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DOI: 10.4274/forbes.galenos.2026.60437

Original Article

Impact of Preprocedural Ultrasound-Guided Marking on Spinal Anesthesia Success in Elderly Patients Undergoing Lower Extremity Orthopedic Surgery: A Retrospective Study

KOCA et al. Ultrasound-Guided Marking Improves Neuraxial Block Success

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Cite as: Koca H, Aksu H, Küçükgüçlü S. Impact of preprocedural ultrasound-guided marking on spinal anesthesia success in elderly patients undergoing lower extremity orthopedic surgery: a retrospective study.

16.03.2026
09.07.2026
Epub: 13.07.2026

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ABSTRACT

Background and Objective

Anatomical and physiological changes in geriatric patients may make spinal anesthesia technically challenging. The traditional manual palpation technique is a blind approach, and anatomical variations may reduce block success and increase complications. Ultrasonography can provide guidance for spinal anesthesia. This study investigated the effect of preprocedural ultrasound-guided marking on block success in patients aged ≥65 years undergoing lower extremity orthopedic surgery.

Materials and Methods

This retrospective observational study included 180 patients aged ≥65 years who underwent lower extremity orthopedic surgery under spinal anesthesia at Dokuz Eylül University Hospital. Of these, 88 patients were in the ultrasound-guided marking group and 92 in the manual palpation group. The primary outcome was first-attempt success of spinal anesthesia. Secondary outcomes included puncture attempts, needle redirections, time to cerebrospinal fluid return, and spinal needle-placement time.

Results

Demographic characteristics were similar between the groups. The number of spinal punctures and needle redirections was significantly lower in the ultrasound group. In addition, **spinal needle-placement** time was significantly shorter in the ultrasound group ($p < 0.001$). Successful spinal anesthesia with a single puncture was achieved in 73.9% of patients in the ultrasound group and 44.6% in the manual palpation group ($p < 0.001$).

Conclusion

Preprocedural ultrasound-guided marking was associated with higher first-attempt success, fewer puncture attempts, fewer needle redirections, and shorter needle-placement time in elderly patients undergoing spinal

anesthesia for lower extremity orthopedic surgery. Given the retrospective non-randomized design, these findings should be interpreted as an association rather than a definitive causal effect.

INTRODUCTION

Advancements in technology have extended average lifespans globally, leading to an increased need for anesthesia in geriatric patients. Procedures such as hip replacement, knee replacement, and hip fracture repair are commonly performed in this population. The decreased physiological adaptive capacity and the presence of accompanying systemic diseases in geriatric patients increase the risk of perioperative complications. Regional anesthesia has been shown to reduce complications as well as mortality and morbidity rates in geriatric patients. However, there is still no clear consensus regarding the safest anesthesia method for these patients.[1–3]

Regional anesthesia is frequently preferred for lower extremity surgeries in geriatric patients. Compared with general anesthesia, it has the potential to reduce cardiovascular and pulmonary complications. Spinal anesthesia is one of the most used regional anesthesia techniques for lower extremity surgeries. However, this technique may present certain challenges in elderly patients. Age-related changes such as increased spinal curvature, dorsal kyphosis, vertebral collapse, intervertebral disc dehydration, osteophyte formation, and calcification of the supraspinous, interspinous, and ligamentum flavum ligaments make midline approaches more difficult. In addition, decreased epidural resistance, reduced epidural fat, and foraminal narrowing increase epidural compliance, which may lead to higher block levels with the same volume of local anesthetic. Sclerotic changes and calcifications in the intervertebral foramina can also narrow the space, and calcification of the ligamentum flavum may occur. These anatomical changes, together with difficulties in positioning elderly patients, make central spinal blocks particularly challenging.[3,4] The success of spinal anesthesia depends on the experience of the anesthesia provider, the anatomical characteristics of the patient, and the techniques used. Therefore, accurate identification of anatomical landmarks is essential for successful spinal anesthesia.

