Are There Correlations Between Facet Joint Parameters and Lumbar Disk Herniation Laterality in Young Adults?

Song Ke
First Affiliated Hospital of Dalian Medical University
Ming Yang
First Affiliated Hospital of Dalian Medical University
Wentao Zhang
First Affiliated Hospital of Dalian Medical University
Tianze Sun
First Affiliated Hospital of Dalian Medical University
Jing Zhang
First Affiliated Hospital of Dalian Medical University
Zhonghai Li (lizhonghaispine@126.com)
First Affiliated Hospital of Dalian Medical University

Research Article

Keywords: Lumbar disk herniation (LDH), Facet joints, Facet orientation (FO), Facet tropism (FT), Risk factors

Posted Date: October 19th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-976388/v1

Abstract

Background: We aimed to determine whether there is an association, in young adults, between the occurrence of lumbar disk herniation（LDH）at a given segment and the segment’s facet joint parameters [facet orientation (FO) and tropism (FT)]. In addition, associations between facet joint parameters in the corresponding segment and LDH laterality were also investigated.

Methods: We retrospectively analyzed data from 529 patients who were between 18 and 35 years old, who had experienced single-level LDH (L4–5 or L5–S1) between June 2017 and December 2019, and with less than 2 years of clinical history. We included an additional 122 patients with no history of LDH as an age-matched control group. LDH were classified by laterality (left-sided, right-sided, or central herniation). At each level (L4–L5 or L5–S1 segments), we investigated the relationship between facet joint parameters and herniation laterality.

Results: FO_A values at the L4–L5 level and the L5–S1 level were significantly lower and FT was higher for the LDH group compared with those for the control group. The level at which LDH occurred, FO_L, FO_R, and FT differed significantly among the three groups. There was a significant association between herniation laterality and FO at the L4–L5 level but not at the L5–S1 level.

Conclusions: Abnormal facet joint parameters are significantly associated with LDH. Young adults with higher FT should be paid more attention, to prevent the occurrence of LDH. At the L4–L5 level, intervertebral disk herniation tended to occur ipsilateral to the side with a lower facet joint angle when FT was present.

Introduction

Low back pain is the second most common complaint encountered by primary care physicians; over the past few decades [1–4], it has been the musculoskeletal condition that is the most capable of affecting quality of life. It is estimated that 80% of the population will be afflicted with low back pain at some point in their lives [5]. Intervertebral disk diseases and their associated pathologies are common causes of low back pain. LDH, which can occur when there is degeneration as a result of spinal disease, is the displacement of the nucleus pulposus or annulus fibrosis beyond the intervertebral disk space. Because LDH is a major health care problem, numerous studies have been performed to identify risk factors (such as sex, age, height, smoking status, region, and occupation [6, 7]).

In the spinal column, bilateral facet joints and their corresponding intervertebral disk form a three-joint complex. Facet joints play a significant role in stabilizing the spine during complex loading and in controlling six-degree-of-freedom motion. Facet orientation (FO) and tropism (FT) are two important structural parameters of the facet joint. Numerous studies have examined the relationship between facet joint parameters and LDH [8–10]. In previous studies, we showed that FT and FO were independent risk factors for recurrent LDH and chronic low back pain, which suggested that these parameters may play an important role in pathogenesis [11–13]. Some have found that asymmetric facet joints may cause LDH, while others report that FT is not a relevant factor[8, 9, 14–17]. A previous study showed that FO and tropism significantly influence intervertebral disk biomechanics [18]. FT may lead to bilateral asymmetric bearing stresses in the intervertebral disk, but to our knowledge no studies have investigated whether this is the case. Therefore, we hypothesized that there is a relationship between facet joint parameters and the LDH laterality in the corresponding segment.

LDH is one of the most common disorders, with a prevalence of approximately 77.8% among adults[19]. Although the frequency of this condition in children and adolescents has not been precisely defined, it is generally believed to be much lower than that in adults. On the basis of previous findings[10, 20, 21], age is an important factor to consider when studying the relationship between facet joint parameters and LDH—in older patients, LDH is normally caused by chronic degeneration; in contrast, the causes of LDH in younger patients are diverse and include trauma, familial predisposition, obesity, and degeneration.

In the present study, we aimed to determine whether there is an association, in young adults, between the occurrence of LDH at a given segment and the segment's facet joint parameters. In addition, associations between facet joint parameters in the corresponding segment and LDH laterality were also investigated. To the best of our knowledge, this is the first study to focus specifically on correlations between facet joint parameters and LDH laterality.

Materials And Methods

Patient population

We conducted a retrospective clinical study. In our hospital, we had observed that, for adults over the age of 35 years, computed tomography (CT) images of the lumbar spine commonly showed *lumbar* facet joint osteoarthritis and degenerative *lumbar* scoliosis and that LDH was more common, which could influence our investigations. Thus, to eliminate the influence of age, we selected a young adult population (between 18 and 35 years old) because few youth under the age of 18 years had undergone CT scans.

Data from patients between 18 and 35 years old and with less than 2 years clinical history who had experienced single-level LDH (L4–L5 or L5–S1 segments) during the period from June 2017 to December 2019 were included in this study. These patients had been referred to our institution for diagnostic evaluation of the lumbar spine, using computed tomography (CT), and for treatment for LDH. Patients with LDH were classified by herniation laterality—grouped into left-sided, right-sided, or central protrusions—for each level (L4–5 or L5–S1).

In addition, data from patients who were between 18 and 35 years old with digestive system diseases, who had undergone abdominal CT scanning, and with no LDH were included as a control group. Patients with recurrent LDH, far lateral LDH, calcified LDH, previous spinal surgery or trauma, inflammatory disease, spondylolisthesis, myopathy, degenerative lumbar scoliosis, Paget's disease, or spinal metastasis were excluded from this study. All patients or relatives provided informed consent to participate in this study.

