Original Article

HEALTH SCIENCES
MEDICINE

DOI: 10.32322/jhsm.1215575

J Health Sci Med 2023; 6(2): 456-461

Do we know the normal anterior-posterior diameters of the spinal cord and canal in newborns?

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Cite this article as: Özbey Ö, Arslan FZ, Körez MK, Payaslı M. Do we know the normal anterior-posterior diameters of the spinal cord and canal in newborns?. J Health Sci Med 2023; 6(2): 456-461.

ABSTRACT

Aim: We aim to reveal the normal anterior-posterior diameter of the spinal cord and canal at cervical, thoracic and lumbar levels in newborn with sonographic measurements and to create a reference value. Also, we aim to reveal whether the anterior-posterior diameter at these levels will vary with the newborn's head circumference, gender, height and weight. Thus, we aim to be one of the pioneering studies in the literature

Material and Method: Statistical analysis was performed to determine normal anterior-posterior diameter for the spinal canal and spinal cord at each vertebral level, and their correlations with birth weight, length and head circumference.

Results: 188 newborns were included. The mean anteroposterior spinal canal diameter in male newborns was significantly higher compared to females (9.27±0.83 vs 9.00±0.79, p=.020). There was a positive correlation between spinal cord anterior-posterior diameter and head circumference at thoracic level, which was statistically significant. There was a positive correlation between spinal canal diameter and height at thoracic level. There was a positive correlation between spinal canal diameter and weight at lumbar level.

Conclusion: The establishment of the normal values for anterior-posterior diameters of the spinal cord in healthy newborns may contribute the current literature data.

Keywords: Diameter, infants, neonates, spinal canal, spine ultrasound

INTRODUCTION

Neonatal spinal ultrasonography (US) is a valuable, noninvasive, does not contain ionizing radiation, first-line imaging modality that is frequently used in newborns, to investigate the spinal cord (1). US provides an excellent acoustic window that allows visualization of the spinal cord and canal since the posterior elements of the vertebrae are not fully ossified in newborns However, a complete and adequate neonatal spinal US examination requires plenty of experience, to precisely detect the pathologies of the spinal cord, it is necessary to accurately know the anatomy and the conditions that can be considered as normal (2). Except for a recently published study, there is no study including a large series of patients revealing normal values of the spinal cord and canal in newborns. Normal anterior-posterior (AP) diameter values of the spinal cord and canal are evaluated visually by radiologists so far (3). Determining objective normal values for AP diameters of the spinal cord and spinal canal on US may faciliate detecting pathologies such as mass formations in the spinal cord that do not create a recognizable echo difference, spinal cord injury and edema, and isoechoic hematoma that does not lead any significant echo difference.

In this prospective study, we aim to reveal the normal AP diameter values of the spinal cord and canal at cervical, thoracic and lumbar levels in newborn babies with sonographic measurements and to create a reference value range. Also, we aim to reveal whether the AP diameter values at these levels will vary with the newborn's head circumference, gender, height and weight. Thus, we aim to be one of the pioneering studies in the literature.

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Received: 07.12.2022 **Accepted:** 19.02.2023

MATHERIAL AND METHOD

The study was carried out with the permission of Başakşehir Çam and Sakura City Hospital Clinical Researches Ethics Committee (Date: 30.06.2021, Decision No: 2021.06.133). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki. Oral and written consents were obtained from parents of all patients who participated in our study.

In this prospective study; 191 newborns were included between 2020-2021 years. Newborn babies who were reported as completely normal in obstetric US follow-ups and who were evaluated as normal in the postnatal physical examination were included in our study. It was excluded from our study because of the detection of lipoma at the level of the cauda equina fibers in 1 newborn, the detection of patency in the posterior vertebral elements (occult type spinal dysraphism) in 1 newborn, and the detection of diastometomyelia in 1 newborn. A total of 188 healthy newborns (89 male, 99 female) were included in our study. Newborns with any known abnormality in the antenatal obstetric US, those who had undergone any surgery in the neck or waist region, those with a known postnatal disease, and those with a known disease history such as diabetes in their mother were excluded from the study. Again, patients with sacral dimples, hair growth and lumbar lump in the postnatal physical examination were not included in the study.

