Original Article

Correlation between depth of subarachnoid space in the lumbar region estimated by Stocker's formula, ultrasound, and depth of needle insertion: A prospective observational study

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Abstract

Background and Aims: The main challenge in administration of spinal anesthesia in patients is the unpredictability of the exact skin to subarachnoid space depth (SSD). Approximation of SSD and needle length comes at the expense of patient comfort and multiple attempts increases complications. Our study aimed to evaluate the validity of Stocker's formula to estimate SSD in comparison to ultrasonography and depth of needle insertion. We also aimed to determine an equation to describe the relationship between patient weight and SSD in an Indian population.
Material and Methods: This was a prospective observational study. A total of 234 adults of American Society of Anesthesiologists (ASA) category 1 and 2 were selected for the study. The patients underwent spinal anaesthesia and SSD data were determined using weight-based Stocker's formula (DS), ultrasonography (DU), and actual depth of needle insertion (DA). Correlation analysis was performed to determine variables that can predict the SSD. A linear regression was calculated to describe the relationship between patient weight and SSD. SSD data were determined using weight-based Stocker's formula ultrasonography, and actual depth of needle insertion.
Results: Mean SSD using Stocker's formula, ultrasonography, and actual depth of needle insertion was 4.92 ± 0.6 cm, 4.47 ± 0.6 cm, and 4.81 ± 0.6 cm. Our study showed a significant correlation between Stocker's formula and SSD measured by actual depth of needle insertion (R^2 = 0.376). This was described by the derived formula: SSD (cm) =2.522+ [0.031 × weight (kg)].
Conclusion: SSD correlates well with the weight of adult patients. Measurement with Stocker's formula and actual depth showed better correlation than Stocker's formula and ultrasonography. This is valuable in resource-poor areas with a lack of ultrasound machines or expertise in training.

Keywords: Spinal needle depth, Stocker's formula, subarachnoid space, ultrasonography

Introduction

Multiple attempts during subarachnoid block can result in complications like post-dural puncture headache, lower back pain, and cause discomfort to the patient, apart from being time-consuming. Apart from knowledge of anatomy and technical skill, a pre-puncture estimate of skin to subarachnoid space depth (SSD) may guide spinal needle placement. Knowledge of SSD would also aid in selecting an appropriate length of the spinal needle.[1]

Ultrasonography accurately identifies the depth of subarachnoid space and may be used as a guide in obese and non-obese

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patients.[2,3] However, the unavailability of ultrasound (USG) machines for routine subarachnoid blocks in many centers and insufficiency in training limit its usage in delivering spinal anesthesia.[4,5] In such circumstances various formulae like Stocker's, Chong's, Craig's, and Bonadio's can mitigate the need for ultrasonography in estimating the SSD.[1]

We conducted this study with the aim (1) to evaluate the accuracy of Stocker's formula in the estimation of SSD in adults by comparing its body-weight-based prediction with ultrasonography-guided estimation and direct depth of needle insertion (2) to determine an equation to describe the relationship between patient weight and SSD in an Indian population.

Material and Methods

This prospective observational study was conducted in a tertiary care hospital, between May 2019 and October 2019. The sample size of the study was calculated (n = 234) following consecutive sampling, using a study done by Balki *et al*.[6] as a reference study. Their study found a strong correlation between the USG-estimated distance to the epidural space and the actual measured needle distance in 46 obese patients.

Approval from the Institutional ethics committee was obtained on 7th of May 2019 with the corresponding IEC number: SMC/IEC/2019/05/004 and CTRI number: CTRI/2019/08/020546.

After obtaining informed consent, the enrolment of 234 patients admitted to the surgical departments of the hospital, was carried out. The inclusion criteria were patients between ages 20 and 50 years of both sexes who belonged to ASA 1, 2, and were undergoing elective surgery under spinal anesthesia. We excluded patients with a history of spinal abnormalities, previous spinal surgery, and parturient patients.