Data collection and Measures

Patients' clinical data were collected from hospital records. We recorded sex, age, body mass index (BMI), current smoking status, alcohol use, occupation, and trauma history. Facet joint parameters (orientation and tropism) were obtained from axial CT images (parallel to vertebral endplates) and were measured with the method previously described by Li et al. and Noren et al[11, 12, 22].

FO is the angle of the facet joint relative to the sagittal plane, when measured in a transverse plane (Figure 1). FT refers to the asymmetry of left (FO_L) and right (FO_R) vertebral facet orientations, which was represented by the absolute value of the difference between FO_L and FO_R). $FO_{L>R}$ was designated as the FO_L was greater than FO_R. FO_A was designated as the average of FO_L and FO_R.

We measured FO_L and FO_R for L4–L5 and L5–S1 segments for each patient (both the LDH group and the control group). To avoid measurement errors, two experienced clinical doctors analyzed the axial CT images independently without knowledge of the patients' group and the objective of our study. We calculated intraclass correlation coefficients for each group to determine the reliability of the measurements (facet orientation) and assessments (herniation laterality) of the 2 observers.

Statistical analysis

Statistical Package for Social Sciences software for Windows (Ver. 17.0, SPSS Inc, Chicago, IL) was used for data analysis. Continuous variables that did not have normal distributions were expressed as median (25th percentile, 75th percentile); categorical variables were expressed as count (percentage). Continuous variables were compared using the Mann-Whitney U test or Kruskal-Wallis H test. Categorical variables were compared between groups using the Pearson $\chi 2$ test. For all comparisons, a *p*-value < 0.05 was considered statistically significant.

Results

Patients

A total of 651 patients (529 with LDH and 122 in the control group) were deemed eligible for this study (367 males and 284 females; mean age 29.9 years). In patients with LDH, 380 (71.83%) had occurred at the L4–L5 level, and 149 (28.17%) had occurred at the L5–S1 level. Herniation laterality was left sided in 234 patients (44.23%), right sided in 207 patients (39.13%), and central in 88 patients (16.64%).

Reliability

The reliability of the two observers was acceptable; the intraclass correlation coefficient was 0.973, which reflected that facet joint parameter measurements were similar. Two example CT images are shown in Figures 2 and 3.

LDH group vs. the control group

The results for group comparisons are presented in Table 1. No significant differences were found between the LDH group and the control group for demographic data (age, BMI, current smoking status, alcohol use, occupation, and trauma history), except for sex. The proportion of male patients in the LDH group was significantly greater than that in the control group ($p = 0.010$). FO_A values were significantly lower for patients with LDH group than for patients without LDH at the L4–L5 level [43 (40.5, 46) vs. 45.5 (39, 51.5), respectively; $p = 0.005$] and at the L5–S1 level [45.5 (44, 47.5) vs. 51 (45.5, 56.5), respectively; $p < 0.001$]. FT was significantly higher for the LDH group than that for the control group at the L4–L5 level [3 (2, 4) vs. 2 (1, 4), $p < 0.001$] and at the L5–S1 level [3 (2, 5) vs. 2 (1, 3), $p = 0.002$].

Table 1
The demographics of the LDH and N-LDH groups

Variable	LDH (n = 529)	N-LDH (n = 122)	*P*
Sex (female: male)	218:311	66:56	0.010*
Age, (years)	32 (26, 34)	31 (28, 33)	0.278
BMI, (kg/m^2)	22.72 (20.66, 24.51)	23.06 (20.99, 25.25)	0.671
Current smoking, n (%)	86 (16.26%)	22 (18.03%)	0.635
Alcohol, n (%)	61 (13.10%)	17 (13.93%)	0.470
Occupation, n (%)			0.420
Worker	269 (50.85%)	55 (45.08%)	
Student	181 (34.22%)	44 (36.07%)	
Office staff	79 (14.93%)	23 (18.85%)	
Trauma history, n (%)	43 (8.13%)	9 (7.38%)	0.783
Level of LDH, n (%)			
L4-L5	380 (71.83%)	-	
L5-S1	149 (28.17%)	-	
FO_A, (°)			
L4-L5	43 (40.5, 46)	45.5 (39, 51.5)	0.005*
L5-S1	45.5 (44, 47.5)	51 (45.5, 56.5)	<0.001*
FT, (°)			
L4-L5	3 (2, 4)	2 (1, 4)	<0.001*
L5-S1	3 (2, 5)	2 (1, 3)	0.002*

* Statistical significance was achieved when $p < 0.05$.

BMI, body-mass index; FO, facet orientation; FT, facet tropism; LDH, lumbar disk herniation; N-LDH, non-LDH; FO_A, the average FO of bilateral facet joints.

Laterality

No significant differences were found between central, right-sided, and left-sided LDH ($p > 0.05$) for demographic data (sex, age, BMI, current smoking status, alcohol use, occupation, and trauma history); statistically significant differences were found for vertebral segment ($p = 0.042$), FO_L ($p = 0.002$), FO_R ($p < 0.001$), and FT ($p < 0.001$) (Table 2).

Table 2

The demographics of LDH_L, LDH_R, and LDH_M groups

Variable	LDH_L (n = 234)	LDH_R (n = 207)	LDH_M (n = 88)	*P*
Gender (female: male)	92:142	87:120	39:49	0.686
Age, (years)	32 (35.25, 34)	33 (26, 34)	31.5 (25.75, 34)	0.612
BMI, (kg/m^2)	22.79 (22.66, 24.79)	22.66 (20.53, 24.45)	22.54 (20.95, 24.05)	0.729
Current smoking, n (%)	36 (15.38%)	36 (17.39%)	14 (15.91%)	0.846
Alcohol, n (%)	37 (15.81%)	31 (14.98%)	15 (17.05%)	0.903
Occupation, n (%)				0.335
Worker	120 (51.28%)	103 (49.76%)	46 (52.27%)	
Student	42 (17.95%)	28 (13.53%)	9 (10.23%)	
Office staff	72 (30.77%)	76 (36.71%)	33 (37.50%)	
Trauma history, n (%)	21 (8.97%)	11 (5.31%)	12 (13.64%)	0.054
Level of LDH, n (%)				0.042
L4-L5	164 (70.09%)	160 (77.29%)	56 (63.64%)	
L5-S1	70 (29.91%)	47 (22.71%)	32 (36.36%)	
FO, (°)				
FO_L	43 (40, 46)	45 (42, 47)	44.5 (41, 47)	0.002*
FO_R	45 (42, 48)	43 (41, 45)	44 (41.25, 47)	<0.001*
FT, (°)	3 (2, 5)	3 (2, 4)	2 (0, 3.75)	<0.001*

* Statistical significance was achieved when $p < 0.05$.

