Original Article

Sagittal Alignment and Coronal Plane Deformity of the Spine in Lumbar Disc Herniation Patients

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Objective: To evaluate sagittal and coronal alignment changes of the lumbar spine in lumbar disc herniation [LDH] patients.

Materials and Methods: A retrospective review was conducted measuring changes in sagittal and pelvic parameters as well as coronal plane deformity changes in sixty-two lumbar disc herniation patients who had been operated on at Ramathibodi Hospital including calculation of differences in changes of the sagittal alignment inpatients with and without coronal plane deformity.

Results: The median interquartile range of pelvic incidence, sacral slope, and pelvic tilt were 48.25$\pm$12.63, 30$\pm$10.75 and 17.5$\pm$11.63 degrees, respectively. The mean lumbar lordosis was 41$\pm$17.25 degrees. Coronal plain analysis found 16.39% of the patients had a significant coronal deformity (defined as a Cobb angle >10 degrees). In 70% of the patients, the deformity was on the curve side (convex side), the same side as the disc lesion, and 90% of the coronal deformities had minimal rotation (Nash & Moe grade 0 or 1). There were no statistically significant differences in sagittal parameters between groups with and without coronal plane deformity with the exception of lumbar inclination.

Conclusion: Lumbar disc herniation can exhibit changes in both sagittal and coronal alignment. Herniation probably decreases sacral slope and lumbar lordosis,but increases pelvic tilt. Coronal deformity was found in about 16% of patients,while most patients had minimal spinal rotation. There was no significant correlation between sagittal and coronal imbalance in the two groups of patients.

Keywords: Sagittal alignment, Coronal alignment, Lumbar disc herniation, Deformity

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Most patients with lumbar disc herniation [LDH] present with leg pain,either with or without neurological deficit. Occasionally they may also present with coronal and/or sagittal plain spinal deformities. In the coronal plain, sciatic scoliosis and lateral shift are terms used to define a condition in which there is a lateral and forward tilt of the trunk secondary to irritation of the nerve root(1).

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In the sagittal plain, the parameters of pelvic incidence [PI], pelvic tilt [PT] and sacral slope [SS] as described by During and Duval-Baeaupere et al are popularly used to describe sagittal plain alignment(2). A series of studies have reported a correlation of the sagittal alignment with several lumbar degenerative diseases including degenerative spondylolisthesis [DS], lumbar disc degeneration [LDD], and LDH(3-5). Those studies indicate that the PI was one of the predisposing factors in the pathogenesis and development of DS(4); however, relatively few published studies have discussed the characteristics of sagittal alignment change in patients with LDH.

In the present study, we determined the

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incidence and severity of both sagittal and coronal plain deformities in LDH patients. We attempted to quantify differences in radiographic parameters between LDH patients and the normal population and to identify correlations between sagittal and coronal deformities in LDH patients.

Materials and Methods

We retrospectively evaluated 96 LDH patients who had been operated on at Ramathibodi Hospital during the period January 2014 through December 2015. Exclusion criteria were (1) age over 60 years, (2) incomplete medical records, (3) poor quality plain radiographs, and (4) congenital structural abnormalities. The Institutional Review Board [IRB] of Mahidol University approved this study. Magnetic resonance imaging [MRI] evaluation by two attending spinal surgeons was used to determine the type of LDH in the subjects. In cases where there were differences between the two surgeons, the situation was discussed among them. Disc herniations were divided into three groups: protruded, extruded and sequestered disc herniation. The presence of disc herniation had been confirmed by intraoperative findings in all cases. Spinal parameters were measured using preoperative AP and lateral standing lumbosacral spine radiographs. After reviewingthe medical data and radiographs, a total of 62 patients were included in the present study.

