Original Article

Radiological Analysis of Thoracolumbar Junctional Degenerative Kyphosis in Patients with Lumbar Degenerative Kyphosis

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Abstract

Background: Thoracolumbar junction (TLJ) is the transitional area between the lower thoracic spine and the upper lumbar spine. Vertebral compression fractures and proximal junctional kyphosis following spine surgery often occur in this area. Therefore, the study of development and mechanisms of thoracolumbar junctional degeneration is important for planning surgical management. This study aimed to review radiological parameters of thoracolumbar junctional degenerative kyphosis (TLJDK) in patients with lumbar degenerative kyphosis and to analyze compensatory mechanisms of sagittal balance.

Methods: From January 2016 to March 2017, patients with lumbar degenerative kyphosis were enrolled in this radiographic study. Patients were divided into two groups according to thoracolumbar junctional angle (TLJA): the non-TLJDK (NTLJDK) group (TLJA <10°) and the TLJDK group (TLJA ≥10°). Complete spinopelvic radiographic parameters were analyzed and compared between two groups. Pearson or Spearman correlation coefficients and independent two-sample *t*-test or Mann-Whitney *U*-test were used.

Results: A total of 77 patients with symptomatic sagittal imbalance due to lumbar degenerative kyphosis were enrolled in this study. There were 34 patients in NTLJDK group (TLJA <10°) and 43 patients in TLJDK group (TLJA ≥10°). The median angle of lumbar lordosis (LL) in the NTLJDK or TLJDK groups was 23.40° (18.50°, 29.48°) or 19.50° (13.30°, 24.55°), respectively. The median TLJAs in all patients and both groups were −11.20° (−14.60°, −4.80°), −3.70° (−7.53°, −1.73°), and −14.30° (−17.45°, −13.00°), respectively. In the NTLJDK group, LL was correlated with thoracic kyphosis (TK; $r = -0.400$, $P = 0.019$), sacral slope (SS; $r = 0.681$, $P < 0.001$), and C7-sagittal vertical axis ($r = -0.402$, $P = 0.018$). In the TLJDK group, LL was correlated with TK ($r = -0.345$, $P = 0.024$), SS ($r = 0.595$, $P < 0.001$), and pelvic tilt ($r = -0.363$, $P = 0.017$). There were significant differences in LL, TLJA, TK, SS, and pelvic incidence (PI) between two groups.

Conclusions: Although TLJDK is common in patients with lumbar degenerative kyphosis, it might be generated by special characteristics of morphology and biomechanics of the TLJ. To maintain sagittal balance, pelvis back tilt might be more important in patients with TLJDK, whereas thoracic curve changes might be more important in patients without TLJDK.

Key words: Lumbar Degenerative Kyphosis; Pelvis Back Tilt; Sagittal Balance; Thoracic Kyphosis; Thoracolumbar Junctional Degenerative Kyphosis

Introduction

In an aging society, degenerative deformities have been among the most notable spinal disorders, owing to their significant impact on health-related quality of life.[1] Lumbar degenerative kyphosis, a sagittal imbalance due to lumbar kyphosis or marked loss of lumbar lordosis (LL), was first described by Takemitsu *et al*.[2] It is caused by particular lifestyles, such as the prolonged crouched posture during agricultural work and certain activities of daily living. Patients with lumbar degenerative kyphosis usually show extensive degenerative changes of the lower lumbosacral discs and facet joints from L2 to S1, with atrophy and fatty changes of the lumbar extensor muscles.[3] The main mechanisms of sagittal balance maintenance are a reduction

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of thoracic kyphosis (TK), intervertebral hyperextension, retrolisthesis, pelvis back tilt, knee flessum, and ankle extension.[4]

The thoracolumbar junction (TLJ), where increasing torsional stiffness and specifically-directed shear loads of the spine have been observed,[5] is the transitional area between the lower thoracic spine and the upper lumbar spine. Vertebral compression fractures and proximal junctional kyphosis (PJK) following spine surgery often occur in this area. Although surgery might be a preferred treatment option for lumbar degenerative kyphosis, conservative treatment could be also a considerable treatment option for patients who is unwilling or has poor medical condition to operate.[6] Therefore, the study of development and mechanisms of thoracolumbar junctional degeneration is important for planning therapy strategies, including surgical management.