BMI, body-mass index; FO, facet orientation; FT, facet tropism; LDH, Lumbar disk herniation; L, left; R, right; M, median; FO_L, angle degree of the left facet joint; FO_R, angle degree of the right facet joint; LDH_L, left side protrusion of LDH; LDH_R, right side protrusion of LDH; LDH_M, utterly central protrusion of LDH.

Stratified analyses of different LDH level, the amount and percentages of different locations of LDH at the L4–L5 and L5–S1 level with $FO_L > FO_R$, $FO_L < FO_R$ and $FO_L = FO_R$ were conducted. Pearson 3×3 and 2×2 contingency tables for $\chi 2$ tests are presented for stratified analyses (Table 3 and Table 4, respectively). There was a significant association between herniation laterality and FO at the L4–L5 level ($p < 0.001$) but not for the L5–S1 level ($p = 0.567$). When central LDH and herniations without FT ($FO_L =$

FO_R) were removed at the L4–L5 level, $FO_L < FO_R$ for 112 of 148 (75.7%) patients with left-sided herniations compared with $FO_L > FO_R$ for 100 of 146 (68.5%) patients with right-sided herniations ($p < 0.001$)

Table 3
Relationship between the location of LDH and different FO of bilateral facet joints in L4-L5 and L5-S1.

Variable	**LDH_L (n = 234)**	**LDH_R (n = 207)**	**LDH_M (n = 88)**	***P***
L4-L5				
$FO_{L>R}$, n (%)	36 (21.95%)	100 (62.50%)	18 (32.14%)	
$FO_{L<R}$, n (%)	112 (68.29%)	46 (28.75%)	20 (35.71%)	
$FO_{L=R}$, n (%)	16 (9.76%)	14 (8.75%)	18 (32.14%)	
Total	164	160	56	<0.001*
L5-S1				
$FO_{L>R}$, n (%)	30 (42.86)	25 (53.19%)	13 (40.63%)	
$FO_{L<R}$, n (%)	33 (47.14%)	18 (38.30%)	12 (37.50%)	
$FO_{L=R}$, n (%)	7 (10%)	4 (8.51%)	7 (21.88%)	
Total	70	47	32	0.567

* Statistical significance was achieved when $p < 0.05$.

LDH, lumbar disk herniation; FO, facet orientation; L, left; R, right; M, median;$FO_{L>R}$, the degree of FO_L higher than the degree of FO_R; $FO_{L<R}$, the degree of FO_R higher than the degree of FO_L; $FO_{L=R}$, the degree of FO_R equal with the degree of FO_L; LDH_L, left side protrusion of LDH; LDH_R, right side protrusion of LDH; LDH_M, utterly central protrusion of LDH.

Table 4
Relationship between the location of LDH and different FO of bilateral facet joints in L4-L5.

Variable	LDH_L	LDH_R	*P*
$FO_{L>R}$, n (%)	36 (24.3%)	100 (68.5%)	
$FO_{L<R}$, n (%)	112 (75.7%)	46 (31.5%)	
Total	148	146	<0.001*

* Statistical significance was achieved when $p < 0.05$.

LDH, lumbar disk herniation; FO, facet orientation; L, left; R, right; $FO_{L>R}$, the degree of FO_L higher than the degree of FO_R; $FO_{L<R}$, the degree of FO_R higher than the degree of FO_L; LDH_L, left side protrusion of LDH; LDH_R, right side protrusion of LDH.

Discussion

Structure and functional characteristics of the intervertebral disk and facet joints

An intervertebral disk consists of three structurally different tissues: the annulus fibrosus, the nucleus pulposus, and two cartilaginous endplates that connect the disk to adjacent vertebrae [23, 24]. Throughout a person's lifetime, their intervertebral disks undergo morphological and functional degeneration. Degeneration of the intervertebral lumbar disks can result in herniation of the nucleus pulposus, which causes the inflammation or compression of neighboring tissues and a series of clinical symptoms. The highest incidences of disk herniation are for the L4–L5 and L5–S1 disks, with a combined incidence of 95%.[25] LDH is a serious threat to the health of the older and middle-aged adults. However, with the increasing pressure of daily life, the amount of activity and load on the spine have slowly increased. This has resulted in adults being more likely to experience LDH at a younger age—there is an increasing number of patients with LDH in the youth population. Because LDH experienced by youth patients usually do not have a long-term physical labor occupation or previous trauma as a cause, if relevant risk factors are identified early on, it may be possible to intervene prior to the start of the disease to prevent LDH.

The facet joints are the only synovial joints in the lumbar spine. Both sides of the facet joints and the corresponding intervertebral disk form a three-joint complex. Previous studies have shown that the two facet joints, with the intervertebral disk, carry loads in the lumbar spine [11, 26, 27] and that any deformity in one facet joint could cause asymmetric stress distribution to all three structures. Facet joints share the vertical compression loads of the lumbar spine and also protect the intervertebral disks from being subjected to excessive rotation [28]. The role of facet joint abnormality as a cause of LDH has been well studied during recent years [8–10, 15, 29–31]. Nevertheless, it remains unclear whether changes in facet joint geometry (FO and FT) are natural morphological variations or the result of reconstruction.

