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The Role of B-mode Ultrasonography in the Anatomical Evaluation of the Cervical Region of the Spine in Adolescents

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Abstract

Objective: Ultrasonographic evaluation of the anatomy of the intervertebral discs, vertebral canal of the cervical spine in practically healthy adolescents.

Materials and methods: The study included 72 healthy children with normal neurologic status, 35 of them aged 13-15 years, 37-16-18 years old. Ultrasonography (USG) was performed at the level of disks C_2-C_3, C_3-C_4, C_4-C_5, C_5-C_6, C_6-C_7, C_7-Th_1 in longitudinal and transverse projections. In the longitudinal projection, the height of the intervertebral discs (IVD) and vertebral bodies (V), their ratio (IVD/V), and in the transverse projection - the sagittal size of the IVD, the spinal canal (SC), their sagittal size ratio IVD/SC, the width of spinal nerve canals (NC), the yellow ligament thickness, the sagittal size of the anterior dural space (ADS), their ratio of the ADS and SC (ADS/SC). In addition to the quantitative parameters of the IVD and SC, the echo structure of the nucleus pulpous (NP) and fibrous ring (FR) was also studied.

Results: The highest sagittal size IVD and SC in the age groups 13-15 (15.6 ± 0.8 mm and 16.4 ± 0.9 mm) and 16-18 years (16.9 ± 0.7 mm and 17.3 ± 0.8 mm) was recorded at the level of C_2-C_3. Only in the age group 16-18 years were no significant differences ($p<0.05$) compared with the level of C_7-Th_1 (17.3 ± 0.8 mm in front of 15.2 ± 0.7 mm). In both age groups, the height of the IVD was also the highest at C_2-C_3 (4.2 ± 0.23 mm and 4.5 ± 0.37 mm), but no significant differences compared with the levels of C_2-C_3 and C_7-Th_1 has not been revealed.

SC area was calculated from the linear dimensions and on the perimeter. At the level of C_2-C_3 in 13-15 years, these figures were 188 ± 11 mm^2 and 287 ± 14 mm^2, aged 16-18 years - and 195 ± 12 mm^2 312 ± 14 mm^2. At the level of C7-Th1 these figures were 152 ± 8 mm^2 ($p<0.05$), 158 ± 7 mm^2 ($p<0.01$), 236 ± 12 mm^2 ($p<0.001$), 248 ± 9 mm^2 ($p<0.001$).

The thickness of the yellow ligament (YL (TAR-reject) increases from top to bottom, it was the highest level of C_6-C_7 in the age group 16-18 years and was 2.8 ± 0.24 mm significantly ($p<0.05$) higher than at the level of C_2 C_3 (2.1 ± 0.15 mm).

Sagittal size anterior dural space (ADS) in all children at all levels of IVD profit lower than the rear PDS index ADS/PDS was lowest at C_4-C_5 and was 0.82 ± 0.03.

Conclusion: In adolescents, the sagittal size of the intervertebral disc and spinal canal, the height of the IVD, the frontal size, the area of the SC, the width of the spinal nerve canals, the dural spaces have the largest value at the C_2-C_3 level, the smallest at the C_6-C_7 and C_7-Th_1 levels. The smallest ratio of IVD/SC is observed at the level of C_2-C_3. The maximum thickness of the yellow ligament is recorded at the level of C_6-C_7, the smallest sagittal dimension of the anterior dural space is determined at the level of C_6-C_7 and C_7-Th_1.

