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Original Article

Ultrasound Assessment of Lumbar Dural Sac Diameter in Pregnant Patients Compared to Age Matched Non-Pregnant Women

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Abstract

Background
Spinal anesthesia in obstetric practice is a gold standard practice. Pregnancy causes changes in lumbar spine anatomy, including the dimension of the dural sac. However, if pregnancy alone is responsible for these changes or other variables combine to create these changes remains undetermined. This study aims to compare the dural sac diameter in pregnant and their age matched non-pregnant counterparts and its association with other clinical parameters.

Materials and Methods
An observational cross-sectional study was conducted in 40 term pregnant and 40 non-pregnant age matched controls. The dural sac diameter at L3-L4 interspace was measured in sitting position in both groups. Reliability was assessed with intraclass correlation coefficient. The difference in mean dural sac diameter was assessed. Stratified Linear regression was used to assess the association between age, body mass index and gestational age and dural sac diameter within each group.

Results
The median dural sac diameter was significantly smaller in pregnant patient's median: 1.12 cm (IQR: 0.20) compared to the non-pregnant group median: 1.31 cm (interquartile range: 0.20) $P < 0.001$. Ultrasound measurement demonstrated reliability in both groups non pregnant= 0.933(95% CI: 0.888-0.961) and pregnant = 0.874 (95% CI: 0.805-0.929). Age was associated significant decrease in dural sac diameter in non-pregnant group ($B=-0.011$ cm/year ($p =0.033$) but non-significant in pregnant group.

Conclusion
Dural sac diameter is significantly reduced at late term pregnancy compared to non-pregnant women. Ultrasound provides good reliability for this measurement.

Keywords: *Cerebrospinal fluid, Pregnancy, Spinal anesthesia, Ultrasonography*

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Introduction

Spinal anesthesia is the standard practice for safe and effective surgical analgesia during obstetric procedures. However, cranial spread of intrathecal local anesthetics remains unpredictable due to intra-individual variability [1]. The dural sac, which contains the cerebrospinal fluid (CSF), significantly influences the distribution [2, 3]. Ultrasound imaging allows for measurement of the dural sac dimensions, serving as a surrogate for CSF volume [4]. Variations in dural sac width, including diameter, may contribute to the inter-individual variability [5].

Pregnancy induces anatomical changes, including increased lumbar lordosis, hormonal softening of ligaments and compression of the dural sac by engorged epidural venous plexus [6]. While ultrasound feasibility for measurement and drug optimization based on dural sac dimension is established in non-pregnant populations, data regarding women in their third trimester remain limited [2, 7].

Therefore, this study aims to address this gap by comparing the lumbar dural sac diameter at L3-L4 interspace between pregnant women in their third trimester and age matched non pregnant controls using ultrasound. Additionally, the study evaluates whether individual clinical parameters specifically age, Body Mass Index (BMI) and gestational age act as independent predictors of dural sac diameter within each group.

Materials and Methods

This prospective observational cross-sectional study was carried out in the preoperative room of the department of anesthesiology Kathmandu Medical College Teaching Hospital, Kathmandu, Nepal. The data was collected from July 2025 to December 2025. Ethical approval was obtained from institutional review committee reference no. 25052025/12. Written and informed consent was obtained from all participants before the enrollment. Participants in both groups were female aged 18 to 45 years. The pregnant group included women in their third trimester of pregnancy (37-40 weeks of gestation) who were scheduled for elective cesarean section. The non-pregnant group included age-matched female patients scheduled for elective surgery. Non-pregnant status was confirmed by history and urine pregnancy test when indicated. Participants were excluded if they had a history of prior spine surgery, known structural spine abnormalities such as scoliosis or kyphosis, inability to maintain sitting position for image acquisition, poor ultrasound image quality or if they declined to participate. A total of 80 female patients, 40 in each group; were recruited using consecutive sampling. To ensure the study was adequately powered to detect a clinically meaningful difference, the sample size was calculated based on the difference in mean dural sac diameter (DSD) between two groups. Using a significance level (α) of 0.05 and a study power ($1-\beta$) of 90% following formula was applied $n = 2\,(Z\alpha + Z\,[1-\beta])^2 \times SD^2 / d^2$, where, $Z\alpha = 1.96$, $Z\,(1-\beta) = 1.28$, SD = 0.34, d (effect size) = 0.25, based on prior literature by Onuki et al [8]. This gave a sample size of 38.88 in each group; to account for potential data loss, sample size was rounded up to 40 participants in each group.

