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Research Article

The Role of B-mode Ultrasonography in the Anatomical Evaluation of the Lumbar Intervertebral Discs in Adolescents

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Received: December 19, 2017; **Published:** February 23, 2018

Abstract

The presence of degenerative changes in intervertebral discs among adults is well known, but they also appear in adolescents. It is called juvenile disc disorder, or juvenile discogenic disorder, this disease usually leads to pain in the lower back. Traditional plain X-rays does not allow visualizing intervertebral discs, ligamentous apparatus of the spinal column. Currently, magnetic resonance imaging (MRI) is the standard method of visualization of Soft tissue in the spine, which include intervertebral discs, ligamentous apparatus, spinal cord. This method is the expensive. Considering the lower costs, accessibility, high resolution and real-time imaging, the ultrasonography can be the relevant alternative for screening.

Objective: The aim of the study was to evaluate the possibilities of ultrasonography in evaluation of the anatomy of the intervertebral discs, lumbar spine canal in practically healthy adolescents.

Material and Methods: The study included 93 healthy children with normal neurologic status, of which 31 at the age of 13 - 14 years, 33 - at the age of 15 - 16 years and 29 - at the age of 17 - 18 years old. Ultrasonography (USG) was performed at the level of disks L1 to S1, in longitudinal and transverse projections. In the longitudinal projection, the height of the intervertebral discs (IVD) and vertebral bodies (VB), 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 echo structure of the nucleus pulpous (NP) and fibrous ring (FR) was studied.

Results: The height of the discs in the examined children ranged from 9 to 11 mm, the vertebral bodies - from 24 to 34 mm, the index IVD / VB - from 0.29 to 0.39, respectively. The sagittal size of the SC for all levels varied from 16.7 to 20.3 mm, the frontal size from 19.6 to 23.8 mm, respectively. There were no statistically significant differences between these parameters, depending on the age of the children. The area of the SC among children aged 13 - 14 years was 190,5 ± 8,4 mm^2, in the age of 15 - 16 - 197,5 ± 9,2 mm^2, in the age of 17 - 18 years - 211,5 ± 9,7 mm^2 respectively. A significant difference ($p < 0.05$) was obtained by comparing the area of the SC between the children aged 13 - 14 and 17 - 18 years. The thickness of the yellow ligament varied from 2.0 to 3.0 mm, the width of the channels of the spinal nerve - from 8.4 to 9.7 mm, respectively. The ratio of sagittal size of SC and IVD (SC/IVD) was greatest in children aged 13 - 14 years and was 0,65 ± 0,03; the lowest - among children aged 17 - 18 years (0,56 ± 0,02). In each age group and in terms of the IVD level, the magnitude of this level decreased unreliably. In children aged 13 - 14 years, the structure of the NP was uniform, at 15 - 16 years - in half the cases, the echogenicity increased slightly, at 17 - 18 years, in 30 - 40% of cases, its posterior shift was noted. In all cases, the fibrous ring had clear, even contours. In children aged 13 - 14 years, the structure of the NP was uniform, at 15 - 16 years - in half the cases, the echogenicity increased slightly, at 17 - 40 years, in 30 - 40% of cases, its posterior shift was noted. In all cases, the fibrous ring had clear, even contours. Its rear contour at the level L1-L2 - L3-L4 is slightly concave, at level L4-L5 and L5-S1 even.

Conclusion: In children from the age of 13 to 18, the sagittal size of the lumbar intervertebral discs, spinal canal, the width of spinal nerve canal, the thickness of the yellow ligament, the area of the vertebral canal increases ($P < 0.05$) and the SC/IVD index decreases ($P < 0,05$). In this age period, the echostructure of the pulpous nucleus changes insignificantly, in the form of an increase in echogenicity and in a few cases its displacement toward the fibrous ring. However, there is no change in the fibrous ring.

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. The lumbar spine allows for flexion, extension, and lateral bending. White and Panjabi investigated the Range of Motion at each spine level and report that the ROMs of flexion and extension are greater in the cervical and lumbar regions; meanwhile, the Range of Motions of lateral bending are not significantly different among regions, and those for rotation are limited in cervical and lumbar regions [1]. 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 - anulus 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 [2].

