ISSN: Applied For
Frequency: Quarterly
Website: http://ijcmhs.com/

Original Research Article

Comparison of Hemodynamic Stability Between Ultrasound-Guided and Landmark-Guided Spinal Anaesthesia in Patients Undergoing Elective Lower Limb Surgery

Dr Safoora Siddiqui[1], Dr Shruti[2]

[1]*Assistant Professor, Shri Atal Bihari Vajpayee Medical College and Research Institute, SABVMCRI Bangalore*
[2]*Icu Registrar, Anaesthesia, Sagar Hospital, Jayanagar*

OPEN ACCESS

Corresponding Author:

Dr Safoora Siddiqui
Assistant Professor, Shri Atal Bihari Vajpayee Medical College and Research Institute, SABVMCRI.

Received: 12-01-2025
Accepted: 20-01-2026
Published: 10-02-2026

ABSTRACT

Background: Spinal anaesthesia is widely used for elective lower limb surgery, but intraoperative hypotension remains a common concern. Ultrasound guidance may improve the technical accuracy of neuraxial procedures; however, its influence on hemodynamic stability compared with the conventional landmark-guided technique requires further evaluation.
Methods: This prospective, randomized comparative study was conducted at Rajarajeshwari Medical College and Hospital, Bengaluru, over one year. A total of 100 patients undergoing elective lower limb surgery under spinal anaesthesia were allocated equally into an ultrasound-guided group (Group U, n = 50) and a landmark-guided group (Group L, n = 50).
Results: First-attempt success was significantly higher in Group U than in Group L (86.0% vs 62.0%; P = 0.006). The ultrasound-guided group required fewer needle insertion attempts and redirections and had a shorter procedure duration. Mean systolic blood pressure and mean arterial pressure were significantly better maintained during the early intraoperative period in Group U.
Conclusion: Ultrasound-guided spinal anaesthesia was associated with improved procedural efficiency and greater hemodynamic stability compared with landmark-guided spinal anaesthesia in patients undergoing elective lower limb surgery.

Keywords: *Ultrasound-guided spinal anaesthesia; landmark-guided spinal anaesthesia; hemodynamic stability; hypotension; mean arterial pressure; lower limb surgery; neuraxial anaesthesia.*

INTRODUCTION

Spinal anaesthesia is one of the most commonly used regional anaesthetic techniques for surgical procedures involving the lower abdomen, pelvis, and lower limbs. It provides rapid and reliable sensory and motor blockade while allowing patients to remain spontaneously breathing and avoiding many of the airway manipulations associated with general anaesthesia. In elective lower limb surgery, including procedures involving the hip, knee, leg, and foot, spinal anaesthesia is particularly useful because it can provide adequate surgical anaesthesia with relatively small doses of local anaesthetic. However, despite its clinical advantages, spinal anaesthesia can produce important cardiovascular changes, particularly hypotension and bradycardia. Hypotension during neuraxial anaesthesia is clinically significant because prolonged or severe reductions in arterial blood pressure may compromise perfusion of vital organs and may require intravenous fluid administration or treatment with vasopressor drugs [1].

The principal hemodynamic effects of spinal anaesthesia arise from blockade of the sympathetic nervous system. Sympathetic blockade causes arterial and venous vasodilatation, which can reduce systemic vascular resistance and venous return. Depending on the extent of the block and the physiological condition of the patient, cardiac output and stroke volume may also decrease [2]. These changes can result in a fall in systolic blood pressure and mean arterial pressure, sometimes accompanied by bradycardia. Hemodynamic responses may be especially important in elderly patients and individuals with cardiovascular disease, hypertension, reduced physiological reserve, or other associated illnesses. Evidence from elderly patients undergoing lower limb and hip surgery shows that hypotension remains an important cardiovascular adverse effect of spinal anaesthesia, and the dose and extent of neuraxial blockade can influence its occurrence [3]. Therefore, maintaining stable blood pressure, heart rate, and tissue perfusion throughout the perioperative period is an important goal during spinal anaesthesia.

The success and safety of spinal anaesthesia also depend on accurate identification of the appropriate lumbar intervertebral space and successful placement of the spinal needle into the subarachnoid space. Traditionally, spinal anaesthesia is performed using a landmark-guided technique. In this technique, the anaesthesiologist palpates surface anatomical landmarks, particularly the iliac crests and lumbar spinous processes, to estimate the desired intervertebral level and determine the needle insertion point. Although this method is simple, inexpensive, and widely practised, its accuracy may be affected by obesity, poorly palpable spinous processes, degenerative spinal changes, scoliosis, previous spinal surgery, and age-related anatomical alterations. Repeated needle insertion, redirection, or multiple puncture attempts may subsequently be necessary in technically difficult cases.

Ultrasonography has therefore emerged as an important adjunct for neuraxial anaesthesia. Preprocedural or real-time ultrasound imaging can provide information about vertebral anatomy that cannot be obtained by surface palpation alone. It can assist in identifying the midline, locating an appropriate intervertebral space, determining the optimum needle insertion point and trajectory, and estimating the depth of the neuraxial structures. A recent Cochrane systematic review concluded that ultrasound guidance reduces the number of attempts required for successful neuraxial anaesthesia and reduces needling time compared with conventional anatomical landmarks. It also probably increases the likelihood of successful neuraxial puncture on the first attempt [4]. Similarly, a large network meta-analysis involving 74 studies and 7,090 patients found that preprocedural and real-time ultrasound guidance improved first-pass success compared with the anatomical landmark approach [5].

The benefit of ultrasound appears to be particularly relevant when anatomical landmarks are difficult to identify. Chin et al. demonstrated that, among adult orthopaedic patients with difficult surface anatomical landmarks, ultrasound imaging substantially increased successful dural puncture at the first needle insertion attempt and reduced both needle insertions and needle passes [6]. In patients undergoing elective hip and knee joint replacement, Srinivasan et al. also found that preprocedural ultrasound-guided spinal anaesthesia significantly reduced the number of needle passes and insertion attempts required to reach the subarachnoid space compared with the conventional landmark-guided technique [7]. More recently, Uyel and Kilicaslan studied elderly patients undergoing elective orthopaedic lower extremity surgery and reported a first-attempt success rate of 74.4% with preprocedural ultrasound compared with 53.8% using conventional landmark palpation. Ultrasound guidance was also associated with fewer needle insertion attempts and redirections [8]. Similar advantages have been observed in patients with abnormal spinal anatomy, including scoliosis and previous lumbar surgery [9].