Keywords: Spinal; Ultrasonography; Intervertebral discs; Nerve canals

Introduction

Movement in each segment of the spinal column is provided by intervertebral discs, intervertebral joints and ligaments. An intervertebral disc lies between adjacent vertebrae and each disc forms a fibrocartilaginous joint (a symphysis). Intervertebral discs (IVD) in the spine act as shock absorbers. IVD consist of an outer fibrous ring – annulus fibrosis (AF), which surrounds an inner gel-like center, the nucleus pulposus (NP). The AF consists of several layers (laminae) of fibrocartilage made up of both type I and type II collagen. Type I is concentrated towards the edge of the ring where it provides greater strength. The stiff laminae can withstand compressive forces. The fibrous IVD contains the NP and this helps to distribute pressure evenly across the disc. This prevents the development of stress concentrations which could cause damage to the underlying vertebrae or to their endplates. The NP contains loose fibers suspended in a mucoprotein gel. The nucleus of the disc acts as a shock absorber, absorbing the impact of the body's activities and keeping the two vertebrae separated. It is the remnant of the notochord [1].

There is one disc between each pair of vertebrae, except for the first cervical segment, the atlas. The atlas is a ring around the roughly cone-shaped extension of the axis (second cervical segment). The axis acts as a post around which the atlas can rotate, allowing the neck to swivel. There are 6 discs in the neck (cervical region).

During development and at birth, vertebral discs have some vascular supply to the cartilage endplates and the annulus fibrosis. These quickly deteriorate leaving almost no direct blood supply in healthy adults [2].

According to various data, the prevalence of neck pain among adolescents varies from 5% to 72% and tends to increase. It should be noted that for a long time many authors believed that the emergence of cervical pain syndrome is possible only in persons of mature and advanced age. In the latter, there is an increase in the number of children with complaints of discomfort in the cervical spine, headaches and dizziness, which neurologists and pediatricians are regarded as a manifestation of vegetative-vascular dystonia. However, these complaints can be caused by functional and organic changes, bone and soft tissue structures of the cervical spine [3].

Before age 40 approximately 25% of people show evidence of disc degeneration at one or more levels. Beyond age 40, more than 60% of people show evidence of disc degeneration at one or more levels on magnetic resonance imaging [4]. It is important to study clinically, as intervertebral discs degenerate sooner than any other connective tissue, often leading to back pain [5].

Among the diseases of the spine, the leading place is occupied by degenerative processes and intervertebral discs (IVD), which begin already in childhood and are a frequent cause of cervical and headaches. In the early stages of the development of the disease, clinical signs may either be absent or be barely noticeable for diagnosis.

In children, the discs are about 85% water. The discs begin to naturally lose hydration during the aging process. As the disc loses hydration, it offers less cushioning and becomes more prone to cracks and tears [6].

Studies show that a plurality of adults have no symptoms related to degenerative disc disease, even though a high percentage of these adults still shows signs of disc degeneration on an MRI somewhere on the spine. One study found that about half of people start showing some signs of disc degeneration on an MRI by their early 20s [7]. When degenerative disc disease develops in the cervical spine, it can occur in any of the cervical discs but is slightly more likely to occur at the C_5-C_6 level [8].

Traditional plain X-rays does not allow visualizing intervertebral discs, ligamentous apparatus of the spinal column. Currently, magnetic resonance imaging (MRI) is the main method of visualization of intervertebral discs, ligamentous apparatus, spinal cord [9].

In recent years, ultrasonography in the B-mode has been used to evaluate these structures [10,11]. In previous studies, the normative parameters of the lumbar spine column in older children are presented [12]. Development of normal ultrasound semiotics of the cervical spinal column in adolescents is an actual task.

Objective

Ultrasonographic evaluation of the anatomy of the intervertebral discs, vertebral canal of the cervical spine in practically healthy adolescents.

Materials

The study included 72 healthy children with normal neurologic status, 35 of them aged 13-15 years, 37 of them aged 16-18 years old. Ultrasonography (USG) was performed at the level of disks C_2-C_3, C_3-C_4, C_4-C_5, C_5-C_6, C_6-C_7, C_7-Th_1 in longitudinal and transverse projections. In the longitudinal projection, the height of the intervertebral discs (IVD) and vertebral bodies (V), their ratio (IVD/V), and in the transverse projection - the sagittal size of the IVD, the spinal canal (SC), their sagittal size ratio IVD/SC, the width of spinal nerve canals (NC), the yellow ligament thickness, the sagittal size of the anterior dural space (ADS), their ratio of the ADS and SC (ADS/SC). In addition to the quantitative parameters of the IVD and SC, the echo structure of the nucleus pulpous (NP) and fibrous ring (FR) was also studied (Figures 1-5).

