Analysis of Correlation Between Vertebral Endplate Change and Lumbar Disc Degeneration

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

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Background: To evaluate the correlation between vertebral endplate change and the level of lumbar disc degeneration via magnetic resonance imaging (MRI).

Material/Methods: A total of 345 patients who were recruited from our hospital from May 2012 to May 2016 were evaluated for the presence of intervertebral disc degeneration or herniation. The degree of degeneration was assessed according to Pfirrmann grade. Vertebral endplate change was evaluated based on the endplate concave angle (ECA), and Modic change on sagittal MRI. The correlation between ECA and lumbar disc degeneration or Modic change and lumbar disc degeneration was analyzed.

Results: The results showed that there was no statistically significant difference in comparison of the ECAs in adjacent L3–5 vertebra between males and females. With the aggravation in degenerative changes of L3–5 discs, the ECAs of adjacent L3 superior endplate, L4 inferior and superior endplates and L5 inferior endplate were gradually enlarged, indicating the positive correlation between the lumbar disc degeneration and ECAs. The rate of Modic change in females was higher than that in males without a statistically significant difference. Area of Modic change was positively correlated with the degree of lumbar disc degeneration. Additionally, we also identified the positive correlation between the rate of Modic change and the degree of lumbar disc degeneration.

Conclusions: Endplate angle and lumbar disc degeneration are positively correlated. The endplates and endplate signal changes can reflect the degree of disc degeneration and Modic changes can reflect the rate of clinical lumbar disc degeneration degree.

MeSH Keywords: Intervertebral Disc Degeneration • Lumbar Vertebrae • Magnetic Resonance Imaging • Back Pain

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Background

Increasing numbers of people suffer from back pain and its related diseases, which are a major human health problem. Various factors contribute to those diseases, including muscle strain, spondylolisthesis, osteoporosis, and degenerated intervertebral discs. Lumber disc degeneration is one of the common factors causing back pain [1,2]. Clinical diagnosis of lumber disc degeneration relies on its symptoms, magnetic resonance imaging (MRI), and histopathological examinations.

The vertebral endplate is composed of trabecular bone layers with porous structures, by which the vertebral endplate provides nutrition to intervertebral discs. The vertebral endplate is a central sunken form, which transmits pressure transmission better from adjacent intervertebral discs. With the increase of age, the cartilage endplate concaves deeply [3]. As a pressure transmitter between the vertebral body and intervertebral disc, the vertebral endplate can disperse pressure during pressure transmission. Lumbar disc degeneration is always accompanied by corresponding changes in the endplate [4].

Previous studies on the morphology of endplates mainly focused on the structure, depth, maximal sagittal diameter, and transverse diameter [5–7]. However, there are few studies reporting the correlation of lumbar disc degeneration with endplate concave angle (ECAs) and endplate signals.

In this study, we investigated the correlation of lumbar disc degeneration with ECA and endplate signal through the measurement of ECA and observation of Modic changes, performed quantitative studies through using the ECA and the rate in changes of area caused by Modic change, and conducted in-depth studies on the classification of lumbar disc degeneration via radiographic images, so as to provide better guidance for clinical practice.

Material and Methods

Patients

We enrolled a total of 345 patients who received an MRI examination at our hospital for pain in the lower back and legs between May 2012 and May 2016, in which patients who received the spinal operation, or suffered from congenital deformity, trauma, tumor, infection, or systemic diseases causing bone abnormality were excluded. Among those included patients, the age ranged from 18 to 65 years, and there were 201 males with an average age of (38.51±14.67) years and 144 females with an average age of (39.45±13.64) years.

Magnetic resonance imaging

All MRI scans were obtained on a 1.5T GE HDx Superconductive Signa MRI scanner (General Electronics Healthcare, Milwaukee, WI, USA) using the spine phased array coil and fast spin echo (FSE), and during the scans, the head of patient was firstly placed in supine position. Scan parameters were set as follows: Sagittal T1WI (T1-weighted) image [TR (time of repetition)/TE (echo time) 450 ms/10.1 ms] and T2WI (T2-weighted) (TR/TE 2140 ms/108 ms), T2WI with fat-suppression (TR/TE 2140 ms/108 ms), axial T2WI image (TR/TE 3260 ms/106 ms); slice thickness of sagittal scanning=4 mm, interval=0.5 mm, FOV (Field of View) 32×32cm, matrix 320×224; slice thickness of axial scanning=4 mm, interval=1 mm, FOV 20×20 cm, matrix 320×224. All image analyses were performed using GE ADW (Advantage Development Workstation) 4.3.