The purpose of this study was to review and compare radiological parameters of TLJDK in patients with lumbar degenerative kyphosis and to analyze relevant compensatory mechanisms maintenance of sagittal balance.

Methods

Ethical approval

The study was conducted in accordance with the *Declaration of Helsinki* and was approved by the Ethics Committee of Peking University People's Hospital (No. 2016PHB186-01). Informed written consent was obtained from all patients before their enrollment in the study.

Patients

From January 2016 to March 2017, patients with symptomatic sagittal imbalance due to lumbar degenerative kyphosis from the Department of Spinal Surgery, Peking University People's Hospital were enrolled in this study. Patients were divided into two groups according to thoracolumbar junctional angle (TLJA): the non-thoracolumbar junctional degenerative kyphosis (NTLJDK) group (TLJA $<10°$) and the thoracolumbar junctional degenerative kyphosis (TLJDK) group (TLJA $\geq 10°$). Complete radiographic evaluations in patients with suspected sagittal imbalances were performed using a full-length 36-inch standing lateral radiograph of the entire spine, with arms held at 60° of forward flexion, and with hips and knees fully extended.

The inclusion criteria were as follows: patients with sagittal imbalance due to lumbar kyphosis or marked loss of LL. The exclusion criteria were as follows: history of trauma or surgery to the spine, pelvis, or other positions; any comorbidity that may affect the spinopelvic alignment, such as pelvic deformities, leg length discrepancy, and spondylolisthesis; and incompleteness of patient's information or absence of some measurements.

Sagittal balance was determined by measuring the sagittal vertical axis (SVA) with a plumb line from the center of the C7 vertebral body to the posterior sacral prominence on the lateral radiograph. A regional sagittal modifier was included to describe each of the three regions of the spine: LL, TLJA, and TK. The LL was measured from the L1 superior end plate to the S1 superior end plate by the Cobb method. The TLJA was measured from the T11 superior end plate to L1 inferior end plate. The main TK was measured from the T4 superior end plate to T12 inferior end plate. In terms of TK, TLJA, and LL, lordosis was defined as positive and kyphosis as negative.

Pelvic incidence (PI), sacral slope (SS), and pelvic tilt (PT) were measured in each whole spine lateral view. PI was defined as the angle between the line perpendicular to the sacral plate and the line connecting the midpoint of the sacral plate to the bicoxofemoral axis. SS was the angle between the S1 superior end plate and a horizontal line. PT was defined as the angle between a vertical line originating at the center of the bicoxofemoral axis and a line drawn between the same point and the middle of the superior end plate of S1 [Figure 1].

The intra-rater reliability of these variables was assessed in 10 patients with the measurement obtained by the one observer each three times at different intervals.

Statistical analysis

The statistical analysis was performed using SPSS version 20.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics were displayed as mean ± standard deviation (SD) or median (Q1, Q3). Correlations between spinopelvic parameters were determined using the Pearson or Spearman correlation coefficient. Independent two-sample *t*-test and Mann-Whitney *U*-test were used to compare the variables between the two groups. Intraclass correlation

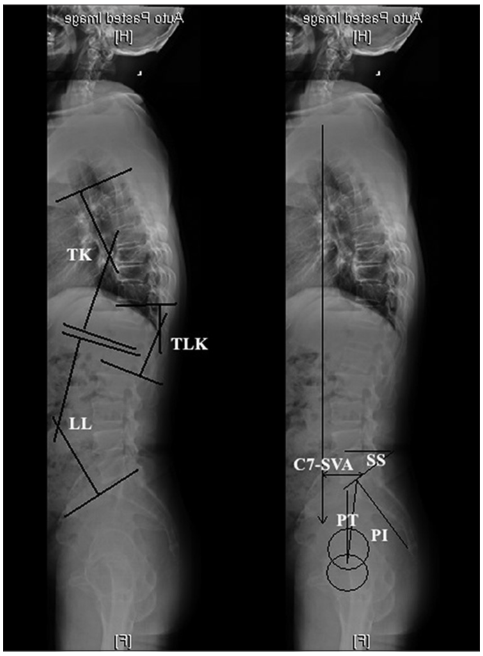

Figure 1: Measurements of spinopelvic parameters. LL: Lumbar lordosis; TK: Thoracic kyphosis; SS: Sacral slope; TLK: Thoracolumbar kyphosis; PI: Pelvic incidence; PT: Pelvic tilt; C7-SVA: C7-sagittal vertical axis.

coefficients (ICCs) were used to measure intra-rater reliability. A $P < 0.05$ was considered statistically significant.

