

Original Article

Correlative analyses of isolated upper lumbar disc herniation and adjacent wedge-shaped vertebrae

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Abstract: Background: Upper lumbar disc herniation (ULDH) is easy to be misdiagnosed due to its special anatomical and atypical clinical features. Few studies have identified the relationship between ULDH and adjacent wedge-shaped vertebrae (WSV). Hypothesis: WSV may have some indicative relations with ULDH. Patients and methods: Between January 2003 and October 2013, 47 patients (27 males and 20 females; mean age, 41.2 years) with single-level ULDH (as study group) and 47 sex- and age-matched healthy volunteers (as control group) were studied by radiograph. The two groups were compared with respect to age, sexual proportion, body mass index (BMI), kyphotic angle, and the proportion of WSV. Also, correlative analyses were conducted in the study group to investigate the relation between the kyphotic angle of target vertebrae and other factors including age, BMI, Cobb angle, JOA score and bone mineral density (BMD). Results: The average kyphotic angle in the study group was 11° (4°-22°), while the average kyphotic angle in the control group was 2° (0°-7°). Obviously, the mean kyphotic angle in the study group was statistically larger than that in the control group ($t=13.797$, $P<0.001$). The proportion of WSV in the study group was significantly larger than that in the control group ($\chi^2=36.380$, $P<0.0001$). The correlations between kyphotic angles and other items (i.e., age, BMI, BMD, Cobb angle and JOA score) in the study group and the control group were low or uncorrelated. Conclusions: WSV are indicatively associated with adjacent ULDH. Thus, ULDH should be alerted when WSV are first found in radiograph and accompanied by clinical symptoms.

Keywords: Disc herniation, upper lumbar spine, wedge-shaped vertebrae, correlative analysis

Introduction

Upper lumbar disc herniation (ULDH) is relatively uncommon. Only 1% to 11% of herniated discs originate from upper lumbar levels [1-4]. Although some reports have described the atypical features of ULDH [4-6], few of them mentioned its etiology [4].

Unlike lower lumbar disc herniation whose typical symptom is "sciatica", the symptoms of ULDH are varied because it usually consists of a compact neural component and conus medullaris in the dural sac [7]. Due to its low morbidity, it is relatively difficult for clinical doctors to accurately diagnose ULDH at the first visit. Computed tomography (CT) or magnetic resonance imaging (MRI) exams for ULDH might be ignored so that patients probably have to wait for a longer time to be diagnosed or they might be misdiagnosed.

Based on our observations, ULDH occurred frequently in patients with adjacent vertebral wedge-shaped deformities. However, there were few conclusive studies on the relationship between ULDH and adjacent wedge-shaped vertebrae (WSV).

The purpose of this clinically controlled study is to explore the relationship between ULDH and WSV. In the present study, we only aim at isolated lumbar disc herniation because fewer influencing factors are involved compared with multi-lumbar disc herniation.

Patients and methods

From June 2003 to October 2013, 96 patients (52 males and 44 females) with single-level ULDH (confirmed by MRI) between T12-L3 vertebrae underwent operation in our medical center. 49 of them were excluded. The exclusion

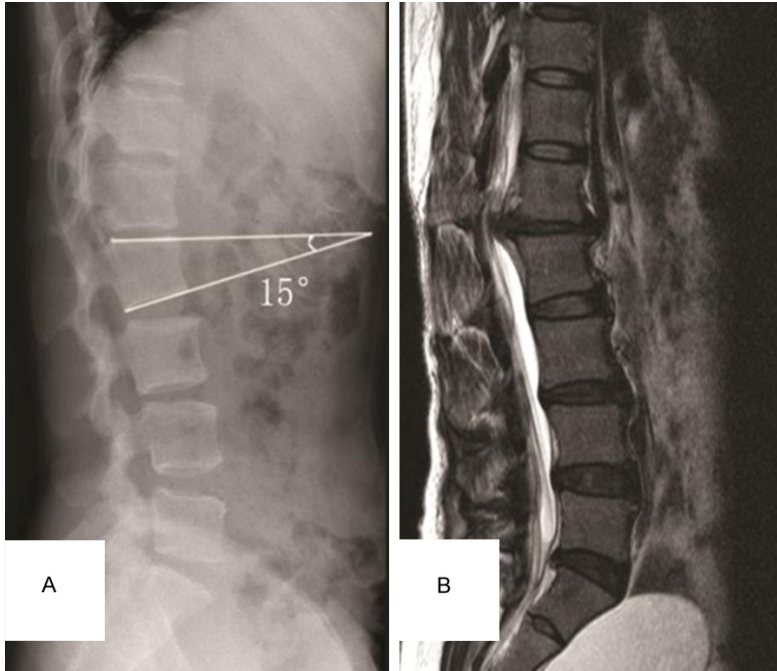


Figure 1. A. The kyphotic angle was defined as the angle from the superior endplate to the inferior endplate of the objective vertebral body. In this case, a patient with 15 kyphotic angle of L2. B. The magnetic resonance image shows the L1/2 disc herniation.

criteria included infection, tumor, scoliosis, osteoporosis, and a history of falling and back injury within 1 year before operation. A total of 47 patients were included in the study group. The average age of the study group at the time of surgery was 41.2 years (range, 19-66 years). One patient had Scheuermann's disease. In the study group, 40 patients (85.1%) admitted previous history of back injury. Twenty-four patients were diagnosed of compression fracture, and all of them were treated with non-surgery treatment at that time. The mean time from injury to symptom occurrence was 7.4 years (from 2.3 to 15.4 years).

