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ORIGINAL STUDY

Spinopelvic parameters in degenerative spondylolisthesis

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The purpose of this study was to compare various sagittal spinopelvic parameters between patients with and without degenerative lumbar spondylolisthesis (DLS).

A total of 165 patients who underwent surgery for low back and/or radicular pain were divided into two groups: those without DLS (non-DLS group; n = 85) and those with DLS (DLS group; n = 80).

In all sagittal spinopelvic parameters, no significant difference was found between the non-DLS and DLS groups. The mean pelvic incidence (PI) value of the DLS group (56.4°) was almost similar to that of the non-DLS group (57.5°). The cross-sectional ratio of lumbar musculature was significantly smaller in the DLS group than in thenon-DLS group (p = 0.046).

Contrary to the results of previous studies, a high PI may not be a predisposing factor for DLS development. Atrophy of back extensor muscles may play a role in the pathogenesis of DLS.

Keywords : sagittal spinopelvic parameters, pelvic incidence, back extensor muscle, degenerative lumbar spondylolisthesis.

INTRODUCTION

As sagittal spinal balance is emphasized as an important concept in the treatment of spinal disorders, many studies have investigated the correlation among pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), lumbar lordosis (LL), and thoracic kyphosis (TK) in the normal population *(9,10,13)*. Recent studies suggested that the stable relationship between the trunk, pelvis, and lower limbs is disturbed in spondylolisthesis, and increased PI may be an important factor predisposing to the progression of spondylolisthesis *(1-3,5,12)*. Barrey et al. *(2,3)* reported that PI is higher in patients with DLS than in a control group and that sagittal imbalance develops with the loss of LL. They also presumed that PT increases and SS decreases as a consequence of compensatory mechanisms if positive sagittal imbalance develops, and that the resulting pelvic backtilt as well as hyperextension and retrolisthesis in the upper lumbar spine limit the anterior displacement of the axis of gravity. However, the results of other spinopelvic parameters and the related explanations are still contradictory.

The purpose of this study was to compare various sagittal spinopelvic parameters between patients with and without degenerative lumbar

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spondylolisthesis (DLS) and to confirm the differences related to sagittal alignment. As some patients have significant sagittal imbalance relative to the severity of their spondylolisthesis, we also investigated the relationship between muscular atrophy of back extensors and sagittal spinal alignment.

MATERIALS AND METHODS

We retrospectively reviewed 165 patients who underwent surgery for low back and/or radicular pain from 2012 to 2016. We selected patients aged >40 years and with available standing whole-spine radiographs. DLS was defined as an anterior slip of the upper vertebra of 5% or more. Patients who underwent revision surgery, those who underwent long fusion surgery for correction of a deformity including scoliosis or degenerative flatback, those who underwent surgery for trauma or tumor, and patients with isthmic spondylolisthesis were excluded.

The patients were divided into two groups: those without DLS (non-DLS group; n = 85) and those with DLS (DLS group; n = 80). In the DLS group, 68 patients had one-level DLS, 11 patients had two-level DLS, and 1 patient had three-level DLS. Sixty-eight patients in the DLS group had grade I (5-25%) spondylolisthesis and 12 patients had grade II (25-50%) spondylolisthesis according to the Meyerding-Newman classification. The DLS group consisted of 19 men and 61 women, and the non-DLS group consisted of 33 men and 52 women. The mean patient age was 68.2 years (range, 52-80 years) and 67.5 years (range, 51-81 years) in the DLS and the non-DLS group, respectively (Table I).

Table I. — Patients' demographic characteristics

	Non-DLS Group	DLS group	p-value
No. of Patients	85	80	
Age, yr (range)	67.5 ± 7.6 (51-81)	68.2 ± 7.8 (52-80)	0.561
Gender (n)			0.028
Males	33	19	
Females	52	61	

DLS: Degenerative Spondylolisthesis.