Results

A total of 77 patients with symptomatic sagittal imbalance due to lumbar degenerative kyphosis (47 females and 30 males; mean age: 65.8 ± 8.0 years; age range: 48–82 years) were enrolled in this study. Most patients had characteristic clinical signs, including difficulty in walking and standing due to the back and buttock pain, and inability to lift heavy objects. There were 34 patients in NTLJDK group (TLJA <10°) and 43 patients in TLJDK group (TLJA ≥10°) [Figure 2].

The NTLJDK group consisted of 12 males and 22 females, with a mean age of 65.5 ± 6.0 years (range: 55–75 years). The TLJDK group consisted of 18 males and 25 females, with a mean age of 66.1 ± 9.3 years (range: 48–82 years). The median of LLs in the NTLJDK and TLJDK groups was 23.40° (18.50°, 29.48°) and 19.50° (13.30°, 24.55°), respectively. The maximum and minimum LLs of all patients was −15.60° and 35.40°. The median TLJAs in all patients and in both groups was −11.20° (−14.60°, −4.80°), −3.70° (−7.53°, −1.73°), and −14.30° (−17.45°, −13.00°), respectively. There was no significant difference in C7-SVA between the NTLJDK and TLJDK groups (68.93 ± 46.15 mm vs. 66.58 ± 44.04 mm, $t = 0.228$, $P = 0.821$).

Very good intra-rater ICCs were achieved for the measurement of C7-SVA (ICC = 0.954, 95% confidence interval [*CI*]: 0.990–0.999), LL (ICC = 0.928, 95% *CI*: 0.789–0.981), TK (ICC = 0.936, 95% *CI*: 0.813–0.983), TLK (ICC = 0.920, 95% *CI*: 0.767–0.978), PI (ICC = 0.947, 95% *CI*: 0.845–0.986), PT (ICC = 0.977, 95% *CI*: 0.932–0.994), and SS (ICC = 0.953, 95% *CI*: 0.862–0.987).

Table 1 displays the correlation coefficients between parameters in two groups. In the NTLJDK group, LL was correlated with TK ($r = -0.400$, $P = 0.019$), SS ($r = 0.681$, $P < 0.001$), and C7-SVA ($r = -0.402$, $P = 0.018$); but was not correlated with PI ($r = 0.281$, $P = 0.107$), TLJA ($r = -0.099$, $P = 0.579$) and PT ($r = -0.243$, $P = 0.166$). In the TLJDK group, LL was correlated with TK ($r = -0.345$, $P = 0.024$), SS ($r = 0.595$, $P = 0.000$) and PT ($r = -0.363$, $P = 0.017$); but was not correlated with PI ($r = 0.266$, $P = 0.085$), TLJA ($r = -0.153$, $P = 0.328$), or C7-SVA ($r = -0.169$, $P = 0.280$) [Figure 3].

There were significant differences in LL ($z = -2.021$, $P = 0.043$), TLJA ($z = -7.499$, $P < 0.001$), TK ($t = 3.325$,

Table 1: Correlation coefficients between spinopelvic parameters in NTLJDK and TLJDK groups

Spinopelvic parameters	NTLJDK group (n = 34)		TLJDK group (n = 43)	
	r	*P*	*r*	*P*
LL–TK	−0.400	0.019	−0.345	0.024
LL–SS	0.681	<0.000	0.595	<0.001
LL–PI	0.281	0.107	0.266	0.085
LL–PT	−0.243	0.166	−0.363	0.017
LL–C7-SVA	−0.402	0.018	−0.169	0.280
LL–TLJA	−0.099	0.579	−0.153	0.328

NTLJDK: Non-thoracolumbar junctional degenerative kyphosis; TLJDK: Thoracolumbar junctional degenerative kyphosis; LL: Lumbar lordosis; TK: Thoracic kyphosis; SS: Sacral slope; TLJA: Thoracolumbar junctional angle; PI: Pelvic incidence; PT: Pelvic tilt; C7-SVA: C7-sagittal vertical axis.