Nevertheless, ultrasound guidance does not produce uniformly superior results in every clinical setting. Its effectiveness can depend on operator experience, patient anatomy, ultrasound technique, and whether a midline or paramedian approach is used. For example, a randomized trial involving elderly patients demonstrated that preprocedural ultrasound did not consistently improve spinal anaesthesia performance when the procedure was carried out by novice anaesthesia residents [10]. These findings indicate that the benefits of ultrasound should not be assumed to extend automatically to every outcome.

Importantly, most previous comparisons between ultrasound-guided and landmark-guided spinal anaesthesia have concentrated on technical outcomes such as first-attempt success, number of needle passes, number of punctures, procedure duration, patient discomfort, and procedural complications [4-10]. Comparatively less attention has been given to whether the method used to identify and access the subarachnoid space is associated with differences in intraoperative hemodynamic stability. The major physiological determinants of spinal anaesthesia-induced hypotension remain the degree of sympathetic blockade, intrathecal drug dose, block height, patient characteristics, and cardiovascular reserve [1-3]. Therefore, although ultrasound may provide more accurate anatomical identification and reduce repeated puncture attempts, whether these procedural advantages translate into more stable blood pressure and heart rate following spinal anaesthesia requires further investigation.

Assessment of hemodynamic stability through parameters such as systolic and diastolic blood pressure, mean arterial pressure, heart rate, incidence of hypotension or bradycardia, and requirement for vasopressors can provide clinically meaningful evidence regarding the comparative effects of the two techniques. Therefore, the present study aims to compare hemodynamic stability between ultrasound-guided and landmark-guided spinal anaesthesia in patients undergoing elective lower limb surgery. Such a comparison may help determine whether the use of ultrasound offers benefits beyond improved technical performance and may contribute to the selection of a safer and more effective approach to spinal anaesthesia in routine lower limb surgical practice.

MATERIALS AND METHODS

Study Design and Setting

This prospective, randomized, parallel-group comparative study was conducted in the Department of Anaesthesiology, Rajarajeshwari Medical College and Hospital, Bengaluru, Karnataka, India, over a period of one year from march 2024 to February 2025 Adult patients scheduled for elective lower limb surgery under spinal anaesthesia were screened for eligibility. The study was designed to compare the intraoperative hemodynamic stability of ultrasound-guided spinal anaesthesia with that of conventional landmark-guided spinal anaesthesia.

A total of 100 patients were enrolled and randomly allocated in a 1:1 ratio to one of two groups: Group U, in which spinal anaesthesia was performed after preprocedural lumbar ultrasonography (n = 50), and Group L, in which spinal anaesthesia was performed using conventional surface anatomical landmarks (n = 50).

The primary outcome was intraoperative hemodynamic stability, assessed using changes in systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), incidence of hypotension, and requirement for vasopressor therapy. Secondary outcomes included first-attempt dural puncture success, number of needle insertion attempts, number of needle redirections, duration of spinal anaesthesia performance, incidence of bradycardia, and procedure-related adverse events. These outcomes are consistent with those already defined in the manuscript.

Study Population
Patients aged 18–65 years who were scheduled to undergo elective lower limb surgery under spinal anaesthesia and belonged to American Society of Anesthesiologists (ASA) physical status I or II were considered eligible.

Inclusion Criteria
Patients were included when they:
1. were aged 18–65 years;
2. were scheduled for elective lower limb surgery under spinal anaesthesia;
3. had ASA physical status I or II; and
4. provided written informed consent.

Exclusion Criteria
Patients were excluded in the presence of refusal of spinal anaesthesia or study participation; local infection at the puncture site; coagulation abnormalities or therapeutic anticoagulation; known hypersensitivity to the intended local anaesthetic; severe spinal deformity; previous major lumbar spinal surgery likely to interfere with neuraxial access; severe neurological disease; severe cardiovascular instability; uncontrolled systemic illness; or emergency surgery.

Sample Size
A total of 100 consecutive eligible patients were recruited during the predefined study period, with 50 patients assigned to each study group. The sample represented the feasible recruitment available during the study period. Because no formal a priori power calculation was performed, this is acknowledged as a limitation of the study.

Randomization and Allocation Concealment
Patients were randomly allocated in a 1:1 ratio to **Group U (ultrasound-guided spinal anaesthesia) or Group L (landmark-guided spinal anaesthesia)** using a computer-generated randomization sequence. Allocation concealment was maintained using sequentially numbered, opaque, sealed envelopes. The envelope corresponding to each participant was opened immediately before performance of spinal anaesthesia.

Preanaesthetic Assessment and Preparation
All participants underwent standard preanaesthetic evaluation before surgery. Age, sex, weight, height, body mass index, ASA physical status, relevant medical history, comorbidities, current medications, and type of lower limb surgical procedure were recorded.

Patients fasted according to institutional guidelines. Standard monitoring consisting of continuous electrocardiography, pulse oximetry, and non-invasive blood pressure monitoring was instituted.

Patients were allowed to rest for [5/10] minutes before baseline measurements were recorded. Baseline heart rate, SBP, DBP, MAP, and peripheral oxygen saturation were documented before performance of spinal anaesthesia.

Landmark-Guided Spinal Anaesthesia
Patients in Group L were positioned in the same manner as those in Group U. The iliac crests were palpated bilaterally, and Tuffier's/intercristal line was used to estimate the lumbar vertebral level. The midline and appropriate lumbar intervertebral space were identified by surface palpation.

Following identical aseptic preparation and local infiltration, spinal puncture was performed using a **25-gauge [Quincke/pencil-point] spinal needle via the midline approach**. After confirmation of free cerebrospinal fluid flow, the same intrathecal anaesthetic drug, concentration, dose, and volume used in Group U were administered.

Standardization of the Intervention
To minimize potential operator-related confounding, all spinal procedures were performed by anaesthesiologists with experience in both conventional spinal anaesthesia and neuraxial ultrasonography.

This operator-experience information is important because ultrasound success is strongly operator dependent.

The L3–L4 intervertebral space was selected as the intended site for spinal needle insertion.The intrathecal local anaesthetic, dose, concentration, baricity, patient positioning, oxygen administration, fluid regimen, sedation protocol, and criteria for vasopressor administration were standardized between groups.

Assessment of Sensory and Motor Block
Sensory blockade was assessed using loss of cold sensation and pinprick following intrathecal injection. Motor blockade was assessed clinically before commencement of surgery.