The following parameters were measured in preoperative standing whole-spine radiographs: PI, SS, PT, TK, LL, sagittal vertebral axis of the C7 plumb line (C7SVA), sacrofemoral distance (SFD), C7SVA/SFD ratio, and segmental lordosis at each level (L1-2, L2-3, L3-4, L4-5, and L5-S1). PI was defined as the angle between the perpendicular line to the upper sacral endplate at its midpoint and the line connecting this point to the femoral head axis. SS was defined as the angle between the horizontal line and the upper sacral endplate. PT was defined by the angle between the vertical line and the line through the midpoint of the sacral plate to the femoral head axis. LL was defined as the angle between the upper L1 endplate and the upper sacral endplate. TK was defined as the angle between the upper T4 endplate and the upper T12 endplate. SVA was defined as the horizontal offset from the posterosuperior corner of S1 to the C7 plumb line. In T1 axial magnetic resonance imaging of the lumbar spine, the cross-sectional area (CSA) ratio (paraspinal muscles to the intervertebral disc) at the L4-5 level was measured to identify the influence of lumbar musculature on sagittal balance. Measurement of the CSA ratio was based on the protocol that had been previously reported by one of the authors *(6)*. All parameters were measured and analyzed using picture archiving and communication system that was invented by the medical information technology team in our hospital. All measurements were performed by surgeons specializing in spine surgery and repeated by the same surgeon 1 month later. The average values of measurements taken at two different time points were used for the final analyses.

Statistical anaylsis was performed using the SPSS program (version 16; SPSS Inc., Chicago, IL, USA). The independent two-sample t-test was employed for the analysis of the differences of sagittal parameters between the two groups. Because the male-to female ratio was significantly different between the two groups (Table I), adjusted means were calculated and generalized regression analysis was performed.

RESULTS

The results are summarized in Table II, which provides the data of the radiologic parameters of the DLS group compared with those of the non-DLS group. In all sagittal spinopelvic parameters, no significant difference was found between the non-DLS group and the DLS group except C7SVA. The mean PI value of the DLS group (56.4°) was almost similar to that of non-DLS group (57.5°). SS averaged 33.1° in the DLS group and 35.7° in the non-DLS group. PT averaged 23.9° in the DSL group and 24.6° in the non-DLS group. TK averaged 26.8° in the DLS group and 25.2° in the non-DLS group. LL averaged -39.5° in the DLS group and -37.5° in the non-DLS group. While there was no difference in SFD and C7SVA/SFD ratio between the two groups, C7SVA was significantly larger in the non-DLS group than in the DLS group ($p = 0.035$). The mean CSA ratio at the L4-5 level was 0.93 in the DLS group and 1.33 in the non-DLS group. The CSA ratio was significantly smaller in the DSL group than in the non-DLS group ($p = 0.046$).

When comparing segmental lordosis at each lumbar level between the two groups, lordosis at L4-5 was significantly greater in non-DLS group than in the DLS group ($p = 0.001$). While there was no difference in segmental lordosis at L3-4 and L5-S1 between the two groups, lordosis at L1-2 and L2-3 were significantly greater in the DLS group than in the non-DLS group (Table II).

When comparing adjusted means for the difference of male-to-female ratio, the estimated values were similar to those in the results using crude means. In regression analysis, C7SVA, the CSA ratio, segmental lordosis at L1-2, L2-3, and L4-5 were also significantly different variables between the two groups (Table III).

DISCUSSION

PI is an anatomic pelvic parameter that is specific for each person and is constant from early adulthood *(9)*. The other measures of spinopelvic sagittal shape are position-dependent variables. As PI is the sum of SS and PT, a high PI predisposes to a high