Measurements were made of a total of 11 spinal parameters. The eight sagittal parameters were pelvic incidence [PI], defined as the angle between a line perpendicular to the S1 endplate at its midpoint and a line connecting the same point to the hip axis (the center of the bicoxofemoral axis); sacral slope [SS], defined as the angle between a horizontal line and the sacral endplate; pelvic tilt [PT], defined as the angle between a vertical line originating at the hip axis and a line drawn between the same point and the mid-point of the superior endplate of S1; total lumbar lordosis [LL], defined as the angle between the upper endplate of T12 and the upper endplate of S1; proximal lumbar lordosis [PLL], defined as the angle between upper endplateof T12 and the upper endplateof L4; distal lumbar lordosis [DLL], defined as the angle between the upper endplate of L4 and the upper endplate of S1; lumbar inclination [LI], defined as the angle between a vertical line and a line draw between the center of the T12 body and the midpoint of the S1 endplate; and sacro-femoral distance [SFD], defined as the distance between the center of the femoral head and the midpoint of the S1 endplate in the horizontal plane (Figure 1 and 2). The three coronal parameters were the Cobb angle, defined as the angle between the upper endplate of the proximal end and the upper endplate of the distal end of the curve of lumbar scoliosis; the lumbar apical vertebral translation, defined as the distance between the center of the apex vertebra; and the center sacral vertical line [CSVL], defined as a vertical line drawn from the midpoint of first sacral endplate,plus the Nash & Moe grade for vertebral rotation (Figure 3).

All measurements were performed independently by two spine surgeons using online radiograph software (PACS: Picture Archiving and Communication System). Interobserver reliability for radiographic parameters was determined by two observers twice with a 1-week interval. The intraclass-

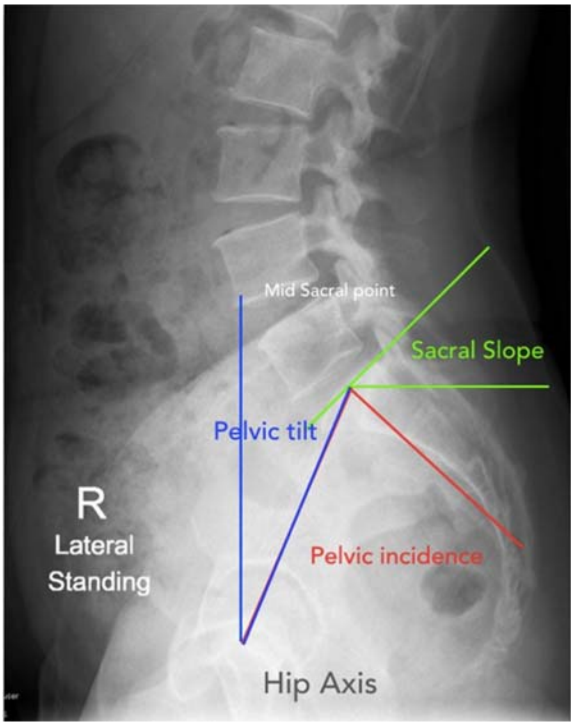

Figure 1. Measurement of sagittal parameters[1]. Pelvic incidence is defined as the angle between a line perpendicular to the S1 endplate at its midpoint and a line connecting the same point to the hip axis (the center of the bicoxofemoral axis). Sacral slope is defined as the angle between a horizontal line and the sacral endplate. The pelvic tilt is defined as the angle between a vertical line originating at the hip axis and a line drawn between the same point and the midpoint of the superior endplate of the S1 body.

