Original Article

Value of findings of diffusion-weighted magnetic resonance imaging in patients with lumbar disc degeneration

Ismail Salk[1], Vedat Sabanciogullari[2], Ali Cetin[3], Hatice Balaban[4], Seref Kelkit[5]

ABSTRACT

Objectives: To determine the value of diffusion-weight MRI findings in patients with lumbar disc degeneration.

Methodology: Lumbar discs of 52 consecutive patients were imaged at 1.5 T MR including T2 and diffusion weighted imaging. Apparent diffusion coefficient (ADC) values, T2 signal intensity and height of the five lumbar intervertebral discs were measured and disc and endplate degenerations were graded.

Results: The mean ADC was $0.90\times10H^{3}$ $mm^{2}/s\pm0.27$ (±S.D.) and the mean T2 was 93.98±32.32. There was significant correlation between mean diffusion and the T2 signal intensity values of all lumbar discs. The age of the cases was negatively correlated with the T2 signal intensities and ADC values and positively correlated with the disc height of from L1-L2 to L5-S1. There was no significant correlation between the disc height of from L1-L2 to L5-S1 and the measured ADC values and the T2 signal intensities.

Conclusions: Evaluation of lumbar disc degeneration with diffusion weight MRI can be a useful procedure in the clinical practice for patients with several lumbar symptoms. There is need for the improvement of image quality of diffusion weighted MRI imaging for more precise diagnosis of the lumbar diseases.

KEY WORDS: Diffusion weighted imaging, Intervertebral disc, Disc degeneration.

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INTRODUCTION

There is no consensus on what disc degeneration actually is or how it should be distinguished from the physiologic processes of growth, aging, healing, and adaptive remodeling. The underlying cause of disc degeneration is tissue weakening occurring primarily from genetic inheritance, aging, nutritional compromise, and loading history. The precipitated cause is structural disruption occurring from injury or fatigue failure. The degenerative features are most likely to influence patients' prognosis and which are the best targets for therapeutic interventions. The discs are vulnerable to a greater or lesser extent, and the vulnerability can only be gauged from the violence, or otherwise, required to disrupt the disc and initiate degeneration.[1]

Magnetic resonance imaging (MRI) is the most important method to describe intervertebral disc degen-

eration. Degeneration of the disc is discerned as a decreased signal intensity of the nucleus pulposus on T2-weighted images.[2,3] The degenerative disc disease is to some degree an age-related phenomenon. Signal intensity changes in the bone marrow adjacent to the vertebral body had been appeared to be a part of this process.[4,5]

The intervertebral disc is an avascular structure and, hence, its nutrition depended diffusion of nutrients. Diffusion-weighted MRI is a noninvasive method for the measurement of diffusion of water in the frame of discs in vivo and, so it is suited for clinical exams evaluating pathologic degenerations in water diffusion related to disc disease.[6]

In the literature, there are a few studies conducted regarding diffusion weighted MRI for the investigation of degenerative disc disease, although there are many studies investigating the value of diffusion-weighted MRI in patients with assessment of acute stroke, characterizations of multiple sclerosis, tumors, and abscesses of the brain. Various musculoskeletal structures and pathologies have also been examined with diffusion-weighted MRI in patients with muscle, cartilage, soft-tissue pathologies, necrotic and viable tumor tissue, knee joint effusions, and traumatic bone marrow edema[7], and the differentiation of acute benign osteoporotic fractures from malignant compression fractures.[8]

The aim of the present study was to determine the value of diffusion-weight MRI findings in patients with lumbar disc degeneration.

METHODOLOGY

Study population: Total 52 patients underwent clinical MR imaging of the lumbar spine at MRI Unit of Sivas Numune Hospital between January and November 2009. An inclusion criterion for the current study was the presence of chronic low back pain without a confirmed diagnosis. Exclusion criteria were current infections of the vertebral column, pregnancy, metallic implants, claustrophobia, tumor, metastases, and vertebral abnormality. The study was approved by the Human Ethics Committee of Sivas Province, and all participants gave written informed consent.

MRI evaluation: MRI was performed using a spine array surface coil on a 1.5-T whole-body MR system (Magnetom Symphony, Siemens, Erlangen, Germany). A lumbar spine MRI examination was conducted with a transmitted body coil. Examination included T2-weighted fast spin-echo sagittal images with effective echo time and repetition times (TE/TR) of 114/4030 ms. A field of view (FOV) of 300 mm, matrix of 320×192 matrix and 4.8 mm sections were used. Two averages were acquired and the echo train length was 23. T2-weighted images were used for visual grading of intervertebral disc degeneration and for measuring the signal intensity of the disc and its height.

