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Evaluation of the Conus Medullaris with 2D and 3D Ultrasonography in Fetal Neural Tube Defect Anomalies

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ABSTRACT

This study aimed to evaluate the fetal conus medullaris (CM) using 3D ultrasonography in fetuses with central nervous system (CNS) anomalies and in healthy fetuses. The aim was to evaluate the vertebral ending levels of CM and its utility as a biomarker in prenatal diagnosis.

This prospective study, conducted at the Obstetrics and Perinatology Clinic of Van Yüzüncü Yıl University, Faculty of Medicine, included 80 pregnant women between 11 and 22 weeks of gestation with a singleton pregnancy, aged 18 to 45, and with a body mass index (BMI) <30. 40 women with fetal CNS anomalies were included in the patient group, while 40 healthy pregnant women were included in the control group. All pregnant women underwent 2D ultrasonography followed by 3D ultrasonography. The ending level of the CM relative to the vertebral column and various biometric measurements were recorded. Data were analyzed using SPSS 27.0.

When demographic data were analyzed, no significant difference was found between the two groups in terms of age, height, weight, and gestational age ($p>0.05$). The distances between the CM and the lower end of the sacrum (CM–Os Sacrum) and the anterior abdominal wall (CM–Abdomen) were also similar ($p=0.279$ and $p=0.299$). When the ending levels of the CM relative to the lumbar vertebrae were evaluated, it was observed that the CM most frequently ended at the L4 level in 23 patients (53.5%) in the patient group, at the L3 level in 15 patients (37.5%), and at the L2 level in 2 patients (5%). In the control group, it was observed that the CM ended at the L3 level in 23 patients (57.5%) and at the L2 level in 17 patients (42.5%). While it was found that the CM extended to the L4 level in the patient group, this ending was not observed in the control group. Ending at the L2 level was more frequently observed in the control group (42.5% vs 5%). In subgroup analyses, it was determined that the CM ending was more caudal in cases with anomalies such as spina bifida and anencephaly.

The ending level of the CM at the vertebral end, particularly its extension to the L4 level, may be a powerful biomarker for identifying CNS anomalies prenatally. This study demonstrates the utility of prenatal 3D ultrasound assessment of the CM ending level in the early diagnosis of CNS anomalies.

Keywords: Conus medullaris, neural tube defect, 3D ultrasonography, central nervous system abnormalities

Introduction

The central nervous system (CNS) is one of the earliest and most complex structures in embryological development. This system, consisting of the brain and spinal cord, plays a central role in regulating motor, sensory, cognitive, and autonomic functions (1). Disruptions in any of the cell proliferation, migration, and organizational processes that occur during the embryonic period can lead to permanent structural and functional disorders (2). These anomalies are associated with high morbidity and mortality rates and significantly impact quality of life. Therefore, early and accurate detection of such disorders in the prenatal period is critical for perinatal management and the planning of postnatal treatment.

Developing prenatal imaging techniques have made significant progress in detecting fetal structural anomalies. Ultrasonography, in

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particular, is the preferred method for fetal screening due to its non-invasive nature, widespread availability, and reliability (3). While standard two-dimensional (2D) ultrasonography is effective in the general evaluation of fetal anatomical structures, it can be inadequate in some cases. Three-dimensional (3D) ultrasonography, which has become increasingly popular in recent years, allows for more detailed examination of the CNS and spinal structures, particularly because of its multiplanar reconstruction feature (4). The volumetric data obtained with 3D ultrasonography increases diagnostic accuracy in the evaluation of fetal cranial and spinal structures and provides the physician with more anatomical detail.

The conus medullaris (CM) is the conical ending portion of the spinal cord and, during normal development, is located at the L1–L2 vertebral levels in the later weeks of pregnancy (5). The prenatal location of this structure is an important indicator for assessing fetal neurological development. A more caudal-than-normal termination of the CM may suggest abnormal fixation of the spinal cord, such as tethered cord syndrome, and is frequently associated with neural tube defects such as spina bifida, anencephaly, and Chiari malformation. Therefore, accurate and reliable determination of the fetal CM ending level is of clinical importance in monitoring fetal spinal cord development, especially in high-risk pregnancies.

Studies to this day have demonstrated that the vertebral ending of fetal CM can be determined prenatally by ultrasonography and that this level may be a potential biomarker for the preliminary diagnosis of certain pathological conditions. However, the relationship between CM ending and CNS anomalies has not been adequately supported by large-sample studies, particularly those using 3D ultrasonography.

In this context, this study aimed to evaluate fetal CM in pregnancies with CNS anomalies using 3D ultrasonography and compare it with healthy pregnancies. The study analyzed the final position of the CM relative to the lumbar spine, along with measurements of various biometric parameters, to assess whether the data obtained could contribute to prenatal diagnostic processes. This study aims to demonstrate the diagnostic value of 3D ultrasonography in fetal spine assessment and the role of the CM in prenatal diagnosis.