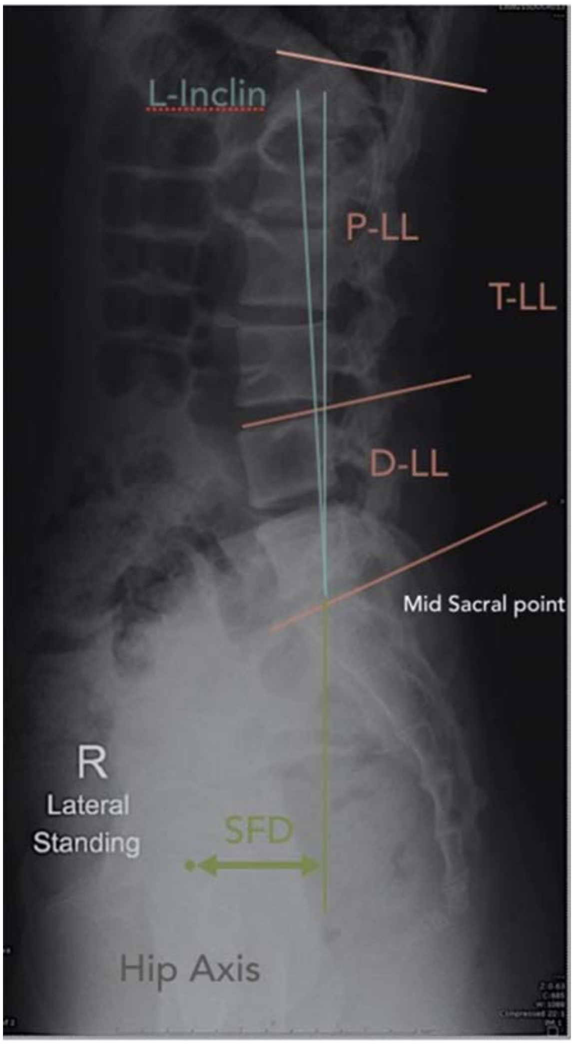

Figure 2. Measurement of sagittal parameters[2]. Total lumbar lordosis [T-LL] is defined as the angle between the upper endplate of T12 and the upper endplate of S1. Proximal lumbar lordosis [P-LL] is defined as the angle between the upper endplate of T12 and the upper endplate of L4. Distal lumbar lordosis [D-LL] is defined as the angle between the upper endplate of L4 and the upper endplate of S1. Lumbar inclination is defined as the angle between a vertical line and a line that drawn between the center of the T12 body and the midpoint of the S1 endplate. Sacro-femoral distance [SFD] is defined as the distance between the center of the femoral head and the midpoint of the S1 endplate in the horizontal plane.

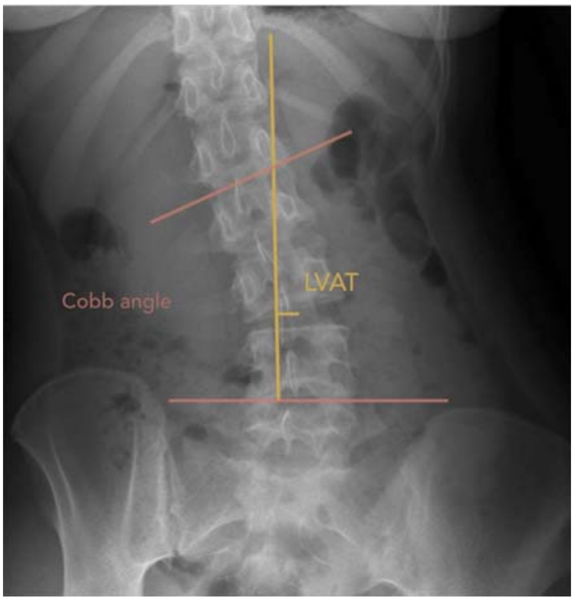

Figure 3. Measurement of coronal parameters. Cobb angle is defined as the angle between the upper endplate of the proximal end and the upper endplate of the distal end of the lumbar scoliosis curve. The lumbar apex vertical translation is defined as the distance between the center of the apex vertebra and the center of the sacral vertical line.

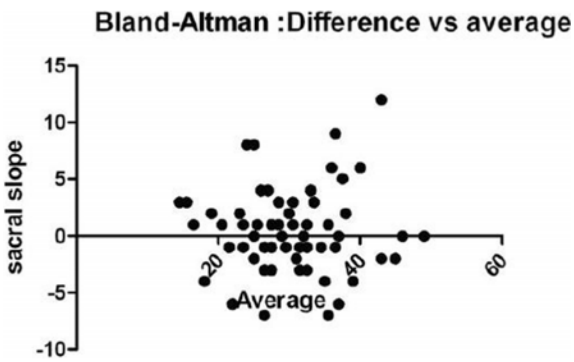

Figure 4. Bland-Altman agreement plot between observers for sacral slope indicated an interobserver reliability of 0.88.

correlation coefficient [ICC] of the sacral slope was 0.88. The Bland-Altman agreement plot of the two observers is shown in Figure 4. Results are shown as median and interquartile range [IQR] as the outcomes were non-parametric. The Mann-Whitney U Test was used to compare sagittal parameters with and without coronal plane deformities. Statistical analysis was conducted using GraphPad Prism version 5.

Results

Nighty-six patients met the inclusion criteria, while 34 patients were excluded due to poor quality of plain radiographs or incomplete medical records. The characteristics of the 62 patients are described in Table 1. The mean age of the patients was 43.72 years and the average BMI was 26.001 kg/m^2. By gender, 52% were male and 48% were female. The most common level was L4-5 (61%) and the most common type of LDH was protruded disc herniation (52%).

