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A Study of Lumbar Disc Herniation and Facet Joint Asymmetry

Qi Lai[1,2], Yuan Liu[1,2], Runsheng Guo[1,2], Xin Lv[1,2], Qiang Wang[1,2], Jianghao Zhu[1,2], Bin Zhang[1,2], Min Dai[1,2]

[1]*Department of Orthopedics, Artificial Joints Engineering and Technology Research Center of Jiangxi Province, The First Affiliated Hospital of Nanchang University, Nanchang, China*

[2]*Multidisciplinary Therapy Center of Musculoskeletal Tumor, The First Affiliated Hospital of Nanchang University, Nanchang, China*

Purpose: To investigate the association of facet joint asymmetry with lumbar disc herniation at the lower lumbar spine.

Methods: A total of 90 patients (ages 18–40 years) with single-level disc herniation (L3–L4, L4–L5, or L5–S1) were included in the study. Facet asymmetry was defined as a difference of 10° in facet joint angles between right and left sides. Normal discs in the same segment of other individuals were used as a control. Patients had facet asymmetry measured for L3 to S1 through 3.0T magnetic resonance imaging, and information was collected, including age, sex, degenerative degree of lumbar facet joints, and the presence or absence of lumbar disc herniation and type.

Results: At the L3 to L4 level, 2 cases had facet asymmetry in 8 patients with lumbar disc herniation, compared with 17 cases of facet asymmetry in 82 patients without disc herniation ($P = 0.7776$, $r = 0.030$). At the L4 to L5 level, there were 21 cases of facet asymmetry in 45 patients with lumbar disc herniation, compared with 5 cases of asymmetry in 45 patients without disc herniation ($P = 0.00019$, $r = 0.392$). At the L5 to S1 level, there were 25 cases of facet asymmetry in 37 patients with lumbar disc herniation, compared with 11 cases of facet asymmetry in 53 patients without disc herniation ($P = 0.0000$, $r = 0.492$). There were 23 cases of facet asymmetry in 28 disc herniations of side type compared with 2 cases of facet asymmetry in 9 herniations of center type ($P = 0.0008$, $r = 0.364$). There was no

Corresponding author: Min Dai, Department of Orthopedics, the First Affiliated Hospital of Nanchang University, 17 Yongwai Street, Nanchang, Jiangxi 330006, People's Republic of China.
Tel.: 00 86 0791 88694758; E-mail: Liuyuanzyj5257@126.com
Qi Lai, Yuan Liu and Runsheng Guo contributed equally to this work and should be considered co-first authors.

significant difference in the relationship between age, facet joint degeneration, and lumbar facet joint asymmetry ($P > 0.05$).

Conclusion: Facet asymmetry is significantly associated with lumbar disc herniation at the L4 to L5 and the L5 to S1 levels, whereas there is an obvious association with the side type of lumbar disc herniation at the L5 to S1 level.

Key words: Facet joint asymmetry – Lumbar disc herniation – Type of herniation – MRI

Low back pain is a common clinical symptom, and it results in mental as well as economic problems for the patient. The causes of low back pain are complex and diverse, mainly due to intervertebral disc problems. Meanwhile, some researchers also found that the lumbar facet joint was one of the sources of low back pain—namely, the mechanisms of lumbar facet joint inflammation. And so, paying attention to the lumbar facet joints, we started to investigate lumbar facet joint biomechanics. Thus, we can come to understand the relationship of the lumbar facet joint to its related diseases in a more profound way. Some scholars put forward the viewpoint that the structural asymmetry of the lumbar facet joint is related to degenerative disease of the lumbar spine. In 2001 Fujiwara *et al*[1] proposed that lumbar facet joint nonsymmetry was associated with lumbar facet joint osteoarthritis. The Chinese scholars Yao *et al*[2] argued that the nonsymmetric lumbar facet joint was related to lumbar spondylolisthesis .Before that, Cassidy *et al*[3] had shown that the nonsymmetric lumbar facet joint was irrelevant to lumbar disc herniation. Lee *et al*[4] reported that the lumbar disc and the bilateral facet joint could combine to form a 3-joint complex of the spine. In a 3-joint complex of the spine, a slight movement in 1 part may affect the situation as a whole. Therefore, if the lumbar facet joint has an injury, it may lead to an imbalance of the sport line of the spine, which will affect 3-dimensional movement and the load-carrying capability of the disc.[4,5] Hence, the authors wondered whether facet asymmetry was associated with lumbar disc herniation, and so we researched the association of facet asymmetry with lumbar disc herniation using a large sample of 3.0T magnetic resonance imaging (MRI).

