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Research Article

Possibilities of Ultrasound in Visualization of Cervical Disc Protrusion Detected by MRI in Adolescents and Young Adults

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Abstract

Objective: The aim of this study was to evaluate the possibilities of ultrasound in diagnosing of the cervical disc protrusion in adolescents detected by MRI and to determine what factors may affect the quality of disc imaging using ultrasound.

Materials and Methods: A retrospective analysis of the results of ultrasonography was carried out in 67 patients with protrusion of the cervical intervertebral discs diagnosed by MRI. The age of the patients ranged from 17 to 21 years, including 28 girls and 39 boys. All patients had clinical signs of degenerative disc disease and complained of cervicogenic pain.

Ultrasonography of the cervical spine held on the levels from C2-C3 to C7-Th1 in sagittal and axial projections. The results given as mean (standard deviation) and $p < 0.05$ were considered significant.

Results: The coincidence of the results of MRI and ultrasound took place in 64 (95,5 ± 2,5%) cases of cervical discs protrusion. In 4 (6,0 ± 2,9%) cases the protrusion was localized at the level of C2-C3, in 9 (13,4 ± 4,2%) - at the level of C3-C4, in 16 (23,9 ± 5,2%) - C4-C5, in 25 (37,3 ± 5,9%) - C5-C6, in 10 (14,9 ± 4,4%) - at the level C6-C7, in 3 (4,5 ± 2,5%) - at the level C7 -Th1, respectively.

Central localization of cervical disc protrusion was noted in 32 (47.8 ± 6.1%) cases, paramedial - in 23 (34.3 ± 5.8%) and foraminal - in 12 (17.9 ± 4.7%) cases. US revealed medial protrusion in 34 (50.7 ± 6.1%) cases, paramedical - in 19 (28.4 ± 5.5%) cases, and foraminal - in 11 (16.4 ± 4.5%) cases.

Conclusion: Ultrasonography can be an alternative method for diagnosing cervical disc protrusion. When imaging the anterior dural space at the level of the cervical discs, ultrasonography has an advantage over MRI. Visualization of C7-Th1 with USG in athletes is limited due to the development of muscle mass in the neck.

Keywords: *Spine; Ultrasound; MRI; Disc Degeneration; Cervical Discs Protrusion*

Introduction

The intervertebral disc (IVD) is a fibro-cartilaginous structure, the main function of which is to soften the compressible load between the vertebral bodies, as well as to provide flexibility. IVD differs from other connective tissues in the body in that age-related changes (aging) occur in it at an earlier age. Age-related changes in IVD, indicating the onset of degeneration, are observed already at the age of 11 years, as evidenced by histological studies [1]. The intervertebral disc consist of three major structures: the nucleus pulposus (NP), the annulus fibrosus (AF) and the cartilaginous endplates [2-4].

The NP is a gel-like structure that sits at the center of the IVD and accounts for flexibility of the spine. It is made of 66% to 86% water and of primarily type II collagen. The AF is a ring-shaped disc of fibrous connective tissue that surrounds the NP. It is consisting of 15 to 25

stacked sheets of "radial-ply" formation with collagen, proteoglycans, glycoproteins and elastic fibers. The total proteoglycan contents in the IVD decreases with age, leading to a decrease in the hydrophilicity of the IVD, which leads to a change in the biomechanical properties of IVD fibers. Type II collagen is replaced with type I collagen fibers in the inside of the AF and NP. Yellow pigmentation begins to accumulate in the NP, which also makes it less distinguishable from AF [5].

Disc degeneration begins with dehydration of the nucleus pulposus, which results in increased pressure on the annulus fibrosus. The resistance of the annulus fibrosus to compression forces from the nucleus pulposus increases its rigidity and reduces elasticity. Excessive stress reduces IVD homeostasis. An imbalance in anabolic and catabolic processes often leads to an inflammatory response, which further contributes to the degenerative process [6]. Cervical intervertebral disc degeneration is a common finding on imaging studies, and it is well known that disc degeneration prevalence increases in accordance with age. Several studies have shown a significant correlation between age and disc degeneration, but the specific pattern of cervical disc degeneration with age has not been well studied [7].

Back pain is second only to upper respiratory tract infection as a cause for lost work time. Low back pain (LBP) remains the leading cause of disability and morbidity in modern society. Even up to 70% of the population experiences LBP throughout their lives. Over 5 million people are disabled with low back pain, which makes it the number one disability for workers less than 45 years old. The L5-S1 spine segment is a very common source of low back pain. A wide range of movements and forces acting on this segment increase the risk of injury and thus the development of a degenerative process in it [8,9].