Hemodynamic Monitoring
Heart rate, SBP, DBP, MAP, and SpO_2 were recorded at baseline and following intrathecal injection.

Based on the time points actually presented in Tables 3 and 4, the Methods should explicitly state:

Hemodynamic measurements were recorded at baseline and at 5, 10, 15, 30, 45, and 60 minutes following intrathecal administration.

Do not retain the vague wording "at regular intervals," because the Results analyse these exact measurement times.

Hypotension was defined as a reduction in SBP of more than 20% from baseline or an absolute SBP <90 mmHg, whichever occurred first. Bradycardia was defined as a heart rate <50 beats/minute. These definitions are already clearly specified in the manuscript.

Procedural Outcomes
The following procedural variables were recorded:

- successful dural puncture at the first insertion attempt;
- total number of needle insertion attempts;
- number of needle redirections;
- time required for successful spinal anaesthesia;
- failed spinal anaesthesia;
- requirement for an alternative neuraxial technique; and
- conversion to general anaesthesia.

A needle insertion attempt was defined as a new penetration of the skin. Needle redirection was defined as withdrawal and alteration of the needle trajectory without complete removal of the needle from the skin, consistent with the definitions already provided.

Adverse Events
Patients were prospectively monitored for hypotension, bradycardia, nausea or vomiting, paresthesia during needle insertion, bloody tap, high spinal block, post-dural puncture headache, failed spinal anaesthesia, and neurological complications.

For greater methodological quality, specify how long post-dural puncture headache and neurological complications were followed, for example:

Patients were assessed during the postoperative period and until [discharge/24 h/48 h/7 days] for post-dural puncture headache and neurological symptoms.

Statistical Analysis
Statistical analysis was performed using [IBM SPSS Statistics version 26.0, IBM Corp., Armonk, NY, USA / actual software used]. All statistical tests were two-sided, and a P value <0.05 was considered statistically significant.

Continuous variables were assessed for distributional normality using the Shapiro–Wilk test, together with inspection of histograms and Q–Q plots. Normally distributed continuous variables were expressed as mean ± standard deviation (SD), whereas non-normally distributed variables were summarized as median and interquartile range (IQR). Categorical variables were expressed as frequencies and percentages.

Baseline continuous variables such as age, body weight, body mass index, and baseline hemodynamic measurements were compared between the ultrasound-guided and landmark-guided groups using the independent-samples Student's t test when normally distributed. The Mann–Whitney U test was used for non-normally distributed continuous variables.

Categorical variables, including sex, ASA physical status, type of surgery, first-attempt success, incidence of hypotension, bradycardia, vasopressor requirement, additional intravenous fluid requirement, and adverse events, were compared using the Pearson chi-square test. Fisher's exact test was used when expected cell frequencies were <5.

A linear mixed-effects model with patient-specific random intercepts was used to account for within-subject correlation between repeated measurements. Group, time, and the group × time interaction were included as fixed effects. Estimated marginal means with 95% confidence intervals were obtained, and multiplicity-adjusted pairwise comparisons were performed where appropriate.

The incidence of hypotension, bradycardia, vasopressor use, and other binary clinical outcomes was compared using the chi-square or Fisher's exact test, as appropriate. For major binary outcomes, effect estimates were reported as risk ratios or risk differences with 95% confidence intervals, where applicable.

RESULTS

A total of 100 patients undergoing elective lower limb surgery under spinal anaesthesia were included in the study. Patients were allocated equally to the ultrasound-guided spinal anaesthesia group (Group U, n = 50) and the conventional landmark-guided spinal anaesthesia group (Group L, n = 50). All enrolled patients were included in the final analysis.

The two groups were comparable with respect to demographic and baseline clinical characteristics. No statistically significant differences were observed in age, sex distribution, body weight, body mass index, ASA physical status, or type of lower limb surgical procedure between the groups.

Table 1. Baseline demographic and clinical characteristics of the study participants

Characteristic	Group U (n = 50)	Group L (n = 50)	P value
Age, years, mean ± SD	45.6 ± 12.1	46.8 ± 11.6	0.614
Male, n (%)	31 (62.0)	29 (58.0)	0.838
Female, n (%)	19 (38.0)	21 (42.0)	
Body weight, kg, mean ± SD	68.4 ± 10.5	69.1 ± 11.0	0.746
BMI, kg/m², mean ± SD	24.9 ± 3.2	25.2 ± 3.4	0.651
ASA I, n (%)	28 (56.0)	26 (52.0)	0.841
ASA II, n (%)	22 (44.0)	24 (48.0)	
Knee surgery, n (%)	20 (40.0)	18 (36.0)	0.917
Hip surgery, n (%)	12 (24.0)	13 (26.0)	
Other lower limb surgery, n (%)	18 (36.0)	19 (38.0)	

Ultrasound guidance was associated with improved technical performance during spinal anaesthesia. Successful dural puncture at the first needle insertion attempt was achieved in 43 patients (86.0%) in Group U compared with 31 patients (62.0%) in Group L, representing a statistically significant difference (P = 0.006).

The mean number of needle insertion attempts was significantly lower in the ultrasound-guided group compared with the landmark-guided group (1.16 ± 0.42 vs 1.62 ± 0.72; P < 0.001). Similarly, the number of needle redirections was significantly reduced with ultrasound guidance.

The mean time required to complete spinal anaesthesia was also shorter in Group U than in Group L (4.8 ± 1.6 minutes vs 6.1 ± 2.2 minutes; P = 0.001).

Table 2. Comparison of procedural characteristics between the groups

Procedural variable	Group U (n = 50)	Group L (n = 50)	P value
First-attempt success, n (%)	43 (86.0)	31 (62.0)	0.006
Number of needle insertion attempts, mean ± SD	1.16 ± 0.42	1.62 ± 0.72	<0.001
Number of needle redirections, mean ± SD	0.38 ± 0.61	1.04 ± 0.89	<0.001
Procedure duration, min, mean ± SD	4.8 ± 1.6	6.1 ± 2.2	0.001
Successful spinal anaesthesia, n (%)	50 (100)	50 (100)	1.000

Baseline systolic and diastolic blood pressure values were comparable between the two groups. Following spinal anaesthesia, both groups demonstrated a reduction in blood pressure, although the decline was greater in the landmark-guided group.

At 5 minutes after spinal anaesthesia, mean systolic blood pressure was significantly higher in Group U than in Group L (116.8 ± 11.7 mmHg vs 110.5 ± 12.4 mmHg; P = 0.010). The maximum between-group difference was observed at approximately 10 to 15 minutes following intrathecal injection.