All sonographic evaluations were performed by a radiologist who is specialized in the field of pediatric radiology (Ö.Ö.) with 6 years of experience. In all patients, US were performed in the prone position within 48-72 h of birth using Hitachi ARIETTA 850 SE (Hitachi, Tokyo, Japan). During the examinations, a pillow was placed under the infant's abdomen and the newborn was in the prone position. Prone position allow us to see a better acoustic window since the position leads lumbar cistern distention. All examinations are performed with a high-resolution (7–14 MHz) linear transducer through longitudinal and axial plane from the cervical region to the end of the coccyx.

The examination was started in the longitudinal plane, spinal cord morphology from the craniocervical junction level to the thoracic and lumbosacral regions, the level of termination of the conus medullaris, motion of the spinal cord and nerve roots and the morphology of the filum terminale was evaluated. The first vertebra that showed a deviation from the adjacent vertebrae at the level of the lumbosacral junction was determined as the sacral vertebra. Vertebrae were counted from the lumbosacral junction to the cranial vertebrae. In addition, when it comes to the thoracic region, the vertebra (T12) where the rib articulates was determined and the vertebral levels were also counted down from this level. Unossified or round shaped coccyx was determined. After counting the vertebral levels, the ten axial planes, vertebrae from the craniocervical level to the vertebral column, spinal canal and cord were examined. It was investigated whether there is any fusion defect in the posterior elements, echo of the spinal cord, whether there is any space-occupying lesion within the spinal cord, central echo complex and subarachnoid space, cases with pathology were excluded from the study. AP diameters of the spinal cord and spinal canal were measured. At the cervical level, spinal cord and canal AP diameters were measured at C4-6 levels. Three consecutive measurements were made at T5-8 vertebral levels and the lumbar enlargement (from above and below) level. By calculating the average of the 3 measurements, spinal cord and spinal canal ap diameters were noted for each level. Then, height weight head circumference for each newborn was noted from the medical records recorded in the local database of our hospital.

Statistical Analysis

All statistical analysis was performed using R 3.6.0 (https://www.r-project.org). Shapiro-Wilk's normality test and Q-Q plots were used to normality of the data, and also Levene's test was used to check the homogeneity of the groups. Continuous variables were expressed as mean±standard deviation. Independent samples t-test and Welch's t-test was used to compare the difference of the male and female cohorts at the cervical thoracic and lumbar levels according to spinal cord AP and spinal canal diameter. In addition to, the relationship between the AP diameter of spinal cord and spinal canal at each vertebral level and head circumference, weight, and height was examined using Pearson correlation analysis. A value of p less than .05 was considered as statistically significant.

RESULTS

188 newborns (89 male, 99 female) were included in this study. The mean weight of male patients was 3305.73±539.72 gr, and female patients were 3299.68±461.50 gr. The mean height of male patients was 51.55±2.41 mm, and female patients were 51.31±2.30 mm.

The comparisons of the male and female cohorts at the cervical, thoracic and lumbar levels according to AP diameter of spinal cord and canal was given in **Table 1**. The mean AP diameter of spinal cord for all newborns at the cervical, thoracic and lumbar levels were 4.81±0.41, 3.85±0.36 mm and 5.00±0.31 mm (mean±standard deviation in milimeters), respectively. The mean AP diameter of spinal canal for all newborns at the cervical, thoracic and lumbar levels were (mm) 7.80±0.86, 7.43±0.75, 9.13±0.82 (mean±standard deviation in milimeters) respectively. The mean AP diameter of spinal canal in male newborns was significantly higher compared in female newborns (mm) (9.27±0.83 vs 9.00±0.79, p=.020). However, there was no statistically significantly difference between male and female newborns in terms of the mean AP diameter of spinal cord at any vertebral level, and also spinal canal diameter at cervical and thoracic level. There was statistically significantly difference between male and female newborns in terms of the mean AP diameter of spinal canal at lumbar level (p value= 0.02) (**Table 1**, **Graphic 1**, **Figure 1** and **2**).

