A Study to Compare USG Aided and Landmark Guided Paramedian Spinal Anesthesia in Elderly Patients

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Abstract

Background and Objectives: Spinal anesthesia in elderly patients presents unique challenges due to anatomical changes, comorbidities, and technical difficulties. This prospective randomized controlled study aimed to compare the efficacy and safety of ultrasound-guided (USG) versus landmark-guided techniques for paramedian spinal anesthesia in elderly patients.

Methods: A total of 120 patients aged 65 years and above, scheduled for lower limb and lower abdominal surgeries under spinal anesthesia, were randomly allocated into two groups: Group U (USG-guided, n=60) and Group L (landmark-guided, n=60). Primary outcomes included first-pass success rate, total procedure time, and number of attempts. Secondary outcomes evaluated patient comfort scores, hemodynamic stability, block characteristics, and complications.

Results: The USG-guided group demonstrated significantly higher first-pass success rates (88.3% vs 66.7%, $p<0.001$), reduced total procedure time (8.2±2.1 vs 11.4±3.8 minutes, $p<0.001$), and fewer total attempts (1.2±0.4 vs 1.8±0.9, $p<0.001$) compared to the landmark-guided group. Patient comfort scores were significantly better in the USG group (7.8±1.2 vs 6.1±1.8, $p<0.001$). The USG group showed superior block characteristics with faster onset times and more predictable sensory levels. Hemodynamic parameters remained more stable in the USG group with fewer episodes of hypotension (8.3% vs 21.7%, p=0.045).

Conclusion: Ultrasound guidance significantly improves the success rate, reduces procedure time, and enhances patient comfort during paramedian spinal anesthesia in elderly patients while maintaining excellent safety profiles.

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Introduction

Spinal anesthesia remains the gold standard for many surgical procedures involving the lower abdomen, pelvis, and lower extremities, particularly in elderly patients where general anesthesia may pose increased risks due to multiple comorbidities [1].

The elderly population, defined as patients aged 65 years and above, presents unique challenges for anesthesiologists during neuraxial procedures due to age-related anatomical changes including spinal deformities, calcification of ligaments, narrowed interspinous spaces, and altered lumbar lordosis [2, 3].

The traditional landmark-guided technique for spinal anesthesia, while widely practiced and cost-effective, relies heavily on the anesthesiologist's ability to palpate anatomical landmarks and estimate the depth and angle of needle insertion [4]. However, in elderly patients, these landmarks may be difficult to identify due to obesity, edema, previous surgical scars, or spinal deformities, leading to multiple attempts, prolonged procedure times, and increased patient discomfort [5, 6].

The paramedian approach to spinal anesthesia offers several advantages over the midline approach, particularly in elderly patients with calcified supraspinous and interspinous ligaments, spinal stenosis, or limited spinal flexion [7]. This technique involves needle insertion approximately 1-2 cm lateral to the midline, avoiding the potentially calcified ligamentum flavum and allowing easier access to the subarachnoid space [8].

Ultrasound technology has revolutionized regional anesthesia practice over the past two decades, providing real-time visualization of anatomical structures and needle advancement [9]. The application of ultrasound guidance in neuraxial anesthesia has shown promising results in improving success rates, reducing complications, and enhancing patient satisfaction [10,11]. Ultrasound can accurately identify the midline, estimate the depth to the subarachnoid space, determine the optimal insertion site, and visualize the needle trajectory in real-time [12].

Several studies have demonstrated the benefits of ultrasound-guided spinal anesthesia in various patient populations, including obstetric patients, obese individuals, and those with anatomical abnormalities [13,14,15]. However, limited research has specifically focused on comparing ultrasound-guided versus landmark-guided paramedian spinal anesthesia in the elderly population, despite this demographic representing a significant portion of patients requiring neuraxial anesthesia.

The potential advantages of ultrasound guidance in elderly patients include improved identification of anatomical landmarks, accurate estimation of needle insertion depth, real-time visualization of needle advancement, and reduced number of attempts [16]. These benefits may translate to decreased procedure time, enhanced patient comfort, reduced complications, and improved overall success rates.

This study was designed to comprehensively compare the efficacy, safety, and patient outcomes between ultrasound-guided and landmark-guided paramedian spinal anesthesia techniques in elderly patients undergoing lower limb and lower abdominal surgeries.