In the preoperative room, experienced anesthesiologists conducted all ultrasound examinations. Our department has already conducted two different studies on dural sac dimensions and ultrasound is regularly used for neuraxial blocks in the operating room; therefore, the anesthesiologists involved in the study were well versed with the technique and nuances of neuraxial ultrasound. After explaining the procedure, the participants were placed in the sitting position with the back flexed. A portable ultrasound machine (GE, LOGIQ-e BT12 model) with a curvilinear probe with a 2-5 MHz frequency was used. The probe was placed over the lumbosacral spine and oriented longitudinally in a paramedian sagittal oblique plane. After identifying the sacrum, the probe was moved along the spine to count the lumbar level cranially. First, the intervertebral space at the L5–S1 was identified, then L4–L5 and finally L3–L4. The probe was then oriented to the transverse plane to obtain image of the dural sac at L3–L4 intervertebral space. The dural sac diameter was then measured on the frozen image. The distance between the anterior complex and the posterior complex was defined as the dural sac diameter. The measurement was done using the built-in electronic calipers in the ultrasound machine. Three repeated measurements were taken in each participant and the average was recorded for accuracy and to minimize intra-observer variability. This average was recorded as the primary outcome. The images obtained were graded on a 5-point Likert scale (1=poor, 2= fair, 3=good, 4=very good, 5= excellent). Demographic data like age, height, weight, BMI and gestational weeks were recorded.

Continuous variables were expressed as mean with standard deviation and median with inter-quartile range (IQR). The Shapiro- Wilk test was used to assess for normality in the data, where the p-value greater than 0.05 indicated normal distribution in data and p-value less than or equal to 0.05 suggests non-normal distribution. Because the variables across one or both groups demonstrated non-normal distributions, group comparisons were performed using the non-parametric Mann-Whitney test. Pearson correlation coefficients (r) were calculated to evaluate the relation between DSD and other variables like age, BMI. Stratified simple and multiple linear regression analysis was conducted to analyze the association between different variables like age, BMI and gestational age (in pregnant patients) and DSD. Measurement reliability was quantified using the intraclass correlation coefficient (ICC). Statistical significance was set at α = 0.05, p value of < 0.05 were statistically significant. Data analysis was performed using R studio software (version 2024.4.2.764).

Results

Among the 80 patients analyzed, pregnant women had an average dural sac diameter of median: 1.12 cm (IQR: 0.20 cm) compared to the non-pregnant group median: 1.31 cm (IQR: 0.20 cm); p<0.001. Baseline demographic data, image quality and group comparisons of different variables are tabulated in table 1.

Table 1: Descriptive data of the patients and intergroup comparison

Variable	Non-Pregnant (n=40)		Pregnant (n=40)		p-value
	Mean ± SD	Median (IQR)	Mean ± SD	Median (IQR)	
Average dural sac diameter (cm)	1.28 ± 0.21	1.31 (0.20)	1.12 ± 0.17	1.12 (0.20)	<0.001[a]
Age (years)	30.82±6.63	31.50 (9.00)	30.62±4.56	30.50 (7.25)	0.916[a]
BMI (kg/m²)	24.24±2.73	23.93 (2.92)	31.17±3.21	30.44 (4.30)	<0.001[b]
Gestational age (weeks)	—		37.83 ± 0.78	38 (1.00)	
Image quality score	4.43±0.78	5 (1.00)	3.85±1.25	4 (2.00)	0.044[c]

[a]Non-pregnant group normally distributed; pregnant group non-normally distributed

[b]Pregnant group normally distributed; non-pregnant group non-normally distributed

[c]Both groups non-normally distributed

Linear regression model was constructed to assess association of BMI, age and gestational age with dural sac diameter. In simple linear regression, pregnancy was associated with a 0.16 cm reduction in dural sac diameter (B = -0.16, 95% CI: -0.244 to -0.073, P =0.0004). Table 2 presents unadjusted estimates from simple linear regression between physical characteristics and dural sac diameter for both pregnant and non-pregnant groups. No statistically significant linear relationships were observed. Within the pregnant group, gestational age demonstrated a weak negative correlation with DSD that did not reach statistical significance. (Pearson r = -0.17, p =0.290)

Table 2: Unadjusted linear regression analyses for dural sac diameter, stratified by pregnancy status

Group	Variables	Unstandardized coefficient (B)	95% Confidence Interval (CI)	r (Pearson correlation coefficient)	p-value
Non Pregnant	BMI (kg/m²)	0.014	-0.011 – 0.039	0.176	0.276
	Age (years)	-0.009	-0.019 – 0.001	-0.288	0.072
Pregnant	BMI (kg/m²)	0.002	-0.016 – 0.019	0.032	0.846
	Age (years)	-0.009	-0.021 – 0.002	-0.253	0.116
	Gestational Age (weeks)	-0.038	-0.108 – 0.033	-0.172	0.290

Table 3 presents estimates adjusted for BMI, age, and gestational age. The pregnant group has been adjusted for BMI, age and gestational age and the non-pregnant group has been adjusted for BMI and age. After mutually adjusting for all variables, dural sac diameter was not significantly associated with BMI, gestational age and chronological age in pregnant group. Whereas, in non-pregnant group, maternal age demonstrated a statistically significant, negative association with dural sac diameter, however BMI had no independent association.