At 10 minutes, systolic blood pressure was 113.9 ± 11.5 mmHg in Group U compared with 106.4 ± 12.1 mmHg in Group L (P = 0.002). A similar pattern was observed for diastolic blood pressure.

The differences between the groups gradually decreased as surgery progressed, and by 45 to 60 minutes, systolic and diastolic blood pressure values were no longer significantly different.

Table 3. Comparison of systolic and diastolic blood pressure at different time points

Time point	SBP Group U, mmHg	SBP Group L, mmHg	P value	DBP Group U, mmHg	DBP Group L, mmHg	P value
Baseline	128.4 ± 12.6	129.7 ± 13.1	0.614	75.0 ± 8.2	75.6 ± 8.5	0.720
5 min	116.8 ± 11.7	110.5 ± 12.4	0.010	68.6 ± 7.9	64.9 ± 8.2	0.024
10 min	113.9 ± 11.5	106.4 ± 12.1	0.002	66.2 ± 7.7	61.8 ± 8.0	0.006
15 min	115.2 ± 11.3	108.1 ± 11.8	0.003	67.4 ± 7.6	63.0 ± 7.8	0.005

30 min	119.1 ± 10.9	114.2 ± 11.4	0.030	70.2 ± 7.5	67.1 ± 7.6	0.043
45 min	121.5 ± 10.8	117.8 ± 11.1	0.094	72.0 ± 7.4	69.7 ± 7.5	0.126
60 min	123.0 ± 10.6	120.1 ± 10.8	0.179	73.1 ± 7.3	71.2 ± 7.4	0.199

Mean arterial pressure showed a similar trend. Baseline MAP was comparable between Group U and Group L. At 5 minutes after spinal anaesthesia, mean MAP was significantly higher in the ultrasound-guided group (83.9 ± 8.0 mmHg) compared with the landmark-guided group (78.9 ± 8.6 mmHg; P = 0.003).

The lowest mean MAP was observed at 10 minutes in both groups. At this point, MAP was 81.8 ± 7.8 mmHg in Group U and 76.3 ± 8.2 mmHg in Group L (P < 0.001).

A statistically significant difference between the groups persisted until approximately 45 minutes, after which MAP values became comparable.

In contrast, heart rate showed only modest reductions following spinal anaesthesia. No statistically significant difference in heart rate was identified between the two groups at any of the measured time points.

Table 4. Comparison of mean arterial pressure and heart rate at different time points

Time point	**MAP Group U, mmHg**	**MAP Group L, mmHg**	**P value**	**HR Group U, beats/min**	**HR Group L, beats/min**	**P value**
Baseline	92.8 ± 8.4	93.5 ± 8.7	0.683	76.4 ± 9.1	77.0 ± 9.4	0.746
5 min	83.9 ± 8.0	78.9 ± 8.6	0.003	73.8 ± 8.7	72.5 ± 9.0	0.464
10 min	81.8 ± 7.8	76.3 ± 8.2	<0.001	72.7 ± 8.5	70.7 ± 8.8	0.251
15 min	83.0 ± 7.7	77.8 ± 8.0	0.001	73.3 ± 8.4	71.4 ± 8.6	0.266
30 min	86.0 ± 7.5	81.8 ± 7.8	0.007	74.5 ± 8.2	73.0 ± 8.4	0.368
45 min	88.0 ± 7.4	84.6 ± 7.5	0.025	75.1 ± 8.1	74.0 ± 8.2	0.501
60 min	89.3 ± 7.2	86.7 ± 7.4	0.078	75.6 ± 8.0	74.5 ± 8.1	0.496

Repeated-measures analysis demonstrated a significant group-by-time interaction for mean arterial pressure (P = 0.003), indicating that the magnitude and pattern of MAP reduction following spinal anaesthesia differed between the two groups. No significant group-by-time interaction was observed for heart rate.

Hypotension occurred in 9 patients (18.0%) in the ultrasound-guided group compared with 19 patients (38.0%) in the landmark-guided group. This difference was statistically significant (P = 0.026).

The maximum percentage reduction in MAP from baseline was significantly lower in Group U compared with Group L (16.8 ± 6.1% vs 22.5 ± 7.4%; P < 0.001).

Similarly, the requirement for vasopressor administration was significantly lower in Group U, with 8 patients (16.0%) requiring vasopressor treatment compared with 18 patients (36.0%) in Group L (P = 0.023).

Bradycardia occurred in 3 patients (6.0%) in Group U and 7 patients (14.0%) in Group L; however, this difference did not reach statistical significance.

Table 5. Comparison of hemodynamic instability and interventions

Outcome	**Group U (n = 50)**	**Group L (n = 50)**	**P value**
Hypotension, n (%)	9 (18.0)	19 (38.0)	0.026
Lowest SBP, mmHg, mean ± SD	101.6 ± 10.4	96.2 ± 11.1	0.014
Maximum reduction in MAP from baseline, %	16.8 ± 6.1	22.5 ± 7.4	<0.001
Bradycardia, n (%)	3 (6.0)	7 (14.0)	0.182
Vasopressor required, n (%)	8 (16.0)	18 (36.0)	0.023
Additional IV fluid for hypotension, n (%)	10 (20.0)	20 (40.0)	0.029

Procedure-related complications were uncommon in both groups. Paresthesia during needle insertion occurred in 2 patients (4.0%) in Group U and 5 patients (10.0%) in Group L. Bloody tap occurred in one patient in the ultrasound-guided group and four patients in the landmark-guided group.

Nausea or vomiting was observed in 3 patients (6.0%) in Group U and 8 patients (16.0%) in Group L. None of these differences reached statistical significance.

There were no clinically significant neurological complications in either group. No patient required conversion to general anaesthesia because of failed spinal blockade.

Table 6. Comparison of procedure-related and perioperative adverse events

Adverse event	**Group U (n = 50)**	**Group L (n = 50)**	**P value**
Paresthesia during needle insertion, n (%)	2 (4.0)	5 (10.0)	0.436

Bloody tap, n (%)	1 (2.0)	4 (8.0)	0.362
Nausea/vomiting, n (%)	3 (6.0)	8 (16.0)	0.200
High spinal block, n (%)	0 (0)	1 (2.0)	1.000
Post-dural puncture headache, n (%)	1 (2.0)	1 (2.0)	1.000
Conversion to general anaesthesia, n (%)	0 (0)	0 (0)	–
Neurological complication, n (%)	0 (0)	0 (0)	–

The ultrasound-guided spinal anaesthesia group demonstrated significantly better procedural performance, including a higher first-attempt success rate, fewer needle insertion attempts and redirections, and a shorter procedure duration compared with conventional landmark guidance.