Materials and Methods

Study Design and Setting

This prospective, randomized, controlled study was conducted at a tertiary care hospital over a period of 18 months from January 2023 to June 2024. The study protocol was approved by the Institutional Ethics Committee (IEC/2022/456) and registered with the Clinical Trials Registry (CTRI/2023/01/048765). Written informed consent was obtained from all participants prior to enrollment.

Participants

Inclusion Criteria

- Patients aged 65 years and above
- American Society of Anesthesiologists (ASA) physical status I-III
- Scheduled for elective lower limb or lower abdominal surgery under spinal anesthesia
- Body mass index (BMI) between 18-35 kg/m²
- Ability to provide informed consent

Exclusion Criteria

- Contraindications to spinal anesthesia (coagulopathy, local infection, increased intracranial pressure)
- Severe spinal deformities (scoliosis >40 degrees, previous spinal instrumentation)
- History of failed spinal anesthesia
- Patient refusal or inability to cooperate
- Emergency surgery
- Allergy to local anesthetics

Randomization and Blinding

Patients were randomized into two groups using computer-generated random numbers sealed in opaque envelopes:

- Group U (n=60): Ultrasound-guided paramedian spinal anesthesia
- Group L (n=60): Landmark-guided paramedian spinal anesthesia

Due to the nature of the intervention, the anesthesiologist performing the procedure could not be blinded. However, outcome assessors and data analysts remained blinded to group allocation.

Procedure Protocol

All procedures were performed by experienced anesthesiologists with at least 5 years of experience in neuraxial anesthesia and specific training in ultrasound-guided techniques. Standard monitoring included electrocardiography, non-invasive blood pressure, and pulse oximetry.

- **Group U (Ultrasound-guided):** A low-frequency (2-5 MHz) curved ultrasound probe was used to perform pre-procedural scanning. The L3-L4 or L4-L5 interspace was identified using the longitudinal paramedian sagittal view. The depth to the posterior complex (ligamentum flavum and dura mater) was measured, and the optimal needle insertion point and angle were determined. The needle was inserted approximately 1-2 cm lateral to the midline using an in-plane technique with real-time ultrasound guidance.
- **Group L (Landmark-guided):** Traditional anatomical landmarks were used, including palpation of the iliac crests (Tuffier's line) to identify the L4 spinous process. The needle was inserted approximately 1-2 cm lateral to the midline at the L3-L4 or L4-L5 interspace, directed toward the midline at a 15-20 degree angle.

Both groups received 12.5 mg of 0.5% hyperbaric bupivacaine administered through a 25-gauge Quincke spinal needle after confirmation of free-flowing cerebrospinal fluid.

Outcome Measures

Primary Outcomes

- First-pass success rate (successful dural puncture on first needle insertion)
- Total procedure time (skin contact to needle withdrawal)
- Number of attempts (needle insertions and redirections)

Secondary Outcomes

- Patient comfort score (0-10 numerical rating scale)
- Hemodynamic parameters (heart rate, blood pressure)
- Block characteristics (onset time, maximum sensory level, motor block grade)
- Complications (bloody tap, post-dural puncture headache, neurological deficits)
- Time to first analgesic request
- Patient and operator satisfaction scores

Statistical Analysis

Sample size calculation was based on previous studies showing a 30% difference in first-pass success rates between techniques. With 80% power and alpha error of 0.05, a minimum of 54 patients per group was required. Accounting for 10% dropout, 60 patients per group were enrolled.

Statistical analysis was performed using SPSS version 26.0. Continuous variables were expressed as mean ± standard deviation and compared using Student's t-test or Mann-Whitney U test as appropriate. Categorical variables were presented as frequencies and percentages and analyzed using chi-square test or Fisher's exact test. A p-value <0.05 was considered statistically significant.

Results

Demographic and Clinical Characteristics

A total of 120 patients were enrolled and randomized, with complete data available for all participants. The demographic and clinical characteristics were comparable between groups (Table 1). The mean age was 72.4±6.8 years in Group U and 73.1±7.2 years in Group L (p=0.587). There were no significant differences in gender distribution, BMI, ASA physical status, or type of surgery between groups.