In the traditional manual palpation technique, spinal block performance is based on palpation of the patient's anatomical landmarks. This blind approach can be affected by anatomical variability and may result in decreased block success and increased complications. In elderly patients, the prominence of anatomical landmarks may be reduced, making identification of the correct puncture site more difficult. Ultrasound enables visualization of the spinal structures, needle insertion point, and surrounding anatomy. It allows identification of the spinal midline, intervertebral levels, optimal needle insertion points, the appropriate needle trajectory, and estimation of epidural space depth.[5,6] Ultrasound is a safe, validated, noninvasive, and relatively easy-to-learn method and has been used as a more reliable tool for identifying intervertebral levels. Previous studies have shown that pre-procedural ultrasound scanning can shorten the duration of spinal anesthesia procedures, reduce the number of punctures, and improve first-attempt success rates, particularly in patients with poorly palpable surface landmarks. Additionally, ultrasound-guided marking may help reduce complications associated with spinal anesthesia.[7–11]

The aim of this study was to investigate the effect of ultrasonographic marking before spinal anesthesia on spinal anesthesia success in patients aged 65 years and older undergoing lower extremity surgery. By comparing patients whose neuraxial anesthesia sites were marked using ultrasound with those marked using manual palpation, we evaluated the effect of ultrasound on spinal needle-placement time, first-attempt success rate, number of punctures, and early complication rates.

MATERIALS AND METHODS

Study Design and Ethics Approval

This retrospective study was conducted at Dokuz Eylül University Faculty of Medicine Hospital after obtaining approval from the Non-Interventional Ethics Committee (Approval Number: 2018/17-36). The study included patients aged 65 years and older who underwent lower extremity orthopedic surgery under spinal anesthesia. In this retrospective study, the success of spinal anesthesia was compared between two groups: patients who underwent ultrasound-guided marking before spinal puncture and those in whom the puncture site was determined by manual palpation. Patient allocation to the ultrasound or manual palpation group was based on routine clinical practice rather than randomization. Because the study was retrospective, an a priori sample size calculation was not performed; however, all eligible patients during the study period were included in the analysis. The study was conducted in accordance with the STROBE guidelines for observational studies.

Data Collection

Pre-anesthetic evaluation data (physical examination findings, informed consent forms and anesthesia records) were retrieved from patient files and the hospital information system. The following parameters were used to assess spinal anesthesia success:

• Number of spinal punctures (defined as each needle entry through the skin, regardless of whether it occurred at the same or a different intervertebral level).
• Number of needle redirections (defined as repositioning of the needle without complete withdrawal from the skin).
• Time elapsed from the initial needle insertion to the appearance of cerebrospinal fluid (CSF).
• Spinal needle-placement time (defined as the time from the first needle insertion to needle withdrawal following drug administration into the subarachnoid space). This variable reflects the duration of the needle-placement phase and does not include preprocedural steps such as ultrasound scanning or sterile preparation.

The primary outcome was first-attempt success of spinal anesthesia. Secondary outcomes included the number of puncture attempts, number of needle redirections, time to cerebrospinal fluid return, and spinal needle-placement time.

Demographic data including height, weight, body mass index, surgical type, and American Society of Anesthesiologists (ASA) classification were recorded. Additional procedural data, including spinal needle gauge, number of spinal punctures, number of needle redirections, time from needle insertion to cerebrospinal fluid (CSF) flow and spinal needle-placement time, were also recorded. Early complications such as paresthesia during needle insertion and the presence of blood in the needle during puncture were documented. Anesthesiologist experience was defined as the number of years since the start of anesthesiology residency training. Spinal anesthesia procedures were performed by anesthesia residents with at least two years of experience under the supervision of attending anesthesiologists.

Ultrasound-Guided Marking Technique

Preprocedural ultrasound examination was performed by the same anesthesiologist with six years of experience in neuraxial ultrasonography. Ultrasound imaging was performed using a LOGIQ-E ultrasound device (GE Medical Systems, China) with a 3.5-MHz convex probe.

Patients were placed in the sitting position, and the lumbar spine was scanned starting from the sacrum toward the Tuffier line using longitudinal, paramedian and sagittal views. The L4–L5 interspinous space was identified based on the ultrasound appearance of the transverse spinous process. The optimal needle insertion point was marked on the skin using a surgical marker. In addition, the transverse interlaminar ultrasound view was used to identify the midline of the vertebral column.

After ultrasound-guided marking, patients were transferred to the operating room where routine monitoring was performed according to ASA standards. Sedation with midazolam and/or fentanyl was administered during the procedure according to routine clinical practice.

