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Comparison of the Depth of Subarachnoid Space Using Anthropometric Measurements, Ultrasonographic Measurements and Actual Depth by Needle Insertion in a Patients with Bmi>25kg/M2

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ABSTRACT

Background; Identification of the subarachnoid space during spinal anaesthesia may be challenging in overweight and obese patients because of poorly palpable anatomical landmarks and increased soft tissue thickness. Accurate prediction of subarachnoid space depth (SSD) can improve procedural success and reduce complications. This study compared anthropometric estimation, ultrasonographic measurement and actual needle insertion depth for determining SSD in patients with BMI >25 kg/m².
Methods; This prospective, cross-sectional, observational study was conducted among 140 adult patients undergoing lower abdominal or lower limb surgeries under spinal anaesthesia. SSD was assessed using three methods: anthropometric estimation based on body surface area (BSA), ultrasonographic measurement at the L3–L4 intervertebral space and actual needle insertion depth during spinal anaesthesia. Demographic and anthropometric parameters including age, sex, BMI and BSA were recorded. Statistical analysis was performed using IBM SPSS version 25, and $p<0.05$ was considered statistically significant.
Results; The mean age of participants was 40.18 ± 13.34 years, and the mean BMI was 28.38 ± 3.33 kg/m². The mean SSD estimated by anthropometric formula was 5.33 ± 0.42 cm, while ultrasonographic measurement and actual needle insertion depth were 5.46 ± 0.60 cm and 5.52 ± 0.77 cm respectively. Increasing BMI and BSA were associated with greater SSD values. Significant differences were observed among BMI groups for BSA, anthropometric SSD, ultrasonographic depth and actual needle insertion depth ($p<0.001$). No significant differences were observed based on age or sex.
Conclusion; Ultrasonographic measurement showed close agreement with actual needle insertion depth and proved to be a reliable method for predicting SSD in overweight and obese patients. Anthropometric estimation also demonstrated good predictive value. Preprocedural ultrasound may improve the accuracy and success of spinal anaesthesia in patients with difficult anatomical landmarks.

Keywords: *Spinal anaesthesia; Subarachnoid space depth; Ultrasonography; Body mass index; Obesity; Needle insertion depth.*

INTRODUCTION

Spinal anaesthesia is one of the most commonly employed regional anaesthetic techniques for lower abdominal and lower limb surgeries because of its rapid onset, reliability, reduced systemic drug exposure and favorable postoperative analgesic profile.[1] Successful spinal anaesthesia depends on accurate placement of the spinal needle into the subarachnoid space. Failure to correctly identify the depth of the subarachnoid space may lead to multiple attempts, traumatic puncture, patient discomfort and procedure-related complications.[2]

Identification of the subarachnoid space becomes particularly challenging in overweight and obese patients due to poorly palpable anatomical landmarks and increased soft tissue thickness.[3] Obesity is increasingly prevalent worldwide and poses significant technical difficulties for anesthesiologists during neuraxial procedures.[4] Increased body mass index (BMI) has been associated with greater skin-to-subarachnoid space depth (SSD), resulting in higher rates of failed attempts and procedural complications during spinal anaesthesia.[5]

Conventionally, spinal needle insertion depth is estimated clinically based on the anesthesiologist's experience and surface anatomical landmarks. However, these methods are subjective and may lack accuracy in obese individuals.[6] Therefore, alternative methods such as anthropometric formulae and ultrasonography have gained importance for predicting spinal needle depth before the procedure.[7]

Anthropometric measurements including weight, height, BMI and body surface area (BSA) have been evaluated as predictors of SSD in previous studies. Bonadio et al. proposed a formula correlating SSD with BSA, which demonstrated reasonable predictive accuracy in adults undergoing lumbar puncture.[8] Such formula-based estimations provide a simple, non-invasive and inexpensive approach for predicting spinal needle depth.