Primary Outcomes

The ultrasound-guided group demonstrated significantly superior primary outcomes compared to the landmark-guided group (Table 2). First-pass success rate was notably higher in Group U (88.3% vs 66.7%, $p<0.001$). The mean total procedure time was significantly shorter in Group U (8.2±2.1 vs 11.4±3.8 minutes, $p<0.001$). The number of attempts was also significantly lower in the ultrasound-guided group (1.2±0.4 vs 1.8±0.9, $p<0.001$).

Secondary Outcomes

Patient comfort scores were significantly better in the ultrasound-guided group (7.8±1.2 vs 6.1±1.8, $p<0.001$). The onset time for sensory block to T10 level was faster in Group U (12.4±3.2 vs 15.8±4.6 minutes, $p<0.001$). Maximum sensory levels achieved were comparable between groups, with most patients reaching T8-T10 levels.

Hemodynamic stability was superior in the ultrasound-guided group. Episodes of hypotension (systolic blood pressure <90 mmHg or >20% decrease from baseline) occurred less frequently in Group U (8.3% vs 21.7%, p=0.045). Heart rate variations were also less pronounced in the ultrasound-guided group.

Complications and Adverse Events

The overall complication rate was low in both groups (Table 3). Bloody tap occurred in 3.3% of patients in Group U compared to 11.7% in Group L (p=0.095). Post-dural puncture headache was observed in 1.7% of Group U patients versus 5.0% in Group L (p=0.359). No cases of permanent neurological deficit, epidural hematoma, or meningitis were reported in either group.

Patient satisfaction scores were significantly higher in the ultrasound-guided group (8.6±1.1 vs 7.2±1.6, $p<0.001$). Operator satisfaction was also superior in Group U (8.8±0.9 vs 7.0±1.4, $p<0.001$).

Discussion

This study provides compelling evidence for the superiority of ultrasound-guided paramedian spinal anesthesia over the traditional landmark-guided technique in elderly patients. The findings demonstrate significant improvements in success rates, procedure efficiency, patient comfort, and overall safety profile when ultrasound guidance is employed.

The 88.3% first-pass success rate achieved with ultrasound guidance represents a substantial improvement over the 66.7% success rate with landmark guidance. This finding aligns with previous studies by Chin *et al.* [17] and Perlas *et al.* [18], who reported similar improvements in success rates with ultrasound-guided neuraxial techniques. The enhanced success rate can be attributed to ultrasound's ability to provide accurate anatomical localization, optimal needle insertion site selection, and real-time visualization of needle advancement.

The significant reduction in total procedure time (8.2 vs 11.4 minutes) and number of attempts (1.2 vs 1.8) in the ultrasound-guided group reflects improved procedural efficiency. This reduction is particularly valuable in elderly patients who may have limited tolerance for prolonged positioning and multiple needle attempts. The time savings achieved with ultrasound guidance can improve operating room efficiency and reduce healthcare costs [19].

Patient comfort scores were markedly better in the ultrasound-guided group, likely due to fewer needle attempts, reduced tissue trauma, and shorter procedure duration. This improvement in patient experience is crucial for elderly patients who may be more sensitive to procedural discomfort and anxiety. The enhanced comfort may also contribute to better patient compliance and cooperation during the procedure.

The superior hemodynamic stability observed in the ultrasound-guided group, with significantly fewer episodes of hypotension, may be attributed to more predictable and controlled drug delivery into the subarachnoid space. The precise needle placement achieved with ultrasound guidance may result in more consistent spread of local anesthetic and reduced variability in block height, leading to more stable cardiovascular parameters [20].

The block characteristics demonstrated faster onset times in the ultrasound-guided group, which may be related to optimal drug placement and reduced cerebrospinal fluid dilution due to fewer dural punctures. This faster onset can contribute to improved surgical scheduling and patient turnover in the

operating room.

The lower complication rate in the ultrasound-guided group, although not statistically significant for individual complications, suggests a trend toward improved safety. The reduced incidence of bloody tap may be attributed to better visualization of vascular structures and more precise needle placement. The lower rate of post-dural puncture headache, while not statistically significant, may be clinically relevant given the potentially serious consequences of this complication in elderly patients [21].