Both techniques produced the expected reduction in blood pressure following spinal anaesthesia. However, the reduction in systolic blood pressure and mean arterial pressure was greater in the landmark-guided group, particularly during the first 5 to 30 minutes following intrathecal injection. The incidence of hypotension and requirement for vasopressor support were also significantly lower in the ultrasound-guided group.

Heart rate remained relatively stable in both groups, with no statistically significant differences during the observation period. These findings suggest that ultrasound-guided spinal anaesthesia was associated with improved procedural efficiency and comparatively greater intraoperative hemodynamic stability in patients undergoing elective lower limb surgery.

Figure 1. Comparison of mean systolic blood pressure between ultrasound-guided and landmark-guided spinal anaesthesia groups at baseline and different intraoperative time points

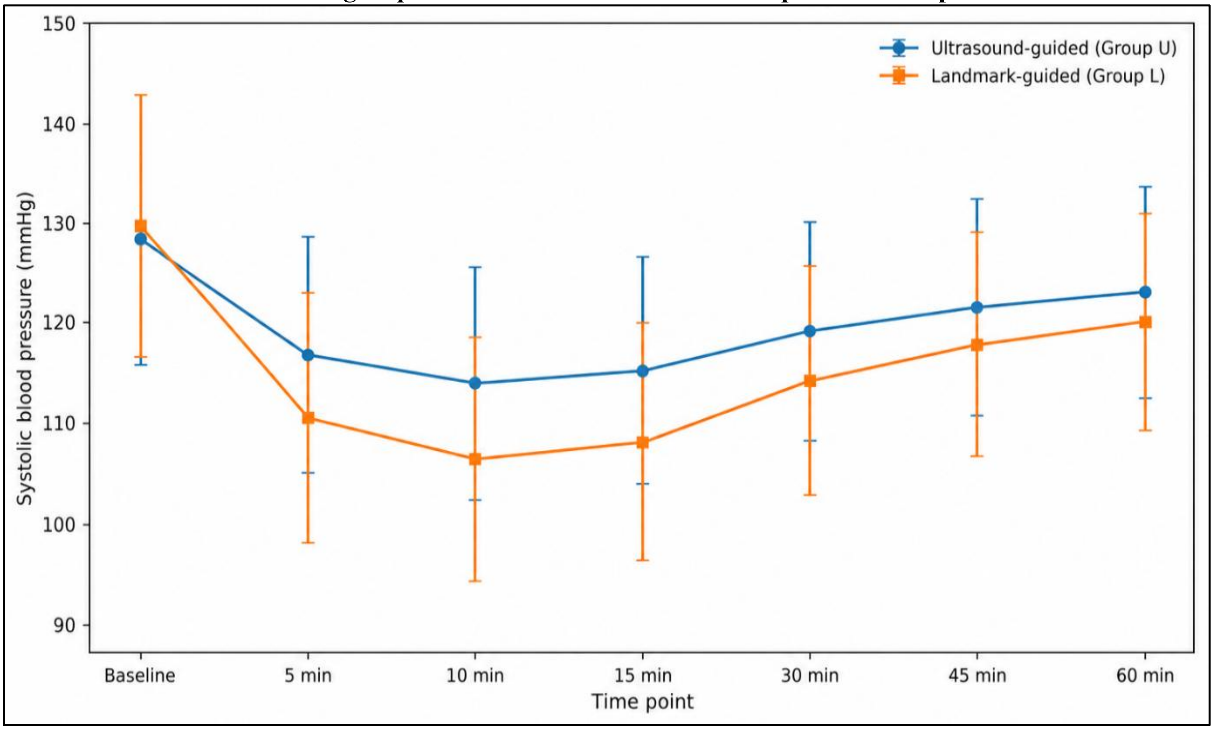

Figure 1 shows the trend in mean systolic blood pressure (SBP) in both groups from baseline to 60 minutes after spinal anaesthesia. Baseline SBP was comparable between the ultrasound-guided group (128.4 ± 12.6 mmHg) and the landmark-guided group (129.7 ± 13.1 mmHg). Following spinal anaesthesia, SBP decreased in both groups, with the greatest reduction occurring during the first 10–15 minutes.

Figure 2. Incidence of intraoperative hypotension in ultrasound-guided and landmark-guided spinal anaesthesia groups

