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Efficacy of Ultrasound-guided versus Palpation-guided Techniques in Spinal Anesthesia: A Randomized Controlled Trial

Ultrason Rehberli ile Palpasyon Rehberli Spinal Anestezi Tekniklerinin Etkinliği: Randomize Kontrollü Bir Çalışma

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Abstract

Objective: This study aims to assess and compare the effectiveness of spinal anesthesia administered through traditional palpation and ultrasound (US) guidance by analyzing the precision of needle placement, procedural success, patient satisfaction, and complication rates.

Method: A prospective, randomized clinical trial was conducted involving 135 patients (American Society of Anesthesiologists I-III) scheduled for lower limb surgery. Participants were randomized into two groups: The palpation group (n=65) and the US-guided group (n=66). Parameters including the accuracy of needle entry point, the number of attempts required to obtain cerebrospinal fluid (CSF), patient satisfaction levels, and the incidence of complications were documented and evaluated.

Results: The success rate of CSF identification on the first attempt was 83.0% in the palpation group and 89.3% in the US guided group (p=0.6). While 28.4% of the spinal punctures in the palpation group were conducted outside the intended intervertebral space, all procedures in the US guided group were accurately localized (p<0.05). There were no statistically significant differences between the groups concerning the total number of attempts, complication occurrence, or patient satisfaction (p>0.05). However, among patients with a body mass index exceeding 30, the US guided group demonstrated a significantly higher success rate and required fewer attempts compared to the palpation group (p<0.01).

Conclusion: US imaging enhances the accuracy of spinal level determination, although both techniques yield comparable overall

Öz

Amaç: Bu çalışma, spinal anestezinin geleneksel palpasyon ve ultrason (US) rehberliği ile uygulanmasının etkinliğini; iğne yerleştirme doğruluğu, işlem başarısı, hasta memnuniyeti ve komplikasyon oranları açısından analiz ederek değerlendirmeyi ve karşılaştırmayı amaçlamaktadır.

Yöntem: Alt ekstremite cerrahisi planlanan, Amerikan Anestezistler Derneği I-III sınıfında 135 hastanın yer aldığı prospektif, randomize bir klinik çalışma yürütüldü. Katılımcılar iki gruba randomize edildi: palpasyon grubu (n=65) ve US rehberli grup (n=66). İğne giriş noktasının doğruluğu, beyin omurilik sıvısına (BOS) ulaşmak için gereken deneme sayısı, hasta memnuniyet düzeyleri ve komplikasyon insidansı gibi parametreler belgelenip değerlendirildi.

Bulgular: İlk denemede BOS elde edilme başarısı, palpasyon grubunda %83,0, US rehberli grubunda ise %89,3 olarak bulundu (p=0,6). Palpasyon grubunda spinal ponksiyonların %28,4'ü hedeflenen intervertebral aralığın dışında gerçekleştirilirken, US rehberli gruptaki tüm işlemler doğru lokalize edilmiştir (p<0,05). Toplam deneme sayısı, komplikasyon insidansı ve hasta memnuniyeti açısından gruplar arasında istatistiksel olarak anlamlı bir fark gözlenmedi (p>0,05). Ancak, beden kitle indeksi 30'un üzerinde olan hastalar arasında, US rehberli grupta anlamlı derecede daha yüksek başarı oranı elde edilmiş ve daha az girişim gerekmiştir (p<0,01).

Sonuç: US görüntüleme, spinal seviye belirlemede doğruluğu artırmaktadır; ancak her iki teknik de genel başarı ve güvenlik profili açısından benzer sonuçlar vermektedir. US'nin avantajları özellikle obezite

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success and safety profiles. The advantages of ultrasonography are particularly evident in patients with obesity or challenging anatomical landmarks. Therefore, its use is recommended as a complementary approach in complex cases. Further large-scale studies are needed to validate these outcomes and support the development of standardized protocols for routine US use in spinal anesthesia.

Keywords: Palpation, spinal anesthesia, ultrasonography

veya anatomik belirteçlerin zor ayırt edilebildiği hastalarda belirgin hale gelmektedir. Bu nedenle, US kullanımı karmaşık olgular için tamamlayıcı bir yaklaşım olarak önerilmektedir. Bu sonuçların doğrulanması ve spinal anestezide rutin US kullanımına yönelik standart protokollerin geliştirilmesi için daha büyük ölçekli çalışmalara ihtiyaç vardır.