Patients and Methods

The authors collected clinical data for patients who visited the orthopedics department of the First Affiliated Hospital of Nanchang University, from January 2015 to October 2015. According to imaging and symptoms, 318 patients received a diagnosis of lumbar disc herniation. But 90 patients met the requirements of this study, including 52 men and 38 women, whose ages ranged from 18 to 40 years and for whom the average age was 49.77 years. Inclusion criteria were: (1) the patient must have received a diagnosis of lumbar disc herniation by 3.0T MRI; (2) the patient must belonged to 1 single-level lumbar disc herniation group (L3–L4, L4–L5, or L5–S1); and (3) the patient must have had no combined problems of cervical or thoracic vertebra. Patients with multiple or recurrent disc herniation, associated spondylolisthesis, spina bifida, transitional vertebra, scoliosis, previous surgery, previous trauma, spinal infection, and significant facetal arthropathy were excluded.

MRI examination

The 90 included patients were required to maintain a standard supine position, and then they were scanned by MRI on sagittal view and cross section at the L1 to S1 level; the lumbar facets were scanned as T2-weighted images on 3.0T MRI (scan thickness was 3 mm and scan distance was 5 mm) because MRI axial T2-weighted images are the best way to visualize facet joints and the lumbar disc. Although the resolution of computed tomography (CT) is higher, using MRI is important to evaluate the degree of lumbar facet joint degeneration, asymmetry, and lumbar disc herniation; therefore, MRI was the best choice.

Measurement methods of the lumbar facet angle

Measurement methods and tools were used on a computer with the HaiTai PACS (Nanjing medical information system company, Nanjing, China) Clinical diagnosis system of the imaging department installed on it. The facet joint angle was measured using new software, and facet joint degeneration was determined according to MRI

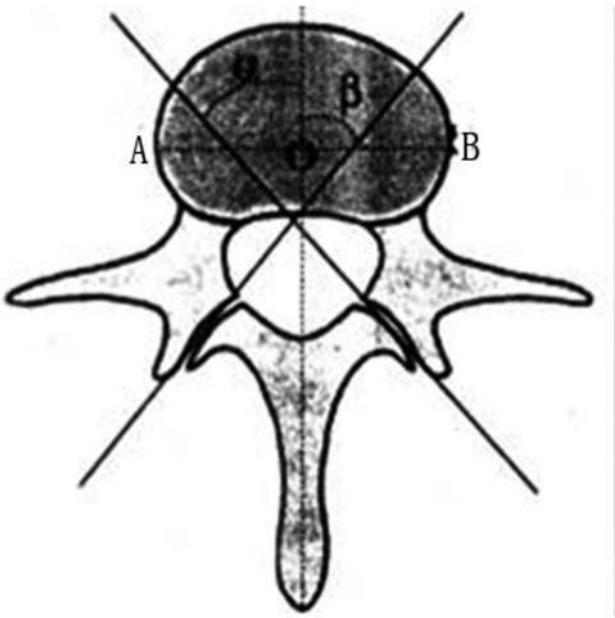

Fig. 1 Measurement chart for facet tropism. AB line is drawn between the 2 margins of each of the superior articular facets. The midsagittal line will pass through the center of the disc (O) and the center of the base of the spinal process. The angle between the facet line and midsagittal line was measured for each side of the spine. The difference of the right (α) and left (β) facet angles for each patient was calculated (AO = BO).