Patient weight was recorded using an electronic ISO certified weighing machine. Weight was then substituted into Stocker's formula [SSD (mm) $=0.5 \times$ weight (kg) $+18$] and SSD was predicted.[7] Before anesthesia the sonography was performed by a consultant anesthesiologist using a SonoScape USG machine (Sonoscape S8 Exp, SonoScape Medical Corp., Guangdong, China) and the depth at L3–L4 was determined and recorded. While scanning the patient, the patient was made to sit straight with knees overhanging the edge of the bed and the probe was kept perpendicular to the skin. For the selection of L3–L4 interspace, a 5–2 MHz curvilinear array transducer was placed by the investigator in a median sagittal plane over the sacrum to visualize the hyperechoic line corresponding to the image of the sacrum. The probe was then moved cephalad in the same plane to identify the various interspinous spaces till the L3–L4 interspace was encountered. At this time, a transverse scan was performed. The midline was identified using the after the shadow of the spine, and the L3–L4 interspinous space was identified by moving the probe slowly cephalad or caudad to obtain the absence of after shadow and the view of the complex formed by the ligamentum flavum-dura mater and to find the vertebral body [Figure 1]. The outlines of the various targets were drawn with a sterile dermographic pen. The optimum sonogram was frozen. With a built-in caliper the distance from the skin to the anterior part of the ligamentum flavum-dura mater complex, which is supposed to be the bottom limit before reaching intrathecal space, was measured.

Thereafter, spinal anaesthesia was performed by manual palpatory method, with the patient in a sitting position with knees flexed. The depth of the needle at which it was inserted was marked by a sterile marker and measured using Vernier calipers. As per department protocol a standard 25 Gauge 9 cm Quincke needle was used in all patients for the procedure. For study purposes, the skin to subarachnoid space calculated using Stocker's formula was called DS, the depth measured using USG was called DU, and actual depth found after performing the procedure by the manual palpatory method was called DA.

Statistical analysis

The statistical analysis was done with the help of the Statistical Package for Social Sciences (SPSS) Version 19 (SPSS Inc., Chicago, IL, USA). The reliability of the study was assessed using Cronbach's alpha and the intraclass correlation coefficient. To evaluate the correlation of the study the analysis of variance (ANOVA) scale and correlation coefficients were used.

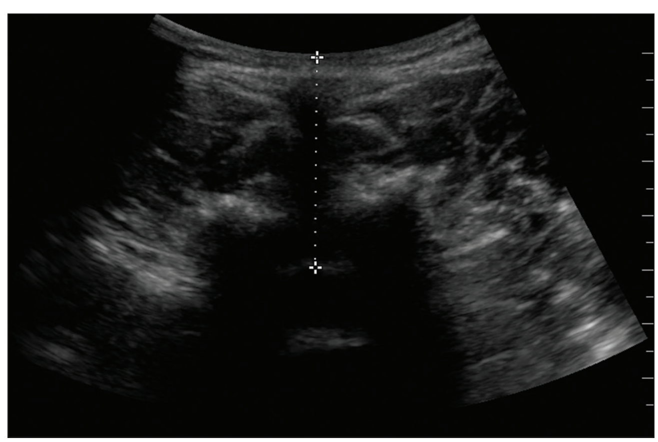

Figure 1: For skin to subarachnoid space depth using ultrasound, the distance from skin to the anterior part of the ligamentum flavum-dura mater complex was measured on a transverse scan at L3–L4 interspace

The analysis was carried out keeping a sample correlation efficient of 0.79 and a population correlation coefficient of 0.71. Data were analyzed using the power of study as 80% and an alpha error of 5%. Finally, a formula was derived by subjecting the data from the correlation table to regression analysis.

Results

A total of 234 patients were recruited in the study, a CONSORT flow chart is provided [Figure 2], of which 176 patients were male (75%) and 58 were female. The surgical procedures were distributed among urology (44%), general surgery (44%), and orthopedics (12%). The mean age of patients was 39 ± 10 years, weighing an average of 62 ± 12 kg. The gender distribution of mean SSD by the three methods is given in Table 1.