Ultrasonography has emerged as a valuable adjunct in regional anaesthesia and neuraxial procedures. Preprocedural spinal ultrasound allows visualization of vertebral anatomy, identification of the intervertebral space and estimation of the skin-to-dura distance.[9] Several investigators have demonstrated a strong correlation between ultrasound-estimated depth and actual needle insertion depth during spinal anaesthesia.[10,11] Ultrasound guidance has also been associated with reduced number of attempts and improved success rates, particularly in patients with difficult spinal anatomy.[12]
Despite increasing use of ultrasound, there remains limited comparative data evaluating anthropometric formulae, ultrasonographic measurements and actual needle insertion depth simultaneously in overweight and obese patients. Accurate prediction of SSD in this population could improve procedural success, minimize complications and reduce patient discomfort.

Therefore, the present study was undertaken to compare subarachnoid space depth estimated by anthropometric formula, ultrasonographic measurement and actual needle insertion depth in patients with BMI >25 kg/m² undergoing spinal anaesthesia. The study also aimed to evaluate the influence of demographic and anthropometric variables on SSD measurements.

MATERIALS AND METHODS

Study Design

This prospective, cross-sectional, observational study was conducted to compare three different methods for determining subarachnoid space depth (SSD) in patients with body mass index (BMI) greater than 25 kg/m² undergoing spinal anaesthesia. The three methods evaluated were anthropometric estimation using formula-based calculation, ultrasonographic measurement, and actual needle insertion depth during spinal anaesthesia. The study aimed to assess the correlation and agreement among these methods under routine clinical conditions.

Study Setting

The study was carried out in the Department of Anaesthesiology at teaching hospitals affiliated with Kasturba Medical College. These tertiary care hospitals routinely perform lower abdominal and lower limb surgeries under spinal anaesthesia and cater to patients from both urban and rural populations.

Study Duration

The study was initiated after approval from the Institutional Ethics Committee (IEC) and registration with the Clinical Trials Registry of India (CTRI). Data collection was conducted prospectively until December 2024.

Study Population

Adult patients scheduled for elective lower abdominal or lower limb surgeries under spinal anaesthesia were screened for eligibility.

Inclusion Criteria

- Patients aged 18–65 years.
- BMI >25 kg/m².
- American Society of Anesthesiologists (ASA) physical status I–III.
- Patients scheduled for elective lower abdominal or lower limb surgeries under spinal anaesthesia.
- Patients willing to provide written informed consent.

Exclusion Criteria

- Refusal to participate or withdrawal of consent.
- Known spinal deformities such as scoliosis or kyphosis.
- Previous spinal surgery or lumbar implants.
- Chronic low back pain or severe degenerative spinal disease.
- Contraindications to regional anaesthesia including coagulopathy or local infection.
- Pregnant patients.
- Patients requiring paramedian or altered angle spinal approach.

Sample Size

The sample size was calculated using the formula:

$$n = \frac{Z^2\sigma^2}{d^2}$$

where:

- $Z = 1.96$at 95% confidence interval,
- $\sigma = 0.3$cm based on previous literature,
- $d = 0.05\sigma$.

Based on these calculations, a minimum sample size of 140 participants was obtained.

Sampling Technique

A convenient non-probability sampling technique was used. Eligible patients attending the pre-anaesthesia clinic and fulfilling inclusion criteria were enrolled consecutively after obtaining informed consent.

Study Procedure

Preoperative Assessment

All participants underwent detailed pre-anaesthetic evaluation. Demographic details including age, sex, occupation, and ASA status were recorded. Height and weight were measured using standardized equipment, and BMI was calculated using the formula:

$$BMI = \frac{Weight\ (kg)}{Height^2\ (m^2)}$$

Body surface area (BSA) was calculated using the Du Bois formula:

$$BSA = 0.007184 \times Height^{0.725} \times Weight^{0.425}$$

The estimated SSD was then derived using the anthropometric formula based on BSA.

