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Efficacy of preprocedural ultrasound-guided versus landmark-Guided spinal anesthesia in geriatric patients: A randomized comparative study

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Abstract

Background: Age-related degenerative changes in the lumbar spine frequently result in technical difficulty in the standard landmark-guided spinal anesthesia in geriatric populations, leading to multiple needle insertions and manipulations. Preprocedural ultrasound offers non-invasive visualization of internal spine anatomy to align needle guidance.

Objectives: To evaluate the efficacy of preprocedural ultrasound imaging compared to conventional anatomical landmark palpation for spinal anesthesia in elderly patients with challenging spinal anatomy.

Materials and Methods: In this single-center, prospective, randomized, comparative study, 140 geriatric patients (aged 60–90 years, ASA I–III) with degenerative spine changes were randomized into two groups (n = 70 per group): Group 1 (Preprocedural Ultrasound-Guided Spinal Anaesthesia) or Group 2 (Conventional Landmark-Guided Spinal Anaesthesia). The primary objective was to measure the first-pass success rate. Secondary objectives were the total needle insertion attempts, needle redirections required, landmark mapping duration, and total procedure time.

Results: The first-pass success rate was significantly higher in the ultrasound-group than in the standard landmark group (0.84 ± 0.36 vs. 0.65 ± 0.47; p = 0.01). Group 1 also demonstrated a significantly reduced mean number of needle insertion attempts (1.19 ± 0.46 vs. 1.37 ± 0.54; p = 0.035) and required significantly fewer intra-procedural needle redirections (0.74 ± 1.00 vs. 1.17 ± 1.13; p = 0.02). Landmark establishment time (29.23 ± 3.00 seconds vs. 28.77 ± 2.72 seconds; p = 0.35) and overall procedural durations (86.86 ± 10.88 seconds vs. 88.97 ± 11.88 seconds; p = 0.14) were statistically comparable between both groups.

Conclusion: Preprocedural spinal ultrasound provides superior technical efficacy over standard palpatory techniques in geriatric patients. It significantly maximizes initial insertion success while reducing bone contact and corrective needle redirections without extending overall procedural time.

Keywords: Spinal anesthesia, Preprocedural ultrasound, Landmark technique, Geriatric patients, Needle insertion attempts.

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1. Introduction

Spinal anesthesia is a core regional anesthetic modality for lower abdominal, pelvic, and lower extremity surgeries. Compared to general anesthesia, it offers rapid onset, profound sensory and motor blockade, and excellent postoperative analgesia. This makes spinal anesthesia highly advantageous in geriatric population, by preventing airway manipulation, and postoperative cognitive dysfunction.[1]

However, administering spinal anesthesia in older adults is technically challenging due to age-related degenerative changes in the spine (narrowing of the intervertebral disk spaces, osteophytic overgrowth, calcification of the ligamentum flavum etc.).[1,2] This makes traditional landmark-guided approach difficult, leading to higher failure rates.[2] The objective imaging using ultrasound can overcome these challenges in this population.

The preprocedural ultrasound imaging delineates acoustic windows through ossified posterior elements, reflecting distinct hyperechoic signals off the deep dura mater, ligamentum flavum, and posterior vertebral bodies.[3,4] This allows clinicians to precisely determine the optimal needle insertion point, mark the midline, and accurately estimate the skin-to-dura depth.[4] The main concerns preventing routine use of preprocedural spinal ultrasound are prolonged setup times, specialized equipment needs, and limited requirement in uncomplicated spinal anatomy.[5,6] This study was designed to evaluate the first-pass success rate, insertion attempts, corrective redirections, and total time taken in preprocedural ultrasound against conventional landmark technique in elderly patients.