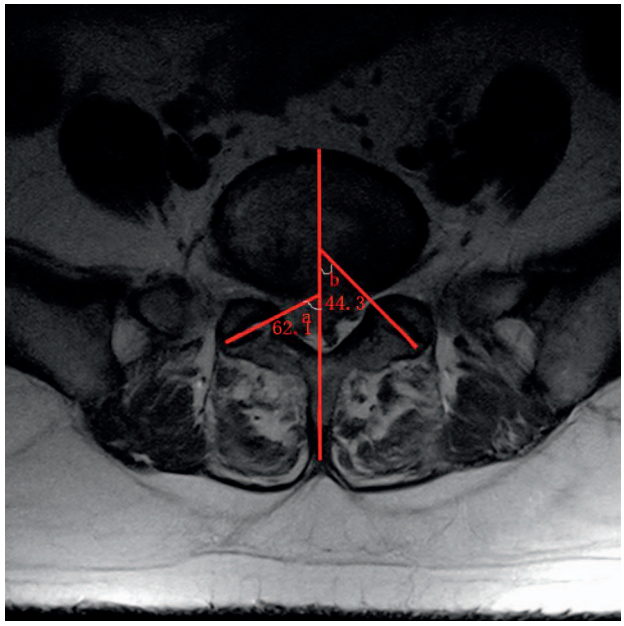

Fig. 2 A case of simple L4 to L5 disc herniation. The difference of the bilateral facet joint angle is 17.8° by the computer system software measurement.

degeneration classification (slight is 0 or 1; severe is 2 or 3). The tool angle, which was a tool for accurately measuring the angle, selects 2 spots and makes a line between the 2 margins of the facets, and selects 2 other spots to make a line passing through the center of the disc (Fig. 1). The tool angle software will quickly and accurately calculate facet angle (Fig. 2). Three orthopaedic surgeons measured the facet joint angles independently. The mean value was taken as the true facet angle in order to minimize observer bias. The difference between right and left facet angles was recorded. Facet asymmetry was defined as a difference between right and left facet angles that exceeded 10°. In biomechanical research, the definition of lumbar facet joint asymmetry is a discrepancy between two lumbar facet joint angles that is greater than 1°. Different scholars have made different definitions of nonsymmetric facet joint. But a discrepancy of more than 10°, which is ideal numerically, is currently recognized by most scholars, whether the measurement error exists or not.

Grouping and statistics

Normal discs in same segment of other individuals were used as a control (for L4–L5 level, there were 21 cases of facet asymmetry in 45 patients with lumbar disc herniation, compared with 5 cases of asymmetry in 45 patients without disc herniation). Fisher exact test was used to determine the statistical significance of categoric variables; $P < 0.05$ was considered significant. Intra Class Correlation Coefficient was employed to determine the reliability between the 3 observers for the measurement of facet angle. A power analysis using SD of tropism measurements was performed by using the t test. The data were analyzed by using SPSS Statistical Software SPSS version 17.0 (SPSS Inc., Chicago, IL).

Results

Via analysis of the relationship between different age groups (≤39, 40–59, and ≥60 years) and facet asymmetry, the result shows that there was no difference in facet asymmetry with regard to age in 90 cases ($P \geq 0.05$; Table 1). Then, we started to investigate the relationship between lumbar facet joint osteoarthritis and facet asymmetry, and we discovered that lumbar facet asymmetry was no different in different groups of degenerative lumbar facet ($P \geq 0.05$; Table 2). Finally, we checked into the

Table 1 Association of facet asymmetry with age in 90 cases

Level and Age	Facet Asymmetry, No.[a] Yes	No	χ^2	*P* Value
L3–L4			3.642	0.162
≤39 y	6	11		
40–59 y	7	42		
≥60 y	6	18		
L4–L5			1.168	0.558
≤39 y	6	11		
40–59 y	15	34		
≥60 y	5	19		
L5–S1			1.791	0.408
≤39 y	6	11		
40–59 y	22	27		
≥60 y	7	17		

[a]No indicates asymmetry is absent; yes indicates that asymmetry is present.

relationship between lumbar disc herniation and facet joint asymmetry, and the result shows (Table 3) that there were 2 cases of facet asymmetry in 8 patients with lumbar disc herniation, compared with 17 cases of facet asymmetry in 82 patients without disc herniation ($P = 0.7776$, $r = 0.030$), at the L3 to L4 level; there were 21 cases of facet asymmetry in 45 patients with lumbar disc herniation, compared with 5 cases of asymmetry in 45 patients without disc herniation ($P = 0.00019$, $r = 0.392$), at the L4 to L5 level; and there were 25 cases of facet asymmetry in 37 patients with lumbar disc herniation, compared with 11 cases of facet asymmetry in 53 patients without disc herniation ($P < 0.0001$, $r = 0.492$), at the L5 to S1 level. Additionally, there were 23 cases of facet asymmetry in 28 instances of disc herniation of the side type, compared with 2 cases of facet asymmetry in 9 instances of the center type, at the L5 to S1 level ($P = 0.0008$, $r = 0.364$; Table 4).