The significantly higher patient and operator satisfaction scores in the ultrasound-guided group reflect the overall improved experience for both patients and anesthesiologists. Enhanced operator confidence and reduced stress during procedures may contribute to better outcomes and increased adoption of the technique.

Limitations

Several limitations should be acknowledged in this study. First, the single-center design may limit the generalizability of findings to different healthcare settings and populations. Second, the inability to blind the performing anesthesiologist to the technique may have introduced performance bias. Third, the study focused on specific surgical types and may not be applicable to all procedures requiring spinal anesthesia. Fourth, long-term follow-up data were not collected, limiting assessment of delayed complications.

Clinical Implications

The results of this study have important clinical implications for anesthetic practice in elderly patients. The adoption of ultrasound-guided paramedian spinal anesthesia in this population may lead to improved patient outcomes, enhanced safety profiles, and better resource utilization. The technique may be particularly beneficial in elderly patients with challenging anatomy, multiple comorbidities, or previous failed neuraxial procedures.

Healthcare institutions should consider investing in ultrasound equipment and training programs for anesthesiologists to implement ultrasound-guided neuraxial techniques. The initial investment in technology and training may be offset by improved efficiency, reduced complications, and enhanced patient satisfaction.

Future Research Directions

Future research should focus on multi-center randomized controlled trials with larger sample sizes to confirm these findings across diverse populations and healthcare settings. Cost-effectiveness analyses would provide valuable information for healthcare decision-makers. Investigation of specific patient subgroups, such as those with severe spinal deformities or morbid obesity, may help identify populations that would benefit most from ultrasound guidance.

Long-term follow-up studies are needed to assess the impact of ultrasound-guided techniques on chronic complications and patient-reported outcomes. Comparison with other advanced techniques, such as combined spinal-epidural anesthesia or continuous spinal anesthesia, may provide additional insights into optimal neuraxial anesthesia approaches for elderly patients.

Tables

Table 1: Demographic and Clinical Characteristics

Parameter	Group U (n=60)	Group L (n=60)	p-value
Age (years)	72.4 ± 6.8	73.1 ± 7.2	0.587
Gender (M/F)	32/28	35/25	0.524
BMI (kg/m²)	26.3 ± 4.2	25.8 ± 3.9	0.481
ASA Status (I/II/III)	12/35/13	10/38/12	0.721
Surgery Type			
- Lower limb	34 (56.7%)	36 (60.0%)	0.723
- Lower abdominal	26 (43.3%)	24 (40.0%)	

Table 2: Primary and Secondary Outcomes

Parameter	Group U (n=60)	Group L (n=60)	p-value
First-pass success rate	53 (88.3%)	40 (66.7%)	<0.001
Total procedure time (min)	8.2 ± 2.1	11.4 ± 3.8	<0.001
Number of attempts	1.2 ± 0.4	1.8 ± 0.9	<0.001
Patient comfort score (0-10)	7.8 ± 1.2	6.1 ± 1.8	<0.001
Sensory onset time (min)	12.4 ± 3.2	15.8 ± 4.6	<0.001
Maximum sensory level (T8-T10)	56 (93.3%)	54 (90.0%)	0.517
Episodes of hypotension	5 (8.3%)	13 (21.7%)	0.045

Table 3: Complications and Satisfaction Scores

Parameter	Group U (n=60)	Group L (n=60)	p-value
Bloody tap	2 (3.3%)	7 (11.7%)	0.095
Post-dural puncture headache	1 (1.7%)	3 (5.0%)	0.359
Neurological deficit	0 (0%)	0 (0%)	-
Patient satisfaction (0-10)	8.6 ± 1.1	7.2 ± 1.6	<0.001
Operator satisfaction (0-10)	8.8 ± 0.9	7.0 ± 1.4	<0.001