Ikeda H., *et al*. (2012) described a case of formation of a herniated cervical intervertebral disc with stenosis of the spinal canal and the development of a symptom of myelopathy, which was eliminated by surgical placement [10]. The results of a study by Makino H., *et al*. (2017) showed that 31% of young women already have degenerative changes by the age of 20, which can progress quickly [11].

According to the results of an MRI study, Suzuki A., *et al*. (2017) propose the following sequence of changes in cervical intervertebral discs indicative of degeneration: (1) decrease and/or change in the intensity of the nucleus pulposus; (2) loss of distinction between nucleus pulposus and annulus fibrosus; (3) positive disc convexity; and (4) reducing the height of the disc. The **K**-coefficients for intra-observer and inter-observer agreement were 0.96 and 0.90, respectively. Severe disc degeneration is most common in the C5/C6 area, followed by C6/C7 and C4/C5 [12,13].

Along with magnetic resonance imaging, which is the main method for imaging intervertebral discs, ultrasonography can be a suitable alternative given its low cost, availability, and well-known recognition of the possibility of the method in obtaining high-quality images of soft tissues.

Objective of the Study

The aim of this study was to evaluate the possibilities of ultrasound in diagnosing of the cervical disc protrusion in adolescents detected by MRI and to determine what factors may affect the quality of disc imaging using ultrasound.

Materials and Methods

A retrospective analysis of the results of ultrasonography was carried out in 67 patients with protrusion of the cervical intervertebral discs diagnosed by MRI. The age of the patients ranged from 17 to 21 years, including 28 girls and 39 boys. All patients had clinical signs of degenerative disc disease and complained of cervicogenic and lumbar pain. The comparative group (CG) consisted of 56 healthy voluntary the same age with normal cervical and lumbar discs and neurologic status.

Ultrasonography of the cervical and lumbar spine held on the levels from C2-C3 to C7-Th1 and on the levels from L1-L2 to L5-S1 in sagittal and axial projections. In sagittal section was measured height of intervertebral discs, in axial section - the structures of discs and spinal canal, determined the degree and localization of disc protrusion. Patients with spinal injuries, scoliosis, ankylosing spondilitis were not included in the studies.

At the level of cervical discs ultrasound was performed with a linear array (5 - 10 MHz), convex (2 - 5 MHz) and microconvex (4 - 9 MHz) probes (Philips HD-11).

The results given as mean (standard deviation) and $p < 0.05$ were considered significant.

Results

Based on MRI results in 4 (6,0 ± 2,9%) cases the protrusion was localized at the level of C2-C3, in 9 (13,4 ± 4,2%) - at the level of C3-C4, in 16 (23,9 ± 5,2%) - C4-C5, in 25 (37,3 ± 5,9%) - C5-C6, in 10 (14,9 ± 4,4%) - at the level C6-C7, in 3 (4,5 ± 2,5%) - at the level C7 -Th1, respectively. There was demonstrated, that the cervical disc protrusion occurs significantly more frequently at the level of C5-C6, C4-C5 and C6-C7 respectively.

As can be seen from the table 1 using a linear US probe with a frequency of 5 - 10 MHz the protrusion was diagnosed in 47 (70.1 ± 5.6%) cases (P < 0,001) - at the level of C2-C3 in 3 (4,5 ± 2,5%) cases, at the level of C3-C4 - in 8 (11,9 ± 4,0%) cases, at the level of C4-C5 - in 13 (19,4 ± 4,8%) cases, at the level of C5-C6 - in 19 (28,4 ± 5,5%) cases, at the level of C6-C7 - in 4 (6,0 ± 2,9%) cases, respectively. In general, using this transducer, disc protrusion was poorly diagnosed at the C5-C6 level (19.4 ± 4.8% vs 37.3 ± 5.9%) and C6-C7 (6.0 ± 2.9% vs 14, 9 ± 4.4%). In all 3 cases, it was not possible to diagnose protrusion at the C7 - Th1 level. Such poor results have been obtained among male weightlifters.