Anahtar kelimeler: Palpasyon, spinal anestezi, ultrasonografi

Introduction

Spinal anesthesia, a regional anesthesia technique, involves the temporary interruption of nerve conduction by injecting an anesthetic solution into the cerebrospinal fluid (CSF). Due to its numerous advantages over general anesthesia, spinal anesthesia has been a trusted method for almost a century, particularly favored for surgeries of the lower abdomen, perineum, and lower limbs (1).

In routine clinical practice, the selection of the appropriate intervertebral space for the central lumbar block is critically dependent on the identification of the L4 vertebra through anatomical landmarks. Notably, the intercristal line—also referred to as Tuffier's line—crosses the spine at the L4 vertebra or the L4-L5 intervertebral space. This line is a vital reference point for anesthesia placement, especially useful in ensuring the puncture is performed at a safe level considering the termination of the adult medullary cone at the lower edge of the L1 vertebral body (2-4).

The palpation method, a traditional technique for administering spinal anesthesia, utilizes landmarks such as the iliac crest and spinous processes. However, the visibility of these landmarks may be compromised by factors including obesity, previous spinal surgeries, pregnancy, and age-related degenerative changes, which can increase the difficulty of the procedure and the risk of complications (5).

To overcome these challenges and improve the precision and safety of identifying the correct intervertebral space, ultrasonography has increasingly been integrated into spinal anesthesia practices in recent years (6).

Studies have employed various intervertebral spaces for spinal anesthesia, such as L2-3 and L3-4 in numerous patients, and occasionally L4-5 or L5-S1 depending on the surgical requirements (7-9). It is crucial to note that the conus medullaris, the lower end of the spinal cord, may extend down to the L3 vertebra in adults, which poses additional risks during puncture (10). Consequently, our study primarily utilized the L3-L4 and L4-L5 intervertebral spaces for punctures, as these spaces are typically safer and provide adequate room for maneuvering, away from the conus medullaris (11).

This study aims to evaluate the efficacy of spinal anesthesia performed using traditional palpation guidance versus ultrasound-guided (US guided) techniques in terms of success rates, anatomical accuracy, the impact of body mass index (BMI) on procedural outcomes, patient satisfaction, and potential complications.

Materials and Methods

This randomized, prospective study was conducted in the operating rooms of University of Health Sciences Turkey, İzmir Tepecik Education and Research Hospital after receiving approval from the Clinical Research Ethics Committee (date: 24.01.19, approval no: 61). Our research adhered to the principles of the Declaration of Helsinki, and written informed consent was obtained from all participants.

Participants

The study included 135 patients aged 18-75 years with an American Society of Anesthesiologists score of 1-2-3 who were scheduled to undergo orthopedic lower extremity surgery. Exclusion criteria included the presence of uncontrolled systemic diseases (such as diabetic neuropathy or hypertensive nephropathy), inability to assume a sitting position, a history of vertebral surgery, and contraindications to regional anesthesia (such as coagulopathy or sepsis). During the procedure, four patients developed syncope and were subsequently excluded from the analysis.

Group Assignment

Patients were allocated into two groups using a computer-generated block randomization method. Group assignments were concealed using sequentially numbered, opaque, sealed envelopes. Group palpation (n=65) underwent the traditional palpation technique to identify the needle insertion site for spinal anesthesia, while Group US guided (n=66) utilized US guidance. The flow

diagram of the patient population is presented in Figure 1. Demographic data, including age, gender, height, weight, and BMI, were recorded for all participants.

Procedures

For patients in Group palpation, spinal anesthesia was administered by an anesthesiologist with at least four years of experience using the classical palpation method. For patients in Group US guided, an anesthesiologist experienced in US identified the needle insertion site and subsequently performed the spinal anesthesia. The SonoSite® M-turbo linear probe with a frequency range of 6-13 MHz was used for ultrasonographic measurements in B mode. To ensure imaging standardization, all ultrasound scans were performed by the same experienced anesthesiologist using a standardized protocol. The probe was positioned in the sagittal plane over the lumbar spine to identify the midline structures, with consistent probe orientation and contact pressure. Bony landmarks such as the spinous processes and iliac crests were used for alignment in each case.