Table 3: Multiple linear regression analyses stratified by pregnancy status

Group	Variables	Unstandardized coefficient (B)	95% Confidence Interval (CI)	p-value
Non Pregnant (Model R^2 =0.145, Adjusted R^2 = 0.098)	BMI (kg/m2)	0.0020	-0.004 – 0.044	0.111
	Age (years)	-0.011	-0.021 – -0.001	0.033
Pregnant (Model R^2 =0.085, Adjusted R^2 = 0.0091)	BMI (kg/m2)	0.003	-0.014 – 0.021	0.731
	Age (years)	-0.009	-0.021 – 0.003	0.162
	Gestational Age (weeks)	-0.032	-0.105 – 0.040	0.372

Where; R^2 = coefficient of determination; Adjusted R^2 = R^2 adjusted for the number of predictors in the model

Image quality was scored on a 5-point scale (1 = poor to 5= Excellent). Overall, 63.75% of images were rated good to excellent. In pregnant group, 45% of images were scored ≥4, compared to 82.5% in the non-pregnant group. Intraclass correlation analysis demonstrated agreement across the three repeated ultrasound measurement in all groups. The overall ICC (2,1) was 0.921 (95% CI: 0.889-0.946). Ultrasound measurement demonstrated reliability in both groups non pregnant= 0.933(95% CI: 0.888-0.961) and pregnant = 0.874 (95% CI: 0.805-0.929).

Discussion

The primary finding of this study is that the pregnant women in their third trimester (37- 40 weeks) have a significantly smaller lumbar dural sac diameter at L3-L4 interspace compared to age matched non-pregnant women median: 1.12 cm (IQR: 0.20 cm) compared to the non-pregnant group median: 1.31 cm (IQR: 0.20 cm); p<0.001. Multiple linear regression analysis demonstrated standard demographic and clinical variables like maternal age; BMI and gestational age have poor association with DSD within the pregnant group, accounting for less than 1% of the variance with the pregnant group (Adjusted R^2 = 0.0091). These findings are consistent with pregnancy related physiological and anatomical changes contributing to a decrease in the dimension of the dural sac, and other parameters such as age, BMI remained statistically insignificant.

Theoretically, this observed reduction in DSD is supported by known changes that occur in a pregnant female. In the late third trimester, the gravid uterus can lead to compression of the inferior vena cava, which leads to venous stasis and congestion of the lumbar venous plexus. Increased lumbar lordosis and hormonal changes leading to ligamentous laxity may alter lumbar spine anatomy [9]. Our findings align with Onuki et al, who used MRI to demonstrate a gestation related reduction in lumbar cerebrospinal fluid volume, suggesting that the external compression by engorged epidural venous plexus leading to decrease in dural sac surface area [8]. This theory is further supported by MRI findings of Xu et al, they observed that the posterior displacement of the dural sac its compression were most pronounced in the L3-L4 level, which is the site of our measurements. This is due to the peak impact exerted by the gravid uterus [10]. In our study a weak negative correlation (r = -0.17) was found between the gestational age and DSD. This association however was not significant (p = 0.290). As the fetus grows, the size of the uterus increases and this leads to increase in the intra-abdominal pressure (IAP) that likely exacerbates the venous engorgement, leading to decrease in DSD as seen in our patients. This data corresponds to the finding of Ni et al [11], who identified intra-abdominal pressure as a key determinant of spinal anesthesia spread. Their research indicated that elevated IAP reduces the dural sac area by forcing the soft tissue inward through the intervertebral foramina. During pregnancy, this effect is amplified; the combination of increased retroperitoneal pressure and hormone-induced laxity compresses the lateral aspect of the dura, resulting in bilateral dural compression. Additionally, the increased IAP also diverts blood into the vertebral venous system.

Beyond the evidence of vascular compression, other biomechanical reasons could very well, explain the decrease in DSD. Yoseph et al, in a recent review, the author has highlighted biomechanical factors during pregnancy. Late pregnancy causes the anterior shift in the center of mass and increased lumbar lordosis which adds on to the strain on the posterior spinal segments [12]. These changes along with ligamentous laxity due to pregnancy leads to crowding in the lumbar spine. Though our study doesn't give any biological plausibility for causation. Our data does show a definitive decrease in DSD in late third trimester pregnancy.