In terms of sagittal plain alignment data, the median pelvic incidence was 48.25 degrees and the interquartile range was 12.63 degrees. The median sacral slope and pelvic tilt were 30 and 17.5 degrees, respectively (IQR 10.75 and 11.625 degrees, respectively). Total lumbar lordosis was 41 degrees with an interquartile range of 17.25 degrees. Proximal lumbar lordosis was 16 degrees with a standard deviation of 15.63 degrees. Distal lumbar lordosis was 25 degrees with a standard deviation of 13.16 degrees. Median sacro-femoral distance was 54.43 (IQR = 26.39 millimeters). Lumbar inclination was 4.5 degrees with an IQR of 8.13 degrees (Table 2).

In the coronal plain, the median Cobb angle was 2.5 degrees (max = 24.5, min = 0 degrees). Ten patients had significant coronal deformities (defined as Cobb angle >10 degrees). In seven patients,the curve side (convex side) was on the same side as the disc herniation lesion. Three patients had the curve side on the side opposite to disc lesion; two had large paracentral disc and one had large central disc pathology. In terms of spinal rotation grade, one patient had Nash & Moe grade 2 vertebral rotation and 5 patients had Nash & Moe grade 1 rotation (Table 3).

Comparison of sagittal parameters between the samples with or without coronal plane deformities is shown in Table 4. There was no statistically significant difference in any sagittal plane parameters between

Table 1. Patient demographic data

Parameter	Mean	Max	Min	SD
Age(years)	43.72	60	17	11.86
Height(cm)	162.67	183.6	141.1	8.69
Weight(kg)	68.69	106	40.9	12.25
BMI(kg/m^2)	26.001	35.37	17.4	4.21

	Parameter (Number of patients)			
Gender	Male 30		Female 32	
Side of herniation	Left 35		Right 27	
Level of herniation	L3-4 4	L4-5 38	L5-S1 17	Multiple 3
Type of herniation	Protruded 32	Extruded 23	Sequestered 7	

Table 2. Median, minimum, maximum, and standard deviation of sagittal parameters

Parameter	Median	IQR	Max	Min
Pelvic incidence (degrees)	48.25	12.63	69.5	32.5
Sacral slope (degrees)	30	10.75	49	14.5
Pelvic tilt (degrees)	17.5	11.63	35.5	4.5
Total lumbar lordosis (degrees)	41	17.25	70.5	-9.5
Proximal lumbar lordosis (degrees)	16	15.63	38	-19
Distal lumbar lordosis (degrees)	25	13.16	41.5	-2
Sacro-femoral distance (mm)	54.43	26.39	80.2	17.94
Lumbar inclination (degrees)	4.5	8.13	15	-16

Table 3. Coronal parameters of 10 scoliotic patients

Case	Lesion side	Curve side	Cobb angle	Nash & Moe grade
1	L	L	24.5	2
2	R	R	17	1
3	L	L	16.5	1
4	R	R	15	0
5	R	R	12.5	0
6	L	R	12.5	0
7	R	R	12	0
8	R	R	12	1
9	R	L	11	1
10	R	L	10	1

Table 4. Comparison of sagittal parameters between the groups with and without coronal plane deformities

Parameters	Cobb >10 (10 patients)		Cobb <10 (52 patients)		*p*-value
	Median	IQR	Median	IQR	
Pelvic incidence(degrees)	43.5	18.5	48	12	0.359
Sacral slope (degrees)	26.25	7.25	31	11	0.09
Pelvic tilt (degrees)	19.25	18.38	17	11.5	0.612
Total lumbar lordosis (degrees)	36.00	18.38	41.5	19.5	0.3496
Distal lumbar lordosis (degrees)	25.5	9.75	25	14	0.639
SFD (mm)	62.75	2.49	52.51	2.55	0.230
Lumbar inclination (degrees)	8	8.5	3	7.5	0.032*

* Statistically significant difference
p-value <0.05

patients with and without scoliosis with the exception of lumbar inclination. Patients with scoliosis had a higher lumbar inclination than patients without scoliosis; the median values were 8 and 3 degrees, respectively (*p*-value = 0.032).