Following skin antisepsis and sterile draping, local anesthesia was applied to the skin and subcutaneous tissue at the marked point. A 25-G or 27-G 90-mm Quincke spinal needle (Braun, Germany) was used. After free cerebrospinal fluid flow was observed, 12–14 mg hyperbaric bupivacaine with 25 µg fentanyl was administered intrathecally.

Manual Palpation Technique

In the manual palpation group, patients were prepared in the operating room with routine ASA standard monitoring, intravenous access, and fluid administration. Patients were placed in the sitting position and the needle insertion site was determined by palpation of the iliac crests and spinous processes. The interspinous space corresponding to the Tuffier line was considered the L4–L5 level and used as a guide for the spinal puncture.

Following skin antisepsis and sterile draping, local anesthesia was applied to the skin and subcutaneous tissue at the determined puncture site. Similar to the ultrasound group, a 25-G or 27-G 90-mm Quincke spinal needle (Braun, Germany) was used. After confirmation of free cerebrospinal fluid flow, 12–14 mg hyperbaric bupivacaine with 25 µg fentanyl was administered intrathecally.

Exclusion Criteria

Patients younger than 65 years, those undergoing emergency surgery, non-Turkish-speaking patients, patients with contraindications to regional anesthesia, patients with a history of vertebral surgery, and patients requiring conversion to general anesthesia were excluded from the study.

In addition, patients with incomplete or missing data regarding spinal anesthesia procedure parameters were excluded.

Patients with non-standard sedation dosing or incomplete sedation records were also excluded to ensure consistency of the dataset.

Statistical Analysis

Statistical analysis was performed using SPSS version 23.0. The normality of numerical variables was assessed using the Kolmogorov–Smirnov test. For normally distributed variables, the independent samples t-test was used, whereas the Mann–Whitney U test was applied for non-normally distributed variables. Categorical variables between the groups were analyzed using the chi-square test. For demographic variables, spinal block-related parameters, and procedure times, independent t-tests were used, while first-puncture success and first-redirection success rates were analyzed using the chi-square test. A p-value <0.05 was considered statistically significant.

RESULTS

The study included a total of 180 patients, with 88 patients in the ultrasound-guided marking group and 92 patients in the manual palpation group.

Baseline demographic and clinical characteristics are presented in Table 1. There were no statistically significant differences between the two groups in terms of age, weight, height, body mass index, sex distribution, American Society of Anesthesiologists (ASA) classification, or type of surgery ($p > 0.05$ for all comparisons).

The distribution of needle types and anesthesiologist experience levels between the groups is presented in Table 2B. No statistically significant differences were observed between the groups for these variables ($p > 0.05$).

Procedural outcomes are summarized in Table 2A. The number of puncture attempts and needle redirections were significantly lower in the ultrasound group compared with the manual palpation group ($p < 0.001$ for both). Time to cerebrospinal fluid (CSF) flow and spinal needle-placement time were also significantly shorter in the ultrasound group ($p < 0.001$ for both). In addition, the first-attempt success rate was significantly higher in the ultrasound group than in the manual palpation group (73.9% vs. 44.6%, $p < 0.001$).

Among patients who achieved successful spinal anesthesia without needle redirection in a single puncture attempt ($n = 20$), 14 patients (70.0%) were in the ultrasound group and 6 patients (30.0%) were in the manual palpation group. However, when analyzed within groups, the first-attempt success rate remained significantly higher in the ultrasound group (73.9% vs. 44.6%).

In subgroup analysis according to spinous process palpability (Table 3), the number of puncture attempts, needle redirections, time to CSF flow, and spinal needle-placement time were significantly lower in the ultrasound group in both patients with palpable and non-palpable spinous processes ($p < 0.001$ for all comparisons).

Similarly, in subgroup analysis according to body mass index (Table 4), all procedural parameters, including number of puncture attempts, needle redirections, time to CSF flow, and spinal needle-placement time, were significantly lower in the ultrasound group in both BMI ≥30 kg/m² and BMI <30 kg/m² subgroups ($p < 0.001$ for all comparisons).

Early complications and sedation requirements are summarized in Table 5. The incidence of paresthesia did not differ significantly between the groups ($p > 0.05$). However, the presence of blood in the spinal needle was significantly higher in the manual palpation group compared with the ultrasound group ($p < 0.001$). In addition, both midazolam and fentanyl dosages were significantly lower in the ultrasound group than in the manual palpation group ($p < 0.001$ for both).