The cells from the disc are subject to senescence and lose their ability to proliferate [3,4]. 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 [5]. 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 [6]. Disc degeneration is not a problem most people associate with adolescents and young adults, but it can develop at a young year. It is called juvenile disc disorder, or juvenile discogenic disorder, this disease usually leads to pain in the lower back. The disorder generally affects young people in their late teens to early 30s. Some patients manifest degenerative disc disease symptoms in their teen years. Sometimes an injury is to blame, but the medical community is divided about other causes. Some physicians/orthopedic/spine surgeons believe a genetic disposition to disc degeneration is a major factor. Others cite wear and tear on the body as the main cause. It is important to study clinically, as intervertebral discs degenerate sooner than any other connective tissue, often leading to back pain [7,8].

Traditional plain X-rays does not allow visualizing intervertebral discs, ligamentous apparatus of the spinal column. Currently, magnetic resonance imaging (MRI) is the standard method of visualization of soft tissue in the spine, which include intervertebral discs, ligamentous apparatus, spinal cord. Decrease in disc height, loss of T2-weighted signal inside the disc and its protrusion are the main MRI findings in a degenerative disease [9]. Considering the lower costs, accessibility, high resolution and real-time imaging, the ultrasonography can be the relevant alternative for screening. In recent years, ultrasonography in the B-mode has been used to evaluate these structures [10]. Development of normal ultrasound semiotics of the lumbar spinal column in adolescents is an actual task. The presented literature data demonstrate the need to study the possibilities of ultrasonography in assessing the anatomy of the intervertebral discs, the vertebral canal of the lumbar spine in practically healthy adolescents.

Objective

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

Material and Methods

The study was conducted in the 12th children's polyclinic in Kharkov (Ukraine). Children were referred by a pediatrician or pediatric orthopedist from among the draftees to assess health, in order to assess whether they can serve in the Army. The consent for the study was obtained from the children, as well as from their parents.

The study included 93 healthy children with normal neurologic status, of which 31 at the age of 13 - 14 years, 33 - at the age of 15 - 16 years and 29 - at the age of 17 - 18 years old. Ultrasonography (USG) was performed at the level of disks L1-L2, L2-L3, L3-L4, L4-L5, L5-S1, 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 SC/IVD, the width of spinal nerve canals (NC), the yellow ligament thickness. 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. Ultrasonography (USG) was conducted on a Philips HD 11XE device using a convection transducer in the frequency range 2 - 5 MHz.

Results

The quantitative parameters of intervertebral discs, vertebral bodies, vertebral canal, their ratios are presented in table 1. The height of intervertebral discs among children aged 13 - 14 years at the level of L1-L2 was 9,2 ± 0,28 mm, at the level of L5-S1 - 10,1 ± 0,37 mm (average 9,7 ± 0,32 mm). At the age of 15 - 16 years it was 9,7 ± 0,36 mm and 10,5 ± 0,41 mm (average 10,1 ± 0,37 mm), and at 17 - 18 years it was 9,1 ± 0,42 mm and 10,4 ± 0,35 mm (average 9,8 ± 0,38 mm) respectively.