In 2012, 47 healthy volunteers were chosen as the control group. Volunteers with previous spinal injury history had been excluded. Control subjects were matched for sex and age (± 12 months). All of the subjects underwent upright lateral radiographs. This study was approved by the Investigational Review Board at our institution, and informed consent was obtained from each patient and healthy volunteer.

The kyphotic angle was defined as the angle formed between a line drawn parallel to the superior endplate and a line drawn parallel to

the inferior endplate [8] (**Figure 1**). In the study group, the vertebra with larger kyphotic angle adjacent to the herniated disc was chosen as the wedge-shaped vertebral body. In the control group, the kyphotic angles were measured at each vertebral body from T12 to L3 of every subject and the biggest angle was chosen for study.

The Cobb angle of the study group was defined as the angle formed between a line drawn parallel to the superior endplate of the upper vertebrae above the objective vertebrae and a line drawn parallel to the inferior endplate below the objective vertebrae.

During the process of our study, the observers who performed the measurements

were not aware of the objective of this work, and the measurements were done in the control group first.

To fairly assess the margins of the vertebrae and kyphotic angles, all images were blindly and randomly evaluated by 3 investigators (Si-Dong Yang, Da-Long Yang, and Wen-Yuan Ding). All endplate damages at the herniated levels were demanded to be marked. Thirty-five patients (74.5%) in the study group had endplate damages at the herniated level. We haven't evaluated the endplate damages in the control group due to lack of CT or MRI.

Statistical analyses were performed using standardized SPSS software (version 12.0, SPSS Inc., Chicago, IL). Two-sample t tests were performed to compare age, body mass index (BMI) and kyphotic angles (in accordance with normal distribution). Sexual ratio and the proportion of WSV were compared between the two groups by chi-square test. Pearson's correlation coefficient was used to determine the correlation between kyphotic angles and age, BMI, Cobb angles, BMD, and JOA score. Statistical significance was defined as a probability value less than 0.05 (i.e., $P < 0.05$).

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Table 1. Information on ULDH and WSV in the study group

Herniated disc level	number	WSV	number
T12/L1	8	T12	8
L1/2	14	L1	11
L2/3	19	L2	15
L3/4	6	L3	8

ULDH: Upper lumbar disc herniation; WSV: wedge-shaped vertebrae.

Table 2. Comparisons of the proportion of WSV in study group and control group

Group	WSV	Non-WSV
Study group ^a	41	6
Control group	12	35

^a $\chi^2=36.380$, $P<0.0001$, compared to control group using Pearson chi-square test. WSV: wedge-shaped vertebrae.

Results

There were no significant differences in baseline data including age, sex, BMI between the study group and the control group (all $P>0.05$). **Table 1** shows the herniated disc levels and WSV of the study group. Apparently, L2-L3 level ranked most of ULDH and WSV. Compared with the control group, the proportion of WSV in the study group was significantly larger ($\chi^2=36.380$, $P<0.0001$) (see **Table 2**).

As shown in **Table 3**, the kyphotic angle was $11^\circ\pm 4^\circ$ (range, 4° - 22°) in the study group and $2^\circ\pm 2^\circ$ (range, 0° - 7°) in the control group. The kyphotic angles in study group were statistically significantly larger than those in the control group ($t=13.797$, $P<0.001$).

As shown in **Tables 3-5**, the correlations between kyphotic angles and other items (age, BMI, BMD, Cobb angle, JOA score) in the study group and the control group were low or uncorrelated.

Discussion

The concept of 'upper lumbar discs' has no clear definition of 'upper' in literature. Many authors have classified lumbar levels in their own way [4, 9-11]. In our study, T12-L1, L1-L2, L2-L3 and L3-L4 levels have been named as 'upper lumbar'. T12/L1 level is included because unlike a thoracic level, this level is not included in ribcage.

Table 3. Kyphotic angle and BMI in study group and control group

Group	Kyphotic angle	BMI
Study group	$11\pm 4^\circ$ ^a	24.17 ± 0.29 ^b
Control group	$2\pm 2^\circ$	24.29 ± 0.22

BMI, body mass index; ^a $P<0.05$ compared to control group; ^b $P>0.05$ compared to control group.