In Group palpation, patients were positioned in a seated posture. For the needle insertion site, the vertebral space along the imaginary Tuffier's line between the crests of the iliac bones or the nearest caudal space to this line was marked. A 25-gauge Quincke spinal needle was used for the procedure. The appearance of CSF confirmed a successful block. After the procedure, the needle insertion site was covered with a small sterile sponge. Following the

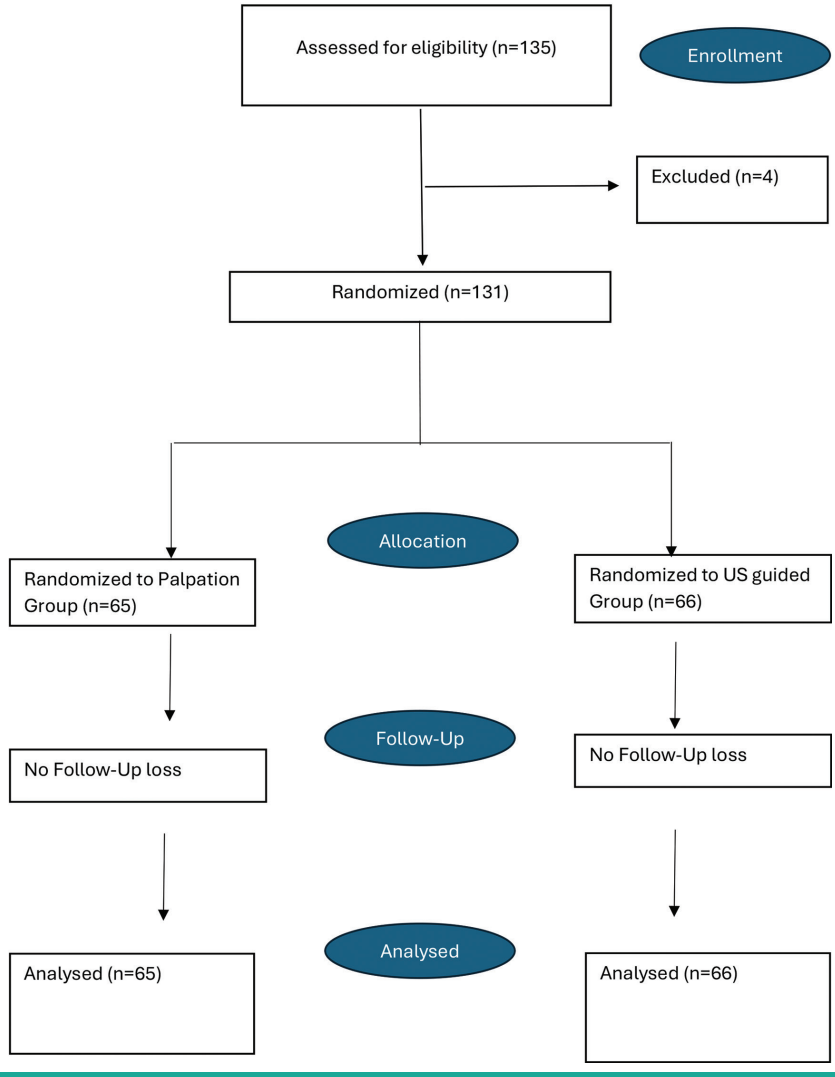

Figure 1. Flow diagram of patient population
US: Ultrasound

operation, patients were repositioned in a seated posture in the post anesthetic care unit, and US was used to identify the vertebral space based on the location of the sterile sponge.

In Group US guided, the US probe was placed sagittally on the sacrum, and as the probe moved towards the neck, spinal landmarks such as the L5 vertebra and the L5-S1 intervertebral space were identified. The desired needle insertion site (L3-4 or L4-5 intervertebral space) was marked at the midpoint between spinous processes. The same spinal needle and procedure were followed as in Group palpation.

Anesthetic medication prepared with 13 mg isobaric bupivacaine (Buvacin®, Vem Ilac Turkey) and 20 mcg fentanyl (Talinat®, Vem Ilac Turkey) was administered intrathecally to both groups. Needle insertion attempt was defined as the removal and reinsertion of the needle through the skin. Adjustments made after the initial needle insertion were not considered as separate attempts.

Outcome Measures

For both groups, we recorded the needle insertion levels, the number of attempts to achieve CSF flow, patient satisfaction and differences in complications. Patient satisfaction was evaluated using a simple 4-point Likert-type scale (1-not satisfied, 4-very satisfied) developed by the authors. All postoperative complications—such as headache, back pain, and neurological deficits—were assessed through daily in-person clinical evaluations conducted during the 72-hour postoperative hospitalization period.