DISCUSSION

This study analyzed retrospective data from geriatric patients undergoing lower extremity surgery under spinal anesthesia. In this retrospective study, preprocedural ultrasound-guided marking was associated with fewer puncture attempts, fewer needle redirections, shorter time to cerebrospinal fluid (CSF) flow, and shorter spinal needle-placement time compared with the manual palpation technique. Additionally, the success rate of achieving spinal anesthesia on the first puncture attempt was higher in the ultrasound group.

The aim of our study was to investigate whether pre-procedural ultrasound scanning improves the first-attempt success rate of spinal anesthesia in geriatric patients and whether it reduces the time required for the procedure, the number of punctures, and the number of needle redirections compared with the conventional palpation technique. The primary outcome of the study was first-attempt success of spinal anesthesia, while secondary outcomes included puncture attempts, needle redirections, time to cerebrospinal fluid return, and spinal needle-placement time. The presence of overweight or obese patients makes palpation of the spinous processes and the crista iliaca more difficult and complicates the determination of the appropriate puncture site by manual palpation.[9] The ability to palpate the spinous processes and to optimally position the patient to increase the intervertebral space are critical factors for the success of spinal anesthesia. Reducing the number of punctures and needle redirections may improve the success rate of spinal anesthesia and may reduce post-procedural complications.[5–7] In this study, palpation of the spinous processes was assessed simply as “palpable” or “non-palpable,” without using a four-stage grading system. The retrospective nature of this study also precluded the use of randomization. Patient allocation was based on routine clinical practice rather than randomization, which introduces potential selection bias and residual confounding. This is particularly relevant because spinous process palpability differed between groups, a factor directly related to procedural difficulty. Although subgroup analyses were performed, residual confounding cannot be fully excluded.

Another limitation of this study is the absence of multivariable adjusted analysis. Although baseline characteristics were broadly similar between groups, unmeasured confounders may have influenced the observed associations. Therefore, the results should be interpreted as an association rather than a definitive causal relationship.

Similar to our findings, many randomized controlled trials have examined the use of ultrasound to facilitate spinal anesthesia in non-obstetric patients. Shaikh et al. in their 2013 meta-analysis involving 1,334 patients across 14 studies, concluded that ultrasound imaging reduces the risk of failed or traumatic lumbar punctures, as well as the number of punctures and needle redirections.[6] Consistent with these findings, the number of punctures and needle redirections was lower in the ultrasound group in our study. It should be noted that needle redirections were not counted as new puncture attempts.

Ultrasound-guided techniques significantly improve the likelihood of a successful puncture on the first attempt compared with conventional palpation techniques. Age-related anatomical changes, such as decreased vertebral height and narrowing of the intervertebral space, make needle placement more challenging. Tessler et al. demonstrated that first-attempt success rates decrease with advancing age, reporting rates of 68.3%, 64.9%, and 61.9% in patients aged <50 years, 50–70 years, and >70 years, respectively.[12] They identified advanced age as an independent risk factor affecting the success of spinal anesthesia. In our study, we included geriatric patients, a population known to have a higher risk of unsuccessful spinal anesthesia. Li et al. compared manual palpation with pre-procedural ultrasound scanning in patients with a body mass index (BMI) ≥30 kg/m² scheduled for elective cesarean delivery.[9] Among 80 patients, they reported higher first-attempt success rates and fewer punctures and needle redirections in the ultrasound group. Similarly, Khan et al. examined 100 patients aged 18–60 years undergoing lower extremity orthopedic surgery with combined spinal-epidural anesthesia and found that the first-attempt success rate was significantly higher in the ultrasound group.[8] Zeng et al. in their study of 144 patients aged >65 years undergoing urological surgery under spinal anesthesia, compared the median approach, paramedian approach, and ultrasound-assisted paramedian approach.[3] Their results demonstrated higher first-attempt success rates and fewer punctures in the ultrasound-assisted paramedian group. Although the paramedian approach used in their study offers advantages, such as a wider interlaminar space and avoidance of supraspinous and interspinous ligaments, their findings are consistent with ours. Srinivasan et al. and Schnabel et al. also demonstrated that the use of ultrasound prior to spinal anesthesia significantly increases the incidence of successful first-attempt punctures.[13,14] Tessler et al. reported first-attempt success rates across three age groups (<50 years, 50–70 years, and >70 years) as 68.3%, 64.9%, and 61.9%, respectively, identifying advanced age as an independent risk factor for the success of spinal anesthesia.[12] In a study by Abdelhamid et al., the effect of ultrasound guidance on the ease of neuraxial anesthesia administration was examined in 90 ASA I–II patients with a mean age of 34.7 years using a midline approach. Compared with our study, which included an older patient population, their results showed a first-attempt success rate of 80% in the ultrasound group and 37.8% in the surface landmark group. Additionally, the number of needle redirections was significantly lower in the ultrasound group. Unlike the study by Abdelhamid et al., our study specifically evaluated the success of spinal anesthesia on the first attempt without any needle redirection.[15] Both the first-attempt success rate and the absence of needle redirections were higher and statistically significant in the ultrasound-guided spinal anesthesia procedures in our study.