Materials and Methods

This prospective cohort study was conducted at the Department of Obstetrics and Gynecology, Van Yüzüncü Yıl University, Faculty of Medicine. Ethical approval was obtained from the Ethics Committee of Van Yüzüncü Yıl University, and written informed consent was obtained from all participants. The study was supported by the Van Yüzüncü Yıl University Scientific Research Projects Commission (Project No: TSG-2022-10008).

A total of 80 pregnant women with a singleton pregnancy between 11 and 22 weeks of gestation, aged 18–45, and a body mass index (BMI) below 30 were included in the study. The patient group consisted of 40 pregnant women with CNS anomalies detected by prenatal ultrasonographic examination. The control group consisted of healthy pregnant women with normal fetal anatomical structures and no anomalies observed on ultrasonographic examination. Multiple pregnancies, pregnant women with a history of chronic diseases (such as diabetes mellitus and hypertension), autoimmune diseases, with chromosomal anomalies, cases of fetal growth restriction, with a BMI ≥30, and cases in which fetal anatomical structures could not be assessed due to insufficient image quality were excluded from the study.

Initially, all cases were evaluated using a Voluson E8 (GE Healthcare, USA) 2D ultrasonography device and then evaluated with 3D ultrasonography. The ultrasonographic examination was performed by the same perinatologist, following standard protocols. A CM image was obtained in the sagittal plane with the fetus in a supine position. The CM level was determined based on prominent anatomic landmarks on the vertebral column and classified as L1–L5. Positioning was based on the number of fetal lumbar vertebrae and sacral location. After determining the location according to the vertebral level, the following distances were measured:

- Conus medullaris – sacrum lower end distance (CM–Os sacrum)
- Conus medullaris – anterior abdominal wall distance (CM–Abdomen)

Fetal biometric parameters were also recorded: abdominal circumference (AC) and femur length (FL). Biparietal diameter (BPD) and head circumference (HC) measurements were not taken due to the neural tube defect. All measurements

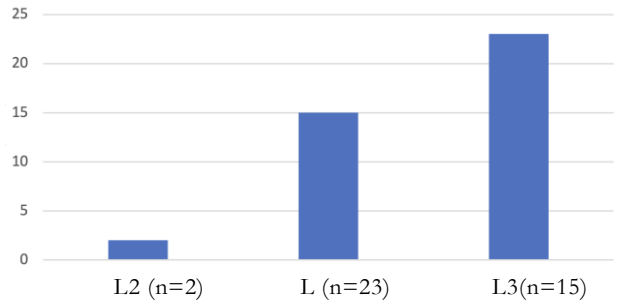

Fig. 1. Lumbar ending levels in the patient group

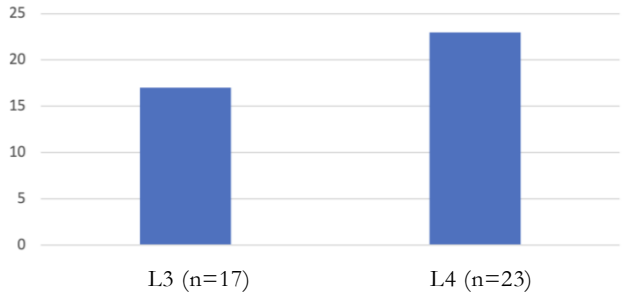

Fig. 2. Lumbar ending levels in the control group

were averaged from three separate measurements and were performed by a single examiner to avoid interobserver variability. The images were stored digitally, and a second examiner repeated the measurements in 10 randomly selected cases to verify consistency.

Statistical analyses were performed using SPSS 27.0 (IBM Corp., Chicago, IL, USA) software. The distribution of continuous variables was assessed using the Kolmogorov–Smirnov test. The independent samples t-test was used for normally distributed data and the Mann–Whitney U test was used for non-normally distributed data in comparisons of groups. The chi-square test (χ^2) was applied for categorical variables. Data are presented as mean ± standard deviation and percentage (%). A p value of <0.05 was accepted as the limit of statistical significance.

Results

When demographic characteristics were compared between the patient and control groups, no statistically significant differences were observed between the parameters of age, height and weight. The mean age was 29.1 ± 6.1 years in the patient group and 27.8 ± 3.9 years in the control group (p=0.295). The mean height was 160.7 ± 5.4 cm in the patient group and 162.8 ± 6.5 cm in the control group (p=0.136). The mean weight was 66.7 kg in the patient group and 69.1 ± 7.6 kg in the control group (p=0.166). No statistically significant difference was observed between the two groups in terms of gestational age (p=0.982). The mean gestational age was 122.7 ± 17.1 days in the patient group and 122.8 ± 21.8 days in the control group (p=0.982). Demographic characteristics and gestational age are shown in Table 1.