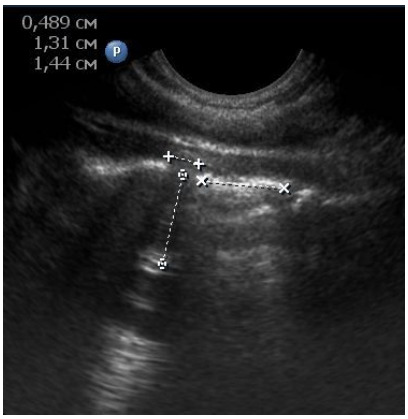

Figure 1: Sagittal section of the spinal motion segment at the level of C_3-C_4. As can be seen on the echogram, the height of the intervertebral disc – 0.489 cm, of the body C_4 -1.31 cm, the anteroposterior size of the disk – 1.44 cm.

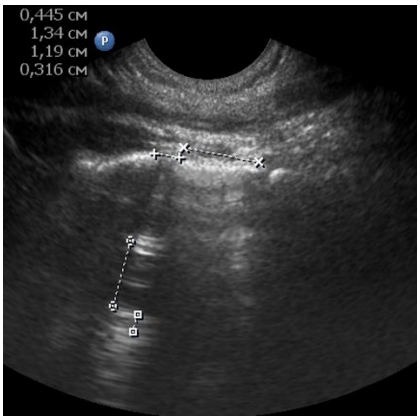

Figure 2: Sagittal section of the spinal motion segment at the level of C_4-C_5. As can be seen on the echogram, the height of the intervertebral disc – 0.445 cm, of the body C_4 -1.34 cm, the anteroposterior size of the spinal cord – 1.19 mm, the thickness of the yellow ligament – 0.316 cm.

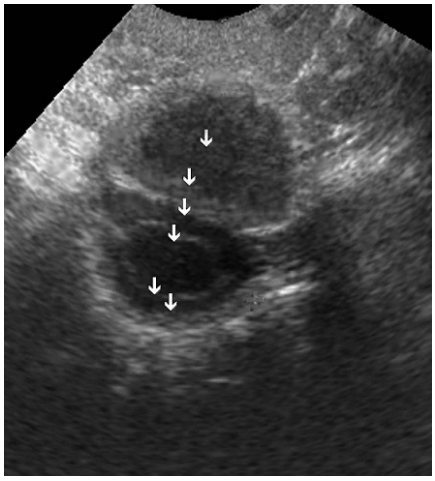

Figure 3: Axial section of the IVD and SC. Top-down arrows show the nucleus pulposus, fibrous ring, anterior dural space, spinal cord, posterior dural space, yellow bundle.

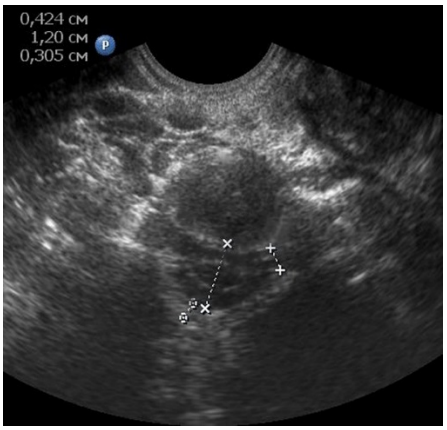

Figure 4: Axial section of the IVD and SC at the level C_6-Th_7. The anterior-posterior spinal nerve canal size – 0.424 cm, spinal cord size – 1.2 cm, the thickness of the yellow ligament – 0.305 cm.