Table 1. The mean AP diameter of spinal cord and canal for the male and female cohorts at the cervical, thoracic and lumbar levels

	All newborns (n=188)	Male (n=89)	Female (n=99)	p value (M. vs F.)
Spinal cord AP diameter				
Cervical	4.81±0.41	4.82±0.48	4.80±0.33	.803[a]
Thoracic	3.85±0.36	3.87±0.40	3.84±0.34	.550[b]
Lumbar	5.00±0.31	5.00±0.32	5.01±0.31	.806[a]
Spinal canal diameter				
Cervical	7.80±0.86	7.80±0.94	7.80±0.79	.960[a]
Thoracic	7.43±0.75	7.44±0.77	7.43±0.74	.889[a]
Lumbar	9.13±0.82	9.27±0.83	9.00±0.79	.020[a]

Values were presented as mean±standard deviation in milimeters. Bold values denote that statistically significant difference. [a]Independent samples t-test, [b]Welch's t-test

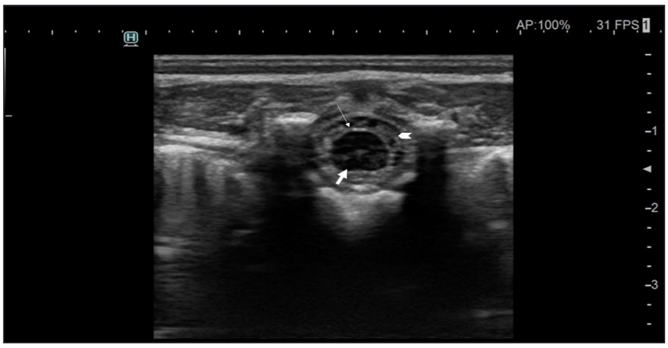
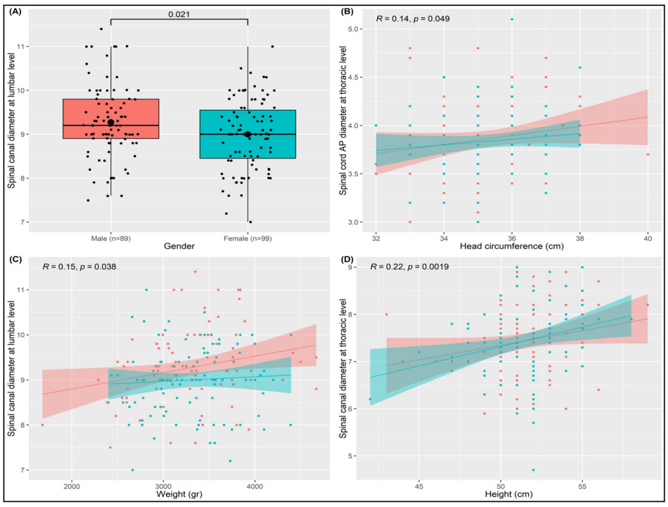


Figure 1. An axial images of spinal cord at the lumbal vertebral level has shown the spinal cord (thick arrow), the dura mater (thin arrow) and the nerve roots (arrowhead) in the subaracnoid space.



Graphic 1. (A) A box-plot, which shows the spinal canal diameter at lumbar level in male and female patients. Data are expressed as median with interquartile range, and dots shows mean value. (B) Scatter plot, which shows the relationship between spinal cord AP diameter at thoracic level and head circumference in each sex. Line shows regression lines, and light colors show confidence intervals in each sex. (C) (B) Scatter plot, which shows the relationship between spinal canal diameter at lumbar level and weight in each sex. Line shows regression lines, and light colors show confidence intervals in each sex. (D) (B) Scatter plot, which shows the relationship between spinal canal diameter at thoracic level and height in each sex. Line shows regression lines, and light colors show confidence intervals in each sex.