Ultrasound Measurement

Ultrasound examination of the lumbar spine was performed in the sitting position using a low-frequency (2–5 MHz) curvilinear probe. The L3–L4 intervertebral space was identified using a transverse spinous process view. The skin-to-subarachnoid space distance was measured from the skin surface to the posterior complex after freezing the optimal image.

Spinal Anaesthesia Procedure

Inside the operating theatre, standard ASA monitors including non-invasive blood pressure, pulse oximetry, and electrocardiography were attached. Intravenous access was secured using an 18G cannula, and patients received preloading with Ringer's lactate solution at 15 mL/kg.

Under strict aseptic precautions, spinal anaesthesia was administered in the lateral decubitus position using a midline approach at the L3–L4 interspace. After local infiltration with 1% lignocaine, a 25G Quincke spinal needle was advanced until free flow of cerebrospinal fluid (CSF) was obtained.

The actual SSD was determined by marking the needle at the skin level immediately after confirmation of CSF flow and measuring the distance from the needle tip to the skin mark using a sterile ruler.

Hyperbaric 0.5% bupivacaine was then administered intrathecally as per surgical requirements.

Study Variables

The following parameters were recorded:

- Age and sex.
- Height, weight, BMI, and BSA.
- Anthropometric formula-based SSD.
- Ultrasound-measured SSD.
- Actual needle insertion depth.
- Number of attempts required for successful spinal anaesthesia.

Statistical Analysis

Data were entered and analyzed using IBM SPSS Statistics version 25. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages.

Comparison among anthropometric SSD, ultrasound SSD, and actual needle depth was performed using repeated measures ANOVA or paired t-test for normally distributed data. Non-parametric tests were used when appropriate.

Correlation among measurement methods was assessed using Pearson's or Spearman's correlation coefficient. Agreement between methods was evaluated using Bland–Altman analysis. A p-value <0.05 was considered statistically significant.

RESULTS AND OBSERVATIONS

A total of 140 patients with BMI >25 kg/m² undergoing lower abdominal or lower limb surgeries under spinal anaesthesia were included in the study. Demographic characteristics, anthropometric measurements, ultrasonographic measurements, and actual spinal needle depth were analyzed.

Age Distribution

The study population consisted of patients across a broad adult age range. The largest proportion belonged to the 46–55 years age group (23.6%), followed by 36–45 years (22.9%) and 18–25 years (20.0%). The mean age of the study population was 40.18 ± 13.34 years.

Table 1: Age Distribution of Study Participants

Age Group (Years)	**Frequency (n)**	**Percentage (%)**
18–25	28	20.0
26–35	24	17.1
36–45	32	22.9
46–55	33	23.6
>55	23	16.4
Total	**140**	**100.0**

The age distribution demonstrates adequate representation of early adulthood to late middle age, improving the generalizability of the findings.

Sex Distribution

Among the 140 participants, females constituted 53.6% while males accounted for 46.4%.

Table 2: Sex Distribution of Study Participants

Sex	**Frequency (n)**	**Percentage (%)**
Female	75	53.6
Male	65	46.4
Total	**140**	**100.0**

The nearly equal sex distribution allowed appropriate comparison between male and female participants regarding subarachnoid space depth measurements.

BMI Distribution

Participants were categorized according to BMI values. Most participants (63.6%) belonged to the BMI range of 25.0–28.0 kg/m².

Table 3: BMI Distribution of Study Participants

BMI Group (kg/m²)	Frequency (n)	Percentage (%)
25.0–28.0	89	63.6
28.1–31.0	30	21.4
31.1–34.0	9	6.4
≥34	12	8.6
Total	**140**	**100.0**

The mean BMI of the study population was 28.38 ± 3.33 kg/m², indicating that the majority of participants were overweight or mildly obese.

Descriptive Statistics

The mean age of participants was 40.18 ± 13.34 years. The mean weight and height were 72.86 ± 12.07 kg and 159.99 ± 7.45 cm respectively. The mean BMI was 28.38 ± 3.33 kg/m².