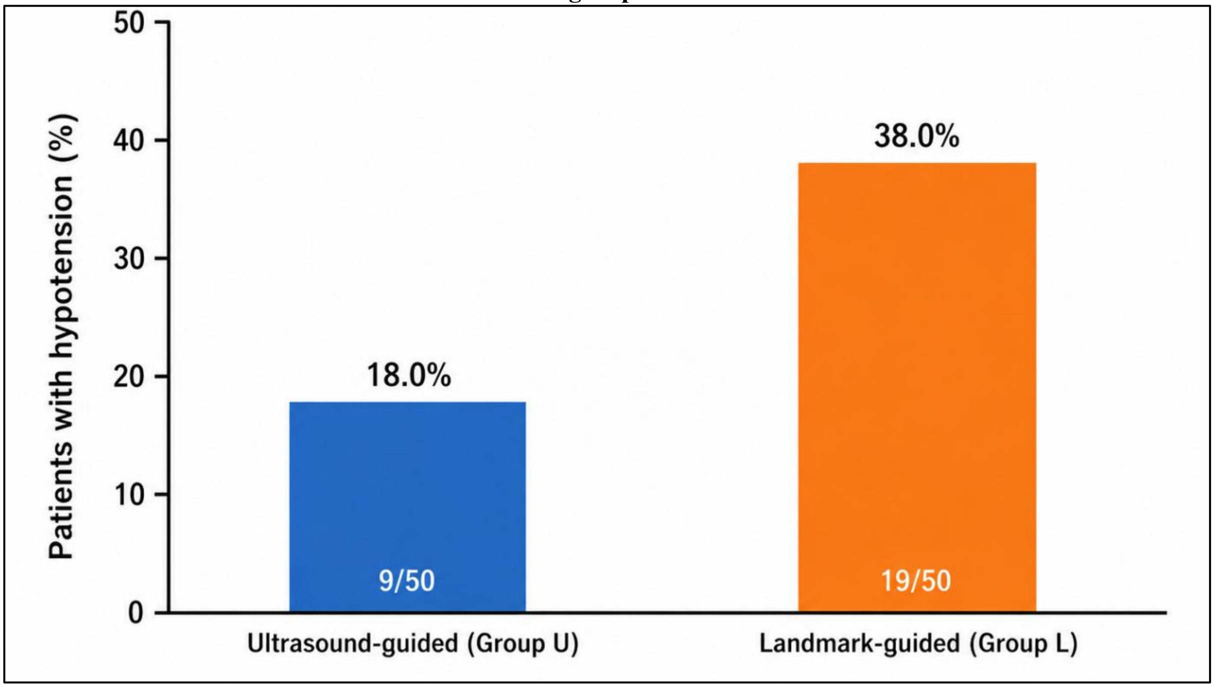

Figure 2 compares the incidence of intraoperative hypotension between the two study groups. Hypotension was observed in **9 of 50 patients (18.0%)** in the ultrasound-guided spinal anaesthesia group and in **19 of 50 patients (38.0%)** in the landmark-guided group.

DISCUSSION

The present study compared the hemodynamic stability and procedural characteristics of ultrasound-guided and conventional landmark-guided spinal anaesthesia in patients undergoing elective lower limb surgery. The principal findings were that ultrasound guidance was associated with a higher first-attempt success rate, fewer needle insertion attempts and redirections, and a shorter spinal anaesthesia procedure time. More importantly, patients in the ultrasound-guided group demonstrated a smaller reduction in systolic blood pressure and mean arterial pressure during the early period following spinal anaesthesia. The incidence of hypotension was significantly lower in the ultrasound-guided group than in the landmark-guided group, 18.0% versus 38.0%, respectively. Vasopressor requirement and the need for additional intravenous fluid administration were also lower with ultrasound guidance. In contrast, changes in heart rate and the incidence of bradycardia were not significantly different between the two groups.

The technical findings of the present study are consistent with a substantial body of evidence supporting the use of neuraxial ultrasonography to facilitate spinal needle placement. In the present study, successful dural puncture at the first insertion attempt was achieved in 86.0% of patients in the ultrasound-guided group compared with 62.0% in the landmark-guided group. Lim et al. conducted a randomized controlled trial comparing preprocedural ultrasound with manual palpation and reported first-attempt success rates of 64% and 52%, respectively. Although the difference in first-attempt success did not reach statistical significance in their study, the ultrasound group had a significantly shorter spinal procedure time and greater patient satisfaction [11]. Differences between their findings and the current results may be related to variations in patient characteristics, operator experience, ultrasound technique, and definitions of procedural success.

The benefit of ultrasound appears to become more evident in patients in whom neuraxial access may be technically challenging. Park et al. studied elderly patients undergoing orthopaedic surgery and found that ultrasound-assisted paramedian spinal anaesthesia significantly reduced the number of needle passes compared with the landmark-guided technique. First-pass success was 65.0% with ultrasound compared with only 17.5% using landmarks. Ultrasound guidance was also associated with lower procedural pain and discomfort [12]. These observations support the present finding that visualization of the lumbar anatomy before needle insertion can reduce unnecessary needle manipulation.

Comparable findings have also been reported specifically in patients undergoing lower limb orthopaedic procedures. Khan et al. evaluated 100 patients undergoing lower limb orthopaedic surgery and reported a first-pass success rate of 86.0% with ultrasound assistance compared with 60.0% using surface landmarks. The number of puncture attempts and the time required to establish the neuraxial block were also reduced with ultrasound guidance [13]. Interestingly, the 86.0% first-pass success reported by Khan et al. is identical to the rate observed in the ultrasound-guided group in the present study. Although their study evaluated combined spinal-epidural anaesthesia rather than spinal anaesthesia alone, the similarity strengthens the evidence that preprocedural ultrasonography may improve the efficiency of neuraxial needle placement in lower limb surgery.

A systematic review and meta-analysis by Perlas et al. also demonstrated that neuraxial ultrasound provides useful anatomical information, including identification of the midline, intervertebral level, interlaminar space, and estimated depth of the neuraxial structures. Their analysis supported improved precision and reduced technical difficulty when ultrasound was incorporated into lumbar neuraxial procedures [14]. The present study supports these observations, as the mean number of needle insertion attempts was 1.16 ± 0.42 in the ultrasound-guided group compared with 1.62 ± 0.72 in the landmark-guided group. Needle redirections were similarly reduced.

The ability of ultrasound to provide anatomical information before puncture may explain these procedural advantages. Chin et al. demonstrated that the quality of preprocedural lumbar ultrasound images can help predict the technical difficulty of subsequent spinal anaesthesia in orthopaedic patients. Clear visualization of the posterior and anterior neuraxial complexes was associated with easier spinal needle placement [15]. Ultrasound may therefore permit the anaesthesiologist to select a more appropriate interspace and needle trajectory before skin puncture rather than relying solely on surface anatomical landmarks.

Nevertheless, the technical advantage of ultrasound is not universal. Srinivasan et al. compared preprocedural ultrasound-guided paramedian spinal anaesthesia at L5-S1 with a conventional landmark-guided midline technique in patients undergoing hip or knee joint replacement. They did not find a reduction in the primary outcome of needle passes, and first-pass success was actually higher in the conventional group in that particular study [16]. Such conflicting evidence is important because it indicates that ultrasound guidance itself does not guarantee easier spinal anaesthesia. Its effectiveness can depend on the chosen intervertebral level, midline versus paramedian approach, quality of ultrasound visualization, operator experience, and characteristics of the patient population. Therefore, the present findings should be interpreted as supporting ultrasound as a useful procedural adjunct rather than suggesting that it should invariably replace a conventional landmark technique.

The most clinically relevant finding of the present study was the difference in hemodynamic stability. Both groups demonstrated an expected reduction in arterial blood pressure following spinal anaesthesia; however, the magnitude of this decline was greater in the landmark-guided group. Mean arterial pressure reached its lowest mean value at approximately 10 minutes in both groups, but remained significantly higher in the ultrasound-guided group. The maximum percentage reduction in MAP from baseline was 16.8 ± 6.1% with ultrasound compared with 22.5 ± 7.4% with landmark guidance.