An important consideration when interpreting our findings is the definition of the time-related variables. In this study, the recorded time reflects the spinal needle-placement phase (from needle insertion to cerebrospinal fluid [CSF] flow and completion of intrathecal injection) rather than the entire preprocedural workflow. Preprocedural ultrasound scanning and sterile preparation were performed before needle insertion and were not included in the recorded time. Therefore, the shorter duration observed in the ultrasound group represents improved technical performance during needle placement rather than a reduction in total clinical preparation time. Li et al. performed spinal anesthesia in the lateral position on obese patients scheduled for cesarean delivery and divided them into two subgroups based on BMI: 30–34.9 kg/m² and 35–43 kg/m².[9] They found that in the group with lower BMI the spinal needle-placement time was longer in the ultrasound group, whereas in the higher BMI group the duration was shorter in the ultrasound group compared with the manual palpation group. As BMI increases, palpation becomes more difficult, making the advantages of ultrasound more pronounced. Chin et al. compared pre-procedural ultrasound with manual palpation for spinal anesthesia in 120 patients undergoing orthopedic surgery with difficult surface landmarks.[16] They observed that although the time spent locating the puncture site was longer in the ultrasound group, the shorter duration of the spinal anesthesia procedure compensated for this difference, resulting in no overall disadvantage in spinal needle-placement time compared with the manual palpation group. Abdelhamid et al. evaluated the duration of spinal anesthesia as the time from needle insertion to drug delivery into the subarachnoid space and found it to be shorter in the ultrasound group.[15] Similarly, Srinivasan et al. and Abdelhamid et al. reported longer procedure durations in the ultrasound group because the time required for interspinous space marking was included in their measurements.[13,15] In contrast, Geng et al., in their study of 200 geriatric patients undergoing lower extremity surgery under neuraxial block, did not include interspinous space evaluation in their time measurements and found that procedure duration was significantly shorter in the ultrasound group.[17]

In a study conducted on patients with challenging surface anatomical landmarks, Chin et al. evaluated 120 orthopedic surgery cases in which spinous processes were difficult to palpate and reported that the first-attempt success rate for spinal anesthesia was higher in the ultrasound group.[16] In our study, when comparing patients whose spinous processes could not be palpated, although the number of patients with non-palpable spinous processes was statistically higher in the ultrasound group, the number of punctures, needle redirections, the time from needle insertion to cerebrospinal fluid (CSF) flow, and the spinal needle-placement time were significantly lower in the ultrasound group.

Studies on this topic in obese patients have predominantly focused on pregnant populations. In this patient group, ultrasound-guided approaches reduce the number of punctures and shorten the procedure duration in technically difficult cases.[9,18,19] A study conducted in 2011 highlighted that pre-procedural ultrasound evaluation of the lumbar region in morbidly obese pregnant patients can accurately predict needle length, thereby avoiding unnecessary punctures, reducing procedure time, and lowering complication rates.[20] Similarly, in our study, among patients with BMI >30 kg/m², the number of punctures, needle redirections, the time from needle insertion to cerebrospinal fluid (CSF) flow, and the spinal needle-placement time were significantly lower in the ultrasound group.

