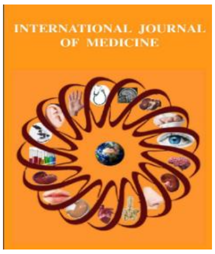

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Original Research

Comparative Analysis of Actual Skin-to-Subarachnoid Space Depth Versus Depth Predicted by Ultrasonographic and Anthropometric Measurements

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Abstract

Introduction: Accurate identification of skin-to-subarachnoid space depth (SSD) is crucial for successful spinal anaesthesia. Incorrect estimation may result in multiple punctures, failed attempts, bloody taps, and patient discomfort. Traditional anthropometric formulas provide indirect estimates, while ultrasonography offers real-time visualization of spinal anatomy. However, limited adult population data exist comparing these methods with actual needle depth. ***Materials and Methods***: This prospective cross-sectional observational study was conducted on 180 adult patients (ASA I-II) undergoing elective surgeries under spinal anaesthesia. SSD was predicted using anthropometric formulas (Stocker's and Chong's modified) and ultrasonographic measurement at the L3-L4 interspace. Actual SSD was recorded during spinal needle insertion. Correlation and agreement between predicted and actual SSD were analysed. **Results:** Ultrasonographic SSD showed the strongest correlation with actual needle depth ($r = 0.88$, $p < 0.001$), outperforming anthropometric formulas. Stocker's and Chong's formulas demonstrated moderate correlations. Bland-Altman analysis revealed minimal bias with ultrasonography. ***Conclusion***: Pre-procedural ultrasonography provides the most accurate estimation of SSD and should be incorporated into routine spinal anaesthesia practice, especially in patients with variable body habitus.

Keywords: *Spinal anaesthesia, skin-to-subarachnoid depth, ultrasonography, anthropometric formula, lumbar spine*

Introduction

Spinal anaesthesia, also known as subarachnoid block, is one of the most frequently employed regional anaesthetic techniques for surgeries involving the lower abdomen, pelvis, and lower limbs. The success of spinal anaesthesia relies on accurate identification of the subarachnoid space and precise deposition of local anaesthetic agents. One of the critical determinants of procedural success is the skin-to-subarachnoid space depth (SSD), defined as the distance between the skin surface and the subarachnoid space[1].

Inaccurate estimation of SSD may result in repeated needle insertions, traumatic punctures, bloody cerebrospinal fluid (CSF) taps, post-dural puncture headache, and increased patient anxiety[2]. These complications not only affect patient comfort but also prolong procedure time and increase the risk of failure. Traditionally, anaesthesiologists rely on tactile feedback and clinical experience, which may be unreliable, particularly in obese patients or those with altered spinal anatomy[3].

Anthropometric-based prediction formulas, such as Stocker's and Chong's modified formulas, have been proposed to estimate SSD using parameters like weight, height, and body mass index (BMI). While these formulas offer simplicity and ease of use, they provide indirect estimations and may lack accuracy across different populations[4-6].

The advent of ultrasonography has revolutionized regional anaesthesia by allowing direct visualization of spinal structures, including the ligamentum flavum-dura mater complex and posterior longitudinal ligament[7]. Pre-procedural ultrasound enables accurate measurement of SSD, identification of optimal intervertebral space, and determination of needle trajectory, thereby improving success rates and reducing complications[8]. Several studies have demonstrated superior correlation between ultrasonographically measured SSD and actual needle depth compared to anthropometric formulas[9-11]. However, variability exists based on patient demographics, ethnicity, and body habitus. Moreover, limited studies have directly compared ultrasound-derived SSD, anthropometric predictions, and actual needle insertion depth in the adult Indian population.

Therefore, the present study was designed to evaluate the correlation between actual SSD observed during spinal anaesthesia and SSD predicted using ultrasonographic measurements and anthropometric formulas. Identifying the most accurate and reliable method will help optimize spinal anaesthesia practice and improve patient safety.

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Materials and Methods

This prospective cross-sectional observational study was conducted at The Oxford Medical College, Hospital and Research Centre, Bengaluru, after obtaining institutional ethical committee approval. Written informed consent was obtained from all participants.

Study Population

A total of 180 adult patients scheduled for elective surgeries under spinal anaesthesia were enrolled.

Inclusion Criteria

- Age between 18 and 60 years
- Eiter sex
- ASA physical status I or II
- Patients undergoing elective surgeries under spinal anaesthesia

Exclusion Criteria

- Previous spinal surgery
- Spinal deformities or anatomical abnormalities
- Local site infection
- Paramedian spinal approach
- Refusal to consent

Preoperative Assessment

All patients underwent routine pre-anaesthetic evaluation. Anthropometric measurements including height and weight were recorded.