The mean BSA was 1.83 ± 0.16 m². The mean SSD estimated by anthropometric formula was 5.33 ± 0.42 cm, while ultrasonographic SSD and actual needle insertion depth were 5.46 ± 0.60 cm and 5.52 ± 0.77 cm respectively.

Table 4: Descriptive Statistics of Study Variables

Variable	Mean	Standard Deviation
Age (years)	40.18	13.34
Weight (kg)	72.86	12.07
Height (cm)	159.99	7.45
BMI (kg/m²)	28.38	3.33
BSA (m²)	1.83	0.16
SSD by Anthropometry (cm)	5.33	0.42
Ultrasonographic Measurement of Depth (cm)	5.46	0.60
Actual Depth by Needle Insertion (cm)	5.52	0.77

The close similarity among the three SSD measurements indicates good agreement between anthropometric estimation, ultrasonographic assessment, and actual needle depth.

Gender-wise Comparison of Measurements

Comparison of BSA and SSD measurements between male and female participants revealed no statistically significant differences.

Table 5: Gender-wise Comparison of Study Variables

Variable	Female (n=75) Mean ± SD	Male (n=65) Mean ± SD	t-value	p-value
BSA (m²)	1.84 ± 0.18	1.82 ± 0.15	0.549	0.584
SSD by Anthropometry (cm)	5.34 ± 0.45	5.32 ± 0.67	0.313	0.755
Ultrasonographic Depth (cm)	5.50 ± 0.39	5.41 ± 0.86	0.831	0.408
Actual Needle Insertion Depth (cm)	5.60 ± 0.52	5.42 ± 0.63	1.357	0.177

Although females showed marginally higher values for all measured parameters, the differences were not statistically significant ($p>0.05$).

Comparison of Measurements Across BMI Groups

Descriptive analysis demonstrated a gradual increase in estimated and measured SSD values with increasing BMI categories.

Table 6: Descriptive Statistics According to BMI Groups

Variable	25.0–28.0	28.1–31.0	31.1–34.0	≥34	Total
BSA (m²)	1.77 ± 0.15	1.89 ± 0.11	1.86 ± 0.12	2.06 ± 0.14	1.83 ± 0.16
SSD by Anthropometry (cm)	5.20 ± 0.38	5.49 ± 0.37	5.45 ± 0.31	5.83 ± 0.37	5.33 ± 0.42
Ultrasonographic Depth (cm)	5.25 ± 0.45	5.73 ± 0.46	5.47 ± 0.73	6.30 ± 0.83	5.46 ± 0.60
Actual Needle Depth (cm)	5.26 ± 0.45	5.82 ± 0.66	5.57 ± 1.18	6.63 ± 1.21	5.52 ± 0.77

The findings suggest that higher BMI groups tended to have greater subarachnoid space depth measurements across all three assessment methods.

ANOVA Analysis

One-way ANOVA demonstrated statistically significant differences among BMI groups for all measured variables.

Table 7: ANOVA Comparison Among BMI Groups

Variable	F-value	p-value
BSA (m²)	16.505	<0.001
SSD by Anthropometry (cm)	12.978	<0.001
Ultrasonographic Measurement of Depth (cm)	18.069	<0.001
Actual Needle Insertion Depth (cm)	18.362	<0.001

The analysis indicates that increasing BMI was significantly associated with greater estimated and measured subarachnoid space depths.

DISCUSSION

The present study compared subarachnoid space depth estimated by anthropometric formula, ultrasonographic measurement and actual needle insertion depth in overweight and obese patients undergoing spinal anaesthesia. The findings demonstrated close agreement among the three methods, with ultrasonographic measurements showing particularly strong correlation with actual needle insertion depth.

In the present study, the mean age of participants was 40.18 ± 13.34 years, with most patients belonging to the 36–55 years age group. Age did not significantly influence SSD measurements. Similar findings were reported by Sahin et al., who observed that age had minimal impact on spinal depth measurements in adults undergoing neuraxial blockade.[13] This suggests that body habitus and anthropometric variables may play a more important role than age in determining SSD.