Parameters	Age	The level of the IVD				
		L1-L2	L2-L3	L3-L4	L4-L5	L5-S1
The height of the IVD, mm (HIVD)	13 - 14	9,2 ± 0,28	9,3 ± 0,32	9,6 ± 0,31	9,8 ± 0,35	10,1 ± 0,37
	15 - 16	9,7 ± 0,36	9,8 ± 0,31	10,1 ± 0,34	10,2 ± 0,39	10,5 ± 0,41
	17 - 18	9,1 ± 0,42	9,4 ± 0,37	9,2 ± 0,41	9,4 ± 0,45	10,4 ± 0,35
The height of the V body, mm (Hvb)	13 - 14	25,3 ± 1,8	25,4 ± 1,7	26,1 ± 1,9	25,9 ± 2,1	26,3 ± 1,9
	15 - 16	29,4 ± 2,1	30,3 ± 2,3	30,6 ± 2,2	31,2 ± 2,3	30,9 ± 2,4
	17 - 18	31,2 ± 2,3	31,7 ± 2,4	32,1 ± 2,3	31,8 ± 2,1	31,6 ± 2,2
HIVD/Hvb	13 - 14	0,36 ± 0,02	0,37 ± 0,03	0,37 ± 0,02	0,38 ± 0,03	0,38 ± 0,03
	15 - 16	0,33 ± 0,02	0,32 ± 0,02	0,33 ± 0,02	0,33 ± 0,02	0,34 ± 0,02
	17 - 18	0,29 ± 0,01	0,30 ± 0,02	0,29 ± 0,02	0,30 ± 0,02	0,33 ± 0,02
Sagittal size SC, mm	13 - 14	18,4 ± 1,1	18,2 ± 0,9	18,1 ± 1,1	17,3 ± 0,9	17,6 ± 0,9
	15 - 16	18,1 ± 0,9	17,9 ± 0,8	17,8 ± 0,9	18,2 ± 1,1	17,9 ± 0,8
	17 - 18	19,2 ± 1,2	18,9 ± 1,1	19,1 ± 1,2	18,9 ± 1,1	18,7 ± 1,1
Sagittal size IVD, mm	13 - 14	28,3 ± 2,1	27,9 ± 1,5	28,1 ± 2,3	28,4 ± 2,1	30,8 ± 2,3
	15 - 16	31,4 ± 1,9	30,8 ± 2,1	30,6 ± 2,2	31,9 ± 2,4	32,1 ± 2,5
	17 - 18	32,1 ± 2,2	31,7 ± 1,8	32,6 ± 2,1	33,8 ± 1,7	33,5 ± 2,4
SC/IVD	13 - 14	0,65 ± 0,03	0,65 ± 0,03	0,64 ± 0,02	0,59 ± 0,03	0,57 ± 0,02
	15 - 16	0,58 ± 0,02	0,58 ± 0,02	0,58 ± 0,02	0,58 ± 0,02	0,56 ± 0,02
	17 - 18	0,60 ± 0,02	0,60 ± 0,03	0,59 ± 0,02	0,56 ± 0,02	0,56 ± 0,02

Table 1: *Normal ultrasound parameters of IVD and SC in healthy children.*

The height of vertebral body among children aged 13 - 14 years at the level of L2 was 25,3 ± 1,8 mm, at the level of S1 - 26,3 ± 1,9 mm (average 25,8 ± 1,8 mm). At the age of 15 - 16 years it was 29,4 ± 2,1 mm and 30,9 ± 2,4 mm (average 30,1 ± 2,2 mm), and at 17-18 years it was 31,2 ± 2,2 mm and 31,6 ± 2,2 mm (average 31,4 ± 2,3 mm) respectively (Figure 1, 2).

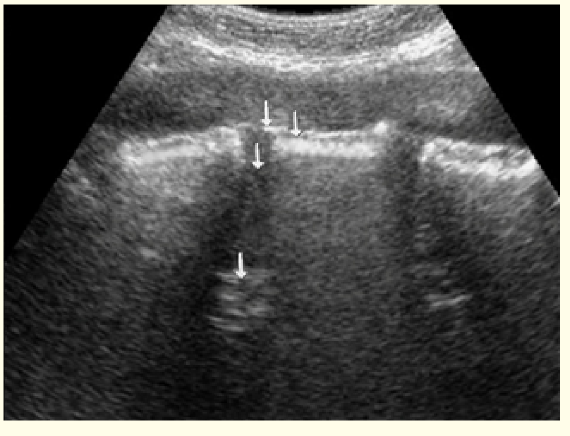

Figure 1: *Visualization of the L1, L2, L3 vertebrates and L1-L2, L2-L3 intervertebral discs. From the top down the arrows show the anterior longitudinal ligament, the anterior contour of the vertebral body, the intervertebral disc, the spinal cord.*

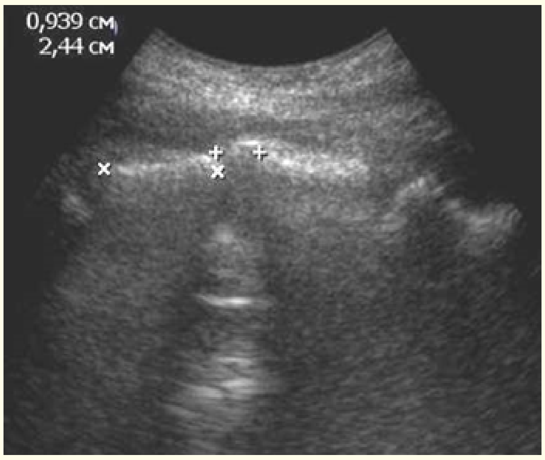

Figure 2: *Measurement of the height of the vertebral body of L4 (2,44 cm) and intervertebral disc of L4-L5 (2,44cm.)*