Classification of lumbar disc degeneration

All patients with lumbar disc degeneration were evaluated and classified according to Pfirrmann grade [8].

Measurement of endplate concave angle and Modic change

Measurement of endplate concave angle (ECA): On the central sagittal T2WI of lumbar vertebra (indicating the integral outline of acantha), the bone endplate of vertebra was in arc shape, and a line was drawn from the summit/bottom of arc along to the endpoints, and the angle between these 2 lines was considered as the ECA. If endplates were lacking in some sites due to the Schmorl nodes, the endplate arc should be completed first according to the adjacent endplate arc, and then the bottom of arc was identified (Figure 1).

Modic change is a signal change of endplates after intervertebral disc degeneration on MRI. According to signal changes, Modic changes were classified into 3 types: type I (low T1 signal, high T2 signal), type II (high T1 signal, moderate T2 signal), and type III (low T1and T2 signal) [9].

Measurement of area rate of Modic change [9]: Area rate of Modic change, i.e. the ratio of changed Modic area measured on the central sagittal T2-weighted MRI image to maximal area of vertebra (Figure 2). If there were multiple Modic changes in vertebra, the total changed area was considered as the changed Modic area of vertebra.

Statistical analysis

SPSS 20.0 statistical software (IBM, USA) was applied to perform the normality test and tests for homogeneity of variances of measurement data in each group. Between the male
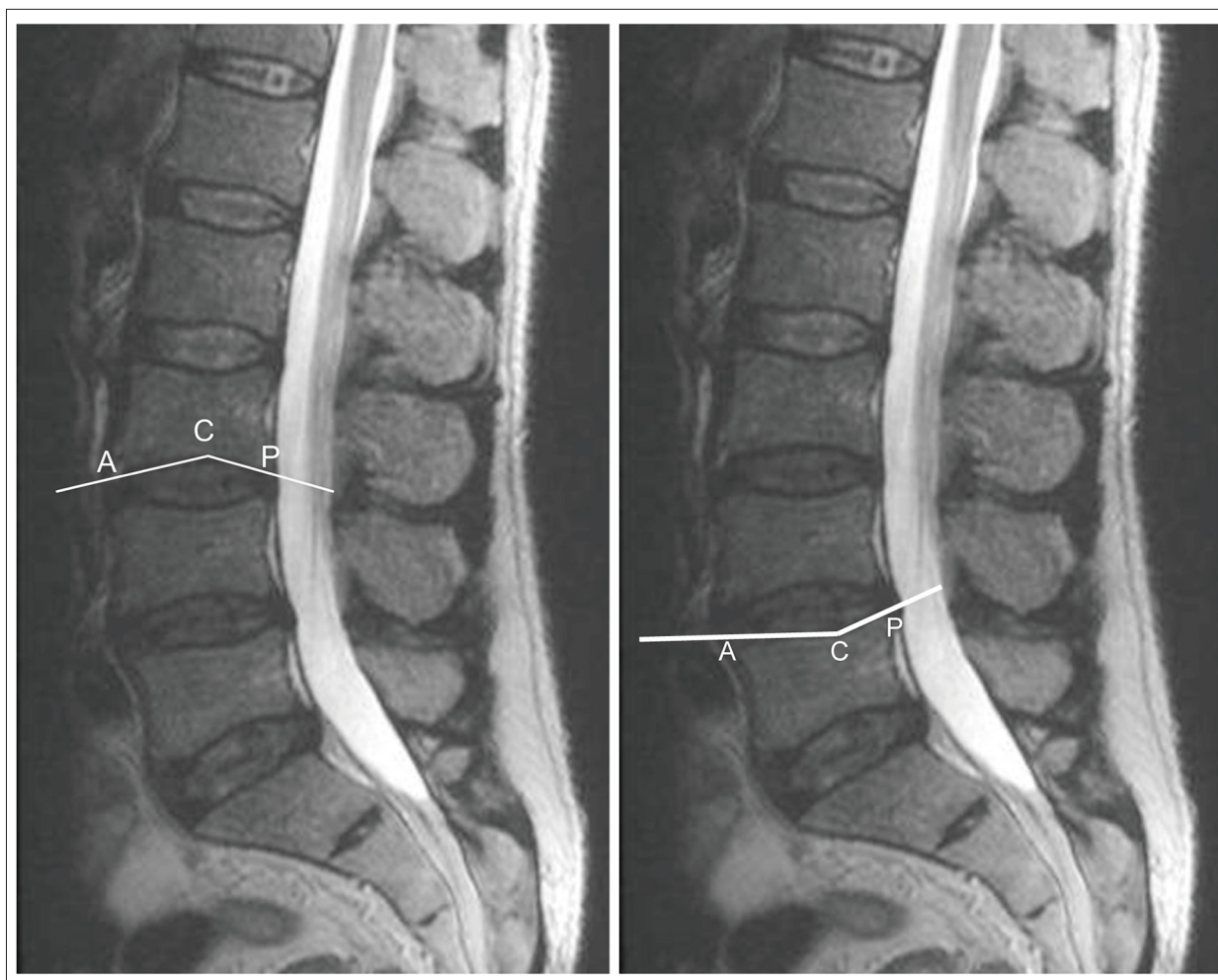
Figure 1. Measurement of endplate concave angle. A and P point are the highest or lowest points of the endplate. C point is the lowest or highest point of the endplate. ∠ACP is the endplate concave angle (ECA).