Prediction of SSD

Predicted SSD was calculated using:

- Stocker's Formula: SSD (mm) = 0.5 × weight (kg) + 18
- Chong's Modified Formula: SSD (cm) = 10 × [weight (kg) / height (cm)] + 1

Ultrasonographic Measurement

Patients were positioned sitting with flexed spine. Using a low-frequency (2-5 MHz) curved-array probe, ultrasonography was performed in the midline transverse view at the L3-L4 interspace. The distance from the skin to the anterior aspect of the ligamentum flavum–dura mater complex was measured using electronic calipers.

Actual SSD Measurement

Under strict aseptic precautions, spinal anaesthesia was performed at the L3-L4 interspace using a 25G Quincke needle via the midline approach. Upon free flow of CSF, the needle was marked at skin level, withdrawn, and the depth of insertion measured using a sterile ruler.

Statistical Analysis

Data were analysed using SPSS software. Continuous variables were expressed as mean ± SD. Pearson's correlation coefficient assessed relationships between predicted and actual SSD. Bland-Altman analysis evaluated agreement. A p-value <0.05 was considered statistically significantfor the categorical data analysis. P < 0.05 was considered statistically significant.

Results

Table 1. Demographic Characteristics of Study Population

Variable	Value
Age (years)	38.9 ± 9.6
Male/Female	96 / 84
Weight (kg)	64.3 ± 11.2
Height (cm)	162.5 ± 8.4
BMI (kg/m²)	24.3 ± 3.9

The study population consisted predominantly of middle-aged adults with a wide BMI distribution.

Table 2. Mean SSD Measurements by Different Methods

Method	Mean SSD
Actual needle depth (cm)	4.96 ± 0.58
Ultrasonography (cm)	4.89 ± 0.55
Stocker's formula (cm)	5.32 ± 0.61
Chong's formula (cm)	5.18 ± 0.64

Ultrasonography closely approximated actual SSD compared to anthropometric formulas.

Table 3. Correlation Between Predicted and Actual SSD

Method	r value	p value
Ultrasonography	0.88	<0.001
Stocker's formula	0.62	<0.001
Chong's formula	0.59	<0.001

Ultrasonography demonstrated a strong positive correlation with actual SSD.

Table 4. Bland-Altman Analysis (Mean Bias)

Method	Mean Bias (cm)
Ultrasonography	−0.07
Stocker's formula	+0.36
Chong's formula	+0.22

Ultrasonography showed minimal bias and best agreement.

Table 5. Gender-wise Comparison of Actual SSD

Gender	SSD (cm)	p value
Male	5.08 ± 0.56	0.03
Female	4.82 ± 0.51	

Males demonstrated slightly higher SSD.

Table 6. SSD According to BMI Categories

BMI Category	SSD (cm)
Normal	4.62 ± 0.44
Overweight	5.02 ± 0.53
Obese	5.48 ± 0.61

SSD increased significantly with BMI.

Discussion

Accurate prediction of skin-to-subarachnoid space depth is fundamental for successful spinal anaesthesia. In this study, ultrasonographic measurement demonstrated superior accuracy and correlation with actual needle insertion depth compared to anthropometric formulas. These findings reinforce the growing role of ultrasound in regional anaesthesia.

The strong correlation observed between ultrasonographic SSD and actual depth (r = 0.88) aligns with findings reported by Girimurugan et al. and Sutagatti et al., who showed ultrasound to be a reliable predictor across different patient populations[4,7]. Ultrasonography allows direct visualization of spinal structures, eliminating variability introduced by soft tissue thickness and body habitus.

Anthropometric formulas, though convenient, demonstrated only moderate correlation. Stocker's formula tended to overestimate SSD, particularly in overweight and obese patients. Similar trends were reported by Tyagi et al. and Khandelwal et al., suggesting that formula-based predictions may lack generalizability across populations[6,12].

BMI emerged as a significant determinant of SSD, corroborating earlier studies that identified BMI as the strongest predictor of increased SSD[2,8]. Male patients showed slightly greater SSD, likely due to higher muscle mass and body habitus differences.

The minimal bias observed with ultrasonographic measurement on Bland-Altman analysis highlights its reliability and clinical utility. Incorporation of ultrasound may reduce multiple puncture attempts, procedure time, and complications, especially in technically difficult cases.

Limitations of this study include single-centre design and exclusion of patients with spinal deformities. However, the large sample size and standardized methodology strengthen the validity of findings.

Conclusion

Pre-procedural ultrasonographic measurement of skin-to-subarachnoid space depth provides the most accurate estimation compared to anthropometric formulas. Routine use of ultrasound-guided assessment can enhance success rates, minimize complications, and improve patient comfort during spinal anaesthesia. infection as well as preventing the development of resistant strains.

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