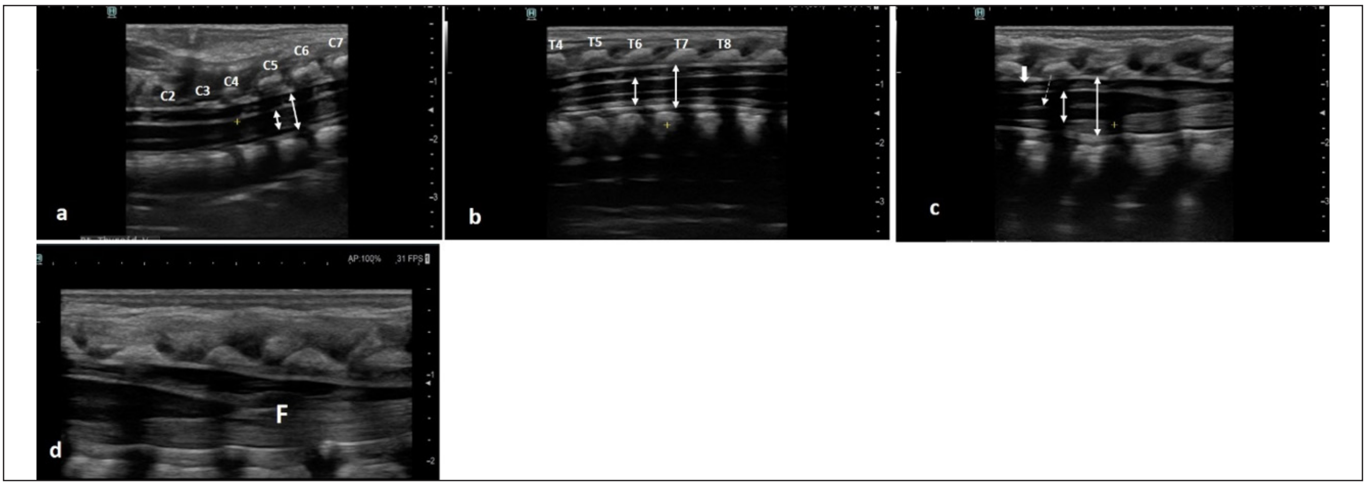


Figure 2. In a one-year-old newborn, median longitudinal scan of a.) the cervical region showing spinal cord (short line) and the spinal canal (long line). Cervical vertebrae are seen as echogenic foci. The cervical anterior-posterior diameter of the spinal cord and canal is measured at C5 and C6 levels. b.) On sagittal image of the thoracic spine, the spinal cord (short line) and spinal canal (long line) diameters measured at T6 and T7 levels. Spinous processes of the thoracal vertebrae are seen in as echogenic foci. c.) on lumbosacral level, central echogenic complex is seen (thin arrow), the lumbar enlargement (short line) and spinal canal (long line) whicch is below the the lumbar enlargement level is demonsrated. Subarachnoid space is also seen (thick arrow). d.) Median longitudinal scan of the lumbosacral region demonstrating the filum terminale (F) and the medullary cone

A Pearson product-moment correlation was run to determine the relationship between the AP diameter of spinal cord and canal at each vertebral level and head circumference, weight, and height, and results were given in **Table 2**. There was a positive correlation between spinal cord AP diameter and head circumference at thoracic level, which was statistically significant (r=0.144, p=0.049). There was a positive correlation between spinal canal diameter and height at thoracic level, which was statistically significant (r=0.225, p=0.002). There was a positive correlation between spinal canal diameter and weight at lumbar level, which was statistically significant (r=0.151, p=0.038). No statistically significant correlation was found between the other relationships (**Table 2**).