The level of IVD	MRI n = 67	US, type of transducers		
		Linear (5 - 10 MHz)	Convex (2 - 5 MHz)	Microconvex (4 - 9 MHz)
	1	2	3	4
C2-C3	4 (6.0 ± 2.9%)	3 (4.5 ± 2.5%)	3 (4.5 ± 2.5%)	4 (6.0 ± 2.9%)
C3-C4	9 (13.4 ± 4.2%)	8 (11.9 ± 4.0%)	8 (11.9 ± 4.0%)	9 (13.4 ± 4.2%)
C4-C5	16 (23.9 ± 5.2%)	13 (19.4 ± 4.8%)	14 (20.9 ± 5.0%)	16 (23.9 ± 5.2%)
C5-C6	25 (37.3 ± 5.9%)	19 (28.4 ± 5.5%)	21 (31,3 ± 5.7%)	25 (37.3 ± 5.9%)
C6-C7	10 (14.9 ± 4.4%)	4 (6.0 ± 2.9%)	8 (11.9 ± 4.0%)	9 (13.4 ± 4.2%)
C7-Th1	3 (4.5 ± 2.5%)	-	-	1 (1.5 ± 1.5%)
Total	67 (100,0%) P 1-2 < 0,001 P 1-3 < 0,01	47 (70.1 ± 5.6%)	54 (80.6 ± 4.8%)	64 (95.5 ± 2.5%) P 4-2 < 0,01 P 4-3 < 0,001

Table 1: *Comparison of the results of MRI and US in the diagnosis of cervical disc protrusion.*

Using a convex US probe with a frequency of 2 - 5 MHz the protrusion was diagnosed in 54 (80.6 ± 4.8%) cases (P < 0,01) - at the level of C2-C3 in 3 (4,5 ± 2,5%) cases, at the level of C3-C4 - in 8 (11,9 ± 4,0%) cases, at the level of C4-C5 - in 14 (20,9 ± 5,0%) cases, at the level of C5-C6 - in 21 (31,3 ± 5,7%) cases, at the level of C6-C7 - in 8 (11,9 ± 4,0%) cases, respectively. In all 3 cases, it was not possible to diagnose protrusion at the C7 - Th1 level.

In the diagnosis of disc protrusion, the best results are obtained using a microconvex probe - in 64 (95,5 ± 2,5%) cases. At the C6-C7 level, in one case, and at the C7-Th1 level, in two cases, protrusion in athletes due to the muscle mass of the neck was not diagnosed

According to the localization of protrusion within the spinal canal, 3 types were identified: central (medial), paramedial, and foraminal (Table 2). According to the results of MRI, central localization of cervical disc protrusion was noted in 32 (47.8 ± 6.1%) cases, paramedial - in 23 (34.3 ± 5.8%) and foraminal - in 12 (17.9 ± 4.7%) cases. Ultrasound examination revealed medial protrusion in 34 (50.7 ± 6.1%) cases, paramedial protrusion in 19 (28.4 ± 5.5%) cases, and foraminal protrusion in 11 (16.4 ± 4.5%) cases. In two cases paramedial and foraminal protrusion of C7-Th1 was not diagnosed by ultrasound, and in two cases paramedial protrusion was regarded as medial.

Types of protrusion	Cervical (n = 67)	
	MRI	US (Microconvex probe -4-9 MHz)
Central	32 (47.8 ± 6.1%)	34 (50,7 ± 6.1%)
Paramedial	23 (34.3 ± 5.8%)	19 (28.4 ± 5.5%)
Foraminal	12 (17.9 ± 4.7%)	11 (16.4 ± 4.5%)

Table 2: *Types of cervical and lumbar intervertebral disc protrusion.*

A comparative assessment of degenerative changes in cervical discs was carried out according to the results of MRI and ultrasound. The frequency of occurrence of the following changes in discs was studied:

1) Diffuse increase in echogenicity of the nucleus pulpous;
2) Calcification of the nucleus pulposus;
3) Displacement of the hyperechoic nucleus pulposus;
4) Thinning of the fibrous ring;
5) Narrowing of anterior dural space at the level of cervical discs (Table 3).