Discussion

Our study measured sagittal and coronal alignment parameters in LDH patients. In a study of Korean volunteers by Lee et al(6), the mean sagittal parameters in a normal population were pelvic incidence 47.80 degrees, sacral slope 36.30 degrees, pelvic tilt 11.50 degrees, total lumbar lordosis 49.60 degrees, sacro-femoral distance 23.0 mm., and lumbar inclination 5.0 degrees. There are some differences in race, mean age of the population, and radiographic technique in between that study and the present study. The LDH patients in the present study tended to have a lower sacral slope and lumbar lordosis, and a higher pelvic tilt than the normal Korean population. Patients with LDH had more pelvic tilt and a greater sacro-femoral distance but lower sacral slope and lumbar lordosis. In a study of sagittal alignment differences between LDH subjects and matched healthy subjects, Endo K et al(3) found a higher sagittal vertical axis [SVA] and pelvic tilt angle but a lower lumbar lordosis angle in the lumbar disc herniation patients. These findings are similar to the results of our study; however, the Endo study did not evaluate pelvic or coronal alignment parameters. The present study also included pelvic incidence, sacral slope, and pelvic tilt which are more commonly used for evaluating the sagittal alignment before and after spinal surgery. In terms of lumbar lordosis, we found less lordosis in both total and distal lumbar segments compared to normal population data.

Changes in sagittal and coronal alignment in LDH patients may be due to a protective mechanism designed to avoid sciatic pain. Decreases in distal lumbar lordosis may be explained by compensation of pathologic disc level to decrease disc pressure and/or secondary protective muscle contraction[7,8]. A previous study using electromyography stated that the positive balance in lumbar disc herniation was mainly caused by decreased trunk muscle strength, especially the extensor muscle[9]. The sacral slope is then reduced to compensate for the loss of lumbar lordosis to keep the center of gravity in a balanced position but without causing a change in pelvic incidence.

Coronal plane deformity occurs frequently in LDH patients. Our data shows the median Cobb angle was 2.5 degrees; however, the incidence of significant coronal alignment change (>10 degrees) was 16.39%. We found that the curve side predicts the herniation side in about 70% of cases, a finding similar to previous studies. Matsui et al[10] reported that 80% of trunk shift occurred at the opposite side from the disc lesion, while Zhu Z et al[1] reported 84.6% (22/26 LDH patients) had the convex side of the curve on the same side as the disc herniation. We also measured rotational change and found that 90% of the LDH patients with scoliosis had a minimal rotation of the spine (Nash & Moe grade 0 or 1), and only one case had a grade 2 rotational deformity. This appears to support the theory that scoliosis in LDH is not a structural curve but rather that it could be the result of a protective mechanism of the body. We also evaluated the relationship between coronal deformities and sagittal alignment, but we found no significant correlation between the coronal plane and the sagittal plane (Table 4). We hypothesize that the mechanism of sagittal alignment changes may not be related to coronal deformity in LDH patients.

One strength of our study is that we collected data on both sagittal and coronal plane deformities and included pelvic parameters that had not been well documented in earlier studies, allowing us to calculate the correlation between sagittal and coronal parameters. There are limitations in our study. As we used retrospective data, we were not able to obtain the whole spine lateral radiographs needed to evaluate all sagittal alignment parameters. In addition, the small sample size precluded subgroup analysis. Third, our study did not collect or compare parameters of the normal Thai population, something which might have added some benefit and increased the ability to reach conclusions related to changes in sagittal profiles of LDH patients.

Conclusion

In lumbar disc herniation patients, there are changes in both sagittal and coronal alignment. Herniation probably decreases sacral slope and increases pelvic tilt while preserving pelvic incidence. In those patients, lumbar lordosis is decreased while the sacro-femoral distance is increased. The incidence of coronal deformity in LDH patients is about 16% and 90% of the patients have minimal rotation of the spine. The curve side predicts the side of disc herniation in about 70% of cases. There is no significant correlation between sagittal and coronal imbalance.

What is already known on this topic?

Lumbar lordosis change and/or coronal plane deformity can occur in lumbar disc herniation patients. Few studies have reported decreased lumbar lordosis or increased positive balance in these LDH patients; however, intensive study of sagittal and pelvic parameters and details of coronal plane deformity in lumbar disc herniation patients has not been well conducted.

What this study adds?

This study included important sagittal and pelvic parameters as well as coronal deformities occurring in lumbar disc herniation patients. There was a trend toward decreased sacral slope and lumbar lordosis and an increase in pelvic tilt in LDH patients. Additionally, we found no significant correlation between sagittal plane change and coronal plane deformity in LDH patients.

Potential conflicts of interest

The authors declare no conflicts of interest.

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