and female groups, the independent sample *t* test was performed for the comparison of measured ECAs. One-way analysis of variance (ANOVA) was carried out for the comparison between ECA and classification of lumbar disc degeneration. Chi-square test was performed for the correlation of incidence rates of Modic changes between the male and female groups. One-way ANOVA was performed for analysis of the correlation between area rate of Modic change and lumbar disc degeneration. Differences were considered statistically significant at $p<0.05$.

Results

ECA

The distribution of ECAs in male group and female group is shown in Table 1.

Statistical analysis revealed that there was no statistically significant difference in comparison of L3–5 intervertebral ECAs between the male and female groups.

Correlation of ECA and lumbar disc degeneration

With the aggravation in L3–5 lumbar disc degeneration, gradual increases were seen in the adjacent L3 inferior ECA, L4 superior and inferior ECAs and L5 superior ECA. The results showed that there was a positive correlation between the classification of lumbar disc degeneration and vertebral ECAs (Table 2, Figure 3).

Modic change

The incidence rate of Modic change in males was 31.3% (63/138), while this rate in females was 39.6% (57/144). Results suggested that the incidence rate of Modic change in females was higher than that in the males, but the difference between
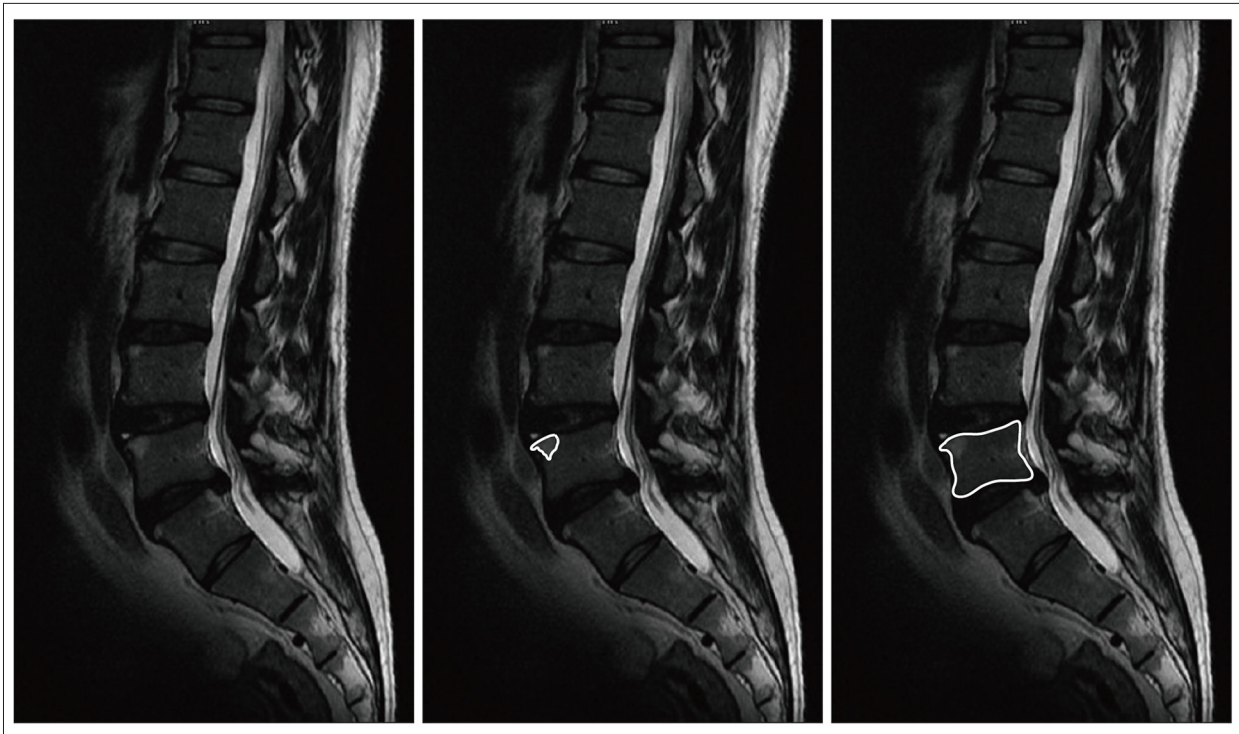
Figure 2. Measurement of Modic change rate. On sagittal plane of T2-weighted MR image, the rate of Modic change is the area of Modic change/the area of the whole vertebra.