ULDH presents a difficult diagnostic and treatment challenge [6, 11]. Unlike the typical symptom of 'sciatica' in lower lumbar disc herniation, ULDH does not always induce the radiating pain down the back of the leg. Instead, ULDH often causes the insidious onset of pain in the groin or in the front of the thigh [4-6] and even myelopathy [6]. Therefore, it has a tendency to be misdiagnosed, and often takes a long time to be diagnosed accurately [12].

Hsu [4] found that patients with isolated high lumbar disc lesions were relatively young (mean age, 40.7 years), a finding similar to our study (mean age, 41.2 years). They also mentioned that those patients under 50 years of age also had pre-existing or coexisting abnormalities such as Scheuermann's disease and previous fractures that may have predisposed the disc to further injury under mechanical stress.

Based on our observations, ULDH was found to occur frequently in patients with adjacent vertebral wedge-shaped deformities. In our study, ULDH was significantly related with adjacent WSV, and the kyphotic angles of adjacent vertebrae were significantly larger than those in healthy people ($P<0.001$).

There are two main reasons that may explain this relationship between ULDH and WSV. Firstly, WSV can change the mechanics of adjacent levels by increasing the angle of superior endplate tilt. Briggs [13] pointed out that the composite mass of the superior vertebral levels, head and arms may translate slightly anteriorly. The moment arm distance between the vertebral centroid and composite centre of mass of the trunk will increase, thereby increasing the flexion moment at that level and contiguous levels [13]. As a result, shear forces were greater at the level of WSV and one level above, while compression forces were greater at one level below WSV compared to equivalent level mean forces of the non-fracture group. These results strongly suggest that the presence of WSV is associated with increased loads locally

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Table 4. Comparisons between kyphotic angle and age or BMI in study group and control group, respectively

Groups	Comparisons	r	P-value
Study group	Age and kyphotic angle	0.146	0.233
	BMI and kyphotic angle	0.015	0.011
Control group	Age and kyphotic angle	0.049	0.560
	BMI and kyphotic angle	-0.025	0.328

BMI, body mass index; r, correlation coefficient.

Table 5. Comparisons between kyphotic angle and Cobb angle or JOA score or BMD in study group

Comparisons	r	P-value
Cobb angle and kyphotic angle	0.125	0.037
JOA score and kyphotic angle	-0.008	0.024
BMD and kyphotic angle	0.059	0.682

JOA score, Japanese Orthopaedics Association score; BMD, bone mineral density.

and in adjacent levels, in agreement with Rohmann's study [14]. We believe that increased shear forces and compression forces secondary to WSV will not only influence the adjacent vertebra, but also accelerate the degeneration and even the herniation of adjacent intervertebral discs [15-18].

Compression fracture is another factor that may contribute to the link between ULDH and WSV. During the development of compressing fracture, vertebra collapse, annulus tear and endplate damage could happen at the same time. Annulus tear [19, 20] and endplate injury [21-23] are believed to be the reasons for disc degeneration. The nutrition of the disc is thought to be impaired by trauma, as the gateway of nutrient supply (vertebral endplate) is essential to maintain the integrity and function of the avascular intervertebral disc [24]. It is proved that endplate fracture can cause degenerative changes both in humans [25-27] and in animal models [28, 29]. In our study group, 40 patients (85.1%) admitted previous history of back injury; 24 patients (51.1%) admitted previous compression fracture; and 35 patients (74.5%) had endplate damages at the herniated levels. Therefore, WSV could be seen as a signal indicating existence of previous fracture which may cause ULDH.

Kerttula pointed out that wedged compression fractures did not usually cause symptoms, at

least at a young age [23]. In this study, the mean time from injury to symptom appearance is 7.4 years. We postulate that biomechanical changes induced by WSV in adjacent levels may not cause clinical symptoms in a short time, but it may finally result in disc degeneration or even disc herniation after a relatively long period of time. In our study, WSV is found to be highly associated with adjacent disc herniation. The mean kyphotic angle of WSV in the study group is 11°.

Usually this wedge deformity is too tiny to be noticed. However, this single kyphosis may be responsible for a subtle change in curvature which is sufficient to significantly increase loading. When the kyphotic angle of WSV in a symptomatic patient is larger than 11°, ULDH is recommended to be alerted.

Results from this study are expected to remind doctors of ULDH when they encounter symptomatic patients with WSV. According to our limited observations, WSV frequently occurs in upper lumbar spine. We postulate that wedge fracture frequently occurs in thoracolumbar spine. Besides, compared with lower lumbar spine, upper lumbar alignment is more straight and perpendicular to the horizontal plane, which makes them more vulnerable to the influence of biomechanical changes.

Inevitably, this study still has some shortcomings, e.g., its retrospective character as well as small sample size. Due to our small size of samples, more studies are needed to further testify the theory above. Prospective studies with larger sample size and longer-time follow-ups are essential in the future.

In summary, the present study suggests that WSV in upper lumbar spine is indicatively correlated to adjacent ULDH. Thus, doctors should be alerted to ULDH when WSV are first found in radiograph and also accompanied by clinical symptoms.

Disclosure of conflict of interest

None.

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