Multiple puncture attempts during spinal anesthesia can cause patient discomfort and increase the risks of spinal hematoma, post-dural puncture headache, and nerve injury. Accurate identification of the interspinous space is a crucial step for successful spinal anesthesia. This minimizes the number of punctures, thereby reducing the risks of spinal hematoma, dural puncture headache, neural trauma, and patient discomfort.[21,22] The traditional manual palpation technique relies on palpation of anatomical landmarks, and this blind approach may lead to complications due to variability in patient anatomy. In their study, Lim et al. reported a significantly lower incidence of paresthesia in the ultrasound group.[23] Similarly, Dhanger et al. observed that both the number of patients experiencing paresthesia and those with blood in the spinal needle were statistically lower in the ultrasound group.[18] In our study, there was no significant difference between the groups in terms of paresthesia occurrence. However, the number of patients with blood detected in the spinal needle was higher in the manual palpation group. The total number of patients with paresthesia in our study was very small, which may explain the lack of statistical significance; studies with larger patient populations might yield more meaningful results. The need for sedation during spinal anesthesia procedures was significantly lower in the ultrasound group in our study. We attribute this finding to the prolonged procedure duration, multiple attempts, and the increased incidence of paresthesia during manual palpation procedures, all of which may contribute to higher sedation requirements in this group.

Our study has several limitations. First, the data were collected retrospectively, which precluded a randomized controlled design. A larger sample size could have provided more robust results, particularly in subgroup analyses of patients with high BMI or non-palpable spinous processes. Another limitation was the involvement of multiple practitioners in the administration of spinal anesthesia. However, there were no statistically significant differences in practitioner experience levels, and their impact on study outcomes was likely minimal. Additionally, the retrospective design prevented the assessment of patient satisfaction levels, which could have provided additional insights. During spinal anesthesia procedures, the doses of midazolam and/or fentanyl administered for sedation in both groups were determined at the discretion of the practitioner without the use of a standardized sedation scale. These doses were obtained from anesthesia records, which may have introduced variability. In our study, we used pre-procedural neuraxial ultrasound to identify the spinal anesthesia puncture site and compared this with the traditional manual palpation method. Although real-time ultrasound imaging during neuraxial anesthesia allows visualization of the entire needle trajectory during advancement, this approach is technically more challenging and often requires two operators. Patients who required conversion to general anesthesia were excluded, which may have led to a relative overestimation of procedural success. In addition, long-term outcomes were not available because of the retrospective design and the focus on peri-procedural variables.

CONCLUSION

Despite these limitations, our findings suggest that preprocedural ultrasound-guided marking is associated with improved first-attempt success and reduced technical difficulty during spinal anesthesia in elderly patients. This approach may be particularly useful in patients with difficult anatomical landmarks. However, prospective randomized studies with multivariable adjustment are needed to confirm whether this association reflects an independent effect.

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

Variable	Ultrasound Group (n=88)	Manual Palpation Group (n=92)	p-value
Age (years), mean ± SD	73.56 ± 7.44	73.33 ± 7.29	0.834
Weight (kg), mean ± SD	77.78 ± 12.33	75.56 ± 13.22	0.246
Height (cm), mean ± SD	166.00 ± 9.55	166.11 ± 11.03	0.938
BMI (kg/m²), mean ± SD	28.46 ± 5.50	27.46 ± 4.90	0.199
BMI >30 kg/m², n (%)	32 (36.4%)	24 (26.1%)	0.137
BMI <30 kg/m², n (%)	56 (63.6%)	68 (73.9%)	
Male sex, n (%)	28 (31.8%)	31 (33.7%)	0.789
Female sex, n (%)	60 (68.2%)	61 (66.3%)	
ASA class, n (%)			0.940
ASA I	3 (3.4%)	4 (4.3%)	
ASA II	64 (72.7%)	67 (72.8%)	
ASA III	21 (23.9%)	21 (22.8%)	
Surgery type, n (%)			0.768
Hip/Femur	33 (37.5%)	31 (33.7%)	
Knee/Tibia/Fibula	54 (61.4%)	59 (64.1%)	
Other	1 (1.1%)	2 (2.2%)	
Palpable spinous process, n (%)	54 (61.4%)	72 (78.3%)	**0.013***
Non-palpable spinous process, n (%)	34 (38.6%)	20 (21.7%)	

Data are presented as mean ± standard deviation or number (percentage).
BMI: body mass index.
* $p < 0.05$ indicates statistical significance.