Statistical Analysis

Based on a power analysis (assuming a Kappa agreement coefficient of 0.40 for accuracy determination, an alternative coefficient of 0.60, with 80% power and a 5% margin of error), the required sample size was determined to be 127 patients.

The data obtained were recorded using the statistical package program (SPSS, version 24.0, SPSS, Chicago, USA). As descriptive statistics, the numbers (n), percentages (%), mean ± standard deviations, and median (interquartile range) values were given. The Pearson chi-square test and Fischer's exact test were used for the analysis of the categorical variables. The normal distribution of the data for the continuous variables was evaluated by Shapiro-Wilk, the normality test, and Q-Q graphs. In comparing the continuous variables of the two groups, the independent sample t-test was used for variables with a normal distribution, and the Mann-Whitney U test was used for variables with a non-normal distribution. The evaluations were made within a 95% confidence interval, and $p<0.05$ was considered statistically significant.

Results

The demographic data of the patients are presented in Table 1. No significant differences were observed between the groups in terms of age, weight, height, BMI, or gender ($p>0.05$).

In the palpation group, the success rate for locating CSF on the first attempt was 83.0%, decreasing to 12.3% on the second attempt and 1.5% on the third attempt. In the US guided Group, the success rate on the first attempt was 89.3%, with 10.7% on the second attempt, and no patients requiring a third attempt. Both groups achieved comparable success rates ($p=0.6$).

In the palpation group, postoperative evaluation of the levels revealed that in 18 patients (28.4%), the procedure was performed outside the safest ranges according to the literature. In contrast, in the US guided Group, as the levels were pre-determined, spinal anesthesia was successfully administered within the safe ranges in all 65 patients (100%). The difference between the groups was statistically significant ($p<0.01$). A detailed analysis of the vertebral level ranges is presented in Table 2.

In the palpation group, spinal anesthesia could not be performed in 2 patients despite 3 repeated attempts, necessitating a switch to general anesthesia. Similarly, in the US guided Group, 1 patient required a transition to general anesthesia after 3 unsuccessful attempts.

Both groups demonstrated similar palpability of anatomical landmarks, and the number of needle insertion attempts was likewise comparable.

To evaluate the impact of BMI on the success of spinal anesthesia, needle attempt rates were compared across different BMI categories in the palpation and US guided groups.

In the palpation group, patients with a BMI >30 required ≥2 attempts in 10 patients, whereas only 6 patients successfully received spinal anesthesia with <2 attempts. Conversely, among patients with a BMI ≤30 in the same group, only 1 required ≥2 attempts, while 38 achieved success with <2 attempts.

In the US guided group, patients with a BMI >30 showed a more favorable distribution, with only 5 requiring ≥2

attempts and 13 achieving success with <2 attempts. Similarly, among patients with a BMI ≤30 in the US guided group, 3 required ≥2 attempts, while the majority (35 patients) succeeded with <2 attempts.

The results, summarized in Table 3, demonstrated statistically significant differences between the groups (p<0.01).

Patient satisfaction levels did not refer significantly between the groups, indicating comparable experiences across both techniques (p=0.12).

Similarly, postoperative complication rates remained consistent between the palpation and ultrasound-guided groups, with statistical analysis revealing no discernible difference (p=1.00).

Discussion

In our study, the efficacy of spinal anesthesia performed using traditional palpation guidance versus US guided techniques was evaluated in terms of success rates, anatomical accuracy, the impact of BMI on procedural outcomes, patient satisfaction, and potential complications.

Firstly, no significant demographic differences were observed between the groups regarding age, weight, height, BMI, or gender ensuring that the observed differences in outcomes were not confounded by patient characteristics. This consistency in baseline characteristics allows for a fair comparison between the two techniques in spinal anesthesia.