Figure 2: Typical thoracolumbar junctional degenerative kyphosis in a patient with lumbar degenerative kyphosis.

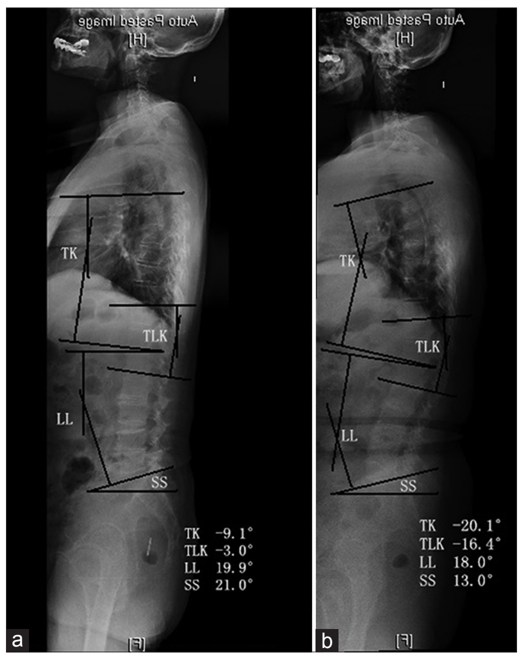

Figure 3: Reduction of thoracic kyphosis and pelvis back tilt to maintain sagittal balance in (a) a NTLJDK patient and (b) a TLJDK patient. LL: Lumbar lordosis; TK: Thoracic kyphosis; SS: Sacral slope; TLK: Thoracolumbar kyphosis; NTLJDK: Non-thoracolumbar junctional degenerative kyphosis; TLJDK: Thoracolumbar junctional degenerative kyphosis.

$P = 0.001$), SS ($z = -3.185$, $P = 0.001$), and PI ($t = 2.130$, $P = 0.036$), while there were no significant differences in C7-SVA ($t = 0.228$, $P = 0.821$) and PT ($t = -0.681$, $P = 0.498$) between the two groups [Table 2]. Significant differences of TK and SS between two groups suggested that, for patients with TLJDK, pelvis back tilt might be more important, while reduction of TK might play a more important role for patients without TLJDK [Figure 4].

Discussion

Lumbar degenerative kyphosis, a severe stage of spinal degeneration, often causes severe low back pain that radiates to the lower limbs. This type of local sagittal imbalance can induce global sagittal imbalance and may substantially affect quality of life. In our clinical practice, We found that unlike PJK following spinal instrumentation surgery or compression fractures of TLJ, thoraolumbar junctional kyphosis often accompanied lumbar degenerative kyphosis. This type of thoracolumbar junctional kyphosis involves particular degeneration of the area or the consequence of severe lumbar degeneration. In this study, no correlations between LL and TLJA were found in the TLJDK group. We, therefore, speculated that this type of thoracolumbar junctional kyphosis might be generated by particular characteristics of morphology and biomechanics of TLJ, especially in the patients with poor bone density, high body mass index, and/or prolonged bent posture.

As noted in the study of Glassman *et al.*,[7] quality of life in patients with adult spinal deformity was substantially related to sagittal deformity, not to coronal deformity. The studies revealed that after surgery to correct adult spinal deformity, patients with sagittal imbalance still had obvious pain and unsatisfactory quality of life.[8,9] Moreover, worse thoracolumbar alignment was associated with severity of central lumbar stenosis, which is a common lumbar degeneration.[10] When severe degeneration of the