Table 2. Correlation of the AP diameter of spinal cord and canal for all cohorts at the cervical, thoracic and lumbar levels

	Head circumference (cm)	Weight (gr)	Height (cm)
All newborns (n=188)			
Spinal cord AP diameter			
Cervical	0.032 (.659)	–0.053 (.474)	–0.003 (.973)
Thoracic	0.144 (.049)	0.121 (.097)	0.042 (.565)
Lumbar	0.024 (.744)	0.043 (.556)	0.046 (.528)
Spinal canal diameter			
Cervical	–0.026 (.720)	0.064 (.380)	0.038 (.608)
Thoracic	0.092 (.207)	0.122 (.096)	0.225 (.002)
Lumbar	0.057 (.435)	0.151 (.038)	0.073 (.320)
Males (n=89)			
Spinal cord AP diameter			
Cervical	0.069 (.520)	–0.048 (.654)	–0.027 (.800)
Thoracic	0.163 (.126)	0.146 (.171)	–0.003 (.981)
Lumbar	0.120 (.264)	0.032 (.764)	0.007 (.945)
Spinal canal diameter			
Cervical	–0.024 (.824)	–0.005 (.960)	–0.035 (.747)
Thoracic	0.168 (.116)	0.174 (.104)	0.194 (.069)
Lumbar	0.165 (.121)	0.237 (.025)	0.058 (.590)
Females (n=99)			
Spinal cord AP diameter			
Cervical	–0.015 (.882)	–0.060 (.553)	0.029 (.773)
Thoracic	0.122 (.230)	0.090 (.374)	0.087 (.390)
Lumbar	–0.063 (.536)	0.056 (.585)	0.087 (.394)
Spinal canal diameter			
Cervical	–0.029 (.778)	0.151 (.135)	0.119 (.241)
Thoracic	0.023 (.823)	0.065 (.520)	0.254 (.011)
Lumbar	–0.056 (.582)	0.059 (.563)	0.072 (.477)

Values were presented as Pearson correlation coefficients (p-value). Bold values denote that statistically significant difference.

DISCUSSION

Spinal cord injury is mostly seen in small children in the pediatric population, however overall frequency is very rare in very young children. Young children are more prone to traumas in terms of the spinal injury because of less muscle development and increased head-body proportion in the head direction (4). Radiological evaluation of young children for spinal cord injury may be difficult due to undesirable radiation exposure and lack of experience. The incidence of pediatric spine injuries has been reported as 2% to 5% of all spine injuries (5). Although spinal cord injuries in the pediatric population are very rare, the situation leads to quite morbidity and mortality (6). Trauma, serious falls, sports injuries, or child abuse are among the known causes of spinal cord injury, and edema or hemorrhage that expands the ap diameter of cord can be seen in these patients. Launey et al. (7). reported in a metaanalyse that nearly 44% of the patients diagnosed with spinal cord injuries can not improve and continue to suffer from morbidity of injury. Cord injury, which is a rare but serious condition especially in young children, is often overlooked (8). Most studies in the literature on spinal injury in the pediatric population have not specifically examined newborns (6,9).