Spinal anesthesia can be safely administered at any level below the termination of the spinal cord. In our study, the L3-L4 and L4-L5 intervertebral spaces were chosen as the

Table 1. Comparison of demographic characteristics of group palpation and group US guided

	Group palpation	Group US guided	p-value
Age (year)	47.77±15.29	46.38±15.31	0.60†
Weight (kg)	79.85±14.35	81.30±15.01	0.57†
Length (m)	1.70±0.09	1.71±0.09	0.61†
BMI (kg/m²)	26.40 (5.55)	27.40 (5.38)	0.55†
Gender			
Female n (%)	24 (63.15%)	14 (36.85%)	0.05†
Male n (%)	41 (44.0%)	52 (56.0%)	0.05†

†: The Pearson chi-square test and Fischer's exact test have been used, US: Ultrasound, BMI: Body mass index

Table 2. Comparison of preoperative and postoperative vertebral levels in group palpation and group US guided

Vertebral level	Group palpation	Group US guided	p-value
L1-L2	4 (6.3%)	0 (0.0%)	
L2-L3	13 (20.6%)	0 (0.0%)	
L3-L4	29 (46.0%)	22 (33.8%)	<0.01*
L4-L5	16 (25.3%)	43 (66.2%)	
L5-S1	1 (1.5%)	0 (0.0%)	
Total (percent)	63 (100.0%)	65 (100.0%)	

*: Mann-Whitney U test has been used, US: Ultrasound

Table 3. Comparison of attemp rates based on BMI* in the palpation and US guided groups

Groups	Attemps ≥2	Attemps <2	p-value
Group palpation (BMI >30)	10 (62.5%)	6 (37.5%)	
Group palpation (BMI ≤30)	1 (2.6%)	38 (97.4%)	
Group US guided (BMI >30)	5 (27.8%)	13 (72.2%)	<0.01
Group US guided (BMI ≤30)	3 (7.9%)	35 (92.1%)	

*: Mann-Whitney U test has been used, BMI: Body mass index, US: Ultrasound

reference levels due to their greater distance from the conus medullaris and their wider anatomical dimensions (12).

In the study by Furness et al. (13), magnetic resonance imaging (MRI) validation demonstrated a 71% correlation in patients where US was used for localization, compared to only 30% with the conventional palpation method.

Radiographic methods or MRI are considered the gold standard for accurately identifying vertebral levels. However, in the operating room setting, US offers a more practical and objective alternative. Broadbent et al. (14) and Whitty et al. (15) previously reported the inaccuracies associated with the palpation method, highlighting that anesthetists often misidentify the correct intervertebral space. Broadbent et al. (14) found that accurate localization occurred in only 29% of patients, with more than half of the placements being at a higher level than intended. Similarly, Whitty et al. (15) reported that 44% of spinal blocks were performed at a different level than predicted, with an accuracy rate of only 52%.

Consistent with the literature, one of the most noteworthy findings in our study was the challenge of accurately identifying vertebral levels. In the palpation group, 28.4% of procedures were performed outside safe anatomical boundaries, whereas all procedures in the US guided Group were conducted within safe limits. This finding highlights a fundamental limitation of the palpation method, suggesting that it may be less reliable, particularly in patients with less prominent or difficult-to-palpate anatomical landmarks.

In the study by Chin et al. (16) on spinal anesthesia using US, successful block placement was achieved in 84% of patients on the first attempt, 14% on the second attempt, and 2% on the third attempt. Similarly, Lahham et al. (17), in their study on lumbar puncture, reported no significant difference between the US guided and conventional palpation groups in terms of the number of attempts required. In the systematic review conducted by Young et al. (18), it was demonstrated that the use of preprocedural ultrasound improved efficacy indicators such as the first-pass success rate, without leading to an increase in procedure time. In another systematic review conducted by Makino et al. (19), it was also demonstrated that the US-guided technique improves the success rate.

In our study, success rates were comparable between the groups (83.0% in the palpation group and 89.3% in the US guided Group). Although a small subset of patients in both groups required a second attempt, none of the patients in the US guied Group required a third attempt. This finding suggests that US imaging may provide a significant advantage in facilitating accurate needle placement. Previous studies have also demonstrated that ultrasound guidance can enhance precision in neuraxial anesthesia procedures, thereby reducing the need for multiple needle insertions (16,17).

The technical difficulty of spinal anesthesia is closely related to the palpability of anatomical landmarks (3). The quality of these landmarks serves as an indicator of whether regional anesthesia will be challenging (20). In the study by Chin et al. (16), successful spinal anesthesia was achieved using US in 38% of patients despite non-palpable anatomical landmarks. Furthermore, in another study by Chin et al. (16), among 60 patients in whom the spinal level was identified using US, only one patient resulted in failure. This patient was classified as morbidly obese (BMI >35) and had non-palpable anatomical landmarks. In a study conducted by Kalagara et al. (21), it was demonstrated that preprocedural ultrasound facilitates the accurate identification of the midline, vertebral level, and depth, thereby enabling optimal trajectory planning and improving the success of neuraxial block placement with fewer needle passes, particularly in patients with challenging anatomical features. In a randomized controlled trial conducted by Bilge and Başaran (22) in 2025, prepuncture ultrasound imaging was shown to be beneficial in spinal anesthesia for pregnant women with class 3 obesity, particularly in cases where anatomical landmarks were not clearly identifiable using conventional palpation techniques.