Table 2: Comparison of spinopelvic parameters between NTLJDK and TLJDK groups

Spinopelvic parameters	NTLJDK group ($n = 34$)	TLJDK group ($n = 43$)	Statistical values	P
LL (°)	23.40 (18.50, 29.48)	19.50 (13.30, 24.55)	−2.021*	0.043
TLJA (°)	−3.70 (−7.53, −1.73)	−14.30 (−17.45, −13.00)	−7.499*	<0.001
TK (°)	−15.20 ± 9.34	−22.71 ± 10.22	3.325†	0.001
SS (°)	27.00 (21.00, 32.00)	22.00 (16.00, 25.00)	−3.185*	0.001
PI (°)	47.12 ± 10.27	42.40 ± 9.16	2.130†	0.036
PT (°)	21.09 ± 8.38	22.30 ± 7.26	−0.681†	0.498
C7-SVA (mm)	68.93 ± 46.15	66.58 ± 44.04	0.228†	0.821

The data are shown as mean ± SD or median (Q1, Q3). *Mann-Whitney *U*-test ; †independent two-sample *t*-test . NTLJDK: Non-thoracolumbar junctional degenerative kyphosis; TLJDK: Thoracolumbar junctional degenerative kyphosis; LL: Lumbar lordosis; TK: Thoracic kyphosis; SS: Sacral slope; TLJA: Thoracolumbar junctional angle; PI: Pelvic incidence; PT: Pelvic tilt; C7-SVA: C7-sagittal vertical axis; SD: Standard deviation.

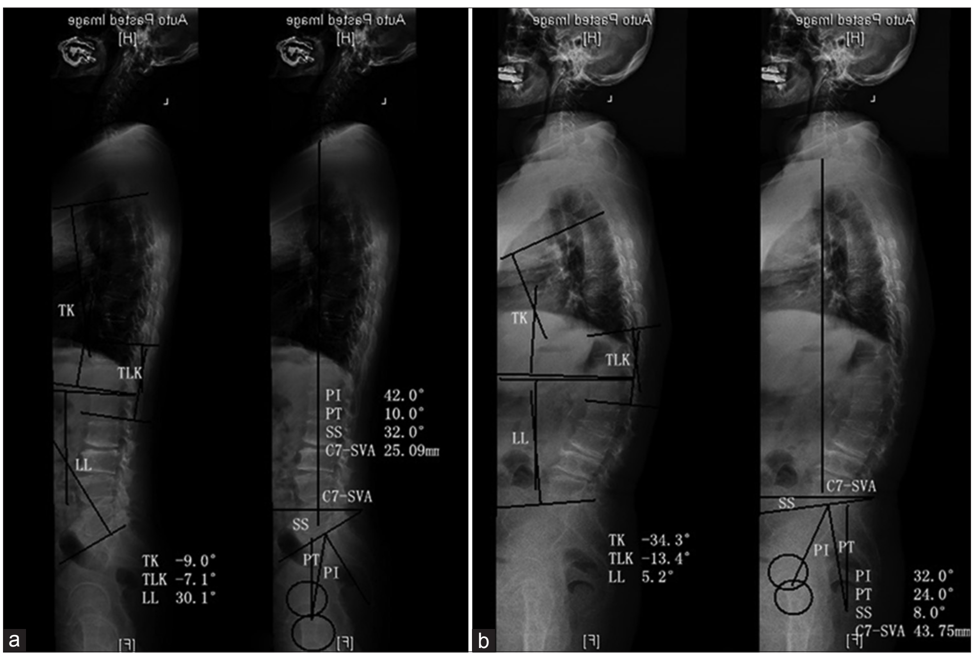

Figure 4: For patient in NTLJDK group, TK −9.0°, SS 32.0°, PT 10.0° showed reduction of thoracic kyphosis to maintain sagittal balance (a); for patient in TLJDK group, TK −34.3°, SS 8.0°, PT 24.0° showed pelvic back tilt to maintain sagittal balance (b). NTLJDK: Non-thoracolumbar junctional degenerative kyphosis; TLJDK: Thoracolumbar junctional degenerative kyphosis; LL: Lumbar lordosis; TK: Thoracic kyphosis; SS: Sacral slope; TLK: Thoracolumbar kyphosis; PI: Pelvic incidence; PT: Pelvic tilt; C7-SVA: C7-sagittal vertical axis.

lumbar and TLJ extends throughout the entire length of spine, eventually sagittal balance and quality of life will be seriously affected. We anticipated that this study of degenerative mechanisms would contribute to disease prevention, assist in planning surgical management, and improve prognosis.