Parameters of degenerative changes	MRI (n = 67)	US (n = 67)
Diffuse increase in echogenicity of the nucleus pulposus	53 (79.1 ± 5.0%)	46 (68.7 ± 5.7%)
Calcification of the nucleus pulposus	31 (46.3 ± 6.1%)	35 (52.2 ± 6.1%)
Displacement of the hyperechoic nucleus pulposus	34 (50.7 ± 6.1%)	47 (70.1 ± 5.6%) P < 0,05
Thinning of the fibrous ring	53 (79,1 ± 5.0%) P < 0,05	42 (62.7 ± 5.9%)
Narrowing of anterior dural space at the level of cervical discs	49 (73.1 ± 5.4%)	61 (91.0 ± 3.5%) P < 0,01

Table 3: *Comparative evaluation of changes in cervical discs with protrusion by MRI and US.*

Diffuse increase in echogenicity of the nucleus pulpous was revealed on MRI in 53 (79.1 ± 5.0%) cases, on ultrasound - in 46 (68.7 ± 5.7%) cases; calcification of the nucleus pulposus - in 31 (46.3 ± 6.1%) and 35 (52.2 ± 6.1%) cases; displacement of the hyperechoic nucleus pulposus - in 34 (50.7 ± 6.1%) and 47 (70.1 ± 5.6%) cases (P < 0.05); thinning of the fibrosus ring - in 53 (79.1 ± 5.0%) and 42 (62.7 ± 5.9%) cases (P < 0.05); narrowing of anterior dural space at the level of cervical discs - in 49 (73.1 ± 5.4%) and 61 (91.0 ± 3.5%) cases (P < 0.01), respectively. Displacement of the hyperechoic nucleus pulposus it was visualized reliably on ultrasound (P < 0.05) more often than on MRI (Figure 1 and 2). In sagittal projection, the thinning of the fibrosus ring was better diagnosed on MRI (P < 0.05) than on ultrasound.

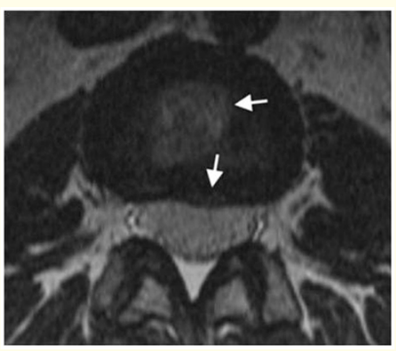

Figure 1: *MRI visualization of displacement of the hyperechoic nucleus pulposus (upper arrow). The bottom arrow shows incipient disc bulging.*

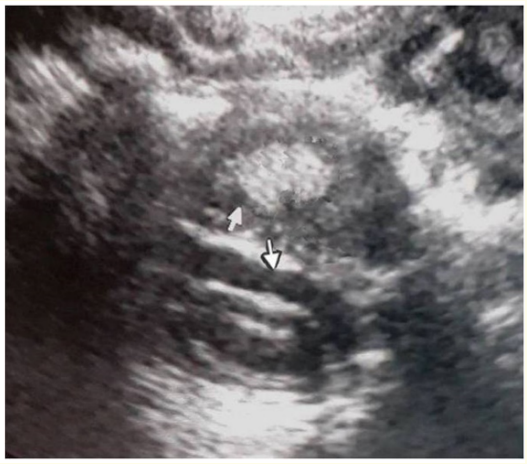

Figure 2: *US visualization of displacement of the hyperechoic nucleus pulposus (upper arrow). The bottom arrow shows incipient disc bulging.*

Narrowing of anterior dural space at the level of cervical discs with the help of a microconvex probe during ultrasound was determined more qualitatively and was the main indirect sign for suspicion and accurate determination of the presence of disc protrusion. At the same time, the main sign of protrusion was the protrusion of the discs towards the spinal canal more than 2 mm from the normal boundaries (Figure 3-5).

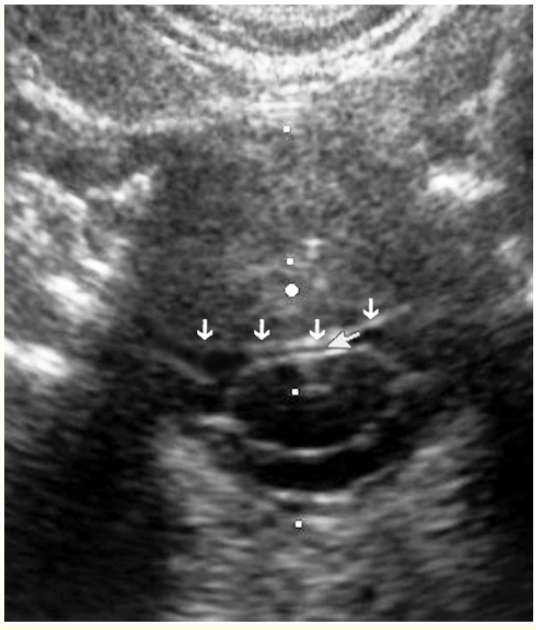

Figure 3: *Medial circular protrusion of the C5-C6 (vertical arrows). The anterior dural space is narrowing (horizontal arrow).*