Females constituted 53.6% of the study population, while males accounted for 46.4%. Although females showed slightly higher mean SSD values than males, the differences were not statistically significant. Similar observations were made by Craig et al., who found no significant sex-related differences in lumbar puncture depth after adjustment for body habitus.[14] The absence of significant gender variation in the present study indicates that sex alone may not be a reliable predictor of SSD.

The mean BMI in the present study was 28.38 ± 3.33 kg/m², confirming that the study population predominantly consisted of overweight and mildly obese individuals. Increasing BMI categories demonstrated progressively higher SSD values across all measurement techniques. This finding is consistent with previous reports showing a positive association between obesity and spinal needle depth.[15] Stiffler et al. also demonstrated that obese patients require greater needle insertion depth because of increased subcutaneous tissue thickness.[16]

The mean SSD estimated by anthropometric formula in our study was 5.33 ± 0.42 cm, while ultrasonographic SSD and actual needle insertion depth were 5.46 ± 0.60 cm and 5.52 ± 0.77 cm respectively. The close similarity among these values indicates good predictive accuracy of both anthropometric and ultrasonographic methods. Bonadio et al. first described the relationship between BSA and lumbar puncture depth and proposed a predictive formula that demonstrated satisfactory correlation with actual depth.[8] Our findings support the usefulness of anthropometric formulae in estimating SSD in overweight patients.

Ultrasonography demonstrated particularly close approximation to actual needle insertion depth in the present study. Similar results were reported by Balki et al., who found a strong correlation between ultrasound-measured depth and actual epidural needle depth in obese patients.[17] Sahin et al. also concluded that preprocedural spinal ultrasound provides accurate estimation of skin-to-subarachnoid space distance and facilitates successful neuraxial block placement.[13]

The present study observed statistically significant increases in SSD values with increasing BMI groups. Both ultrasonographic depth and actual needle insertion depth were greatest in patients with BMI ≥34 kg/m². These findings are in agreement with studies conducted by Stocker et al. and Abe et al., who demonstrated that increasing BMI significantly increases neuraxial depth measurements.[18,19]

One important observation in the current study was the absence of significant differences based on age or sex, while BMI and BSA showed clear associations with SSD. This highlights the importance of considering anthropometric parameters rather than demographic characteristics alone during preprocedural planning for spinal anaesthesia.

The use of ultrasound before spinal anaesthesia offers several clinical advantages. It helps identify the optimal intervertebral space, predicts needle depth and may reduce multiple puncture attempts, particularly in obese individuals with poorly palpable landmarks.[20] Reduced attempts may lower the incidence of traumatic puncture, post-dural puncture headache and patient discomfort.

The present study has certain limitations. It was conducted at a single tertiary care center and involved only patients with BMI >25 kg/m². The findings may therefore not be generalizable to underweight individuals or patients with severe spinal deformities. Additionally, operator experience in ultrasound-guided spinal assessment could influence measurement accuracy.

Despite these limitations, the study provides valuable comparative data regarding anthropometric estimation, ultrasound assessment and actual needle depth in overweight and obese patients. The findings support the routine use of preprocedural ultrasonography as a reliable and practical tool for predicting spinal needle depth and improving the success of spinal anaesthesia.

CONCLUSION

The present study demonstrated a strong correlation between anthropometric estimation, ultrasonographic measurement and actual needle insertion depth for determining subarachnoid space depth in overweight and obese patients undergoing spinal anaesthesia. Ultrasonographic assessment closely approximated the actual spinal needle depth and proved to be a reliable, non-invasive bedside tool. Increasing BMI and BSA were associated with greater subarachnoid space depth, whereas age and sex showed no significant influence. Preprocedural ultrasound may therefore improve the accuracy and success of spinal anaesthesia, particularly in patients with difficult anatomical landmarks.

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