The overall mean SSD of the study population as predicted using Stocker's formula (DS) was 4.92 ± 0.6 cm. The mean SSD measured by ultrasonography (DU) and depth of needle insertion (DA) was 4.47 ± 0.6 cm and 4.81 ± 0.6 cm respectively. By the ANOVA test, the correlation between DS and DA was better than DS and DU, with the highest correlation seen between DU and DA [Table 2]. Figure 3 shows the relation of DU and DA with the weight of the patient.

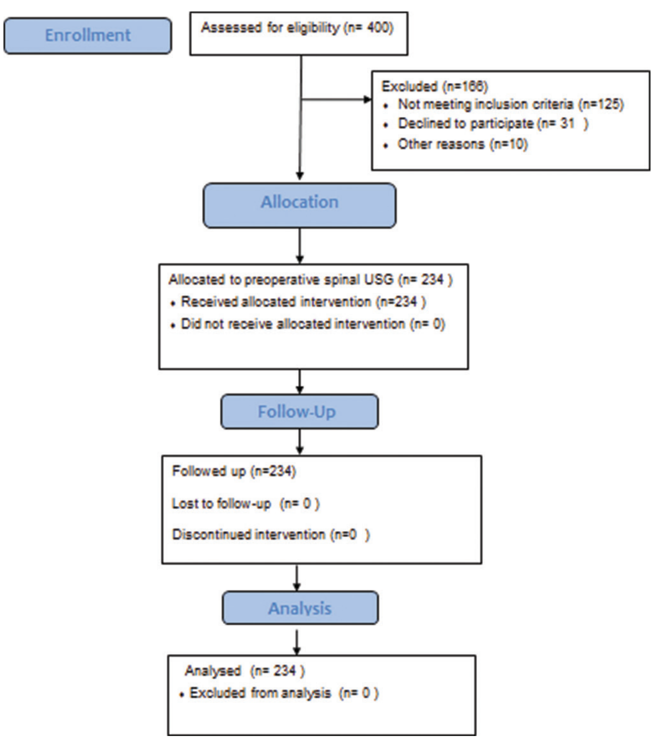

Figure 2: Modified consort flowchart, non-randomized single arm study, recruitment initiated in May 2019, study concluded in October 2019

Multiple regression analysis between the SSD values obtained by DA and DU using weight, age, and gender showed that the weight was the only significant predictor of the SSD using both needle and USG methods [Table 3]. The mean SSD values obtained using the USG showed a negative correlation with age. The regression equation for the association between weight (kg) and depth of the skin to the subarachnoid space using data obtained from DU values was: SSD (cm) =2.522+ [0.031 × weight (kg)] ($P < 0.05$; $R^2 = 0.376$; standard error of estimate = 0.4990) [Table 4]. Table 5 is the ANOVA table, which reports how well the regression equation fits the data (i.e., predicts the dependent variable). This table indicates that the regression model predicts the dependent variable significantly well.

Discussion

The skin to SSD can vary between individuals depending on physical characteristics such as age, weight, race, gender, and habitus.[8] This may result in variations in SSD that produce a learning curve in administering spinal anaesthesia. Wenk *et al.*[9] reported the overall success rate of spinal anesthesia administered by trainees was 72% versus the 100% success rate observed among consultants. The success rate of trainees in patients with normal habitus was 83.3% and 52.4% in patients with difficult anatomy.[9] Thus, a pre-puncture estimate of the skin to SSD is useful in guiding spinal needle placement especially in interns and other trainees.

