Original Article

Correlation between sagittal morphology of lower lumbar end plate and degenerative changes in patients with lumbar disc herniation

ABSTRACT

Objective: As an important anatomic factor in the process of lumbar disc herniation (LDH), the correlation between end plate sagittal morphology and intervertebral disc degeneration (IDD) is unclear. Moreover, research on imaging data of lumbar end plate in patients with LDH is still insufficient. Our study aimed to observe the morphological change of the lower lumbar end plate (L3-S1) in patients with LDH on magnetic resonance imaging (MRI) and analyze its correlation with the degree of IDD.

Materials and Methods: A total of 116 patients were included in the study. Based on their MRI, we divided end plates into three types (concave, flat, and irregular), assigned intervertebral discs with Grade I–V given 1–5 points successively according to the Pfirrmann system, and determined whether there was Modic change of each end plate. The correlation between the morphology of the end plate and the degree of IDD was analyzed.

Results: There was an excellent interobserver agreement for each item we analyzed (interclass correlation coefficient >0.75). Concave end plate appeared most frequently (187, 53.7%) and was mainly distributed in L3/4 and L4/5, whereas irregular end plate was the least common type (54, 15.5%) and mainly concentrated in L5/S1. The IDD degree of the corresponding disc increased gradually from concave (3.27 ± 0.81) to irregular end plates (4.25 ± 0.79) ($P < 0.05$). Irregular end plates were more likely to have Modic changes than concave and flat end plates ($P < 0.05$).

Conclusion: The sagittal morphology of the lower lumbar end plate is related to modic changes and degree of IDD (based on the Pfirrmann grading system) in patients with LDH, and the concave end plate mostly reflects a lower degree of lumbar disc degeneration, which has substantial clinical significance.

Keywords: Lumbar disc herniation, lumbar end plate, magnetic resonance imaging, sagittal morphology

INTRODUCTION

Lumbar disc herniation (LDH) is an usual type of lumbar degeneration disease, which is a common cause of low back pain and lower extremity dysfunction. Studies indicate that aging, obesity, smoking, end plate injury, lumbar rotation load, and bone mineral density are the risk factors for LDH.[1,2] The end plate is closely adjacent to the intervertebral disc, which is the direct conduction site of disc biomechanics. The mechanism of spinal compensation is complex, and the current cognition is still limited. Clinical studies have shown that the end plate will remodel to adapt to intervertebral disc degeneration (IDD),[3] and imaging changes of end plate are often observed in IDD.[4] With the development of surgical procedures, devices in some technologies such as

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disc replacement and interbody fusion require concave end plate designs to make the implant firmer, and better in accord with the morphological variability and biomechanical demand *in vivo*.[5,6] However, as an important anatomic factor in the process of LDH, the correlation between end plate sagittal morphology and IDD is unclear, and research on imaging data of lumbar end plate in patients with LDH is still insufficient. Because of the special biomechanical environment of the lower lumbar disc, it is more prone to degeneration than the upper lumbar spine.[7] Therefore, our study aims to observe the morphological and signal changes of the lower lumbar end plate (L3-S1) in patients with LDH on magnetic resonance imaging (MRI), analyze the relationship between the morphology of the end plate and the degree of IDD, and explore its clinical significance.

MATERIALS AND METHODS

Patient case selection and evaluation

This study did not need ethical approval from our ethics committee to be performed since it was a retrospective study and we did not have direct contact with the participants. Database records of patients with lower LDH (L3-S1) treated in our hospital were retrospectively collected and analyzed between January 1, 2023 and December 31, 2023 (updated medical record system was used since January 1, 2023). Patients included in the study were required to have available clinical data and should have performed a lumbar MRI. A complete MRI examination must include T1- and T2-weighted turbo spin sagittal images without fat suppression to cover all types of Pfirrmann grading systems.[8] MRI data were gained through a 1.5-T whole-body imaging system. Exclusion criteria were as follows: (1) Patients with a history of tumor, infection, fracture, deformity, spondylolisthesis, ankylosing spondylitis, rheumatism, osteoporosis, or other metabolic conditions that may affect the morphology of lumbar end plate and (2) Patients with previous spinal surgery history. According to the criteria, a total of 116 consecutive patients were involved in the study.