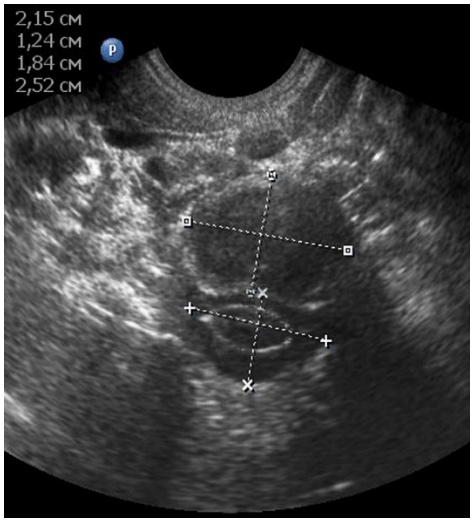

Figure 5: Axial section of the IVD and SC at the level C_5-C_6. Determination of the IVD and SC sizes. The area of the SC by linear dimensions is 1.33 cm^2.

Results

The sagittal size of the C_2-C_3 disc in children aged 13-15 years averaged 15.6 ± 0.8 mm, C_3-C_4 15.1 ± 0.8 mm, C_4-C_5 14.6 ± 0.7 mm, C_5-C_6 – 14.5 ± 0.7 mm, C_6-C_7 – 14.7 ± 0.8 mm, C_7-Th_1- 14.5 ± 0.7 mm, respectively. At the age of 16-18 years, these parameters were 16.4 ± 0.9 mm, 15.9 ± 0.8 mm, 15.4 ± 0.8, 15.3 ± 0.7 mm, 14.9 ± 0.6 mm and 15.1 ± 0.6 mm respectively. There were no significant differences between them (Table 1).

Parameters	Age	The intervertebral disc levels					
		1	2	3	4	5	6
		C2-C3	C3-C4	C4-C5	C5-C6	C6-C7	C7-Th1
Sagittal size	13-15	15.6 ± 0.8	15.1 ± 0.8	14.6 ± 0.7	14.5 ± 0.7	14.7 ± 0.8	14.5 ± 0.7
IVD. mm	16-18	16.4 ± 0.9	15.9 ± 0.8	15.4 ± 0.8	15.3 ± 0.7	14.9 ± 0.6	15.1 ± 0.6
Sagittal size	13-15	16.9 ± 0.7	15.7 ± 0.8	14.9 ± 0.7	14.8 ± 0.7	14.6 ± 0.8	14.8 ± 0.6
SC. mm	16-18	17.3 ± 0.8 P1-5<0.05	16.8 ± 0.7	15.3 ± 0.8	15.4 ± 0.7	15.1 ± 0.6	15.2 ± 0.7
The yellow ligament thickness	13-15	1.9 ± 0.12	2.1 ± 0.13	2.3 ± 0.15	2.5 ± 0.14	2.4 ± 0.19	2.4 ± 0.17

Tyl. mm	16-18	2.1 ± 0.15	2.3 ± 0.14	2.5 ± 0.16	2.4 ± 0.17	2.8 ± 0.24 P5-1<0.05	2.6 ± 0.21
Sagittal size ratio	13-15	0.92 ± 0.03	0.96 ± 0.03	0.98 ± 0.03	0.98 ± 0.03	0.99 ± 0.03	0.98 ± 0.03
IVD/SC	16-18	0.95 ± 0.03	0.95 ± 0.02	1.01 ± 0.04	0.99 ± 0.03	0.99 ± 0.03	0.99 ± 0.03
The height	13-15	4.2 ± 0.23	4.1 ± 0.27	4.3 ± 0.21	4.2 ± 0.25	3.9 ± 0.21	3.7 ± 0.35
IVD. mm	16-18	4.5 ± 0.37	4.3 ± 0.31	4.2 ± 0.28	3.9 ± 0.26	3.7 ± 0.25	3.6 ± 0.27 P1-6<0.05
The width	13-15	22.3 ± 1.0	20.9 ± 0.9	21.3 ± 0.8	21.1 ± 0.9	20.4 ± 0.9	20.5 ± 0.8
SC. mm	16-18	22.6 ± 1.1	22.1 ± 1.2	21.7 ± 1.1	21.4 ± 1.0	21.1 ± 0.8	20.7 ± 0.9