The distance between the CM and the sacrum was measured using ultrasonography in both groups. This distance was 23.3 mm ± 5.4 mm in the patient group and 25.0 mm ± 7.9 mm in the control group, and no statistically significant difference was observed between these values (p=0.279). The distance between the CM and the umbilicus was 24.1 mm ± 6.1 mm in the patient group and 25.8 mm ± 8.5 mm in the control group, and no statistically significant difference was observed between these values (p=0.299). The mean distances between the CM and the sacrum and umbilicus are shown in Table 2.

The CM ending level was observed to end at the L2 level in 2 (5%) patients in the patient group, at the L3 level in 15 (37.5%) patients, and at the L4 level in 23 (53.5%) patients. The distribution of lumbar termination levels of the conus medullaris in the patient group is illustrated in Figure 1. The distribution of lumbar termination levels of the conus medullaris in the control group is shown in Figure 2. In the control group, the CM ending level was observed at the L2 level in 17 (42.5%) patients and at the L3 level in 23 (57.5%) patients. While no patient in the control group observed the CM ending level at the L4 level, this number was found to be 23 in the patient group. The ending levels of the CM in both groups are shown in Table 3.

Discussion

This study aimed to evaluate the level of the CM ending in the vertebral column and its distance from the sacrum and umbilicus in fetuses with CNS anomalies and healthy fetuses using three-dimensional (3D) ultrasonography. The data obtained showed that the CM termination level was significantly more caudal in the patient group. The frequency of CM ending at the L4 level, in particular, suggests that this anatomical finding may be a potential diagnostic tool in CNS anomalies.

In normal fetal development, CM usually ends at the L2-L3 levels, and these levels are considered physiological in the prenatal period. However,

Table 1: Demographic Characteristics and Mean Gestational Age. Sd: Standard Deviation

	Groups	Mean ± SD	P value
Age (years)	Patient (n:40)	29.1 ± 6.1	0.295
	Control (n:40)	27.8 ± 3.9	
Height (cm)	Patient (n:40)	160.7 ± 5.4	0.136
	Control (n:40)	162.8 ± 6.5	
Weight (kg)	Patient (n:40)	66.7 ± 7.3	0.166
	Control (n:40)	69.1 ± 7.6	
Gestational Age (days)	Patient (n:40)	122.7 ± 17.1	0.982
	Control (n:40)	122.8 ±21.8	

Table 2: Comparison of The Distance of The Cm To The Sacrum and Umbilicus. Sd: Standard Deviation

	Groups	Mean ± SD	P value
Distance between the conus medullaris and the sacrum	Patient (n:40)	23.3 mm ± 5.4 mm	0.279
	Control (n:40)	25.0 mm ± 7.9 mm	
Distance between the conus medullaris and the umbilicus	Patient (n:40)	24.1 mm ± 6.1 mm	0.299
	Control (n:40)	25.8 mm ± 8.5 mm	

Table 3: The Level of Ending of The Conus Medullaris. L= Lumbar Vertebra

	Patient	Control
L2	2 (%5)	17 (%42,5)
L3	15 (%37,5)	23 (%57,5)
L4	23 (%53,5)	-

Previous studies have also shown that CM is located at more distal levels in CNS anomalies such as spina bifida and tethered cord syndrome (6,7). In this context, the results of our study are consistent with the literature and support the notion that CM termination level can be considered a non-invasive biomarker of CNS anomalies.

3D ultrasonography provides superior imaging compared to 2D in the evaluation of fetal CM. Technologies such as Volume Contrast Imaging and OmniView allow for more precise determination of the location of the conus at the vertebral level (8). A study by Lei et al. using 3D ultrasonography demonstrated that the CM was located below L3 in fetuses diagnosed with spina bifida occulta, increasing the diagnostic power of this method (9). Similarly, in our study, the CM was observed to be located distally up to L4 in cases with CNS anomalies, and this finding was statistically significant.

In terms of fetal biometric parameters, lower mean values were found in the patient group for measurements such as AC and FL, but the difference was not statistically significant. However, the decrease in these parameters suggests that CNS anomalies are not limited to the CNS but may also affect fetal growth. Indeed, CNS defects accompanied by fetal growth restriction have been associated with adverse effects on fetal development in the literature (10,2).

The relatively small sample size and the wide gestational age range constitute the main limitations of this study. However, restricting the study population to CNS anomalies and the similarity of gestational ages between groups strengthen the internal validity of the study.

In conclusion, this study demonstrates that 3D ultrasonographic assessment of fetal CM ending level is a reliable method for the early prenatal diagnosis of CNS anomalies. CM ending at the L4 level, in particular, is an important

ultrasonographic finding that should be carefully evaluated in high-risk pregnancies. This finding is also a valuable indicator for perinatologists and radiologists, as it enables quantitative analysis of fetal spine development. Future prospective studies with larger sample sizes could evaluate the integration of this parameter into diagnostic, prognostic, and management processes.

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