ADW single-shot spin-echo echo-planar imaging sequence (DW-EPI) of the lumbar spine was performed with a body coil. A TE/TR of 103/4000 ms, FOV of 400x400 mm, matrix of 192x192, one acquisition and scan time of 34 s were used for one mid-sagittal 4.8-mm-thick section. Findings were recorded by disc segment (L1-L2, L2-L3, L3-L4, L4-L5, and L5-S1); and endplates (Figure1 a-c).

Visual degeneration grading: Degeneration of lumbar discs L1-L2, L2-L3, L3-L4, L4-L5 and L5-S1 was classified according to Pfirrmann's[9] grading system. We classified as Grade III represents a combination of both normal and slightly degenerated discs, Grade IV moderately degenerated discs and Grade V severely degenerated discs.

Statistical analysis: ADC values, T2 signal intensities and height of the discs were analyzed with Pearson correlation test. ADC values in different degeneration grades were analyzed with ANOVA with post hoc Tukey test. The SPSS 14.0 software package (SPSS Inc., Chicago, IL, USA) was used for statistical analyses. $P < 0.05$ was considered significant.

RESULTS

The study population consisted of 52 consecutive patients (20 men; mean age, 35.7±10.6 years; age range, 19-55 years; 32 women mean age, 39.1±10.6 years; age range, 20-64 years) evaluated for the etiology of chronic lumbar pain.

The age and body mass index of women and men were found similar ($p>0.05$). From L1-L2 to L5-S1, the T2- and diffusion- weighted signal intensities of women and men were comparable ($p>0.05$). At L1-L2, L2-L3, and L3-L4, the disc height of men were significantly higher than those of the women ($p<0.05$). At L4-L5 and L5-S1, the disc height of women and men were comparable ($p>0.05$).

The Pfirrmann's degeneration grades 3, 4 and 5 shows statistically significant difference (Kruskal-Wallis Test) in the T2 signal intensities and ADC values from L1-L2 to L5-S1. There was significant positive strong correlation ($r=0.89$) between mean diffusion and the T2 signal intensity values of all lumbar discs ($p=0.001$). The age of the cases was negatively correlated with the T2 signal intensities (Pearson correlation $r=-0.70$, $P<0.01$) and ADC values (Pearson correlation – $r=0.64$, $P<0.01$) and positively correlated

with the disc height of from L1-L2 to L5-S1 (Pearson correlation r=0.33, P<0.01).

There was no significant correlation between the disc height of from L1-L2 to L5-S1 and the measured ADC values and the T2 signal intensities (Table-II).

DISCUSSION

A significant difference was observed between measured ADC values and T2 signal intensities and visual lumbar disc degeneration grades in this study. The disc heights of men at L1-L2, L2-L3 were higher than those of the women. There was correlation between mean diffusion and the T2 signal intensity values. The age of the cases was correlated with the T2 signal intensities, ADC values, and the disc height of from L1-L2 to L5-S1 (Table I, II).

Lumbar disc degeneration happens because of different factors and results in a wide variety of conditions. Some of disc degenerations lead to loss of height of the motion segment with related changes in biomechanics of the segment. Disc herniation with radiculopathy and chronic discogenic pain are the results of this degenerative process. The lumbar discs most often affected by degeneration that resulted with herniation are L4-5 and L5-S1, almost certainly because of a combination of degeneration existing for a long time and a following change to resist put in stress. Radicular pain is often related to disc herniation and it is evident that lumbar disc degeneration is multifactorial course and that both mechanical and biochemical disorders occur.[10]

Table-I: Demographic, clinical, and T2- and diffusion- weighted MRI data of 52 patients with chronic lumbar pain.

	Women (n=32)	*Men (n=20)*	*Significance*
Age (y)	39 (20-64)	34 (19-55)	NS
Body mass index (kg/m^2)	27.4 (20-39)	25.1 (19-30)	NS
T2-weighted signal intensity			
L1-L2	95.9 (23.3-170.6)	104.9 (46.3-162)	NS
L2-L3	90.4 (22.9-173.5)	100.4 (30.3-165.2)	NS
L3-L4	72.2 (11.2-149)	79.5 (31.3-139.2)	NS
L4-L5	50.6 (20.9-152.9)	64.9 (18-138.4)	NS
L5-S1	57.2 (21.3-177.9)	72.9 (25.6-138)	NS
Diffusion-weighted signal intensity(×10^{-3} mm^2/s)			
L1-L2	1.18 (0.20-1.65)	1.30 (0.72-1.58)	NS
L2-L3	1.06 (0.36-1.50)	1.27 (0.21-1.61)	NS
L3-L4	0.85 (0.38-1.70)	1.01 (0.17-1.54)	NS
L4-L5	0.59 (0.15-1.41)	0.81 (0.11-1.50)	NS
L5-S1	0.63 (0.03-1.81)	0.78 (0.15-1.31)	NS
Disc height (mm)			
L1-L2	9.15 (6.80-11.60)	9.90 (7.90-12.50)	p=0.019
L2-L3	9.95 (6.80-13.10)	11.25 (8.80-14.60)	p=0.010
L3-L4	10.55 (7.60-14.00)	11.20 (9.10-13.70)	p=0.012
L4-L5	11.40 (4.90-15.10)	11.60 (4.10-13,50)	NS
L5-S1	11.25 (4.10-14.90)	11.30 (7.60-15.10)	NS