The ratio of intervertebral discs height and vertebral body (HIVD/HVB) among children aged 13 - 14 years at the level of L2 was 0,36 ± 0,02, at the level of S1 - 0,38 ± 0,03 (average 0,37 ± 0,025). At the age of 15 - 16 years it was 0,33 ± 0,02 and 0,34 ± 0,02 (average 0,33 ± 0,02), and at 17-18 years it was 0,29 ± 0,01 and 0,33 ± 0,02 (average 0,31 ± 0,015) respectively.

The sagittal size of SC among children aged 13 - 14 years at the level of L1-L2 is 18,4 ± 1,1 mm, L2-L3 - 18.2 ± 0.9 mm, L3-L4 - 18.1 ± 1,3, L4-L5 - 17,3 ± 1,4 mm, L5-S1 - 17,6 ± 1,5 mm. Sagittal sizes of SC in children aged 15 - 16 years were: 18.1 ± 0.9 mm; 17.9 ± 0.8 mm; 17.8 ± 0.9 mm; 18.2 ± 1.1 mm; 17.9 ± 0,8 mm and at 17 - 18 years - 19.2 ± 1.2 mm; 18.9 ± 1.1 mm; 19.1 ± 1.2; 18.9 ± 1.1 mm; 18.7 ± 1.1 mm respectively (Figure 3).

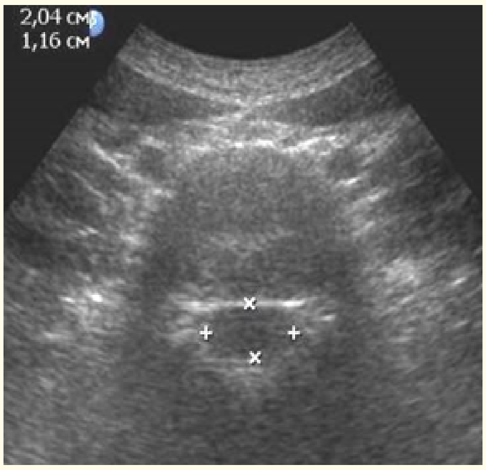

Figure 3: *Measurement of the sagittal and frontal sizes of the spinal canal (1,16 x 2044 cm).*

The index of SC/IVD was greatest in children aged 13 - 14 years old at the level of L1-L2 and was 0.65 ± 0.03; the lowest among children aged 17 - 18 years at the level of L5-S1 and was 0.56 ± 0.02 (P < 0,05). In each age group and in terms of the IVD level, the magnitude of this level decreased unreliably.

The quantitative parameters of yellow ligament thickness, width of spinal nerve canals, area of spinal canal determined by its perimeters and linear dimensions are presented in table 2. The thickness of the yellow ligament at the age of 13 - 14 at the level of L1-L2 was 2.1 ± 0.07 mm, L5-S1 - 2.3 ± 0.09 mm, at the age of 15 - 16 years - 2.3 ± 0.09 mm and 2,4 ± 0.12 mm; at the age of 17 - 18 years - 2.6 ± 0.11 mm and 3.1 ± 0.13 mm respectively.