Table 2 Correlation of facet asymmetry and degenerative lumbar facet (N = 90)[a]

Degenerative Facet Joint	Facet Asymmetry Yes	No	Value χ^2	*P*
L3–L4			0.0011	0.9724
Slight	8	30		
Severe	11	42		
L4–L5			0.8344	0.3609
Slight	6	21		
Severe	20	43		
L5–S1			1.7283	0.1886
Slight	8	19		
Severe	28	35		

[a]According to MRI degeneration classification of lumbar facet (slight is 0 or 1; severe is 2 or 3).

Table 3 Association of facet asymmetry with lumbar disc herniation in patients and control group for all 3 levels

Segment	Disc Herniation		Facet Asymmetry Y	N	Value χ^2	*P*	*r*
L3-4	Y	8	2	6	0.0797	0.7776	0.030
	N	82	17	65			
L4-5	Y	45	21	24	13.8461	0.00019	0.392
	N	45	5	40			
L5-S1	Y	37	25	12	19.8954	0.0000	0.492
	N	53	11	42			

(r is correlation coefficient and <0.5 was considered associated)

Discussion

Research status of the relationship between lumbar facet joint asymmetry and lumbar disc herniation

At present, there are few reports about the asymmetry of lumbar facet joint and lumbar disc herniation and classification, and there is no recognized conclusion. Kalichman *et al*[6] and Kalichman and Hunter[7] reported a significant correlation between lumbar facet joint angle and intervertebral disc herniation, and they considered that serious asymmetry of lumbar facet joints may increase the risk of lumbar disc herniation. Facet joints and intervertebral discs were assessed by CT and X-ray of lumbar spine in the study of Kalichman.[6,7] However, Badgley[8] and Vanharanta *et al*[9] hold that Lumbar facet joint angle does not affect the intervertebral disc, and the lumbar facet joint asymmetry was congenital and therefore irrelevant to age. Therefore, the influence of lumbar facet joint asymmetry on lumbar disc herniation remains controversial; there is no unified theory. The correlation between lumbar facet joint asymmetry and types of lumbar disc herniation has not been reported, so the author aimed to analyze, using lumbar spine MRI measurement of facet joint angle and calculation of facet joint asymmetry, the relevance of facet joint asymmetry and lumbar disc herniation, the relevance of facet joint asymmetry and age, and the relevance of facet joint asymmetry and facet joint degeneration. Thus, we decided to investigate the lumbar facet to prove the association of facet tropism with lumbar disc herniation by using many cases and new technology and software.

Table 4 Association of facet asymmetry with type of lumbar disc herniation in patients and the control group at all 3 levels

Segment	Disc Herniation, No.	Herniation		Facet Asymmetry, No.		Value		
		Type	No.	Yes	No	χ^2	*P*	*r*
L3–L4	8	Center	4	0	4	2.6667	0.1024	—
		Side	4	2	2			
L4–L5	45	Center	16	6	10	0.8382	0.3599	—
		Side	29	15	14			
L5–S1	37	Center	9	2	7	11.1592	0.0008	0.364
		Side	28	23	5			

Relationship between the asymmetry of lumbar facet joints and the age or the degree of joint degeneration

A total of 90 patients were divided into 3 age groups, and lumbar facet joint asymmetry was analyzed in the 3 kinds of segments. The results showed that there were no significant correlations between nonsymmetric lumbar facet joint and age ($P > 0.05$). In addition, 90 cases of lumbar facet joint degeneration were classified by MRI grading (Fujiwara classification): 1 and 2 meant mild degeneration, and 3 and 4 meant severe degeneration. The degree of facet degeneration and facet asymmetry were analyzed by χ^2 test. The results revealed that there was no significant correlation between lumbar facet joint asymmetry and facet joint degeneration. Therefore, we could draw a conclusion that the lumbar facet joint asymmetry was not related to age and degeneration degree, it may be a congenital structural performance.