NS, no significance.

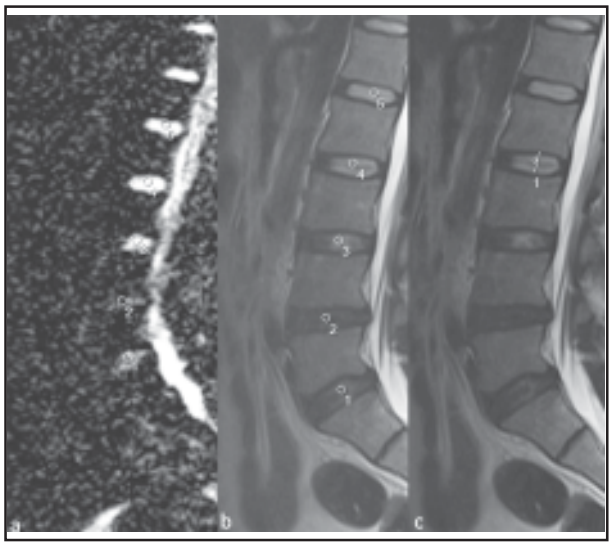

Figure-1: a ADC map, b and c T2-weighted fast spin-echo image of the lumbar spine of one case. ROIs for ADC measurements were placed on L1-2to L5-S1 discs. Line on the T2-weighted image shows height (H) and ROIs indicate measurements for T2 signal intensities.

Kealey et al[6] determined that prospectively the diffusibility of water in normal lumbar discs in adults by using the mean ADC and if a relationship exists between disc ADC and MR findings of disc degeneration. In that study diffusion-weighted MR imaging of the lumbar spine was performed in 39 cases and five volunteers. They reported a significant decrease in the ADC values of degenerated lumbar discs compared with the ADC values of normal discs and also dependence of lumbar disc ADC on anatomic location.

Antoniou et al[11] studied that biochemically determining if the MRI-calculated ADC of fresh cadaveric human discs is a reflection of matrix composition, matrix integrity or both. They confirmed that through the use of MR techniques, the presence of correlations

Table-II: The ADC and T2 signal intensities from L1-L2 to L5-S1 values according to Pfirrmann's[9] visual degeneration grades at L1-L2 to L5-S1.

Intervertebral disc level		*Mean±SD*	*Significance*
L1-L2	ADC	1.15±0.30	p=0.023
	T2	100,29±35.06	p=0.036
L2-L3	ADC	1,04±0.37	p=0.008
	T2	91,81±36,92	p=0.002
L3-L4	ADC	0.90±0.38	p=0.001
	T2	73.27±33,53	p=0.001
L4-L5	ADC	0.70±0.37	p=0.001
	T2	62.40±33.45	p=0.001
L5-S1	ADC	0.71±0.42	p=0.001
	T2	71.05±39.63	p=0.001

particularly between changes in matrix content, and in some cases the integrity of the matrix, with age and disc degeneration, the quality of diffusion in the NP, and hence, the nutritional flow in the disc. They reported that the relation between quantitative biochemical determination of matrix content and integrity and the quantitative MR data.

Abanoz et al[12] evaluated to assess the value of diffusion-weighted steady-state free precession (SSFP) sequence for discriminating between benign and pathologic compression fractures. Forty-nine patients with 63 acute vertebral compression fractures caused by osteoporosis, trauma, malignancy, and infection were examined with a diffusion-weighted SSFP sequence and a signal intensity characteristic was analyzed qualitatively and quantitatively for all sequences. They concluded that diffusion-weighted SSFP sequence might allow the differentiation of acute benign osteoporotic fractures from malignant compression fractures. Benign fractures showed hypointense or isointense signal on diffusion-weighted sequences that reflected persistent free water proton mobility. Malignant fractures showed hyperintensity compared with normal surrounding bone marrow probably due to altered water proton mobility within the neoplasm.