Table 1: Ultrasound parameters of IVD and SC of the cervical region in healthy adolescents.

Sagittal size of the SC among children aged 13-15 years at the level of C_2-C_3 averaged 16.9 ± 0.7 mm, C_3-C_4 15.7 ± 0.8 mm, C_4-C_5 14.9 ± 0.7 mm, C_5-C_6- 14.8 ± 0.7 mm, C_6-C_7- 14.6 ± 0.8 mm, C_7-Th_1 – 14.6 ± 0.8 mm, respectively. At the age of 16-18 years, these parameters were 17.3 ± 0.8 mm, 16.8 ± 0.7 mm, 15.3 ± 0.8 mm, 15.4 ± 0.7 mm, 15.1 ± 0.6 mm and 15.2 ± 0.7 mm, respectively. As can be seen, from the table the greatest sagittal size of the SC in both age groups was observed at the level of C_2-C_3 (16.9 ± 0.7 mm and 17.3 ± 0.8 mm respectively), and the smallest - at the level of C_6-C_7 (14.6 ± 0.8 mm and 15.1 ± 0.6 mm respectively). A significant difference ($p<0.05$) was found among children in the 16-18 age group (17.3 ± 0.8 mm and 15.1 ± 0.6 mm respectively).

We calculated the IVD/SC ratio, the average value of which for children aged 13-15 years was: C_2-C_3 0.92 ± 0.03; C_3-C_4 – 0.96 ± 0.03; C_4-C_5 – 0.98 ± 0.03; C_5-C_6 – 0.98 ± 0.03; C_6-C_7 – 0.99 ± 0.03 и C_7-Th_1 – 0.98 ± 0.03; and at the age of 16-18 years – 0.95 ± 0.03; 0.95 ± 0.02; 1.01 ± 0.04; 0.99 ± 0.03; 0.99 ± 0.03 and 0.99 ± 0.03, respectively. As can be seen, the smallest IVD/SC index occurred in children in the age group of 13-15 years at the C_2-C_3 level, and the largest in children aged 16-18 years at C_4-C_5 level, however, significant differences between the indicators, both by age, and on the level of the disk was not noted.

It is known that traditional radiography does not allow visualization of soft-tissue structures, so the sagittal size of the spinal canal can be more than X-ray by 3-5 mm, than with ultrasound examination, since the thickness of the yellow and posterior longitudinal ligament is not taken into account [9]. If in the lumbar region the largest area of the PC is recorded at the level of L5-S1, then in the cervical region at the level of the overlying disc is C_2-C_3 [12].

The parameters of the width of the spinal nerve canals, sagittal size of the anterior dural space (ADS), the ratio of ADS/SC are presented in Table 2.