Table II. — Comparison of radiographic parameters between non-DLS and DLS groups

	Non-DLS Group	DLS Group	p-value
PI (°)	57.5 ± 10.7	56.4 ± 10.9	0.499
SS (°)	35.7 ± 9.1	33.1 ± 8.9	0.071
PT (°)	24.6 ± 8.9	23.9 ± 8.3	0.635
TK (°)	25.2 ± 10.5	26.8 ± 11.4	0.349
LL (°)	-37.5 ± 12.5	-39.5 ± 13.3	0.335
C7SVA (mm)	68.2 ± 57.5	50.8 ± 46.3	0.035
SFD (mm)	75.0 ± 30.7	68.3 ± 28.9	0.152
C7SVA/SFD ratio	0.78 ± 0.74	0.75 ± 0.70	0.774
CSA ratio	1.33 ± 1.82	0.93 ± 0.55	0.046
Segmental Lordosis			
L1-2	2.13 ± 5.98	-0.48 ± 6.27	0.008
L2-3	-1.58 ± 5.80	-5.22 ± 6.49	< 0.001
L3-4	-7.09 ± 6.71	-8.08 ± 6.76	0.349
L4-5	-13.64 ± 8.50	-9.49 ± 7.58	0.001
L5-S1	-18.74 ± 8.11	-18.38 ± 5.95	0.748

PI: Pelvic Incidence, SS: Sacral Slope, PT: Pelvic Tilt, TK: Thoracic Kyphosis, LL: Lumbar Lordosis, SVA: Sagittal Vertical Axia, SFD: Sacrofemoral Distance, CSA: Cross-Sectional Area.

Table III. — Regression coefficients for each radiographic parameter

Parameters	Coefficients	Standard Error	p-value
PI	-1.14	1.69	0.499
SS	-2.56	1.41	0.071
PT	-0.64	1.35	0.635
TK	1.61	1.71	0.349
LL	1.96	2.03	0.335
C7SVA	-17.40	8.19	0.035
SFD	-6.73	4.67	0.152
C7SVA/SFD ratio	-0.03	0.11	0.774
CSA ratio	-0.40	0.21	0.049
Segmental Lordosis			
L1-2	-2.60	0.96	0.008
L2-3	-3.63	0.96	0.000
L3-4	-0.99	1.05	0.349
L4-5	4.15	1.26	0.001
L5-S1	0.36	1.12	0.748

PI: Pelvic Incidence, SS: Sacral Slope, PT: Pelvic Tilt, TK: Thoracic Kyphosis, LL: Lumbar Lordosis, SVA: Sagittal Vertical Axia, SFD: Sacrofemoral Distance, CSA: Cross-Sectional Area.

SS and/or PT. When a high SS is observed, LL is increased owing to compensatory mechanism. A high LL is clearly associated with high shear forces at the L5-S1 pars interarticularis, thus causing isthmic spondylolisthesis *(4)*.

Although DLS is known to be caused by degenerative changes of a disc or facet joints, only a few studies have reported the association of its pathophysiology with the sagittal spinopelvic parameters *(1-3, 5, 12)*. While the pathophysiology of DLS is still not fully understood and its development is considered multifactorial, several studies documented that a high PI was a predisposing factor for DLS. Schuller et al. *(12)* reported that PT, SS, PI, and LL were significantly higher in patients with DLS than in the control group; however, they did not provide data about the overall sagittal balance. In a study that followed 142 female volunteers for an average of 12 years, the incidence of new DLS was 12.7%, and the patients who developed DLS had greater PI and LL *(1)*. However, our present study showed that there was no statistically significant difference in spinopelvic parameters between the DLS group and the non-DLS group. As this result is contrary to those of previous studies, it challenges the notion that a high PI is a predisposing factor for DLS (Figure 1). Spondylolisthesis was also found to have no significant influence on the sagittal balance. C7SVA was rather larger in the non-DLS group than in the DLS group.

In the current study, segmental lordosis at L4-5 was greater in the non-DLS group than in the DLS group, suggesting that spondylolisthesis at this level, where DLS most commonly develops, causes a certain amount of loss of lordosis. On the contrary, segmental lordosis at L1-2 and L2-3 were greater in the DLS group than in the non-DLS group. This is due to the compensatory mechanism occurring in the upper lumbar segment, which coincides with the findings reported by Barrey et al *(3)*. Therefore, we suggest that significant sagittal spinal imbalance does not develop in patients with DLS because the degree of slippage and kyphosis are relatively small in the DLS group and compensatory mechanisms are working well.