Relationships between facet orientation, facet tropism, and lumbar disk herniation in the corresponding segment

In 1967, Farfan et al. [32] first proposed that facet joint asymmetry was a possible cause of LDH. Since then, studies have yielded conflicting findings about facet joint parameters and the pathogenesis of LDH [17, 33–36].

Van Schaik et al. [37] measured facet asymmetry in 100 patients with backache, sciatica, or both and found that there was an equal distribution of herniation to the side of both the more coronally oriented and more sagittally oriented facet joint. With greater asymmetries, there was a greater incidence of unilateral disk protrusion toward the more coronally oriented joint. Park et al. [38] compared far lateral and posterolateral LDH and found that differences in FT and disk degeneration might able to distinguish far lateral herniation from posterolateral LDH. Noren et al. [22] also concluded that facet joint asymmetry is a risk factor for lumbar disk degeneration and herniation. Karacan et al. [39] observed that patients with LDH had greater asymmetries and more sagittally oriented facet joints and that these alterations were more evident in taller patients. More recently, Wang et al. [40] concluded that measurements taken at different parts of facet joints may result in discrepancies in FT identification; asymmetry between ipsilateral cephalad and caudad portions of the facet is associated with L4–5 LDH in older adult patients.

In contrast, others have found evidence to support that lumbar facet joint asymmetry is congenital and not due to age or degeneration [14, 41–43]. Lee et al. [14] assessed 149 intervertebral disks in 140 adolescents (13 and 18 years) and 119 intervertebral disks in 111 adults (aged 40 and 49 years) with LDH and found that there was no significant difference in FT between herniated and normal disks in both groups, except for at the L4–L5 level in the adults. Thus, FT had not influenced the development of herniation of the lumbar disk in either adolescents or adults. Cassidy et al.[43] found that there was no difference in the distribution of more coronally or sagittally oriented facet joints with respect herniation laterality. Vanharanta et al. [41] showed that there was no association between FT and lumbar disk diseases, such as herniation and degeneration.

In the present study, we compared FO and FT between patients with LDH and patients in a control group; we found that there was a significant relationship between these parameters and LDH at the L4–L5 and L5–S1 levels.

What is the reason for the inconsistencies between the results of previous studies? Many factors, such as the method used to measure facet joint angle, the definition of FT, or the type of control group could affect study findings. The age of the study population was also considered an important factor which influences the results of correlations between facet joint parameters and LDH. Changes in facet joint parameters may be the result of prior LDH, especially in older patients with a long history of LDH, but this hypothesis needs to be verified. Intervertebral disk degeneration is more prevalent with increasing age, and changes such as decreased disk height index and increased sagittal range of motion alter the biomechanics of vertebral segments. As a result, facet joints can be overloaded and become more susceptible to anterior shearing forces, which leads to facet joint remodeling and LDH[21, 29].

At present, it is difficult to know whether changes in facet joint parameters act as the primary morphological variations or it should be recognized as a secondary reconstruction. In the present study, to eliminate the influence of age and prove the initial influence of facet joint parameters on intervertebral disk of the corresponding level, we only included patients between 18 and 35 years of age with a clinical history less than 2 years, which is distinguished from previous studies[9, 21]. We demonstrated that FO and FT were significantly associated with LDH at both L4–L5 and L5–S1 levels. The LDH group had significantly greater FT and lower FO than those in the control group. These differences may be attributed to secondary changes that lead to LDH in young adult patients as a result of facet joint parameter abnormalities, especially in young adult patients who have not engaged in long-term physical labor or experienced previous trauma. Higher FT may be risk factors for LDH in young adult patients.

Biomechanical studies have found that facet joint parameters significantly influence the biomechanics of a corresponding segment [29, 31, 44–47]. Sagittal orientation of the facet joints promote anterior gliding by reducing resistance to anterior shear forces [29], and when tropism is present, segments were found to have a tendency to rotate toward the more oblique facet joint under axial loading. This can place additional torsional loads on the intervertebral disk and plausibly contribute to intervertebral disk or facet injury and degeneration. Nonetheless, the sagittal orientation of facet joints allow a trade-off between angular motion and rotation. Gradually, rotational movement indirectly causes tensile stress in the annulus of the intervertebral disk, leading to protrusion on the sagittal side [48]. In the present study, we found that there was a significant relationship between herniation laterality and FO at the L4–L5 level; intervertebral disk herniation tended to protrude ipsilateral to the side with a lower FO, which could suggest that herniation tended toward the sagittally oriented facet joint whenever there was a combination of sagittal and coronal orientation. However, one previous study provided contradictory evidence[49]; therefore, further clinical and biomechanical research is required.

We also found that FT is significantly related to LDH at the L4–L5 segment but not at the L5–S1 level segment, and that, likewise, there was a significant association between the herniation laterality and FO at the L4–L5 segment but not at the L5–S1 level segment. We speculated the reason for this is that the L5–S1 intervertebral disk is below the iliac crest, which may restrict the motion of that segment; and thus, there may be reduced stress and shear forces in the L5–S1 intervertebral disk.

Limitations and Meaning

This study had several limitations. First, this was a retrospective nonrandomized case-control study with specific groups. Second, we did not use sagittal balance, paraspinal muscle volume, pelvic and angular parameters, and other demographic features that may individually affect the occurrence of LDH. Third, our study was limited by geometric considerations. The articular surface of the facet joint was viewed as a flat plane, which is not the most suitable representation of the complex three-dimensional geometry of the facet joints and their relationship with the lumbar disk degeneration.

Our recent biomechanical research identified the biomechanical influence of facet joint parameters on corresponding segments in the lumbar spine[50]; therefore, in this study, we aimed to determine the relationship between facet joint parameters and LDH in young adult individuals to better understand the mechanisms of degeneration and the progression of degenerative disk disease. To the best of our knowledge, this is the first study to provide evidence to support that there are relationships between the facet joint parameters of a given segment and corresponding disk herniation laterality.

Conclusion

In summary, we showed that facet joint parameters (FO and FT) are related to LDH in young adult patients. Intervertebral disk herniation tended to occur ipsilateral to the side with a lower FO at the L4–L5 segment. The exact mechanisms linking facet joint parameters and LDH require further clinical and biomechanical investigation.