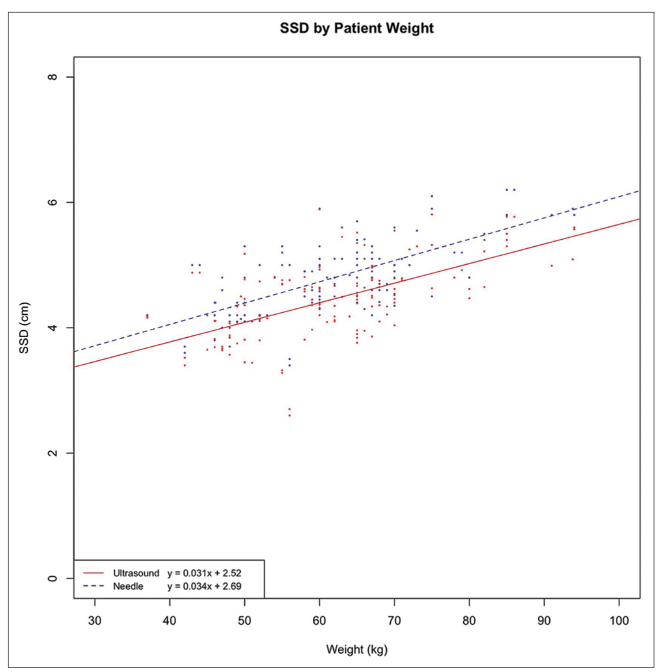

Figure 3: The scatterplot shows the association between the weight of the patients (kg) and depth of SSD (cm) using needle insertion and ultrasound

Table 1: Gender distribution of mean SSD using Stocker's formula (DS), ultrasound (DU), and depth of needle insertion (DA) by independent T-test

Gender	Male Mean±SD	Female Mean±SD	*P*
DS (cm)	5.0473±0.589	4.5436±0.556	0.000
DU (cm)	4.5437±0.574	4.2647±0.745	0.003
DA (cm)	4.8994±0.541	4.5562±0.689	0.000

Table 2: Correlation between DS, DU, and DA by ANOVA test

	Mean	Std. deviation	Pearson correlation coefficient
DU (cm)	4.47	0.6	0.82
DA (cm)	4.81	0.6	
DA (cm)	4.81	0.6	0.70
DS (cm)	4.92	0.6	
DS (cm)	4.92	0.6	0.61
DU (cm)	4.47	0.6	

Table 3: Multivariate regression analysis to determine the covariates influencing SSD

Variable	SSD by the depth of needle (DA)			SSD using ultrasonography (DU)		
	Coeff (B)	SE	*P*	Coeff (B)	SE	*P*
Constant	2.666	0.188	<2e-16	2.869	0.216	<2e-16
Weight	0.034	0.002	<2e-16	0.031	0.0028	<2e-16
Gender	0.002	0.069	0.976	-0.039	0.079	0.6225
Age	0.000 (6)	0.003	0.819	-0.008	0.003	0.0125

Table 4: ANOVA summary table

Model	*R*	R^2	Adjusted R^2	Std. error of the estimate
1	0.613[a]	0.376	0.374	0.49909

[a]*Predictors: (Constant), Weight (kg)*

Many formulae have been derived to estimate the distance between the skin to subarachnoid distance to safely administer anesthesia to the patients.[7,10-12] In this study, we examined the accuracy of SSD predicted by using Stocker's formula to the depth measured by USG and actual depth of needle insertion.[7] The Stocker's formula, given by SSD (mm) =0.5 × weight (kg) +18 uses the weight of the patient in predicting SSD, and the use of a single parameter may be useful in various settings such as in rural or resource-poor facilities.[1] We chose Stocker's formula as it was observed by Prakash *et al.*[1] to be the most accurate in predicting SSD when compared to other formulae in the Indian population. In other populations, other formulae may be more relevant as shown by Taman *et al.*[13]