the male group and female group was not statistically significant (χ^2=2.51, p>0.05, Table 3).

Correlation of Modic change and lumbar disc degeneration

The correlation coefficient between the area of Modic change and lumbar disc degeneration was measured under the T2-weighted MRI, and there was a positive correlation between these 2 parameters (r=0.963, p<0.001). Correlation coefficient between rate of Modic change and lumbar disc degeneration was r=0.972 (p<0.001, Table 4, Figure 4).

Discussion

In this study, we confirmed that there is no difference in comparison of the ECAs or the incidence rate of Modic change between males and females. There is a positive correlation between the ECAs and the degree of lumbar disc degeneration, and Modic change is also positively correlated with the degree of lumbar disc degeneration.

During the lumbar disc degeneration, superior and inferior endplates adjacent to the vertebra are in the shape of central concavity to bear more pressure from the adjacent vertebra, and this bilaterally concentric concavity is conducive to the human beings for long-term adaptation to the pressure

stress and dispersion of axial stress [10]. Studies [11,12] revealed that the concavity of cartilage endplate will be deepened with a gradual increase in age, which is mainly caused by the vertebral degeneration and osteoporosis inside the bones. In 1999, Weber K et al. [13] firstly utilized the double concavity index to evaluate the changes in concavity of endplate, and found that after the lumbar disc degeneration, the ECAs will be increased, and gradually, the endplate will become flat, which is closely correlated with the severity of degeneration. In this study, we confirmed that the vertebral ECAs are positively correlated with the lumbar disc degeneration, which is coincident with the results above. Comparisons between different genders showed that there was no statistically significant difference in comparison of ECAs in the same vertebra, suggesting that gender is not the factor significantly affecting the degree of depression in endplate. The authors in this study believed that due to the flatness of endplate and an increase in sagittal diameter of vertebra, the stressed area is enlarged, thus resulting in a decrease in stress per unit area. Hence, the flatness of endplate (i.e. the enlarged ECAs) might be a self-protective mechanism for vertebra to adapt to the biomechanical changes, which is conducive to the decrease of centralized stress on peripheral endplates and amelioration of damages to vertebra.

Diagnosis of lumbar disc degeneration mainly depends on the imaging examinations, in which MRI has been considered as

Table 1. Comparison of endplate concave angle (ECA) between different genders ($\theta/(°)$, $\bar{\chi}\pm s$).

Gender	L3 caudal endplate	L4 cranial endplate	L4 caudal endplate	L5 cranial endplate
Male	165.4±3.1	165.1±4.2	167.5±4.1	169.5±2.3
Female	165.7±4.4	167.4±3.5	168.5±2.7	170.1±2.8

Table 2. Correlation of endplate concave angle (ECA) and classification of lumbar disc degeneration ($\theta/(°)$, $\bar{\chi}\pm s$).