Table 2A. Comparison of procedural outcomes

Variable	Ultrasound Group (n=88)	Manual Palpation Group (n=92)	p-value
First-attempt success, n (%)	65 (73.9%)	41 (44.6%)	**< 0.001***
Number of puncture attempts, mean ± SD	1.26 ± 0.44	1.64 ± 0.63	**< 0.001***
Number of needle redirections, mean ± SD	2.11 ± 1.62	4.36 ± 2.59	**< 0.001***
Time to CSF flow (s), mean ± SD	61.25 ± 29.71	104.94 ± 69.83	**< 0.001***
Spinal needle-placement time (s), mean ± SD	95.06 ± 36.73	144.80 ± 77.16	**< 0.001***

Data are presented as mean ± standard deviation or number (percentage).
CSF: cerebrospinal fluid.
* $p < 0.05$ indicates statistical significance.

Table 2B. Technical characteristics of the procedure

Variable	Ultrasound Group (n=88)	Manual Palpation Group (n=92)	p-value
Needle type, n (%)			0.498
25 G Quincke	81 (92.0%)	87 (94.6%)	
27 G Quincke	7 (8.0%)	5 (5.4%)	

Anesthesiologist experience (years), mean ± SD	2.50 ± 0.23	2.46 ± 0.26	0.247

Data are presented as mean ± standard deviation or number (percentage).
CSF: cerebrospinal fluid.
* $p < 0.05$ indicates statistical significance.

Table 3. Subgroup analysis according to spinous process palpability

Variable	Ultrasound Group (n=88)	Manual Palpation Group (n=92)	p-value
Palpable spinous process			
Number of puncture attempts, mean ± SD	1.14 ± 0.35	1.52 ± 0.62	< 0.001*
Number of needle redirections, mean ± SD	1.75 ± 1.60	3.88 ± 2.53	< 0.001*
Time to CSF flow (s), mean ± SD	51.62 ± 26.81	92.29 ± 49.64	< 0.001*
Spinal needle-placement time (s), mean ± SD	82.03 ± 29.45	126.84 ± 56.70	< 0.001*
Non-palpable spinous process			
Number of puncture attempts, mean ± SD	1.44 ± 0.50	2.05 ± 0.51	< 0.001*
Number of needle redirections, mean ± SD	2.67 ± 1.51	6.10 ± 3.06	< 0.001*
Time to CSF flow (s), mean ± SD	76.52 ± 27.94	150.50 ± 106.56	< 0.001*
Spinal needle-placement time (s), mean ± SD	115.76 ± 38.02	202.25 ± 109.83	< 0.001*

Data are presented as mean ± standard deviation.
* $p < 0.05$ indicates statistical significance.

Table 4. Subgroup analysis according to body mass index

Variable	Ultrasound Group (n=88)	Manual Palpation Group (n=92)	p-value
BMI ≥ 30 kg/m²			
Number of puncture attempts, mean ± SD	1.43 ± 0.50	2.00 ± 0.58	< 0.001*
Number of needle redirections, mean ± SD	2.96 ± 1.69	6.20 ± 2.24	< 0.001*
Time to CSF flow (s), mean ± SD	75.43 ± 31.30	142.41 ± 102.91	< 0.001*
Spinal needle-placement time (s), mean ± SD	114.46 ± 39.92	193.41 ± 106.86	< 0.001*
BMI < 30 kg/m²			
Number of puncture attempts, mean ± SD	1.16 ± 0.37	1.51 ± 0.61	< 0.001*
Number of needle redirections, mean ± SD	1.62 ± 1.36	3.72 ± 2.39	< 0.001*
Time to CSF flow (s), mean ± SD	53.14 ± 25.69	91.72 ± 48.03	< 0.001*
Spinal needle-placement time (s), mean ± SD	83.98 ± 29.87	124.94 ± 54.09	< 0.001*

Data are presented as mean ± standard deviation.
BMI: body mass index.
* $p < 0.05$ indicates statistical significance.

Table 5. Comparison of early complications and sedation requirements

Variable	Ultrasound Group (n=88)	Manual Palpation Group (n=92)	p-value
Paresthesia, n (%)	6 (6.8%)	14 (15.2%)	0.073
Blood detected in needle, n (%)	2 (2.3%)	18 (19.6%)	< 0.001*
Midazolam dosage (mg), mean ± SD	0.96 ± 0.29	1.26 ± 0.45	< 0.001*
Fentanyl dosage (mcg), mean ± SD	38.06 ± 17.76	47.60 ± 17.57	< 0.001*

Data are presented as mean ± standard deviation or number (percentage).
* $p < 0.05$ indicates statistical significance.