The degree of IDD was judged and scored according to the Pfirrmann grading system[8] which was divided into five grades, with Grade I–V given 1–5 points successively. Based on the classification of Pappou *et al*.,[7] the shape of the end plate was divided into concave, flat, and irregular levels [Figure 1]. When the upper and lower end plates of the same segment had two types of shape, the end plates of the same segment were classified as the severer type. In addition, we determined whether there was a Modic change in each end plate according to the Modic classification [Figure 2].[9]

Statistical analysis

One spine surgeon and one radiologist were selected to be evaluators, whereas they did not know the identity of the patient, the medical history of them, and the original classification used in clinical care. Each evaluator was provided necessary original literature and relevant information to assess cases. In case of controversy, they would discuss until they come to a consensus. If not, another spine surgeon would be asked to assess, and the result of majority approval would be taken.

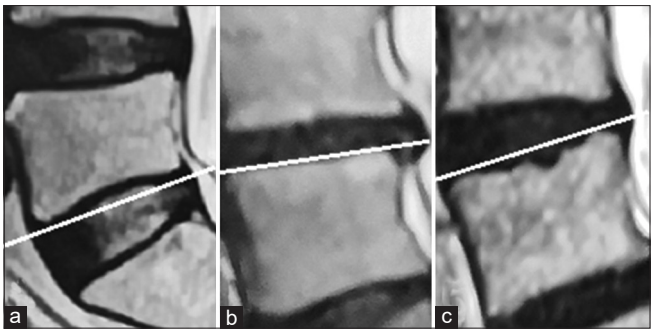

Figure 1: End plate shapes on sagittal T2-weighed magnetic resonance imaging. Concave (a), flat (b), and irregular (c)

All data analyses were performed using the Statistical Packages for the Social Sciences (SPSS) software (version 22.0, IBM, Chicago, United States). Measurement data are expressed as mean ± standard deviation, and ordinal data are expressed as percentages. The interobserver reliability of the evaluations was tested through interclass correlation coefficient (ICC),[10] and the values were expressed with a 95% confidence interval (CI). The larger value represented the better agreement. There were three levels of agreement for ICC, with 0.00–0.40 considered poor agreement, 0.40–0.74 fair to good agreement, and 0.75–1.00 excellent agreement.[11,12] The correlation between end plate shape and degree of IDD was analyzed by rank sum test, whereas the correlation between end plate shape and Modic change, end plate shape and disc herniation were analyzed by the Chi-square test. Meanwhile, $P < 0.05$ was considered statistically significant for all the above.

RESULTS

A total of 116 consecutive cases were involved in our study, including 47 males and 69 females, with a mean age of 52.6 ± 8.4 years (range from 25 to 67 years). There were totally 348 discs and 348 pairs of end plates (L3/4, L4/5, and L5/S1) taken into consideration by each evaluator [Table 1].

Interobserver reliability

Based on the reliability analysis of the results, the interobserver agreement of end plate shape, Pfirrmann classification, Modic change, and disc herniation on MRI images were excellent, ICC values of each item were calculated as follows: 0.895,

0.766, 0.854, and 0.923. The results were considered without significant difference ($P > 0.05$) [Table 2].

Measurements and correlations

Among the three types of morphology, concave end plate appeared most frequently (187, 53.7%) and mainly distributed in L3/4 and L4/5 segments; there were 107 (30.8%) pairs of flat end plates, which increased gradually from L3/4 to L5/S1; irregular end plate was the least common type (54, 15.5%) and mainly concentrated in L5/S1 [Table 3].