Parameters	Age	The level of the IVD				
		L1-L2	L2-L3	L3-L4	L4-L5	L5-S1
The thickness of the yellow ligament	13 - 14	2,1 ± 0,07	2,2 ± 0,07	2,1 ± 0,06	2,2 ± 0,08	2,3 ± 0,09
	15 - 16	2,3 ± 0,09	2,4 ± 0,08	2,2 ± 0,07	2,3 ± 0,09	2,4 ± 0,12
	17 - 18	2,6 ± 0,11	2,8 ± 0,12	2,7 ± 0,11	2,9 ± 0,12	3,1 ± 0,13
The width of the spinal nerve canals, mm	13 - 14	8,5 ± 0,38	8,6 ± 0,42	8,9 ± 0,43	9,1 ± 0,45	9,2 ± 0,39
	15 - 16	8,7 ± 0,36	8,9 ± 0,35	9,1 ± 0,42	8,8 ± 0,39	9,3 ± 0,41
	17 - 18	9,1 ± 0,42	9,3 ± 0,37	9,2 ± 0,41	9,2 ± 0,45	9,1 ± 0,43
The area of the SC (mm^2) by LxM/^{2}	13 - 14	194 ± 9,1	196 ± 8,2	194 ± 7,8	188 ± 8,1	187 ± 7,6
	15 - 16	193 ± 9,4	194 ± 8,9	197 ± 1,2	203 ± 9,5	202 ± 8,9
	17 - 18	207 ± 10,5	209 ± 10,1	219 ± 10,8	212 ± 10,3	216 ± 10,8
The area of the SC (mm^2) by its perimeter (P)	13 - 14	212 ± 10,3	217 ± 11,4	214 ± 12,7	216 ± 11,9	213 ± 11,3
	15 - 16	204 ± 9,8	216 ± 10,9	221 ± 11,6	223 ± 11,2	216 ± 10,8
	17 - 18	215 ± 10,4	213 ± 9,8	229 ± 12,	218 ± 11,5	214 ± 10,3

Table 2: *Normal ultrasound parameters of SC and SNC in healthy children.*

The width of spinal nerve canal in children of 13 - 14 years old at the level of L1-L2 was 8.5 ± 0.38 mm, L5-S1 - 9.2 ± 0.39 mm; at the age of 15 - 16 years - 8.7 ± 0.36 mm and 9.3 ± 0.41 mm; at the age of 17 - 18 years - 9.1 ± 0.42 mm and 9.1 ± 0.43 mm, respectively (Figure 4).

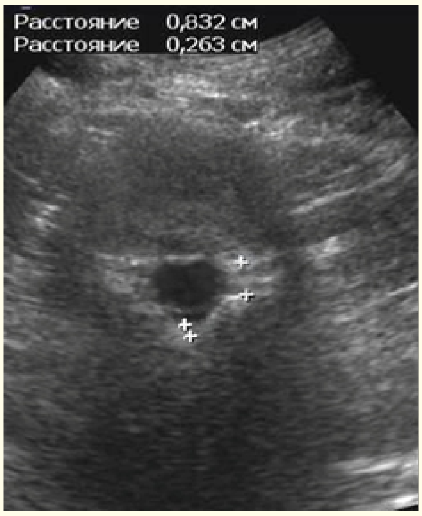

Figure 4: *Measurement of the yellow ligament thickness (0,263 cm) and width of spinal nerve canals (0,832 cm).*

A tendency has been found to increase the thickness of the yellow ligament and the width of spinal nerve canals from the level of L1-L2 to L5-S1 and from 13 - 14 to 17 - 18 years. However, the difference between the parameters, both by age and by IVD level, was not reliable.

The area of the SC determined by the its linear dimensions at the level of L1-L2 was 194 ± 9.1 mm^2; at the level of L5-S1 - 187 ± 7.6 mm^2; at the age of 15 - 16 - 193 ± 9.4 mm^2 and 202 ± 8.9 mm^2; at the age of 17 - 18 years - 207 ± 10.5 mm^2 and 216 ± 8.9 mm2, respectively. A significant difference ($P < 0.05$) was obtained by comparing the size of the SC area at the level of L5-S1 in children aged 13 - 14 years and 17 - 18 years.

The area of the SC determined by the its perimeters at the level of L1-L2 was 212 ± 10.3 mm^2; at the level of L5-S1 - 213 ± 11.3 mm^2; at the age of 15 - 16 - 204 ± 9.8 mm^2 and 216 ± 10.8 mm^2; at the age of 17 - 18 years - 215 ± 10.4 mm^2 and 214 ± 10.3 mm^2, respectively. A significant difference ($P < 0.05$) was obtained by comparing the size of the SC area at the level of L5-S1 in children aged 13 - 14 years and 17 - 18 years.

Discussion

It is known that in the development of degenerative changes in cartilaginous structures, in particular in the intervertebral discs, the role of a genetic disposition, 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.