We divided patients with lumbar degenerative kyphosis into two groups according to TLJA. We defined TLJA ≥10° (kyphosis) as TLJDK. History of old compression fractures and instrumentation surgery were excluded. PJK is a common complication following long instrumented spinal fusion surgery.[11-13] The proximal junctional angle was determined as the Cobb angle between the two level cephalad end plates to the UIV and the caudal end plate of the UIV. PJK was defined by two criteria: (1) proximal junctional sagittal Cobb angle >10°, and (2) proximal junctional sagittal Cobb angle at least 10° greater than the preoperative measurement. Some studies suggested that the TLJ should ideally be slightly lordotic, or at least neutral in the sagittal plane.[14,15] However, an increased TLJ kyphosis has been previously identified both in double major and thoracolumbar adolescent idiopathic scoliosis.[16,17] In this study, most TLJA were kyphotic in patients with lumbar degenerative kyphosis, which was opposed to the study of Jang *et al*.[18] In addition, mean TLJA was about 10°. For these reasons, we identified TLJA ≥10° (kyphosis) as TLJDK.

In both groups, a significant correlation was found between LL and SS, and a correlation between LL and TK. This result suggested that reduction of TK and pelvis back tilt had occurred to maintain sagittal balance. However, the mean C7-SVA in the NTLJDK group was 68.93 ± 46.15 mm, while 66.58 ± 44.04 mm in TLJDK group. Therefore, for patients with lumbar degenerative kyphosis, compensatory mechanisms of thoracic curves and pelvis back tilt could not obtain satisfactory sagittal balance. There were no significant differences in PT and C7-SVA between the two groups. Li *et al*.[19] reported that PT was the most relevant pelvic parameter for global sagittal alignment of the spine in adult patients with idiopathic scoliosis. Lafage *et al*.[20] demonstrated that improvement of SVA was strongly correlated with the improvement of LL and PT. The results of this study suggested the presence of some interrelation between PT and global sagittal alignment in degenerative deformities of spine.

As shown in Table 2, TK was much smaller in the NTLJDK group, and SS was much smaller in the TLJDK group. As noted before, for patients with TLJDK, pelvis back tilt might be more important, while reduction of TK might play a more important role for patients without TLJDK. For flexible spine or local degeneration, such as degenerative lumbar kyphosis without involving the TLJ, changes of thoracic curves may directly affect sagittal balance. However, regarding the extension of degeneration, the findings of this study agreed with the results of Rajnic *et al*.[21] When the spine is rigid (aging is kyphotic and ankylotic), there is no possibility for the patients to reduce the magnitude of the thoracic curve. By the time, lumbar and TLJ kyphosis appeared, the degree of spinal degeneration has already become severe. Therefore, pelvic retroversion might be the major compensatory mechanism for these patients.

For patients with lumbar degenerative kyphosis, restoration of LL as much as possible plays a key role to improve quality of life. Surgical treatment has been reported as a better option compared with conservative treatment in patients with severe degenerative lumbar deformities,[22,23] the goals of which are to obtain a satisfactory balance in both sagittal and coronal planes, achieve a solid fusion, to relieve pain, and to prevent deformity progression. In addition, if the patients with lumbar and TLJ kyphosis were operated on, the fusion level should be past the TLJ to correct deformity. Otherwise, PJK would soon appear and recurrent symptoms may necessitate revision surgery. As noted in Wang *et al*.,[24] following long instrumented posterior spinal fusion, uppermost instrumented vertebrae at the TLJ are risk factors for the development and progression of PJK in patients with degenerative lumbar scoliosis following long instrumented posterior spinal fusion.

There were several potential limitations in this study. First, the number of patients was relatively small. Larger sample size would improve study robustness. Second, in this study, about half of the patients with lumbar degenerative kyphosis also had lumbar scoliosis. Therefore, the relationship between these two typical spinal deformities should be discussed in the future study.

In conclusion, TLJDK is common in patients with lumbar deformity, especially lumbar degenerative kyphosis. This type of thoracolumbar junctional kyphosis might be generated by special characteristics of morphology and biomechanics of the TLJ. To maintain sagittal balance, pelvis back tilt may be more important in patients with TLJDK, while thoracic curve changes may be more important in patients without TLJDK.

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Conflicts of interest

There are no conflicts of interest.

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