Abbreviations

FO: Facet orientation, FT: Facet tropism, LDH: lumbar disc herniation, IVD: Intervertebral discs, AF: Annulus fibrosus, NP: Nucleus pulposus.

Declarations

Acknowledgements

We thank Coren Walters-Stewart, PhD, from Liwen Bianji (Edanz) (www.liwenbianji.cn/) for editing the English text of a draft of this manuscript.

Funding

This study was supported by the Science and Technology Innovation Foundation of Dalian (2020JJ27SN070) and the open project of Key Laboratory for Micro/Nano Technology and System of Liaoning Province, Dalian University of Technology (20210101). The funders had no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Availability of data and materials

Summarized data have been presented in this manuscript. The raw data for this study are located and protected at First Affiliated Hospital of Dalian Medical University. Sharing of the raw data is not suggested, because a secondary analysis is planned.

Authors’ contributions

ZHL contributed to the design of the study. SK drafted the manuscript with the help from MY, WTZ and TZS. JZ and MY helped in the statistical analyses. ZHL and SK contributed to the revision. All authors have read and approved the final manuscript.

Competing interest

The authors declare that they have no competing interests.

Ethics approval and consent to participate

This study was approved by the medical ethics committee of First Affiliated Hospital of Dalian Medical University (PJ-KS-KY-2020-55), and informed written consent was obtained.

Consent for publication

Not applicable.

References

1. Chenot JF, Greitemann B, Kladny B, Petzke F, Pfingsten M, Schorr SG (2017) Non-Specific Low Back Pain. Deutsches Arzteblatt international 114:883-890. doi: 10.3238/arztebl.2017.0883
2. Delitto A, George SZ, Van Dillen L, Whitman JM, Sowa G, Shekelle P, Denninger TR, Godges JJ, Orthopaedic Section of the American Physical Therapy A (2012) Low back pain. The Journal of orthopaedic and sports physical therapy 42:A1-57. doi: 10.2519/jospt.2012.42.4.A1
3. Casser HR, Seddigh S, Rauschmann M (2016) Acute Lumbar Back Pain. Deutsches Arzteblatt international 113:223-234. doi: 10.3238/arztebl.2016.0223
4. Rao D, Scuderi G, Scuderi C, Grewal R, Sandhu SJ (2018) The Use of Imaging in Management of Patients with Low Back Pain. Journal of clinical imaging science 8:30. doi: 10.4103/jcis.JCIS_16_18
5. Ramakrishnan A, Webb KM, Cowperthwaite MC (2017) One-year outcomes of early-crossover patients in a cohort receiving nonoperative care for lumbar disc herniation. Journal of neurosurgery Spine 27:391-396. doi: 10.3171/2017.2.spine16760
6. Wood KB, Devine J, Fischer D, Dettori JR, Janssen M (2010) Vascular injury in elective anterior lumbosacral surgery. Spine 35:S66-75. doi: 10.1097/BRS.0b013e3181d83411
7. Nellensteijn J, Ostelo R, Bartels R, Peul W, van Royen B, van Tulder M (2010) Transforaminal endoscopic surgery for symptomatic lumbar disc herniations: a systematic review of the literature. European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society 19:181-204. doi: 10.1007/s00586-009-1155-x
8. Dai LY (2001) Orientation and tropism of lumbar facet joints in degenerative spondylolisthesis. International orthopaedics 25:40-42. doi: 10.1007/s002640000201

9. Zhou Q, Teng D, Zhang T, Lei X, Jiang W (2018) Association of facet tropism and orientation with lumbar disc herniation in young patients. Neurological sciences : official journal of the Italian Neurological Society and of the Italian Society of Clinical Neurophysiology 39:841-846. doi: 10.1007/s10072-018-3270-0
10. Ishihara H, Matsui H, Osada R, Ohshima H, Tsuji H (1997) Facet joint asymmetry as a radiologic feature of lumbar intervertebral disc herniation in children and adolescents. Spine 22:2001-2004. doi: 10.1097/00007632-199709010-00012
11. Li Z, Gui G, Zhang Y, Zhou Y, Yang M, Chang Y, Xu G, Zhao Y (2020) Are facet joint parameters risk factors for recurrent lumbar disc herniation? A pilot study in a Chinese population. Journal of clinical neuroscience : official journal of the Neurosurgical Society of Australasia 77:36-40. doi: 10.1016/j.jocn.2020.05.048
12. Yang M, Wang N, Xu X, Zhang Y, Xu G, Chang Y, Li Z (2020) Facet joint parameters which may act as risk factors for chronic low back pain. J Orthop Surg Res 15:185. doi: 10.1186/s13018-020-01706-6
13. Li Z, Yang H, Liu M, Lu M, Chu J, Hou S, Hou T (2018) Clinical Characteristics and Risk Factors of Recurrent Lumbar Disk Herniation: A Retrospective Analysis of Three Hundred Twenty-One Cases. Spine 43:1463-1469. doi: 10.1097/brs.0000000000002655
14. Lee DY, Ahn Y, Lee SH (2006) The influence of facet tropism on herniation of the lumbar disc in adolescents and adults. The Journal of bone and joint surgery British volume 88:520-523. doi: 10.1302/0301-620X.88B4.16996
15. Kong M, He W, Tsai Y, Chen N, Keorochana G, Do D, Wang J (2009) Relationship of facet tropism with degeneration and stability of functional spinal unit. Yonsei medical journal 50:624-629. doi: 10.3349/ymj.2009.50.5.624
16. Chadha M, Sharma G, Arora SS, Kochar V (2013) Association of facet tropism with lumbar disc herniation. European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society 22:1045-1052. doi: 10.1007/s00586-012-2612-5
17. Wang H, Zhou Y (2016) Facet tropism: possible role in the pathology of lumbar disc herniation in adolescents. Journal of neurosurgery Pediatrics 18:111-115. doi: 10.3171/2015.7.PEDS15175
18. Kim H-J, Chun H-J, Lee H-M, Kang K-T, Lee C-K, Chang B-S, Yeom JS (2013) The biomechanical influence of the facet joint orientation and the facet tropism in the lumbar spine. The Spine Journal 13:1301-1308. doi: https://doi.org/10.1016/j.spinee.2013.06.025
19. Wei FL, Gao H, Yan X, Yuan Y, Qian S, Gao Q, Guo S, Xue W, Qian J, Zhou C (2020) Comparison of postoperative outcomes between patients with positive and negative straight leg raising tests who underwent full-endoscopic transforaminal lumbar discectomy. Scientific reports 10:16516. doi: 10.1038/s41598-020-73357-w
20. Boden SD, Riew KD, Yamaguchi K, Branch TP, Schellinger D, Wiesel SW (1996) Orientation of the lumbar facet joints: association with degenerative disc disease. The Journal of bone and joint surgery American volume 78:403-411. doi: 10.2106/00004623-199603000-00012