Most of the published works on ultrasonography of the back are devoted to newborns. They show the great possibilities of the method in visualization of the spinal cord with the help of high-frequency sensors [12,13]. Kakitsubata Y., et al. (2005) studied the anatomical structure of 35 lumbar intervertebral discs in 13 human cadaveric specimens using high-frequency transducers. The results of ultrasonography were compared with pathological data. Sonography showed numerous fine linear echoes in the outer portion of the intervertebral disk in 26 (87%) of 30 specimens, which corresponded to the normal concentric arrangement of the fibers in the periphery of the annulus fibrosus. Amorphous areas of low echogenicity in the inner portion of the annulus fibrosus (n = 14, 47%) correlated with degenerative changes of the disk on corresponding microscopic sections. The nucleus pulposus appeared relatively isoechoic (n = 5, 17%) or hyperechoic (n = 4, 13%) to the annulus fibrosus. In degenerative disks (n = 21, 70%), the nucleus pulposus showed decreased echogenicity. The results of the research allowed the authors to conclude: sonography is a simple imaging method that can show the normal lumbar intervertebral disk and degenerative changes in appropriate subjects [14].

We used ultrasound to visualize intervertebral discs in living beings, particularly in older children, in order to develop qualitative and quantitative parameters of unchanged disks, depending on their age and constitutional features. During the study, it was found that the following parameters can have important clinical significance that the ratio of the sagittal size of the spinal canal and intervertebral disc (SC/IVD), the width of the spinal nerve canal. For example, a decrease in the SC/IVD index and width of the spinal nerve canals may indicate an increase in the area and deformation of the disc.

Magnetic resonance imaging is the most accurate method for diagnosing the different stages of osteochondrosis in adults and children [11]. 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 (Figure 5) [15,16].

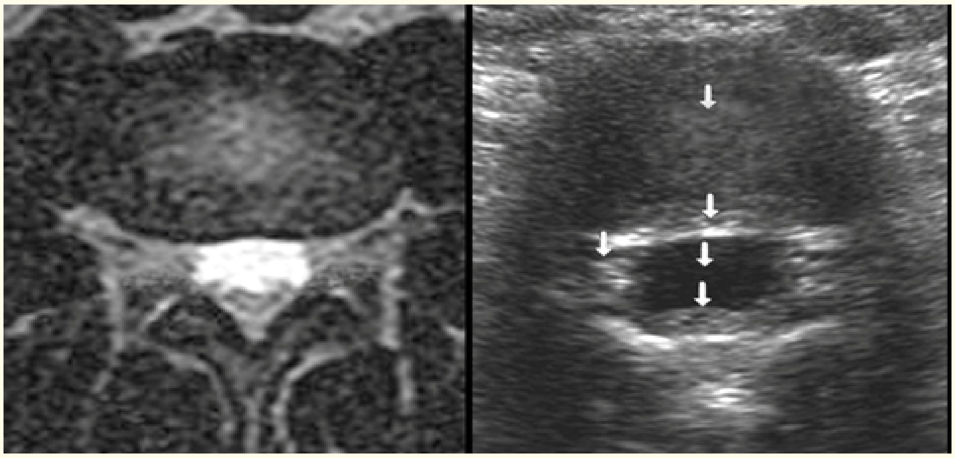

Figure 5: *MRI and ultrasonographic imaging of the intervertebral disc and spinal canal at level of L2-L3. From the top down the arrows show the nucleus pulpous, fibrous ring, spinal canal, yellow ligament. The left arrow shows the spinal nerve.*

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.

Conclusions

1. In children from the age of 13 to 18, the sagittal size of the lumbar intervertebral discs, spinal canal, the width of spinal nerve canal, the thickness of the yellow ligament, the area of the vertebral canal increases ($P < 0.05$) and the SC/IVD index decreases ($P < 0,05$).
2. In this age period, the echostructure of the pulpous nucleus changes insignificantly, in the form of an increase in echogenicity and in a few cases its displacement toward the fibrous ring. However, there is no change in the fibrous ring.

Conflict of Interest

The authors declared no potential conflict of interest with respect to the research, authorship, and/or publication of this article.

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Volume 9 Issue 3 March 2018