Our study showed a significant positive correlation with the weight and SSD in an adult South Indian population. The mean SSD predicted from Stocker's formula using the patient's weight was 4.92 ± 0.6 cm, whereas the mean SSD measured using USG and needle insertion was 4.47 ± 0.6 cm and 4.81 ± 0.6 cm, respectively. No previous studies have compared SSD by formulae, USG, and actual depth of needle insertion. So, our results cannot be compared with those of others. Hazarika *et al.*[14] found the overall mean SSD using USG to be 4.37 ± 0.31 cm which is similar to our study. The mean SSD of our overall study population was higher than was observed by Prakash *et al.*[1] using the Stocker's formula and by the needle insertion method. In addition, we found a greater difference between the mean SSD obtained by the Stockers based formula and by using the needle insertion method. This may be explained by the prevalence of heavier subjects in our study, with an average weight of 62 kg as compared to 57 kg, and a male preponderance of 75% compared to 42%.

Gnaho *et al.*[2] conducted the study in French subjects and found SSD by USG and actual depth were 5.15 ± 0.95 cm and 5.14 ± 0.97 cm ($P < 0.0001$). The shorter SSD in our population is possible because of anthropometric differences between the study subjects, our patients being shorter and less heavy compared with the Western population.

Mean SSD in adult males was significantly longer than females as obtained by the three methods. This is like other studies.[1,13] Unlike other studies, our results do not show an SSD correlation with age.[15,16] Our study agrees with Arzola *et al.*[17] which reported that the USG technique was more accurate in the determination of SSD; however, the drawback was an increase in time taken to complete the procedure.

There was strong correlation noted between ultrasonography (DU) and observed needle depth (DA) with the correlation coefficient of 0.82, whereas the observed needle depth (DA) and Stocker's formula showed a variation of ± 0.1 cm, which was not significant. Pearson correlation coefficient was calculated using mean and standard deviation and the reliability of the values is shown by a Cronbach's alpha value (0.90) indicating an excellent internal consistency and reliability between DU and DA. This shows that DU and DA are closely related. As the values of DU, DS, and DA showed a maximum deviation of ± 0.45 cm (DS and DU) [Table 2], it is possible that the variation in DU and DS values is due to an instrumental error.

The validity of Stocker's formula as highlighted by Prakash *et al.*[1] was tested and compared with USG. Our results show that the newly derived formula for SSD based on the patients' weight [SSD (cm) =2.522+ [0.031 × weight (kg)] is a more reliable and useful indicator of SSD and suggests a weight-based formula for predicting SSD in place of a body mass index (BMI). This can be especially valuable in resource-poor areas with a lack of USG machines or expertise

Table 5: Coefficients table from data on DU and weight from the ANOVA test

Model	Unstandardized coefficients		Standardized coefficients	*t*	Significance
	Beta	Standard error	Beta		
(Constant)	2.522	0.168		14.999	0.000
Weight (kg)	0.031	0.003	0.613	11.833	0.000

and in the training of health care providers for administering spinal anaesthesia.

The study conducted has several limitations (a) male preponderance in the study population, giving a less accurate indicator of the average SSD of females, (b) the data are applicable only when midline approach is used, and a spinal needle is inserted perpendicular to the skin, (c) exclusion of pediatric and older population, (d) exclusion of pregnant women, and (e) exclusion of patients having spinal anomalies.

While a good correlation was found between the subarachnoid depth derived using Stocker's formula and observed needle depth, the importance of the USG-guided method must be highlighted as it provides greater insight into skin thickness and distribution of fat that weight or BMI simply do not allows.

Conclusion

Knowing the approximate depth of the subarachnoid space before performing a subarachnoid block would help in minimizing the number of attempts and thereby patient discomfort. USG guidance has been used successfully to measure the depth of the subarachnoid space. Stocker's formula is one of the several formulae for measurement of this depth. Our study found a good correlation between the measurements obtained by both the methods and highlights the correlation of weight in determining skin to subarachnoid space depth. However, further work is needed to confirm the usefulness and accuracy of the derived formula for clinical application.

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Nil.

Conflicts of interest
There are no conflicts of interest.

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