The timing of these changes is physiologically plausible because the hemodynamic consequences of spinal anaesthesia commonly become most evident during the early period following development of sympathetic blockade. Hypotension results primarily from sympathetic nervous system blockade, leading to vasodilatation, redistribution of circulating blood volume, reduced venous return, and changes in cardiac output. Patient age, baseline cardiovascular condition, level of sensory blockade, intrathecal drug characteristics, and fluid status can substantially modify this response.

Kyokong et al., in a prospective study of 1,220 patients receiving spinal anaesthesia, reported hypotension in 36.8% and bradycardia in 4.9% of patients. Increasing age and a higher sensory block were among the important factors associated with hypotension [17]. The 38.0% incidence of hypotension observed in the landmark-guided group in the present study is therefore within the range reported in previous clinical populations. In contrast, the 18.0% incidence observed with ultrasound guidance was considerably lower.

The requirement for vasopressor therapy followed a similar pattern. Vasopressors were required in 16.0% of patients receiving ultrasound-guided spinal anaesthesia compared with 36.0% receiving landmark-guided spinal anaesthesia. This difference is clinically relevant because vasopressor requirement represents an intervention-based marker of hemodynamic instability rather than a change in blood pressure alone. Mostafa et al. emphasized the importance of maintaining blood pressure after spinal anaesthesia in orthopaedic patients and demonstrated that vasopressor therapy can effectively maintain hemodynamic stability in patients undergoing hip fracture surgery [18]. Their findings support the importance of monitoring both the incidence of hypotension and the therapeutic interventions required to correct it.

Recent evidence also confirms that hypotension remains clinically relevant during spinal anaesthesia for lower extremity orthopaedic procedures. Kavak Akelma et al. prospectively evaluated patients undergoing lower extremity surgery under spinal anaesthesia and identified preoperative perfusion index and ASA status as factors associated with spinal anaesthesia-induced hypotension [19]. Their findings illustrate that the hemodynamic response to spinal anaesthesia is multifactorial and depends on patient characteristics in addition to the neuraxial procedure itself.

For this reason, the lower incidence of hypotension observed with ultrasound guidance in the present study should be interpreted cautiously. Ultrasound does not directly prevent the sympathetic blockade produced by intrathecal local anaesthetic. If the drug dose, baricity, injection technique, patient positioning, and achieved sensory block height are equivalent between groups, there is no established physiological mechanism by which ultrasound imaging alone should substantially alter the cardiovascular consequences of intrathecal anaesthesia. The observed hemodynamic difference may instead be related indirectly to more efficient needle placement, fewer repeated punctures, reduced procedural discomfort, shorter procedural manipulation, more consistent identification of the intended intervertebral space, or other unmeasured clinical factors.

Another possibility is that improved accuracy in selecting the intended intervertebral level may have resulted in more consistent neuraxial drug administration. However, the relationship between puncture level and the ultimate spread of intrathecal local anaesthetic is complex and is influenced by several factors. Consequently, the present findings should not be interpreted as proving that ultrasound itself prevents spinal anaesthesia-induced hypotension. Rather, they suggest an association between ultrasound-assisted spinal anaesthesia and improved perioperative hemodynamic stability that warrants confirmation in larger randomized studies specifically designed with hypotension or change in MAP as the primary endpoint.

Heart rate remained relatively stable in both groups. Although there was a numerical tendency toward a lower heart rate in the landmark-guided group during the first 15 minutes, the differences were not statistically significant. Bradycardia occurred in 6.0% of patients in the ultrasound group and 14.0% in the landmark group, but this difference was also not significant. The absence of a significant difference may partly reflect the relatively small number of bradycardic events and the limited sample size. It also suggests that the main hemodynamic distinction between the techniques in this study was related to arterial pressure rather than chronotropic response.

Procedure-related adverse events were uncommon. Paresthesia, bloody tap, nausea or vomiting, post-dural puncture headache, and high spinal block did not differ significantly between groups. No neurological complications were recorded, and no patient required conversion to general anaesthesia. The low frequency of adverse events limits statistical power to detect differences between techniques. Nevertheless, fewer needle manipulations with ultrasound guidance may be clinically desirable because repeated punctures can increase procedural discomfort and potentially increase the likelihood of traumatic needle placement. The available literature similarly suggests that the clearest and most reproducible advantage of ultrasound lies in improving procedural efficiency rather than demonstrating major differences in uncommon complications [14].

The present findings have practical implications for anaesthetic practice in elective lower limb surgery. Ultrasound-guided identification of lumbar anatomy may be particularly beneficial in patients with poorly palpable landmarks, obesity, degenerative spinal changes, advanced age, or anticipated difficult neuraxial access. Improved first-attempt success and fewer needle redirections may increase operator confidence and patient comfort. If the observed reduction in hypotension and vasopressor requirement is confirmed in further studies, the clinical value of ultrasound may extend beyond technical facilitation to improved intraoperative stability.

Several limitations should be acknowledged. First, this was a single-centre study with a relatively modest sample of 100 patients, which may restrict the generalizability of the findings. Second, complete blinding of the anaesthesiologist performing the procedure was impossible because ultrasound guidance was readily identifiable. This creates the possibility of performance bias. Third, technical success with ultrasound depends substantially on operator experience, and the results may differ when procedures are performed by clinicians with less experience in neuraxial ultrasonography. Fourth, hypotension after spinal anaesthesia is influenced by multiple variables, including intrathecal local anaesthetic dose, sensory block height, fluid administration, patient age, baseline blood pressure, comorbidities, and vasopressor practice. Even with protocol standardization, residual confounding cannot be completely excluded. Fifth, the study was not powered primarily to detect rare adverse events such as neurological injury, high spinal blockade, or post-dural puncture headache.

Most importantly, although improved hemodynamic stability was observed in the ultrasound-guided group, the present study cannot establish that ultrasound imaging directly caused the reduction in hypotension. Future multicentre randomized controlled trials should use a clearly prespecified hemodynamic primary endpoint, standardize intrathecal drug dose and baricity, document maximum sensory block level, standardize fluid and vasopressor protocols, and consider continuous or more frequent blood pressure monitoring. Adjustment for potential predictors of hypotension could further determine whether the association between ultrasound guidance and hemodynamic stability remains after accounting for clinically important confounders.