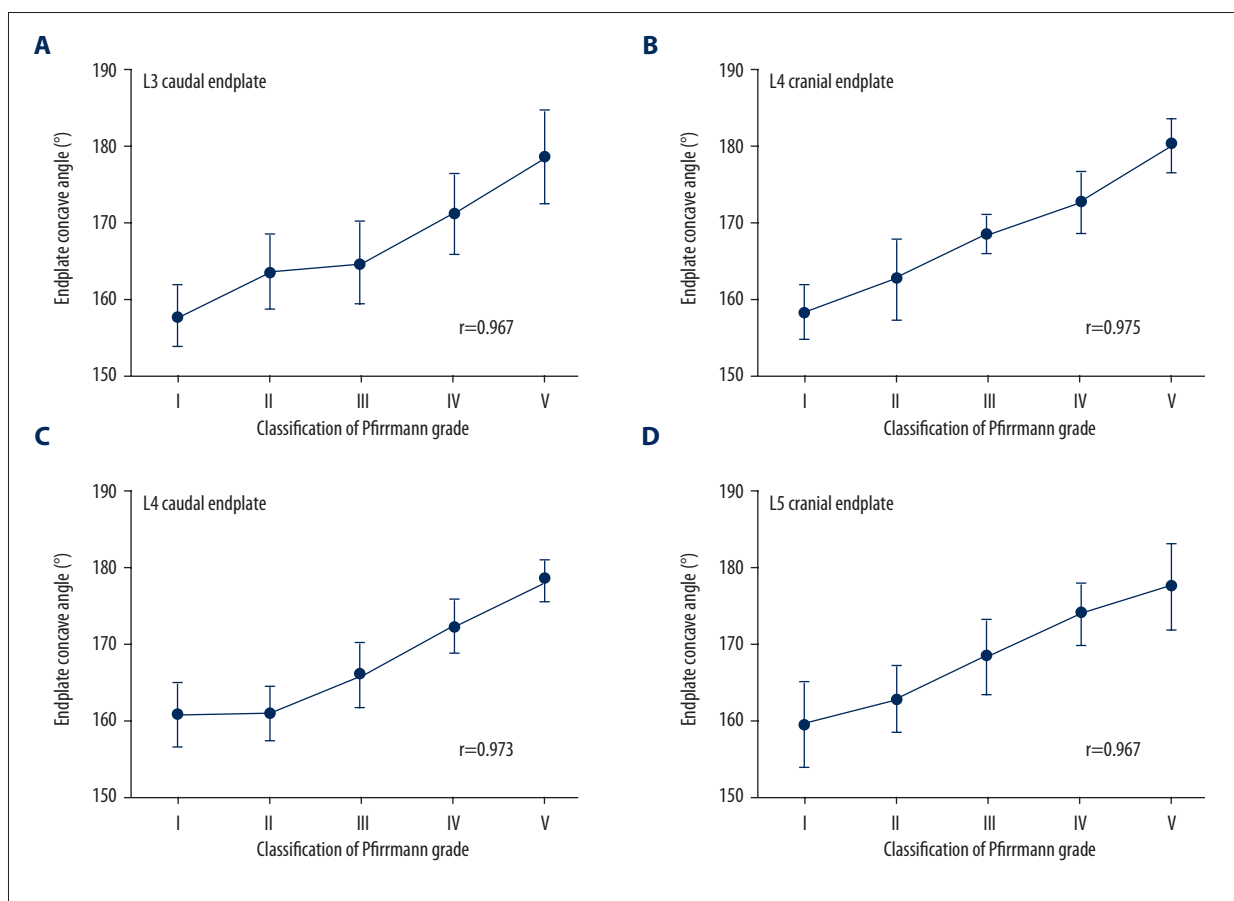| Grade	L3 caudal endplate	L4 cranial endplate	L4 caudal endplate	L5 cranial endplate
I	157.8±4.0	158.1±3.4	161.0±4.1	159.3±5.4
II	163.6±4.7	162.5±5.1	161.2±3.5	162.7±4.3
III	164.8±5.5	168.4±25	166.2±4.3	168.2±4.8
IV	171.2±5.3	172.5±4.1	172.5±3.5	173.7±4.2
V	178.7±6.1	180.1±3.5	178.3±2.7	177.4±5.5

Figure 3. Correlation of endplate concave angle and classification of lumbar disc degeneration. Correlation of endplate concave angle and classification of lumbar disc degeneration in L3 caudal endplate (**A**), L4 cranial endplate (**B**), L4 caudal endplate (**C**) and L5 cranial endplate (**D**). As the intervertebral disc degeneration was aggravating, the adjacent endplate concave angle increased correspondingly.

the best method for evaluating the lumbar disc degeneration; in addition, according to the changes in signal, we can also perform quantitative classification to evaluate the degeneration in nucleus pulposus. In 1987, Schneiderman et al. [14] firstly classified the signals of intervertebral discs into 4 grades according to the T2-weighted image. In 2001, Luoma et al. [15] utilized the relative signals of nucleus pulposus to perform quantitative classification of relative signal intensity (RSI). In 2001, Pfirrmann et al. [8], through a large number of studies and based on the previous discoveries, put forward a more specific classification pattern. In 2007, Griffith et al. [16] thought that Pfirrmann classification could not clearly distinguish the lumbar disc degeneration at early stage, and, thus, proposed

the modified version of Pfirrmann classification. So far, there is no MRI grading system that can systemically and comprehensively reflect all features of lumbar discs in images, or a system meeting clinical needs.