The clinical implication of smaller DSD cannot be overstated. CSF volume is the primary determinant for the spread of spinal anesthesia [13]. Although ultrasound imaging cannot directly determine the volume of CSF in the lumbar spine, it can allow for assessment of the lumbar dural sac dimensions; this can help us derive the dural sac volume [4, 5], and a smaller diameter correlates with lower volume of CSF in the lumbar region. Therefore, when a smaller dural sac is present, a standard fixed dose of an intrathecal local anesthetic drug undergoes less dilution. This could lead to unintended high spinal block and severe hypotension. Conversely, a larger DSD provides a higher volume of CSF and more drug dilution and an inadequate block. Understanding these variations is crucial for optimizing drug dosages. This mechanism is further supported by the study conducted by Xu et al, who demonstrated that higher and better analgesia is achieved in pregnant patients with smaller dural sac diameter. The reason being that the surface area of the dural sac is negatively correlated with longitudinal distribution of local anaesthetic [5]. A smaller surface area of the dural sac means better diffusion, onset and peak effect of local anesthetic after neuraxial block [3].

This explains the reduced doses of intrathecal local anesthetic requirement in pregnant patients to achieve same block height as their non-pregnant counterparts. By using the ultrasound, the clinician can preoperatively determine the dural sac diameter and may optimize the dose of the drug to be injected in the intrathecal space to reduce the incidence of maternal hypotension [4]. However, predictive value of a single-point measurement may not always be predictive of peak sensory level. While DSD is a critical component of lumbar anatomy, it is likely to be one of several multifactorial determinants of intrathecal drug spread [14].

The multiple regression analysis, demonstrated the structural differences between the groups. Within the adjusted analysis for non-pregnant group, advancing chronological age revealed to have a statistically significant independent association with a smaller dural sac diameter ($B=-0.011$ cm/year ($p = 0.033$). This association however, was not apparent in the unadjusted model ($B = -0.009$, $p = 0.072$), suggesting that BMI acted as a suppressor variable, masking the true independent effect of age on dural sac diameter. Existing literature suggests that aging can cause degenerative changes in the spine such as ligamentum flavum hypertrophy or degenerative spondylosis, which can decrease the diameter of the dural sac [15]. However, such statistical significance was not observed in the pregnant group $B = -0.009$ cm/year ($p = 0.162$), potentially because of the impact of soft tissue changes, which could mask or override, subtle degenerative changes seen in healthy adult controls. Furthermore, the study population belonged to 18-45 years age group, which could explain why age modifications remained minor factor. Similarly, there was no independent association between BMI and DSD within either the non-pregnant group ($B = 0.020$, $p = 0.276$) or the pregnant group ($B = 0.003$, $p = 0.731$). While higher BMI can theoretically be associated with decreased volume of the CSF and decreased DSD due external pressure by epidural fat and increases IAP, this association was not established in our data. The difference in DSD between our groups remained significant even when accounting for these factors, reinforcing that pregnancy would be the primary factor for these changes rather than age and BMI.

Our regression analysis additionally demonstrated that gestational age did not demonstrate an association with reduced DSD ($B = -0.032$, $p = 0.372$). However, our study group had a very narrow range of late term pregnancy (37.8±0.8) weeks. This could signify that maximum compression is attained by 37 weeks. Additionally, a longitudinal study with follow-up of pregnant patients from early to late pregnancy would give a better understanding of this concept. The reliability of this study protocol for measurement with ultrasound was supported by high internal consistency. Our data had ICC values ranging from 0.874 in pregnant group and 0.933 for non-pregnant group. Along with this image quality was rated as good or excellent with score≥ 4 in 63.75% in all of our participants, supporting technical validity of the measurements.

The integration of ultrasound measured DSD into clinical practice represents the new frontier in obstetric anesthesia practice. As demonstrated by recent trials in geriatric anesthesia, modification of the subarachnoid dose of local anesthesia according to the size of the dural sac, rather than relying on height and weight can lead to decrease complications [2]. Upgrading to calculation rather than assumption-based practice could lead to safe maternal and neonatal care. To our knowledge this is one of the first study, which has evaluated the dural sac diameter in the pregnant and non-pregnant group ultrasonographically during the perioperative period. And this offers an insight on high impact low-cost assessment of the dural sac, quite sustainable and adaptable in low-income countries.

Though our study has demonstrated significant results, we acknowledge many limitations. One is that our entire sample was taken in sitting position. We know that dural sac diameter can differ with position of the body. Our study was limited in the preoperative period. We did not test the correlation of DSD and sensory block in our population. Ultrasound provides one time measurement of the DSD, however the DSD can change according to position and external pressure. And lastly, this study was conducted in a single center.

Conclusion

In conclusion, ultrasound imaging confirms a statistically and clinically significant narrowing of the dural sac in late-term pregnancy compared to their age matched controls. This reduction is primarily associated with pregnancy. These findings provide anatomical evidence for well-recognized need for reduced dose of local anesthetic dosing in obstetric anesthesia.

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Conflict of interest: None

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