There is no widely accepted nomogram for the AP diameters of the spinal cord and canal in the newborn so far. No morphometric measurement is required to detect pathologies such as congenital malformations, such as myelomeningocele, lipoma, dermal sinus, tight filum terminale syndrome, diastematomyelia or syringomyelia. However, it may be difficult to accurately detect pathologies that cause swelling and do not cause significant echo difference in the cord, such as acquired intraspinal diseases, following birth trauma, or after lumbar puncture, without knowing the normal diameter values of the spinal cord (10). Also, for radiologists with little experience in spinal US, since they are not familiar with such rare conditions that may cause edema in the spinal cord, establishing normal and abnormal diameter values will facilitate the detection of this type of pathologies. In a recent study, Singh et al. (3) reported that the mean AP spinal cord diameter was 4.1±0.5 mm at the cervical level, 3.3±0.3 mm at the thoracic level and 4.4±0.6mm at the lumbar level. The mean AP spinal canal diameter was 7.7±0.7mm at the cervical level, 6.2±0.8mmat the thoracic level, and 8.4±0.7 mm at the lumbar level. In our study, we found that the mean spinal cord AP diameter for all newborns at the cervical, thoracic and lumbar levels were 4.81±0.41, 3.85±0.36 and 5.00±0.31 (mean±standard deviation in milimeters), respectively. The mean spinal canal AP diameter for all newborns at the cervical, thoracic and lumbar levels were 7.80±0.86, 7.43±0.75, 9.13±0.82 (mean±standard deviation in milimeters) respectively. The mean AP spinal cord diameters found in our study were similar to those of Singh et al (3). However we found the mean AP spinal canal diameters slightly larger. This may be secondary to our study has larger-scaled (188 newborns) compared to recent study (37 newborns), another reason may be difference of the nationality and race of this newborns.

The mean AP spinal cord diameters are ranged between 4,40-5,32 mm at different levels in normal and healthy newborns included in our study. And at the level of the lumbar enlargement which is the most prominent and largest level, the mean AP spinal cord diameters are 5.00±0.31 mm. Outside of these ranges may be considered abnormal. To elucidate this issue and determine normal range of the spinal cord and canal diameter; there is a need for larger-scaled, prospective studies examining abnormal values in infants with spinal cord injury and edema, especially in trauma centers. We also found a positive correlation between spinal cord AP diameter and head circumference at thoracic level.

Computed tomography enables excellent view of the bone structure but it cause ionizing radiation and can not reveal properly the soft tissue changes. MRI is the most preferred method in the evaluation of the spinal canal and cord, and US is less frequently preferred in outpatients clinics (11). MRI, on the other hand, is a expensive, is not available in every center and requires sedation for the newborn age group. Unfortunately, neonatal neurosonography is seen as just a basic first line imaging modality that shows only orienting information and does not reveal so much detailed information (12). The most important reason for this perception is poor quality US examinations, since there is a lack of specialized expertise in the field of neurosonography. US for the spinal cord and canal is a little-known issue that has not been emphasized much in radiology practice, and there are almost a few studies in the literature that reveal normal reference values (12). Horst et al. (13) reported that pediatric neurosongraphy results shown great variability and standardization of reporting may reduce such a huge interobserver variability. Due to the lack of a standard examination scheme, many studies on spinal cord injury in neonates have been done with MRI or CT (14,15).

We think that radiologists with limited knowledge and practice in neurosonography would not overlook rare pathologies such as post-traumatic cord edema or congenital stenosis if they knew normal references of spinal cord and canal. Thus, this paper will encourage the radiologist the more effective way while performing spinal US and highlight the value and potential of US.

Our study has several limitations. First we had relatively small sample size. And examinations were only performed by a radiologist, interobserver variability was not investigated. Only healthy newborns included the study which are normal on physical examination and has no symptoms. MRI of the newborns was not seen, which is superior to US in terms of detecting spinal pathologies. The race of the newborns were not investigated, there is a possibility the AP diameters may be change with the ethnicity.

CONLUSION

Paediatric and particularly neonatal neurosonography is still the cornerstone of the neonatal imaging. The normal reference ranges of the spinal canal and cord diameter at different levels in newborns are still remain unknown and there are only few studies on this subject. Revealing abnormal values will provide convenience in difficult-to-diagnose situations such as spinal cord edema that does not cause a pronounced echo and mass effect on the cord. We also think that determining the lower limit values for the cord will increase the role and contribution of US in the visualization of the spinal cord and canal stenosis.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was carried out with the permission of Başakşehir Çam and Sakura City Hospital Clinical Researches Ethics Committee (Date: 30.06.2021, Decision No: 2021.06.133).

Informed Consent: All patients signed the free and informed consent form.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

Author Contributions: All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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