On the other hand, several studies support the finding that restoration of LL during surgery for DLS leads to acceptable clinical results *(7,8,11)*.

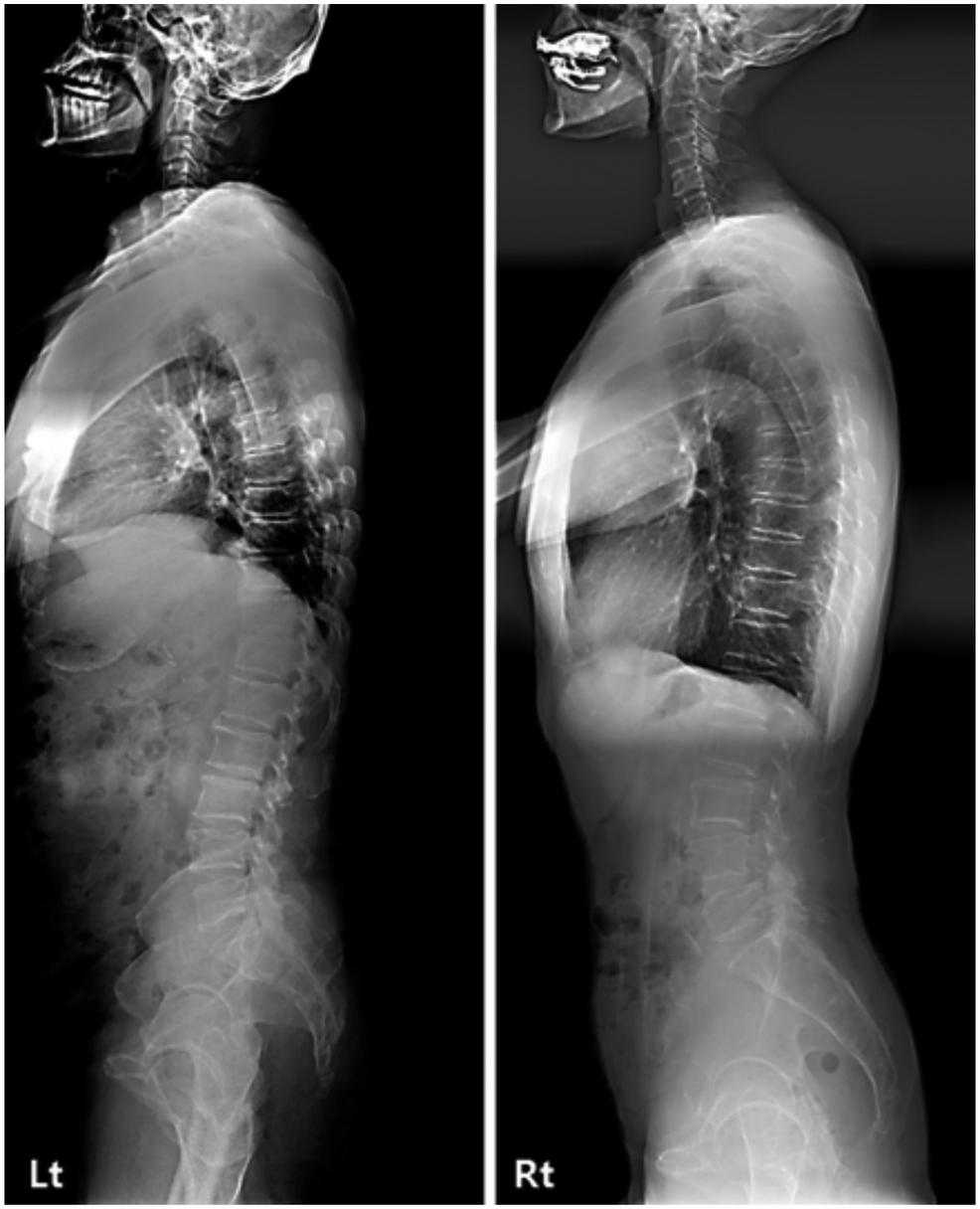

Fig. 1. — Examples of age- and sex-matched patients (73-year-old male patients). Degenerative lumbar spondylolisthesis (DLS) developed in the right patient even though the pelvic incidence of this patient is lower than that of the left patient.
Left: patient from the non-DLS group, right: patient from the DLS group

Kawakami et al. *(7)* suggested that high postoperative LL and reduction of slippage may improve clinical outcomes of fusion surgery for DLS. Kim et al. *(8)* also reported that patients with improved PT after fusion were found to achieve excellent control of low back pain, emphasizing the restoration of lordosis at fused segments.