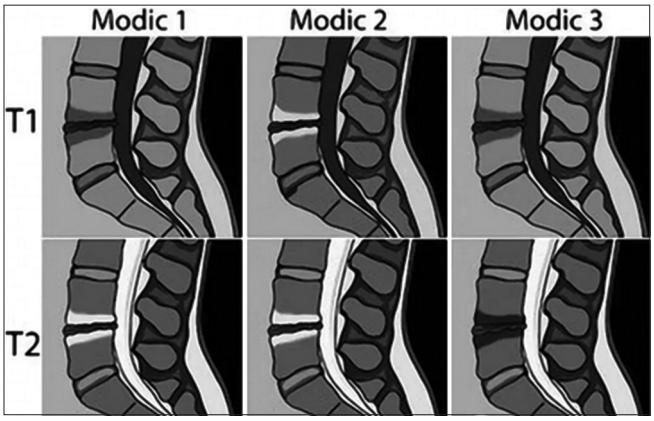

Figure 2: Modic changes on T1- and T2-weighed magnetic resonance imaging

Table 1: General information of the patients

Clinical information	*n*
Sex (male/female)	47/69
Mean age (years)	52.6±8.4
Herniated/nonherniated discs	158/190
Segment of herniation	
L3/4	39
L4/5	65
L5/S1	54

Table 2: Interobserver reliability of each item between evaluators

Items	Interobserver reliability	
	ICC	*P*
End plate morphology	0.895	0.507*
Pfirrmann classification	0.766	0.251*
Modic change	0.854	0.489*
Disc herniation	0.923	0.762*

*There was no significant difference between the two evaluators for the item.
ICC - Interclass correlation coefficient

Table 3: The morphology of end plates in different segments of all patient

Morphology	*n* (%)	End plate segment		
		L3/4	L4/5	L5/S1
Concave	187 (53.7)	97	69	21
Flat	107 (30.8)	13	24	70
Irregular	54 (15.5)	10	12	32

According to the Pfirrmann grading system, the degeneration degree of corresponding intervertebral disc increased gradually from concave (3.27 ± 0.81) to irregular end plates (4.25 ± 0.79) ($P < 0.05$), and IDD of Grade IV accounted for the most. In addition, the proportion of Grade V in irregular end plate is far greater than that of the other two types, as shown in Table 4.

The flat and irregular end plates were more common than the concave ones in the herniated segments ($P < 0.05$), whereas there was no significant difference between the flat and irregular types ($P > 0.05$). On the contrary, the concave end plates appeared most frequently in the nonherniated segments, following by the flat ones, with significant difference ($P < 0.05$). There were 49 segments of end plates (43 in herniated segment) in 37 patients accompanied by Modic changes. Those end plates in herniated segments accompanied by Modic changes mainly belonged to irregular type, with statistical difference ($P < 0.05$), whereas there was no significant difference between the concave and flat type ($P > 0.05$) [Table 5].

DISCUSSION

As a key component of spine structure, end plate plays an important role in nourishing intervertebral disc and conducting stress and has a significant impact on physiological state and pathological changes of intervertebral disc. In the treatment of IDD, motion preservation techniques are increasingly used. However, these techniques have certain requirements for end plate shape and height of intervertebral space. Therefore, it is helpful to study the correlation between morphology of end plate and IDD in clinical work. Previous studies on the morphology of the end plate mostly focused on the anatomical structure or the use of imaging to observe the transverse and sagittal diameter, circumference and area of end plates, as well as the measurement of their concave angle and relative curvature.[13] Although measuring the concave angle can objectively and quantitatively reflect the depression degree of end plate, it is so complex, and the uncertainty of the arc vertex positioning makes larger deviations. By contrast, the method used in this study can intuitively define the shape of end plate, which is simple to operate.

Harrington *et al*.[14] observed the influence of axial shape of the end plates on herniated discs, and pointed out that the end plate morphology with high curvature is an independent risk factor for LDH. Pappou *et al*.[7] analyzed the correlation between end plate morphology and IDD in patients with low back pain. Although their results were similar to ours, the study subjects were different, and they did not take Modic changes and disc herniation into consideration.