In our study, fewer attempts were required in patients with a higher BMI under ultrasound guidance, which is consistent with the findings reported in the literature.

In the meta-analysis conducted by Perlas et al. (23), it was demonstrated that the use of US in spinal and epidural anesthesia increases procedural success while reducing the number of needle insertions and technical difficulties. In our study, despite the advantages offered by the US technique in anatomical localization, overall success rates and complication rates were found to be statistically similar between the two groups. The need for conversion to general anesthesia occurred at comparable rates in both groups (2 patients in the palpation group and 1 patient in the US guided group). Additionally, no statistically significant difference was observed between the groups in terms of the palpability of anatomical landmarks or the total number of needle insertion attempts. These findings

suggest that while US guidance enhances accuracy, the palpation method remains an effective option in patients with easily identifiable anatomical landmarks.

Postoperative patient satisfaction and complication rates were also found to be similar. The proportion of patients without complications was 90.7% in the palpation group and 87.8% in the US guided Group. This finding is consistent with the results reported by Grau et al. (24) and Ansari et al. (25). Multiple needle insertions may increase the incidence of complications such as post-dural puncture headache, paresthesia, hematoma, and infection, all of which can lead to greater intraoperative discomfort and reduced overall patient satisfaction. Therefore, patient satisfaction during spinal anesthesia appears to be influenced not only by the technique used, but also by factors such as the clinician's experience, the number of needle passes, communication with the patient, and the overall comfort of the procedure (26).

Study Limitations

This study has several limitations. First, being a single-center study, the generalizability of the findings to other healthcare institutions may be limited. Additionally, long-term complications following spinal anesthesia were not evaluated; instead, only early postoperative patient satisfaction and complication rates were analyzed. Furthermore, the additional time required for US guidance was not assessed, which could be a crucial factor in clinical practice, particularly in emergency surgical settings. Another limitation is the use of a non-validated, study-specific 4-point Likert-type scale to assess patient satisfaction. Although similar subjective scales have been employed in other studies—such as the 5-point verbal scale reported by Chen et al. (26)—the absence of a standardized, validated tool may limit the reliability and comparability of our satisfaction data. Moreover, our study population did not include morbidly obese patients (BMI >40), making it difficult to draw definitive conclusions regarding the efficacy of US guidance in this specific patient group. Lastly, the clinical feasibility of ultrasound-guided spinal anesthesia was not comprehensively evaluated in terms of training requirements, procedure duration, and cost-effectiveness. These factors are especially relevant in high-volume operating environments, where efficiency and resource allocation are critical. Future multicenter studies with larger and more diverse patient populations are needed to overcome these limitations and provide more robust evidence on the clinical utility and practical implementation of US guidance in spinal anesthesia.

Conclusion

In conclusion, our findings indicate that while palpation and ultrasound US-guided spinal anesthesia techniques offer similar success rates and patient outcomes, US guidance provides superior accuracy in identifying vertebral levels. This technique appears to be particularly advantageous in patients with a high BMI.

Given the potential of US guidance to enhance procedural precision and reduce the risk of mislocated spinal anesthesia, it should be considered as an adjunct to palpation, especially in complex patients where anatomical landmarks are difficult to identify.

Ethics

Ethics Committee Approval: This randomized, prospective study was conducted in the operating rooms of University of Health Sciences Turkey, İzmir Tepecik Education and Research Hospital after receiving approval from the Clinical Research Ethics Committee (date: 24.01.19, approval no: 61).

Informed Consent: Our research adhered to the principles of the Declaration of Helsinki, and written informed consent was obtained from all participants.

Footnotes

This manuscript benefited from language editing and grammatical refinement provided by ChatGPT-4o.

Authorship Contributions

Surgical and Medical Practices: A.E.B., E.A., Concept: A.E.B., Design: A.E.B., Data Collection or Processing: A.E.B., Analysis or Interpretation: A.E.B., E.A., Literature Search: A.E.B., E.A., Writing: A.E.B.

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