In the 1990s, Farfan and Sullivan[10], Noren *et al*[11], and Boden *et al*[12] held that lumbar facet joint nonsymmetric angle was a congenital structural performance, and it was not due to facet joint degeneration; and the direction for lumbar disc herniation emerged because the sagittal or coronal of facet joint tended to change. Van Schaik *et al*[13] used CT scanning of lumbar facet joints to study the trend of the angle for the lumbar facet at each segment, and discovered that some children and adolescents had obvious differences in lumbar facet joints. In 2012, Schmidt *et al*[14] used finite element analysis of multiple stages of lumbar intervertebral disc and lumbar facet joint load, and found that lumbar facet joint and lumbar intervertebral disc herniation were closely related. In addition, they also showed that lumbar facet joint asymmetry was inherent in the structure, but that increasing age may aggravate the degree of asymmetric facet joints. Therefore, the authors believed that lumbar facet joint asymmetry is a congenital structural characteristic, but the growth of the age will increase the degree of asymmetry.

Relationship between lumbar facet joint asymmetry and disc herniation and classification

In the past few years, an increasing number of scholars have been involved in studying the lumbar facet joint. But they hold various viewpoints. Therefore, the authors started to investigate facet and lumbar disc herniation at a cross section of MRI. The statistics analysis results revealed that facet asymmetry was associated with lumbar disc herniation at the L4 to L5 and the L5 to S1 levels ($P < 0.05$), and that facet asymmetry was associated with side type of lumbar disc herniation at the L5 to S1 level ($P < 0.05$).

The motion segment of the spine—also known as the 3-joint complex—its difference of form, and its orientation of bilateral lumbar facet are the most important biomechanics affecting the motion of the intervertebral disc. The motions of bending and twisting of the spinal complex rely on the stability and symmetry of the facet. Hence, a normal lumbar facet angle can keep lumbar motion at a greater extent, about 50° to 60°. If the lumbar facet angles are asymmetric, structure mechanics of lumbar back column may produce a burst seam on the side of the greater facet angle. During lumbar column flexion, the vertebral body will skew towards the side of facet joint with greater angle. Therefore, the motion directions of either side of the vertebral body are different, and that makes a difference in resistance on both sides. Finally, the vertebral body will deviate from the track of primary motion, and the fiber ring on the side with the larger facet angle will have greater traction, so as to affect the motion of the intervertebral disc. With the continuous cycle of lumbar posture convex after buckling in daily life, lumbar facet joint asymmetry affects the biomechanical imbalance of the disc, further affecting the fiber ring, which increases the stress, relaxation, and

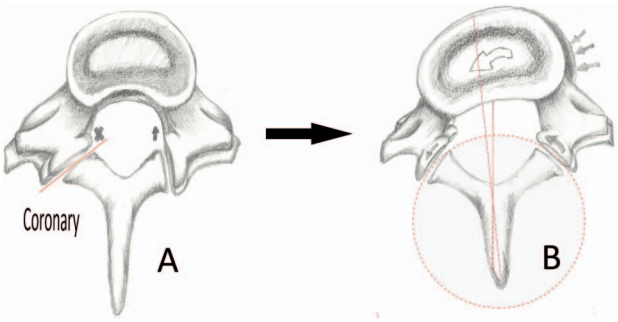

Fig. 3 Simulated asymmetric lumbar facet joints affect the process of lumbar disc herniation. (A) Asymmetric lumbar facet with coronary facet on the right. During the flexion of lumbar spine, the facet joint will rotate to the right and forward, which will lead to turn of the vertebrae (B). Thus, facet asymmetry can lead to unbalanced force for the intervertebral disc.

fracture of nucleus pulposus[15] (Fig. 3), so as to prove that facet asymmetry is associated with lumbar disc herniation at the L4 to L5 and the L5 to S1 levels ($P < 0.05$).