Few studies have concentrated on the significance of paraspinal muscle changes in DLS. Wang et al. *(14)* found that multifidus muscle atrophy decreased in patients with DLS, and suggested that it could be the cause of DLS. In a finite element study evaluating the effect of muscle weakness on DLS, Zhu et al. *(15)* concluded that reducing the force of

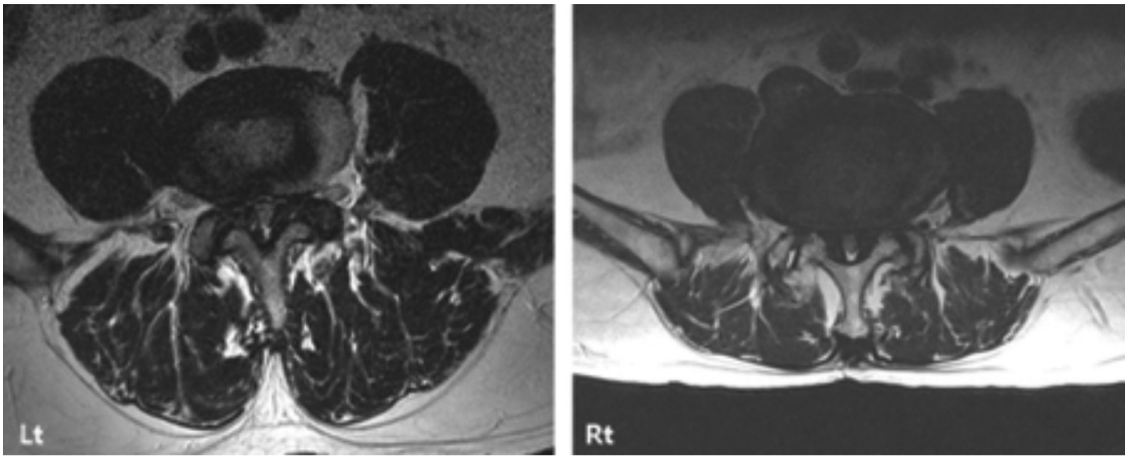

Fig. 2. — Axial images of magnetic resonance imaging at the L4-5 level of each patient in Fig. 1. The right patient with degenerative lumbar spondylolisthesis has a lower cross-sectional area ratio than the left patient

global back muscles might lead to, or aggravate, DLS with forward slipping from a biomechanical point of view. In this study, patients with DLS had severe muscular atrophy of back extensors (Figure 2). The CSA ratio at the L4-5 level was smaller in the DLS group and the difference was statistically significant. However, it remains inconclusive whether back muscle atrophy plays a role in the pathogenesis of DLS. This study did not analyze other factors as confounders. The relationship between muscular atrophy of back extensors and development of DLS deserves additional prospective studies in a large number of patients.

This study has some limitations. Because we retrospectively included patients who underwent surgical treatment for DLS, the patients are not consecutive and their enrollment may have been biased, thus not reflecting the natural history of disease. We also could not use a matched control group in terms of age, gender, or level of spondylolisthesis. Lastly, the correlation of spinopelvic parameters with the severity of DLS from grade I to IV could not be investigated because this study almost exclusively included subjects with low-grade spondylolisthesis (grade I to II).

CONCLUSIONS

There was no difference in the parameters associated with sagittal spinopelvic alignment between patients with and without DLS. DLS did not affect the development of sagittal spinal imbalance. A high PI may not be a predisposing factor for DLS. Atrophy of back extensor muscles may play a role in the pathogenesis of DLS.

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