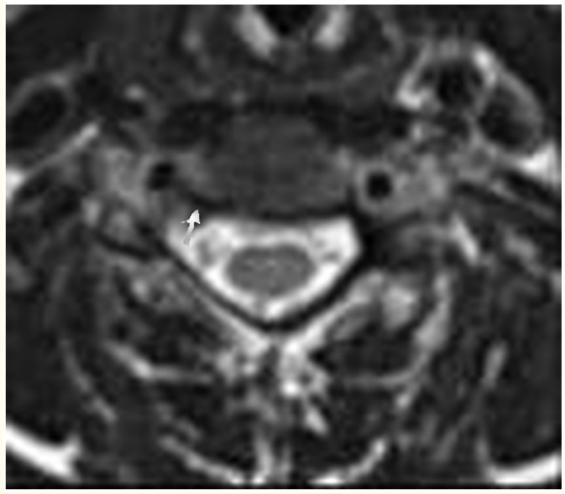

Figure 4: *MRI visualization of the right-sided paramedial-foraminal protrusion C4-C5 (arrow). Narrowing of anterior dural space.*

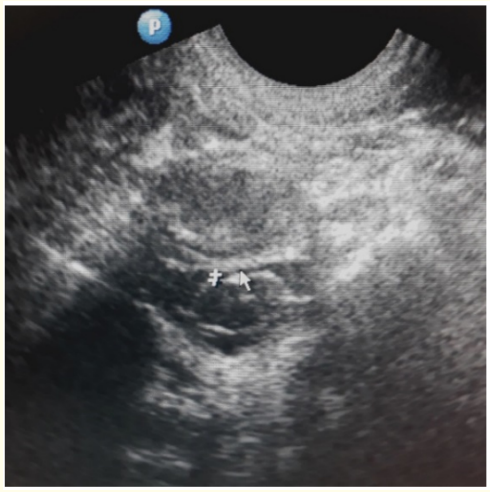

Figure 5: *US visualization of the right-sided paramedial-foraminal protrusion C4-C5 (arrow). Narrowing of anterior dural space.*

Discussion

Being the most common method for examining the musculoskeletal system, radiography allows us to assess mainly bone structures and does not allow visualizing the intervertebral discs, spinal cord, spinal nerves, and ligamentous apparatus. Currently, magnetic resonance imaging is the main method for diagnosing degenerative changes in the intervertebral discs. It should be noted that high-frequency microconvex sensors provide a high-quality image of the spinal motion segment.

Studies by Wasserman MS., *et al*. (2018) and Abdalkader M., *et al*. (2020) carried out with the help of MRI in athletes who participated in the Summer Olympics showed a high incidence of degenerative changes in the cervical and lumbar intervertebral discs in them. The

clinical significance of these articles demonstrates that Olympic athletes have indicators of more severe osteochondrosis of the cervical and lumbar spine than non-athletes, who for a long time may have signs of early degenerative changes in the discs in the form of pain, vertebral instability, neurological disorders [13].

In the publication of Suzuki A., *et al*. [12] studied degenerative changes in the intervertebral discs in a wide age range - from 15 to 79 years, which significantly complicates the statistical analysis of the results. It should be noted that among persons over 40 years old, small-focal degenerative changes within the nucleus pulposus are almost always revealed. The detection of such changes in discs in adolescents is important for preventive measures to delay their progression.

Our studies have shown that discs C5-C6, C4-C5, L4-L5, L5-S1 undergo degenerative changes most often. At the C3-C4 - C5-C6 level, the image quality of the discs with the high-frequency microconvex probe was better than with MRI. The poor quality of C7-Th1 images in athletes is explained by the hypertrophy of their cervical muscles, which increases the distance to the sensor and changes the scanning angle.

Conclusion

USG can be an alternative method for diagnosing cervical and lumbar disc protrusion. When imaging the anterior dural space at the level of the cervical discs, USG has an advantage over MRI. Visualization of C7-Th1 with USG in athletes is limited due to the development of muscle mass in the neck.

Conflict of Interest

The authors declare that they have no conflicts of interest.

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