21. Samartzis D, Cheung JP, Rajasekaran S, Kawaguchi Y, Acharya S, Kawakami M, Satoh S, Chen WJ, Park CK, Lee CS, Foocharoen T, Nagashima H, Kuh S, Zheng Z, Condor R, Ito M, Iwasaki M, Jeong JH, Luk KD, Prijambodo B, Rege A, Jahng TA, Luo Z, Tassanawipas WA, Acharya N, Pokharel R, Shen Y, Ito T, Zhang Z, Aithala PJ, Kumar GV, Jabir RA, Basu S, Li B, Moudgil V, Goss B, Sham P, Williams R (2016) Is lumbar facet joint tropism developmental or secondary to degeneration? An international, large-scale multicenter study by the AOSpine Asia Pacific Research Collaboration Consortium. Scoliosis Spinal Disord 11:9. doi: 10.1186/s13013-016-0062-2
22. Noren R, Trafimow J, Andersson G, Huckman M (1991) The role of facet joint tropism and facet angle in disc degeneration. Spine 16:530-532. doi: 10.1097/00007632-199105000-00008
23. Urban JP, Smith S, Fairbank JC (2004) Nutrition of the intervertebral disc. Spine 29:2700-2709. doi: 10.1097/01.brs.0000146499.97948.52
24. Richardson SM, Mobasheri A, Freemont AJ, Hoyland JA (2007) Intervertebral disc biology, degeneration and novel tissue engineering and regenerative medicine therapies. Histology and histopathology 22:1033-1041. doi: 10.14670/hh-22.1033
25. Dragojlovic N, Stampas A, Kitagawa RS, Schmitt KM, Donovan W (2016) Communicating Hydrocephalus Due to Traumatic Lumbar Spine Injury: Case Report and Literature Review. American journal of physical medicine & rehabilitation. doi: 10.1097/phm.0000000000000540
26. Byrne RM, Zhou Y, Zheng L, Chowdhury SK, Aiyangar A, Zhang X (2018) Segmental variations in facet joint translations during in vivo lumbar extension. Journal of biomechanics 70:88-95. doi: 10.1016/j.jbiomech.2017.09.026
27. Kim HJ, Kang KT, Son J, Lee CK, Chang BS, Yeom JS (2015) The influence of facet joint orientation and tropism on the stress at the adjacent segment after lumbar fusion surgery: a biomechanical analysis. Spine J 15:1841-1847. doi: 10.1016/j.spinee.2015.03.038
28. Yoganandan N, Kumaresan S, Pintar FA (2001) Biomechanics of the cervical spine Part 2. Cervical spine soft tissue responses and biomechanical modeling. Clinical biomechanics (Bristol, Avon) 16:1-27. doi: 10.1016/s0268-0033(00)00074-7
29. Kim HJ, Chun HJ, Lee HM, Kang KT, Lee CK, Chang BS, Yeom JS (2013) The biomechanical influence of the facet joint orientation and the facet tropism in the lumbar spine. Spine J 13:1301-1308. doi: 10.1016/j.spinee.2013.06.025
30. Yang K, King A (1984) Mechanism of facet load transmission as a hypothesis for low-back pain. Spine 9:557-565. doi: 10.1097/00007632-198409000-00005
31. Toyone T, Ozawa T, Kamikawa K, Watanabe A, Matsuki K, Yamashita T, Wada Y (2009) Facet joint orientation difference between cephalad and caudad portions: a possible cause of degenerative spondylolisthesis. Spine 34:2259-2262. doi: 10.1097/BRS.0b013e3181b20158
32. Farfan HF, Sullivan JD (1967) The relation of facet orientation to intervertebral disc failure. Canadian journal of surgery Journal canadien de chirurgie 10:179-185
33. Kalichman L, Suri P, Guermazi A, Li L, Hunter DJ (2009) Facet orientation and tropism: associations with facet joint osteoarthritis and degeneratives. Spine 34:E579-585. doi:

10.1097/BRS.0b013e3181aa2acb

34. Kalichman L, Hunter DJ (2007) Lumbar facet joint osteoarthritis: a review. Seminars in arthritis and rheumatism 37:69-80. doi: 10.1016/j.semarthrit.2007.01.007
35. Gao T, Lai Q, Zhou S, Liu X, Liu Y, Zhan P, Yu X, Xiao J, Dai M, Zhang B (2017) Correlation between facet tropism and lumbar degenerative disease: a retrospective analysis. BMC musculoskeletal disorders 18:483. doi: 10.1186/s12891-017-1849-x
36. Schleich C, Muller-Lutz A, Blum K, Boos J, Bittersohl B, Schmitt B, Gerss J, Matuschke F, Wittsack HJ, Antoch G, Miese F (2016) Facet tropism and facet joint orientation: risk factors for the development of early biochemical alterations of lumbar intervertebral discs. Osteoarthritis Cartilage 24:1761-1768. doi: 10.1016/j.joca.2016.05.004
37. Van Schaik JP, Verbiest H, Van Schaik FD (1985) The orientation of laminae and facet joints in the lower lumbar spine. Spine (Phila Pa 1976) 10:59-63. doi: 10.1097/00007632-198501000-00009
38. Park JB, Chang H, Kim KW, Park SJ (2001) Facet tropism: a comparison between far lateral and posterolateral lumbar disc herniations. Spine 26:677-679
39. Karacan I, Aydin T, Sahin Z, Cidem M, Koyuncu H, Aktas I, Uludag M (2004) Facet angles in lumbar disc herniation: their relation to anthropometric features. Spine (Phila Pa 1976) 29:1132-1136. doi: 10.1097/00007632-200405150-00016
40. Wang Y, Li D, Zhu M, Wang J, Li C, Lin C, Wang J, Teng H (2020) Lumbar Facet Tropism on Different Facet Portions and Asymmetry between Ipsilateral Cephalad and Caudad Portions: Their Correlations with L4/5 and L5/S1 Lumbar Disc Herniation. Spine. doi: 10.1097/BRS.0000000000003614
41. Vanharanta H, Floyd T, Ohnmeiss DD, Hochschuler SH, Guyer RD (1993) The relationship of facet tropism to degenerative disc disease. Spine (Phila Pa 1976) 18:1000-1005
42. Ko HY, Park BK (1997) Facet tropism in lumbar motion segments and its significance in disc herniation. Archives of physical medicine and rehabilitation 78:1211-1214
43. Cassidy JD, Loback D, Yong-Hing K, Tchang S (1992) Lumbar facet joint asymmetry. Intervertebral disc herniation. Spine (Phila Pa 1976) 17:570-574
44. Kong MH, He W, Tsai YD, Chen NF, Keorochana G, Do DH, Wang JC (2009) Relationship of facet tropism with degeneration and stability of functional spinal unit. Yonsei medical journal 50:624-629. doi: 10.3349/ymj.2009.50.5.624
45. Adams MA, Hutton WC (1980) The effect of posture on the role of the apophysial joints in resisting intervertebral compressive forces. The Journal of bone and joint surgery British volume 62:358-362
46. Yang KH, King AI (1984) Mechanism of facet load transmission as a hypothesis for low-back pain. Spine (Phila Pa 1976) 9:557-565
47. Cyron BM, Hutton WC (1980) Articular tropism and stability of the lumbar spine. Spine 5:168-172. doi: 10.1097/00007632-198003000-00011
48. Degulmadi D, Dave B, Krishnan A, Patel D (2019) The Relationship of Facet Joint Orientation and Tropism with Lumbar Disc Herniation and Degenerative Spondylolisthesis in the Lower Lumbar

Spine. Asian spine journal 13:22-28. doi: 10.31616/asj.2018.0116

49. Honggang, Wang, Yue, Zhou (2016) Facet tropism: possible role in the pathology of lumbar disc herniation in adolescents. Journal of neurosurgery Pediatrics

50. Ke S, He X, Yang M, Wang S, Song X, Li Z (2021) The biomechanical influence of facet joint parameters on corresponding segment in the lumbar spine: a new visualization method. Spine J. doi: 10.1016/j.spinee.2021.05.024