According to our results, we found that concave end plate is the main type in intervertebral discs with lower grade of degeneration on MRI. The biomechanical studies[15,16] show that the stress conducted by normal disc is mainly concentrated in the center of the vertebral end plate. The stress not only affects the volume and shape of the disc but also has an effect on the end plate. The load of axial stress, especially, can lead to the deformation of end plate and trabecula under it. That may explain why concave end plate is commonly seen in discs with milder IDD. In addition, when the intervertebral disc degenerates, the hydrodynamic characteristics of the nucleus pulposus gradually disappear, and the stress shifts from the center of the end plate to the periphery, resulting in relatively concentrated stress on the peripheral end plate, which not only increases the shear force and makes it prone to microfracture,[15] but also activate the bone reconstruction process of the end plate and vertebral body,[3] which will eventually lead to the gradual loss of the peripheral height of vertebral body and the flattening of end plate.[17] Meanwhile, the stress load of the peripheral part of lumbar intervertebral disc exceeds the normal range, which will lead to the injury of annulus fibrosus and accelerate the occurrence of LDH. Moreover, studies have shown that the pressure of lumbar end plate increases gradually from the top to bottom.[18] In our study, with the descent of lumbar segments, the concave end plates gradually decreased, and the flat end plates were increasingly common. The end plates of L5/S1 segment were mainly flat type, which may be related to the higher stress load of L4/5 and L5/S1 segments. The proportion of irregular type was the least and mainly concentrated in L5/S1 segment. We believed that the long-term effect of large stress load may easily lead to the irregular shape of end plate. Since L5/S1 segment is located at the lumbosacral junction and has high shear force, irregular end plates are more likely to appear in this segment than in others. In the process of disc herniation, the end plate morphology changes from concave to flat and then irregular, and the degeneration degree of corresponding disc gets increasingly severe. Meanwhile, the herniated discs are mainly accompanied with flat and irregular end plates. The result that the proportion of Grade V IDD in irregular end plate is far greater than that of the other two types can also explain this.

Table 4: The disc degeneration grade and score of patients based on Pfirrmann classification

Morphology	Grade of Pfirrmann classification					Scores of the grade (mean±SD)
	I	II	III	IV	V	
Concave	4	37	51	94	1	3.27±0.81
Flat	0	8	25	70	4	3.84±0.67*
Irregular	0	0	2	33	19	4.25±0.79*,†

*Compared with concave, $P<0.05$; †Compared with flat, $P<0.05$. SD - Standard deviation

Modic changes in MRI signal of end plate are highly correlated with IDD[19] account for approximately 19%–59% of disc degenerative diseases.[20,21] At present, it is generally believed that abnormal stress load after IDD,[4] lumbar instability,[22] and release of inflammatory factors[23] will cause vertebral microfracture and affect local microenvironment of marrow, leading to histological changes which ultimately manifest as changes in MRI signal of end plate. Based on our results, Modic changes accounted for 30% in patients with LDH, and irregular end plates had more Modic changes than the ones of other two types. It is reasonable for us to speculate that the Modic change may be the result of the end plate subjected to long-term abnormal stress and degeneration to a certain extent.

The current study has several limitations. First, limited by the hardware conditions of our radiology department, we did not use computed tomography (CT) reconstruction which was better for evaluating the sagittal morphology of end plate than MRI. Studies have shown that the bony edge of end plate is more easily identified on CT images.[24] Second, the relatively few evaluators. Considering the cognitive differences among specialties, we selected physicians from orthopedics and radiology department to assess the data. Nevertheless, increasing the number of evaluators will eliminate coincidence as much as possible, and improve the reliability of the results. Finally, we did not analyze the coronal morphology of end plate, and its effect on LDH or other lumbar degeneration disease needs further research. Therefore, high-quality, large sample, and multicenter studies should be performed in our future clinical work to provide spine surgeons with the best evidence-based information.

CONCLUSION

The sagittal morphology of lower lumbar end plate is related to Modic changes and degree of IDD (based on Pfirrmann grading system) in patients with LDH, and the concave end plate mostly

Table 5: The relationship among end plate morphology, disc herniation, and modic changes of patients

Morphology	Disc herniation			No disc herniation		
	n	Modic change	No modic change	*n*	Modic change	No modic change
Concave	24	5	19	163	2	161
Flat	41*	9	32*	66*	1	65*
Irregular	44*	29*,†	15†	10*,†	3	7*,†

*Compared with concave, $P<0.05$; †Compared with flat, $P<0.05$

reflects a lower degree of lumbar disc degeneration, which has substantial clinical significance. However, larger sample and multicenter studies should be performed to improve the accuracy and reliability of the finding, and further clinical correlation should be evaluated in future works.

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Conflicts of interest

There are no conflicts of interest.

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