US parameters	**Age**	**The intervertebral disc levels**					
		1	**2**	**3**	**4**	**5**	**6**
		C2-C3	**C3-C4**	**C4-C5**	**C5-C6**	**C6-C7**	**C7-Th1**
The width of spinal nerve canals. mm	13-15	4.6 ± 0.21 P1-6<0.05	4.2 ± 0.25	4.3 ± 0.31	3.9 ± 0.26	3.8 ± 0.23	3.5 ± 0.25
	16-18	4.7 ± 0.29 P1-6<0.05	4.5 ± 0.24	4.6 ± 0.32	4.2 ± 0.27	3.9 ± 0.28	3.6 ± 0.34
Anter-dural space	13-15	4.1 ± 0.29	3.7 ± 0.28	3.6 ± 0.31	3.6 ± 0.27	3.6 ± 0.26	3.4 ± 0.23
ADS. mm	16-18	4.3 ± 0.31	3.9 ± 0.29	3.7 ± 0.24	3.8 ± 0.28	3.6 ± 0.29	3.7 ± 0.21
Poster dural space	13-15	4.6 ± 0.34	4.3 ± 0.31	4.2 ± 0.23	4.3 ± 0.31	4.2 ± 0.31	4.1 ± 0.21
PDS. mm	16-18	4.9 ± 0.28	4.6 ± 0.32	4.5 ± 0.21	4.6 ± 0.29	4.3 ± 0.27	4.4 ± 0.21
ADS/ SC	13-15	0.24 ± 0.02	0.24 ± 0.02	0.24 ± 0.02	0.24 ± 0.03	0.25 ± 0.03	0.23 ± 0.03
	16-18	0.25 ± 0.03	0.23 ± 0.03	0.24 ± 0.02	0.25 ± 0.03	0.24 ± 0.03	0.24 ± 0.03

Table 2: Ultrasound parameters of IVD and SC of the cervical region in healthy adolescents.

As can be seen from the table in both age groups, the greatest width of spinal nerve canals, the ADS sagittal size took place at the level of C_2-C_3. The lowest value of these parameters was recorded at the level of C_6-C_7 and C_7-Th_1. The ratio of ADS/SC at all levels of IVD in both age groups varied within a narrow range - from 0.23 ± 0.03 to 0.25 ± 0.03. A significant difference ($p<0.05$) was noted only between the parameters of the width of the spinal canal nerves.

We measured the thickness of the yellow ligament (YL) covering the posterior and posterolateral inner surface of the spinal canal. In the age group of 13-15 years, the smallest amount of YL thickness was

observed at the level of C_2-C_3 (1.9 ± 0.12 mm), the largest - at the level of C_7-Th_1 - 2.4 ± 0.17 mm, and in the age group of 16-18 years the thickness of the YL was the greatest at the level of C_6-C_7 (2.8 ± 0.24 mm), and it was also significantly ($p<0.05$) higher than the level of C_2-C_3 (2.1 ± 0 15 mm).

The IVD height was measured in the sagittal projection on its anterior section. In both age groups, the value of the largest indicator was at the level of C_2-C_3 (4.2 ± 0.23 mm and 4.5 ± 0.37 mm), the smallest - at the level of C_7-Th_1 (4.5 ± 0.37 mm and 3.6 ± 0.27 mm, P_1-6<0.05).

Frontal size of the spinal canal in children aged 13-15 years was the greatest at the level of C_2-C_3 (22.3 ± 1.0 mm), the smallest - at the level of C_6-C_7 (20.4 ± 0.9 mm), in. The age group of 16-18 years, this figure at the level of C_2-C_3 was 22.6 ± 1.1 mm, the smallest was at the level of C_7-Th_1 (20.7 ± 0.9 mm).

In addition to the quantitative parameters of the vertebral-motor segment, we also studied qualitative parameters – the echogenicity of the nucleus pulpous (NP), the presence of NP displacement toward the posterior contour of the fibrous ring (FR), and the deformation of the anterior dural space (ADS).

Among children aged 13-15 years, the structure of the NP in 41 (61.1%) of cases was homogeneous, in 26 (38.9%) - a small heterogeneity appeared, at 16-18 years homogeneity was noted in 32 (47.8%), a small heterogeneity - 36 (53.7%) cases, in 21 (31.3%) cases it was noted its insignificant displacement back to the side of FR. In all cases, the fibrous ring had clear, even contours. The contours of the dural space in the median and paramedian zones were parallel. The posterior contour of the fibrous ring at the level of C_2-C_3 - C_4-C_5 is slightly concave, at the level of C_5-C_6 and C_6-C_7 - more even.