Figures

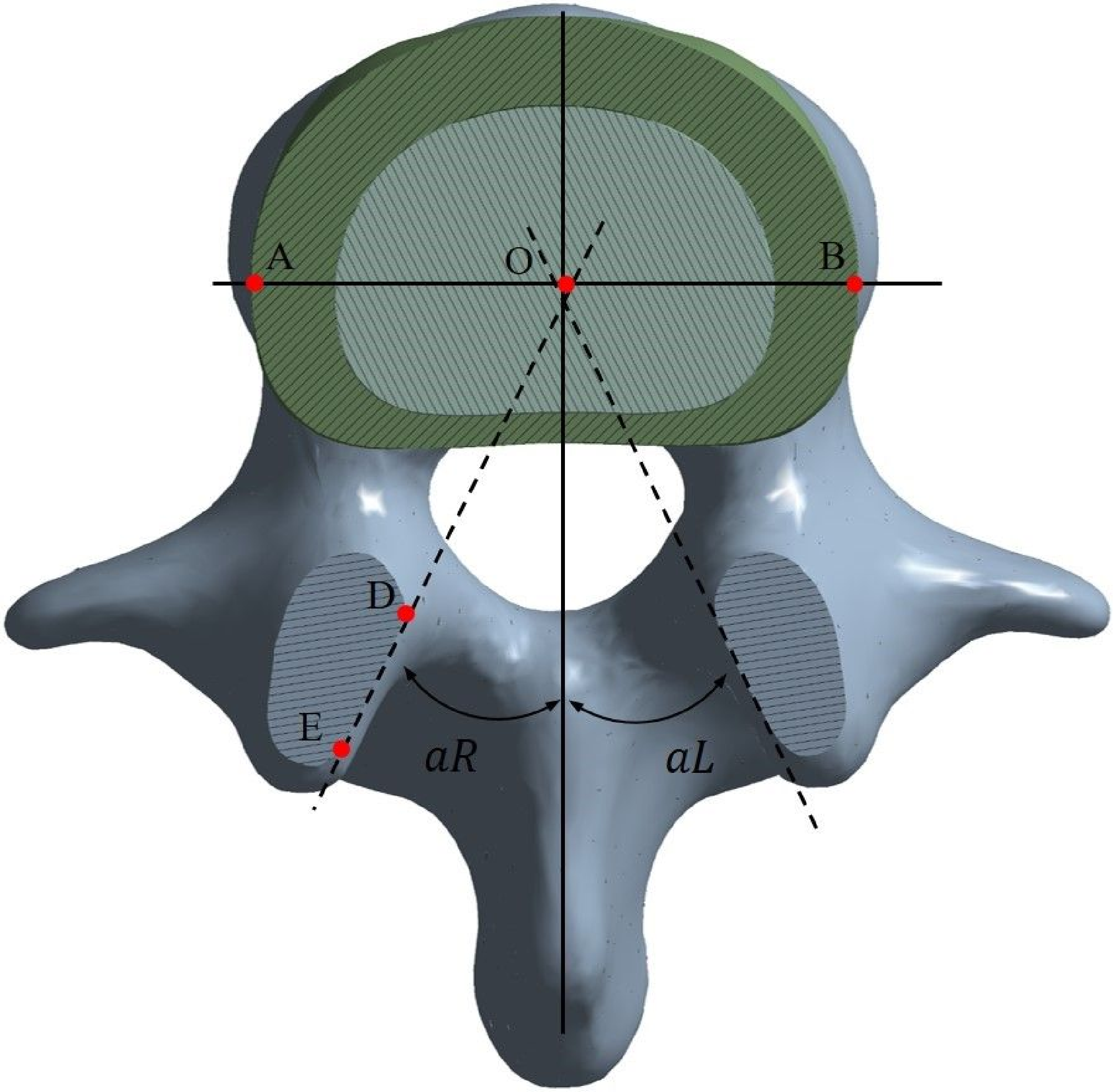

Figure 1

Diagram of the method used to measure the facet joint angle. The facet line is drawn between the 2 peaks of each of the superior articular facets (D and E). The midline is drawn through the center of the lumbar vertebral body (O, AO = OB) and the middle point of the base of the spinous process. The angle between the midsagittal line and facet line was measured for each side of the lumbar vertebral body. FOR = aR, the right facet angle, FOL = aL, the left facet angle), FT = | aR - aL |, the absolute value of FOR and FOL.

Figure 2

A 35-year-old male with a 1-year history of left lower limb radiating pain. The CT image (axial view) of L4-L5 level showed the herniation located on the left side, FOL = 32°, FOR = 41°, FT = 9°.

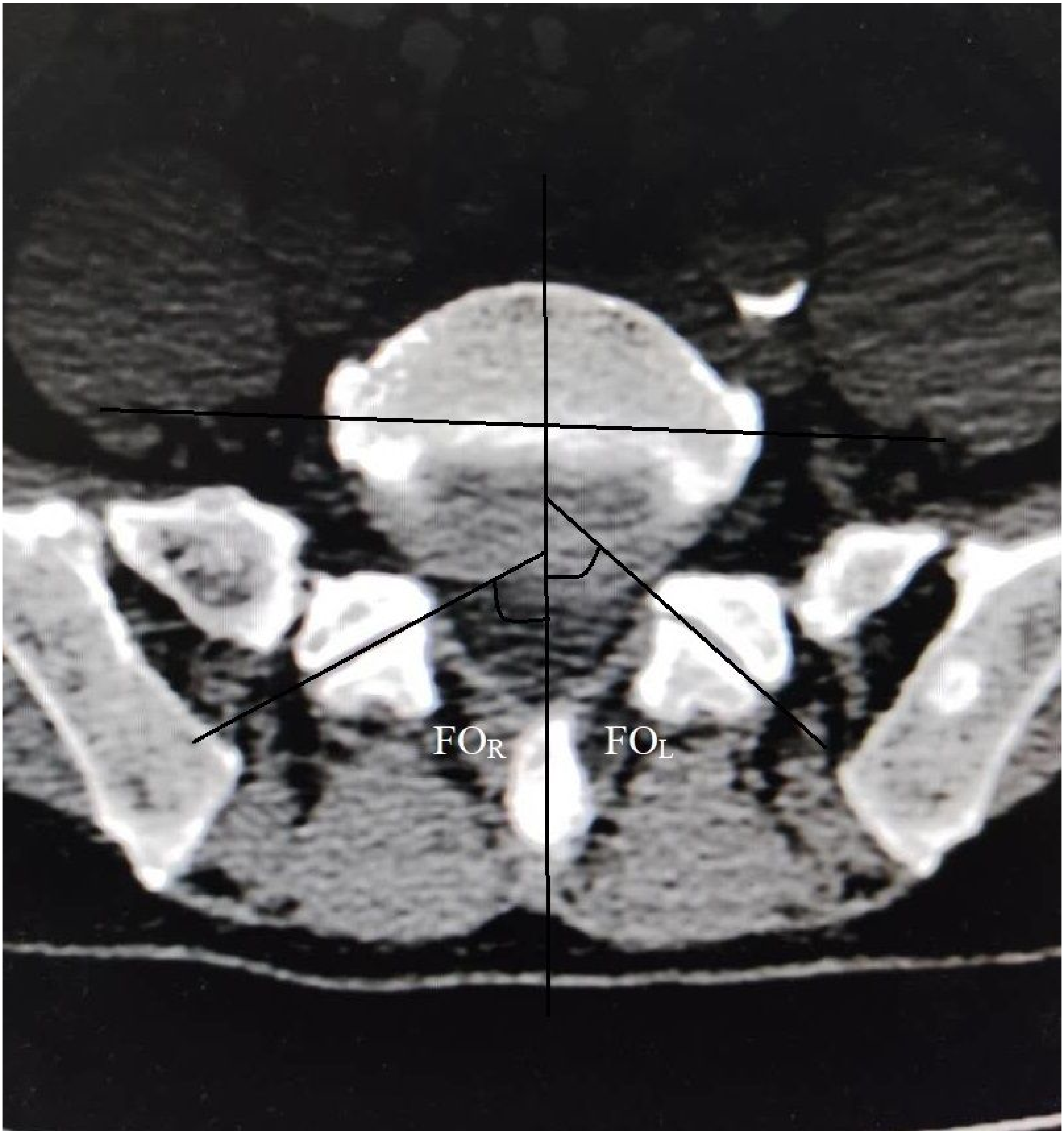

Figure 3

A 27-year-old male with a 2-year history of low back pain and left lower limb radiating pain. The CT image (axial view) of L5-S1 level showed the herniation located on the left side, FOL = 49°, FOR = 62°, FT = 13°.