2. Materials and Methods

This single-center, prospective, randomized, comparative study was conducted at a tertiary care hospital over an 18-month duration from September 2023 to February 2025 after Institutional Ethical Approval. Written informed consent was obtained from each eligible participant. A total of 140 geriatric patients aged 60–90 years, of ASA Grades I–III, scheduled for elective surgical operations under spinal anesthesia were randomly divided into two groups a sealed opaque envelope technique ($n = 70$ per group). Patients with absolute contraindications to central neuraxial blocks (severe uncorrected hypovolemia, localized soft-tissue infection at the intended needle trajectory site, profound coagulopathy, severe stenotic valvular heart disease, or elevated intracranial pressure), or systemic allergy to local anaesthetics were excluded. In group 1 preprocedural spine scanning using a Fujifilm Sonosite ultrasound system equipped with a 3–5 MHz low-frequency curved convex array transducer was done while in group 2 standard surface landmark mapping via manual digital palpation of the spinous processes and Tuffier's line was done. Complete blinding of the operators performing the interventions and the patients was not feasible due to the nature of the ultrasound equipment. However, an independent research observer, completely blinded to group assignments, collected all perioperative data, recorded procedural tracking metrics, and performed statistical logging. All blocks were executed by two primary anesthesiologists with documented technical proficiency in spinal ultrasonography. Patients were placed in a seated posture, and no sedation was administered before or during the blocks.

For the preprocedural ultrasound the convex array transducer was first placed longitudinally over the sacrum in a paramedian sagittal plane to verify a continuous hyperechoic bony line. The probe was then moved cranially to identify and count specific lumbar intervertebral levels (L5–S1 up to L2–L3). The acoustic midpoint of the probe was kept over the target L3–L4 or L4–L5 interlaminar space and marked on the skin. The probe was rotated 90° into a transverse orientation to view the central interspinous structures, lateral articular zones, and deep dura mater. The intersection point was marked as the skin puncture site.

Following standard sterile preparation, spinal anesthesia was administered using 25-gauge Quinke tip needle (12.5 mg of 0.5% hyperbaric bupivacaine with 20 mcg of fentanyl adjuvant). In case of failure of three needle attempts, conversion to general anesthesia was done.

The primary outcome was the first-pass success rate (defined as successful entry into the subarachnoid space with free-flow of cerebrospinal fluid and no needle redirection). Secondary parameters included total needle attempts, total needle redirections, landmark establishment time, and total procedure duration (landmark mapping time plus needle insertion time).

Sample size was calculated using Open Epi software based on previous data,[6] with expected success of landmark guided spinal anesthesia taken as 60% and ultrasound guided spinal anesthesia as 84% (UGSA). Keeping the power of 80% ($\beta = 0.20$) and significance level at 5% ($\alpha = 0.05$), the sample size was estimated to be 64 patients per group. To adjust for dropouts, 70 patients were randomized into each group (140 total). Statistical analysis was done using SPSS software Version 28 (IBM Corp., NY, USA), testing continuous data using Student's independent t-tests and categorical data using Chi-Square tests. A p-value < 0.05 indicated statistical significance.

3. Results

Demographic variables such as age, gender distribution, and baseline physical health stratification demonstrated strong statistical homogeneity between the two groups ($p > 0.05$). **(Table 1)**

The first-pass success rate using preprocedural ultrasound was significantly higher to the standard palpation technique (0.84 ± 0.36 vs. 0.65 ± 0.47; $p = 0.01$). The mean number of needle attempts and corrective needle redirections were also lower in the group using spinal ultrasound and the difference was statistically. The total procedural time between the groups did not differ significantly, indicating that preprocedural spinal ultrasound did not result in delays. (**Table 2)**

Table 1: Baseline demographics

Baseline Variable	Group 1 (Ultrasound, n=70)	Group 2 (Landmark, n=70)	Statistical Value	p-value
Age (Mean ± SD, years)	67.38 ± 6.82	66.98 ± 6.59	$t = -0.353$	0.720
Gender (Male / Female)	49 / 21	53 / 17	$\chi^2 = 0.324$	0.569
ASA Status (I / II / III)	36 / 31 / 4	35 / 27 / 7	$\chi^2 = 1.166$	0.558