CONCLUSION

In patients undergoing elective lower limb surgery, ultrasound-guided spinal anaesthesia was associated with improved technical performance compared with the conventional landmark-guided approach, as demonstrated by a higher first-attempt success rate, fewer needle insertion attempts and redirections, and shorter spinal anaesthesia performance time. The ultrasound-guided group also showed a smaller decline in systolic blood pressure and mean arterial pressure, a lower incidence of hypotension, and reduced vasopressor requirement. Heart rate and bradycardia did not differ significantly between groups. Although these findings suggest that ultrasound-assisted spinal anaesthesia may provide both procedural and hemodynamic advantages, the mechanism underlying the observed difference in blood pressure cannot be attributed to ultrasound guidance alone. Larger, adequately powered randomized studies are needed to confirm whether the technical advantages of neuraxial ultrasonography translate into consistently improved hemodynamic outcomes.

REFERENCES

1. Lee S, Islam N, Ladha KS, Bicket MC, Wijeysundera DN. Prevention of hypotension after neuraxial anesthesia in nonobstetric surgery: a systematic review. Can J Anaesth. 2025;72(5):721-737. doi:10.1007/s12630-025-02925-3.
2. Hofhuizen C, Lemson J, Snoeck M, Scheffer GJ. Spinal anesthesia-induced hypotension is caused by a decrease in stroke volume in elderly patients. Local Reg Anesth. 2019;12:19-26. doi:10.2147/LRA.S193925.

3. Messina A, La Via L, Milani A, Savi M, Calabrò L, Sanfilippo F, et al. Spinal anesthesia and hypotensive events in hip fracture surgical repair in elderly patients: a meta-analysis. J Anesth Analg Crit Care. 2022;2(1):19. doi:10.1186/s44158-022-00047-6.
4. Makino Y, Miyake K, Roche D, Yoshimura S, Nahara I, Sahker E, et al. Ultrasound guidance versus anatomical landmarks for neuraxial anaesthesia in adults. Cochrane Database Syst Rev. 2025;(5):CD014964. doi:10.1002/14651858.CD014964.pub2.
5. Kamimura Y, Yamamoto N, Shiroshita A, Miura T, Tsuji T, Someko H, et al. Comparative efficacy of ultrasound guidance or conventional anatomical landmarks for neuraxial puncture in adult patients: a systematic review and network meta-analysis. Br J Anaesth. 2024;132(5):1097-1111. doi:10.1016/j.bja.2023.09.006.
6. Chin KJ, Perlas A, Chan V, Brown-Shreves D, Koshkin A, Vaishnav V. Ultrasound imaging facilitates spinal anesthesia in adults with difficult surface anatomic landmarks. Anesthesiology. 2011;115(1):94-101. doi:10.1097/ALN.0b013e31821a8ad4.
7. Srinivasan KK, Iohom G, Loughnane F, Lee PJ. Conventional landmark-guided midline versus preprocedure ultrasound-guided paramedian techniques in spinal anesthesia. Anesth Analg. 2015;121(4):1089-1096. doi:10.1213/ANE.0000000000000911.
8. Uyel Y, Kilicaslan A. Preprocedural ultrasonography versus landmark-guided spinal anesthesia in geriatric patients with difficult anatomy: a prospective randomized trial. Eurasian J Med. 2021;53(1):9-14. doi:10.5152/eurasianjmed.2020.20215.
9. Park SK, Bae J, Yoo S, Kim WH, Lim YJ, Bahk JH, et al. Ultrasound-assisted versus landmark-guided spinal anesthesia in patients with abnormal spinal anatomy: a randomized controlled trial. Anesth Analg. 2020;130(3):787-795. doi:10.1213/ANE.0000000000004600.
10. Rizk MS, Zeeni CA, Bouez JN, Bteich NJ, Sayyid SK, Alfahel WS, et al. Preprocedural ultrasound versus landmark techniques for spinal anesthesia performed by novice residents in elderly: a randomized controlled trial. BMC Anesthesiol. 2019;19(1):208. doi:10.1186/s12871-019-0882-8.
11. Lim YC, Choo CY, Tan KTJ. A randomised controlled trial of ultrasound-assisted spinal anaesthesia. Anaesth Intensive Care. 2014;42(2):191-198. doi:10.1177/0310057X1404200205.
12. Park SK, Yoo S, Kim WH, Lim YJ, Bahk JH, Kim JT. Ultrasound-assisted vs. landmark-guided paramedian spinal anaesthesia in the elderly: a randomised controlled trial. Eur J Anaesthesiol. 2019;36(10):763-771. doi:10.1097/EJA.0000000000001029.
13. Khan MA, Gupta M, Sharma S, Kasaudhan S. A comparative study of ultrasound assisted versus landmark technique for combined spinal-epidural anaesthesia in patients undergoing lower limb orthopaedic surgery. Indian J Anaesth. 2022;66(4):272-277. doi:10.4103/ija.ija_775_21.
14. Perlas A, Chaparro LE, Chin KJ. Lumbar neuraxial ultrasound for spinal and epidural anesthesia: a systematic review and meta-analysis. Reg Anesth Pain Med. 2016;41(2):251-260. doi:10.1097/AAP.0000000000000184.
15. Chin KJ, Ramlogan R, Arzola C, Singh M, Chan V. The utility of ultrasound imaging in predicting ease of performance of spinal anesthesia in an orthopedic patient population. Reg Anesth Pain Med. 2013;38(1):34-38. doi:10.1097/AAP.0b013e3182734927.
16. Srinivasan KK, Leo AM, Iohom G, Loughnane F, Lee PJ. Pre-procedure ultrasound-guided paramedian spinal anaesthesia at L5-S1: is this better than landmark-guided midline approach? A randomised controlled trial. Indian J Anaesth. 2018;62(1):53-60. doi:10.4103/ija.IJA_448_17.
17. Kyokong O, Charuluxananan S, Sriprajittichai P, Poomseetong T, Naksin P. The incidence and risk factors of hypotension and bradycardia associated with spinal anesthesia. J Med Assoc Thai. 2006;89 Suppl 3.
18. Mostafa M, Hasanin A, Mostafa M, Taha MY, Elsayad M, Haggag FA, et al. Hemodynamic effects of norepinephrine versus phenylephrine infusion for prophylaxis against spinal anesthesia-induced hypotension in the elderly population undergoing hip fracture surgery: a randomized controlled trial. Korean J Anesthesiol. 2021;74(4):308-316. doi:10.4097/kja.20519.
19. Kavak Akelma F, Mafizer M, Nalbant B. Perfusion index as a predictor of hypotension after spinal anesthesia in lower extremity orthopedic surgery: a prospective observational trial. BMC Surg. 2025;25:348. doi:10.1186/s12893-025-03036-y.