Karchevsky et al[13] investigated that the association of endplate changes with age, height, weight, body mass index (BMI), and gender. One hundred lumbar spines were evaluated and classified the endplate bone marrow abnormalities on sagittal MR images according to the explanations of Modic et al. Endplate changes were correlated with age, gender, and BMI. They proved that fatty endplate changes are the most common. Endplate marrow changes most often arised at the anterior aspect of the endplate, particularly at L4-L5 and L5-S1 levels.

Niinimaki et al[14] investigated that the relation of ADC to degenerative changes in disc morphology and signal intensity in conventional MRI. In that study, lumbar spines of 228 volunteer middle-aged men were scanned with 1.5 T including anatomic and diffusion-weighted imaging. They concluded that there was an important decrease of ADC in moderately degenerated discs compared to normal discs, with T2 signal intensity being the only single measure that correlated with decreased ADC. They suggested that ADC was not dependent on anatomic level. Therefore, ADC measurements of intervertebral discs are more applicable for epidemiological studies than for clinical use with the today's MR technology because of notable overlapping between ADC values of normal and degenerated discs.

Evaluation of lumbar disc degeneration with diffusion weight MRI can be a useful procedure in the clinical practice for patients with several lumbar symptoms. Diffusion weight MRI sequence can be conducted in a short time compared to T2 weighted sequence. There is need for the improvement of image quality of diffusion weighted MRI imaging for more precise diagnosis of the lumbar diseases.

REFERENCES

1. What is Intervertebral Disc Degeneration, and What Causes It?: Conclusions. Available at: http://www.medscape.com/viewarticle/543611_11. Retrieved January 4, 2010.
2. Jensen MC, Kelly AP, Brant-Zawadzki MN. MRI of degenerative disease of the lumbar spine. Magn Reson Q 1994;10(3):173-190.
3. Tertti M, Paajanen H, Laato M, Aho H, Komu M, Kormano M. Disc degeneration in magnetic resonance imaging: A comparative biochemical, histologic and radiologic study in cadaver spine. Spine 1991;16:629-634.
4. Modic MT, Steinberg PM, Ross JS, Masaryk TJ, Carter JR. Degenerative disk disease: Assessment of changes in vertebral body marrow with MR imaging. Radiology 1988;166:193-199.
5. de Roos A, Kressel H, Spritzer C, Dalinka M. MR imaging of marrow changes adjacent to end plates in degenerative lumbar disk disease. AJR Am J Roentgenol 1987;149:531-534.
6. Kealey SM, Aho T, Delong D, Barboriak DP, Provenzale JM, Eastwood JD. Assessment of apparent diffusion coefficient in normal and degenerated intervertebral lumbar disks: initial experience. Radiology 2005;235:569-574.
7. Raya JG, Dietrich O, Reiser MF, Baur-Melnyk A. Methods and applications of diffusion imaging of vertebral bone marrow. J Magn Reson Imaging 2006;24:1207-1220.
8. Yeung DK, Wong SY, Griffith JF, Lau EM. Bone marrow diffusion in osteoporosis: evaluation with quantitative MR diffusion imaging. J Magn Reson Imaging 2004;19:222-228.
9. Pfirrmann CW, Metzdorf A, Zanetti M, Hodler J, Boos N. Magnetic resonance classification of lumbar intervertebral disc degeneration. Spine 2001;26:1873-8.
10. Pathophysiology of Lumbar Disc Degeneration: A Review of the Literature. Available at: http://www.medscape.com/viewarticle/442440. Retrieved January 11, 2010.
11. Antoniou J, Demers CN, Beaudoin G, Goswami T, Mwale F, Aebi M, et al. Apparent diffusion coefficient of intervertebral discs related to matrix composition and integrity. Magn Reson Imaging 2004;22:963-972.
12. Abanoz R, Hakyemez B, Parlak M. Diffusion-weighted imaging of acute vertebral compression: Differential diagnosis of benign versus malignant pathologic fractures. Tani Girisim Radyol 2003;9:176-83.
13. Karchevsky M, Schweitzer ME, Carrino JA, Zoga A, Montgomery D, Parker L. Reactive endplate marrow changes: a systematic morphologic and epidemiologic evaluation. Skeletal Radiol 2005;34:125-9.
14. Niinimaki J, Korkiakoski A, Ojala O, Karppinen J, Ruohonen J, Haapea M, et al. Association between visual degeneration of intervertebral discs and the apparent diffusion coefficient. Magn Reson Imaging 2009;27:641-647.

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Ismail Salk, did conceived, examination of the images and manuscript writing.
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Ali Cetin, did statistical analysis.
Hatice Balaban, did review and final approval of manuscript.
Seref Kelkit, did data collection and examination of the images.