Table 2: Comparison of technical outcomes

Procedural Performance Parameter	Group 1 (n=70)	Group 2 (n=70)	t-Statistic	p-value
First-Pass Success Rate (± SD)	0.84 ± 0.36	0.65 ± 0.47	−2.680	0.010
Total Needle Attempts (Mean ± SD)	1.19 ± 0.46	1.37 ± 0.54	2.123	0.035
Total Needle Redirections (Mean ± SD)	0.74 ± 1.00	1.17 ± 1.13	2.380	0.020
Landmark Mapping Time (seconds)	29.23 ± 3.00	28.77 ± 2.72	−0.950	0.350
Total Procedural Time (seconds)	86.86 ± 10.88	88.97 ± 11.88	1.468	0.140

4. Discussion

Age-related osteophytic changes, ligamentous calcification, and narrowing of intervertebral spaces frequently result in obscured tactile landmarks in elderly patients.[7] This study demonstrated that preprocedural ultrasound for spinal anesthesia significantly optimized the access to subarachnoid space in geriatric patients. The use of ultrasound for identifying the landmark significantly increased the first-pass success rate (0.84 ± 0.36 in Group 1 vs. 0.65 ± 0.47 in Group 2; $p = 0.01$). This finding aligns with the previous studies by Oh et al.[8] and Kamimura et al.,[9] confirming that ultrasound localization results in higher success rate as compared to blind needle insertion technique.

Group 1 required fewer needle reinsertion attempts (1.19 ± 0.46 vs.1.37 ± 0.54; $p = 0.035$) and fewer needle redirections (0.74 ± 1.00 vs. 1.17 ± 1.13; $p = 0.02$). Preprocedural ultrasound helps in precise marking of insertion point which significantly minimizes the technical difficulties during needle advancement. These results are in concordance with the findings of Bae et al.[10] and Sidiropoulou et al.,[11] which showed that preprocedural spine scanning effectively minimizes corrective redirections.

The ultrasound-guided technique has a potential to delay or prolong the overall procedural time due to device configuration and scanning setup.[12] However, this study notes that the time required to establish landmarks was comparable with both the techniques. (29.23 ± 3.00 s vs. 28.77 ± 2.72 s; $p = 0.35$). The total procedural duration also did not differ significantly between the two groups (86.86 ± 10.88 s in Group 1 vs. 88.97 ± 11.88 s in Group 2; $p = 0.14$). The time taken for ultrasound scanning was balanced by the decreased time required for needle insertion and redirection resulting in overall total procedural time being same in both the groups as has been noted in previous studies as well.[13-15]

The study had some limitations as it was a single center study conducted with experienced operators, which may limit the generalizability of the findings to novice trainees. Additionally, the study did not compare real-time ultrasound guidance or collect long-term follow-up data. Further multicentric studies on different set of operators in diverse clinical settings can be done in future.

5. Conclusion

Preprocedural ultrasound mapping significantly improves the technical performance of spinal anesthesia in geriatric patients by providing accurate visualization of spinal structures prior to puncture. The preprocedural ultrasound guidance maximizes first-pass success and reduces needle redirections without extending overall procedural timelines.

Author Contributions

Sushma Athota contributed to the study conception and design, patient recruitment, data collection, and manuscript preparation. Nazia Nazir contributed to the study conception and supervision, data analysis and interpretation, critical revision of the manuscript, and final approval of the version to be published. Both authors reviewed and approved the final manuscript and agree to be accountable for all aspects of the work.

Abbreviations

ASA: American Society of Anesthesiologists; CSF: Cerebrospinal Fluid; UGSA: Ultrasound-Guided Spinal

Anesthesia; SD: Standard Deviation; SPSS: Statistical Package for the Social Sciences.

Ethical Approval

Ethical approval was obtained from the Institutional Ethics Committee (GIMS/IEC-ECR/1224/Inst./UP /2019).

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Conflict of Interest

The authors declare that they have no competing interest.

Use of Artificial Intelligence (AI)

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, interpretation, or writing of this manuscript.

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