Studies have shown that during the lumbar disc degeneration, the re-distributed stress on vertebral endplate is gradually increased, and if the local pressure exceeds the bearing limit of endplate, microfracture in bone trabecula under the endplate and alterations in local spinal microenvironment will occur, thus leading to Modic change [17,18]. In this study, we have confirmed that with the aggravation in lumbar disc degeneration, area rate of Modic change was increased, further proving the close correlation between the Modic change and lumbar disc degeneration, which can provide the evidence for future studies.

Table 3. Comparison of Modic change between different genders (N).

Gender	Modic change	No Modic change
Male	63	138
Female	57	87

Conclusions

ECA is positively correlated with the degree of lumbar disc degeneration. As for Modic change, in addition to the normal

Table 4. Correlation of Modic change and classification of lumbar disc degeneration.

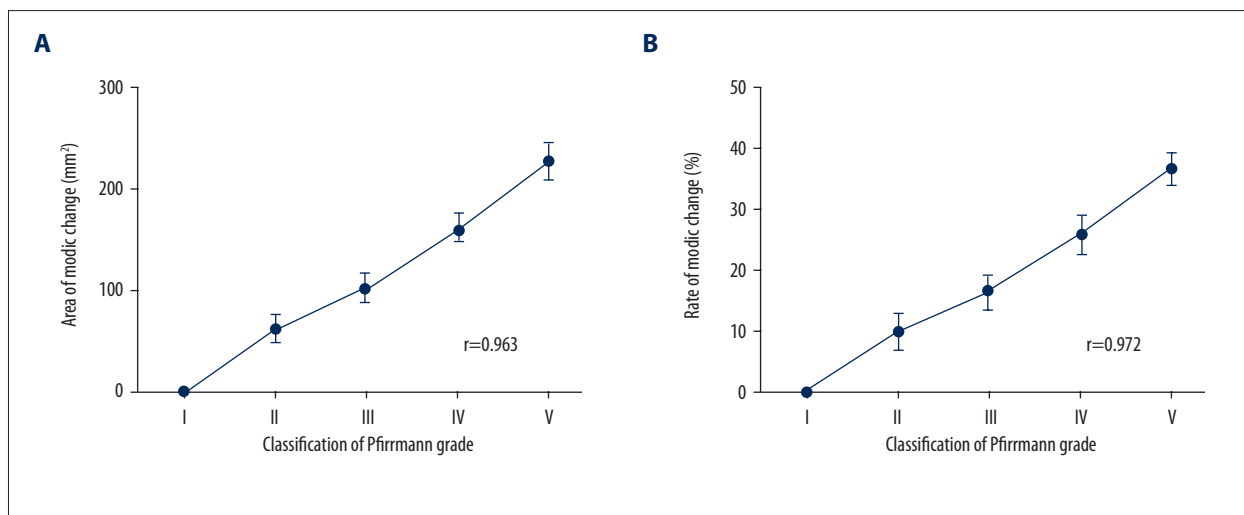| Grade	Number of patients (N)	Area of vertebra (mm^2)	Area of Modic change (mm^2)	Modic change rate (%)
I	0	0	0	0
II	21	623.25±26.12	62.33±12.46	10.00±3.15
III	24	622.54±32.93	103.56±13.53	16.64±2.87
IV	35	622.75±27.45	162.34±14.56	26.07±3.18
V	40	618.98±23.79	228.54±17.39	36.92±2.73

Figure 4. Correlation of Modic change and classification of lumbar disc degeneration. (**A**) Correlation of Modic change area and classification of lumbar disc degeneration. (**B**) Correlation of Modic change rate and classification of lumbar disc degeneration.

intervertebral disc, the area rate of Modic change is also increased with the aggravation in lumbar disc degeneration. Changes in endplate and endplate signal can reflect the degree of lumbar disc degeneration in a certain degree. Thus, in the future, the degree of lumbar disc degeneration can be reflected through measurements of the ECAs and area rate of

Modic change on MRI central sagittal T2-weighted image in clinical practice.

Conflicts of interest

The authors declare no conflicts of interest.

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