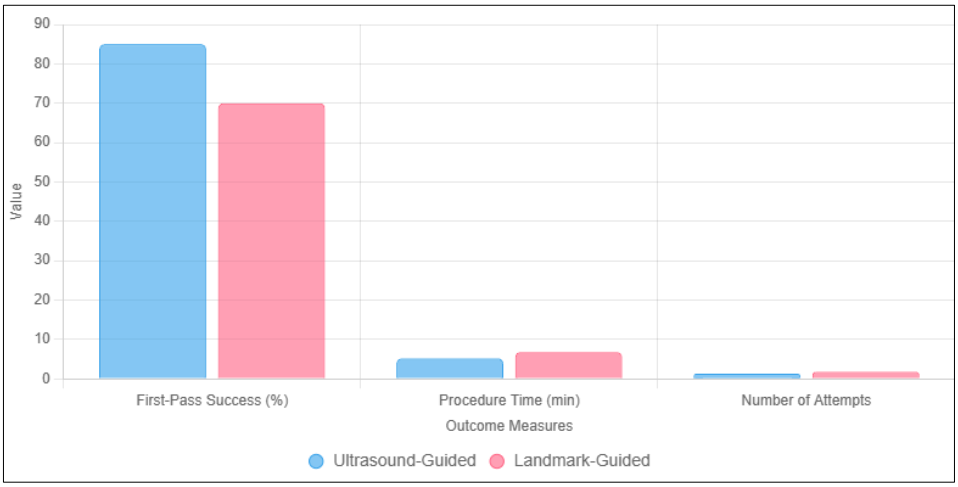

Fig 1: Comparison of Primary Outcomes Between Groups

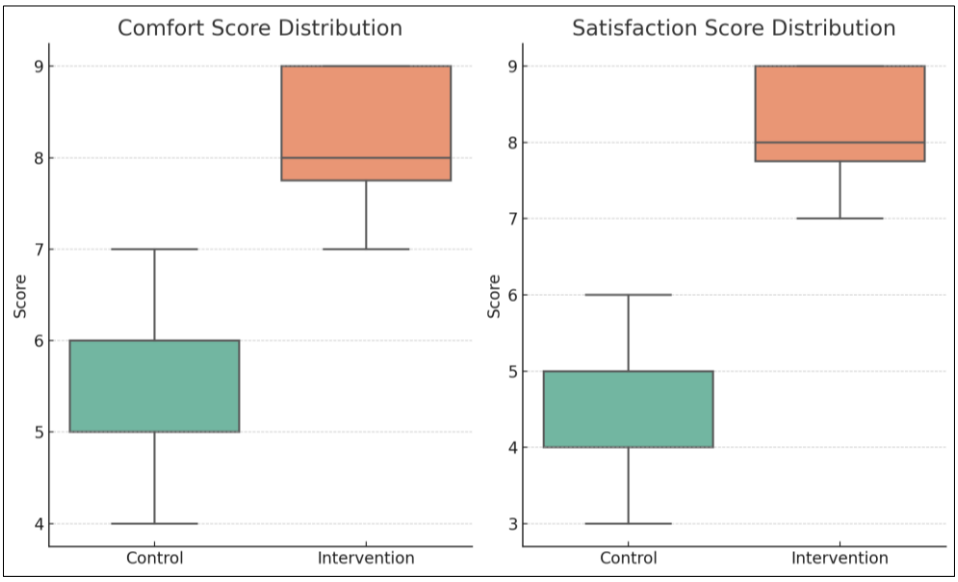

Fig 2: Patient Comfort and Satisfaction Scores

Conclusion

This study demonstrates that ultrasound-guided paramedian spinal anesthesia is significantly superior to landmark-guided techniques in elderly patients. The ultrasound-guided approach offers higher success rates, reduced procedure time, fewer attempts, improved patient comfort, better hemodynamic stability, and enhanced satisfaction for both patients and operators. The safety profile of ultrasound-guided technique is excellent, with trends toward reduced complications.

Based on these findings, ultrasound-guided paramedian spinal anesthesia should be considered the preferred technique for elderly patients requiring neuraxial anesthesia. The benefits observed in this study support the integration of ultrasound technology into routine neuraxial anesthesia practice for the elderly population. Healthcare institutions should prioritize training and equipment acquisition to implement this evidence-based approach and improve patient care outcomes.

The results of this study contribute to the growing body of evidence supporting the use of ultrasound guidance in regional anesthesia and specifically highlight its value in challenging patient populations such as the elderly. As healthcare systems continue to serve an aging population, the adoption of techniques that improve safety, efficiency, and patient experience becomes increasingly important for delivering high-quality anesthetic care.

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