Arjmand and Shirazi-Adl[16] found, in a lumbar spine biomechanical study, that in the lumbar flexion and torsion of the combined movement, the lumbar intervertebral disc in the presence of 2 shearing forces led to edge shear force on the posterior margin of the vertebral body; in the L4 to L5 section and in the L5 to S1 section, the curvature was obvious. So, once lumbar facet joint asymmetry emerged, combined with the exercise of flexion and torsion, the intervertebral interface would have an imbalance of stress that induced nucleus pulposus and sediment movement for a long time. And Kingma *et al*[17] thought that lumbar shear force was different in different segments. For example, the shear force in the front and the back of the vertebral body is not the same in the L4 to L5 and the L5 to S1 levels, and the shear force in L4 to L5 is much smaller than that in L5 to S1. The above phenomenon is caused by two things. On one hand, the bending angle between the L4 and L5 vertebra is smaller than that between the L5 and S1 vertebra; therefore, the vertebral body direction difference of shear force is smaller in the L4 to L5 segment; on the other hand, because the waist stretches muscles to resist part of the shear force of the leading edge of L4 to L5, thus leading to a decrease in the difference between the front and rear shear forces, the shear force combined effect is also weakened (Fig. 4). Therefore, the effect of the asymmetry of the lumbar facet joint on the L5 to S1 intervertebral disc is greater in the flexion and torsion of the spine, so as

Fig. 4 Simulated lumbar shear force and effect. G indicates gravity; F1, horizontal shear force; F2, vertical shear force. Therefore, F1 and F2 affect motion of the lumbar vertebral body, and have a greater impact on L5 to S1.

to prove that facet asymmetry is associated with the side type of lumbar disc herniation at the L5 to S1 level ($P < 0.05$), not at the L4 to L5 level.

Clinical significance of lumbar facet asymmetry

Via our study, we found that lumbar facet joint asymmetry was related to lumbar disc herniation, especially in the L4 to L5 and L5 to S1 segments. Therefore, patients with L4 to L5 or L5 to S1 disc herniation should have the angle of lumbar facet joint measured, and it should be judged whether the bilateral facet joint is symmetric or not. Its possible clinical significance mainly has 3 points. First is the clinical significance—the patient whose lumbar facet joint segment is not symmetric and who has lumbar disc herniation should be recommended for the preferred line of fusion surgery to correct the asymmetry of the facet joints and to restore the stability of the vertebral body (*e.g.*, bone graft fusion). Because the lumbar facet joint is not symmetric, it may possibly recur after lumbar disc excision. The second item of clinical significance pertains to guiding the degree of retention for the lumbar facet joint in the operation. The related literature[18] supports the idea that lumbar facet joint damage greater than 1/2 in the posterior column

mechanical flaws makes it easy to cause spinal instability. Therefore, once the lumbar facet joint is not symmetric, the degree of destruction in the facet joint is significantly reduced, and the biomechanical changes of the spine can be avoided. The third item of clinical significance has to do with directing the fusion of adjacent segments. If doctors encountered patients with L3 to L4 or L4 to L5 lumbar disc herniation in the clinic, whereas the L5 to S1 intervertebral disc was normal but the lumbar facet joints were not symmetric. So in the L4 to L5 lumbar disc herniation of the surgery, surgeons may consider the fusion of the L5 to S1 lumbar facet joint, avoiding long-term lumbar load and other factors that increase lumbar facet joint asymmetry and finally affect the L5 to S1 lumbar disc herniation.

The authors recommend that clinicians pay more attention to the lumbar facet joint and lumbar facet joint osteoarthritis, because if clinicians are only concerned with the intervertebral disc and have no concept of the lumbar facet joints, ignoring the small joints may cause severe issues.

Shortcomings of the study

Low back pain is mainly caused by lumbar disc herniation at the L3 to S1 segments. Therefore, our study mainly discusses correlation of lumbar disc herniation and facet joint asymmetry in the L3 to S1 segments. The study of the cervical spine and thoracic spine is our next step in research.

In addition, this study is mainly a cognitive process of investigating the lumbar facet joint or facet joint structure. Therefore, there are still some drawbacks, such as the lack of a longitudinal comparative study. Therefore, further study will focus on the Finite element analysis and biomechanics of the facet joint and disc in lumbar spine.

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