Discussion

It is known that in the development of degenerative changes in cartilaginous structures, in particular in the intervertebral discs, the role of trauma, dysplasia, frequent hypothermia, instability of the vertebrae, etc. play a role. Given that degenerative changes in intervertebral discs begin as early as adolescence, it was interesting to study the quantitative and qualitative parameters of the discs and the spinal canal. Among all imaging techniques, ultrasonography is the cheapest, safe. It should be noted that the absolute values of the linear dimensions of the disc, vertebral canal, dural space, of the spinal nerves canal depend on the constitutional features of the children, as well as the level of the neck being examined. During the study, it was found that the following parameters can have important clinical significance that the ratio of the sagittal size of the disc and the spinal canal (IVD/SC), the width of the anterior dural space and of the spinal nerve canal. For example, an increase in the IVD/SC index, a decrease in the width of the anterior dural space and the spinal nerve canal may indicate an increase in the area and deformation of the disc. The results of the studies show that the index IVD/SC from C_2-C_3 to C_7-Th_1 increases from 0.92 ± 0.03 to 0.98 ± 0.03 in children aged 13-15 years and from 0.95 ± 0.03 to 0.99 ± 0.03 at the age of 16-18 years. The greatest sagittal size of SC was observed at the level of C_2-C_3 in children aged 16-18 years, the average value was 17.3 ± 0.8 mm.

Magnetic resonance imaging is the most accurate method for diagnosing the different stages of osteochondrosis in adults and children [13]. When using high-frequency micro convex transducer, the echographic image of intervertebral discs and the spinal canal is not inferior in quality to magnetic resonance imaging (Figures 6 and 7).

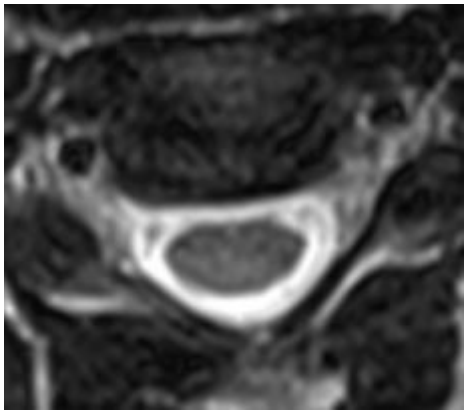

Figure 6: MRI axial view of the cervical IVD and SC at the level C_4-C_5.

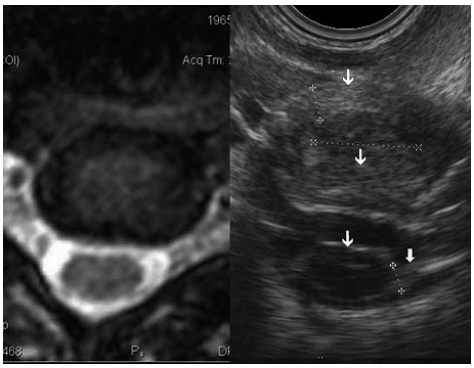

Figure 7: As can be seen, the details of the intervertebral disc and vertebral canal on the ultrasonogram are seen no worse than on MRI.

With ultrasound, patients do not receive radiation exposure. This indicates a great opportunity for echography, especially in pediatrics and use it as a screening study.

Conclusion

In adolescents, the sagittal size of the intervertebral disc and spinal canal, the height of the IVD, the frontal size, the area of the SC, the width of the spinal nerve canals, the dural spaces have the largest value at the C_2-C_3 level, the smallest at the C_6-C_7 and C_7-Th_1 levels. The smallest ratio of IVD/SC is observed at the level of C_2-C_3. The maximum thickness of the yellow ligament is recorded at the level of C_6-C_7, the smallest sagittal dimension of the anterior dural space is determined at the level of C_6-C_7 and C_7-Th_1.

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