Lumbosacral morphology in lumbar disc herniation: a “chicken and egg” issue

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Objective: The aim of this study was to analyze the relationship, if any, between lumbar disc herniation and lumbosacral morphology.

Methods: Intervertebral disc angles (IDA), lumbar lordosis angle (LLA), lumbosacral lordosis angle (LSLA), lumbosacral angle (LSA), and sacral tilt (ST) were measured on lumbar magnetic resonance imaging of 224 patients with LDH (n=151) and without LDH (n=73) and were then compared.

Results: Regarding LLA, LSLA, LSA and ST, there were no significant differences between the 2 groups. The smallest IDA of each level (except L2-L3) was detected at the same level with disc herniation. When the relationship between the grade of disc herniation and IDA was evaluated in patients with LDH, angles of L3-L4 and L4-L5 levels were significantly smaller in patients with extruded disc herniation (p=0.009 and p=0.013, respectively).

Conclusion: Despite changes in IDA by grade and level of disc herniation, no relation was found between lumbosacral alignment and LDH.

Keywords: Intervertebral disc angle; lumbar alignment; lumbar disc herniation; lumbosacral morphology.

Level of Evidence: Level III, Prognostic Study.

Several studies on lumbosacral morphology and sagittal alignment of the lumbar spine appear in the literature. Studies with regard to these issues have been conducted among various populations such as healthy subjects, patients with low back pain (LBP), and patients with spondylolisthesis.⁴⁻⁷ However, the relation between lumbar morphology and lumbar disc herniation (LDH) has been poorly studied,⁸⁻¹⁰ and to our knowledge, no study to date has been conducted concerning both the lumbar sagittal alignment and intervertebral disc angles (IDA) among patients with LDH.

The results of studies on LBP revealed that alteration in lumbosacral alignment is an inevitable consequence of LBP.⁴⁻⁷ It has been suggested that the alteration in lumbosacral alignment is dependent on the function of abdominal and/or back muscles, as well as of pelvic/back ligaments.⁶ Since similar deteriorations might occur in the abdominal and back muscles/ligaments in patients with LDH, we hypothesized that there might also be a relation between lumbosacral morphology and LDH. In other words, deteriorations in lumbosacral morphology might occur in cases of any disc herniation. On the other
hand, altered lumbosacral morphology itself might give rise to LDH. The objective of the present study was to elucidate the relation between lumbosacral morphology and LDH, by taking both lumbar sagittal alignment and IDA into consideration.

**Patients and methods**

The study group was comprised of patients with LBP who had undergone lumbar magnetic resonance imaging (MRI) between January 2013 and July 2013. The MRIs of the patients were extracted from the medical record database. Patients were excluded from the study if they had any record and/or indicator of spondylolisthesis, spondyloarthritis, scoliosis, spinal tumor, severe vertebral fracture, lumbosacral transition, or history of spinal surgery/trauma.

Remaining patients were allocated into 2 groups (LDH group and control group) according to the presence/absence of disc herniation on MRI. Absence of LDH indicated either normal disc or disc bulging without any nerve root and/or spinal cord irritation. Presence of LDH indicated bulging with nerve root and/or spinal cord irritation, as well as protrusion or extrusion of the disc material. Patients with LDH were divided into 3 groups according to the criteria proposed by Jensen et al.\[11\]

The study sample consisted of 224 patients with LBP. There were 94 males and 130 females in the study group, with a mean age of 45.16±13.27 years. Of the subjects, 151 (60 male, 91 female) were in the LDH group, whilst 73 (34 male, 39 female) were in the control group. Mean ages of the LDH and control groups were 47.6±13.1 years (range: 20–75 years) and 40.2±12.4 years (range: 20–65 years), respectively.

Computerized measurement of the below mentioned angles was performed on digitalized MRIs using Enlil PACS System software version 2.5, which allows manual placement of lines and computer calculation of angles (Figure 1).

- **IDA**: The angle between the superior and inferior endplates of adjacent vertebral bodies.
- **Lumbar lordosis angle (LLA)**: The angle between the lines perpendicular to the superior endplate of L1 vertebra and the inferior endplate of L5 vertebra.
- **Lumbosacral lordosis angle (LSLA)**: The angle between the line passing through the centers of L3 and L5 vertebral bodies and the line drawn through the centers of L5 vertebra and S1 vertebra.
- **Sacral tilt (ST)**: The angle between the line tangent to the posterior aspect of S1 and the vertical line.
- **Lumbosacral angle (LSA)**: The angle between the superior endplate of S1 and the horizontal line.\[12,13\]

Statistical analyses were performed by a biostatistician using SPSS software (version 11.5, SPSS Inc., Chicago, IL, USA). Normality of the variables was checked. Mann-Whitney U or Kruskal-Wallis tests were used to analyze abnormally distributed continuous variables. Results were given as median (minimum-maximum). Results with p values less than 0.05 were considered statistically significant.

**Results**

Statistical analysis was performed on data from 224 patients. Lumbosacral morphological parameters of LDH (n=151) and control (n=73) groups are given in Table 1. According to the given data, there was no statistical difference between patients with LDH and controls regarding lumbar sagittal alignment measurements. However, regarding IDA, L4-L5 was significantly smaller in the LDH group than in the control group (p<0.001).

Patients with disc herniations were analyzed by the grade of herniation (Table 2). This analysis revealed that...
L1–L2 and L4–L5 disc angles narrowed as the herniation grade increased, with the lowest value being in patients with extruded disc herniations (p=0.009 and p=0.013, respectively).

IDAs were analyzed with regard to herniation level (Table 3). The smallest IDA for each level (except L2–L3) was detected in patients with a disc herniation at that level (Table 3, Figure 2).

**Discussion**

In the present study, we aimed to elucidate the relation, if any, between LDH and lumbosacral morphology. Several studies have reported the analysis of lumbar sagittal alignment in healthy populations\(^{14}\) or in subjects with LBP.\(^{6}\) However, very few concerned patients with disc herniations.\(^{15}\)

The studies concerning patients with LDH primarily compared subjects with healthy controls. They found that patients with LDH had reduced lumbar lordosis when compared to healthy individuals without LBP. Nevertheless, since LBP itself was linked with less lumbar lordosis, along with a more vertical sacrum,\(^{7}\) the

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**Table 1.** Lumbosacral morphological parameters of controls and patients with LDH.

|                | Controls (n=73) | Lumbar disc herniation (n=151) | p   |
|----------------|----------------|---------------------------------|-----|
| L1–L2          | 2.4 (0.0–6.3)  | 2.5 (-4.3 to 10.0)              | 0.590 |
| L2–L3          | 3.9 (0.0–11.3) | 3.7 (-2.1 to 10.8)              | 0.648 |
| L3–L4          | 5.1 (0.0–10.6) | 5.0 (-5.4 to 14.7)              | 0.529 |
| L4–L5          | 9.3 (1.2–16.4) | 7.5 (0.0–15.8)                  | <0.001 |
| L5–S1          | 16.4 (7.7–25.3)| 15.0 (1.7–25.8)                 | 0.078 |
| Lumbar lordosis angle | 32.1 (6.3–65.9) | 32.4 (12.3–64.5)               | 0.854 |
| Lumbar sacral lordosis angle | 145.4 (127.6–155.0) | 145.4 (126.3–164.8)         | 0.674 |
| Sacral tilt    | 48.4 (31.5–65.9)| 49.8 (28.0–70.0)                | 0.346 |
| Lumbosacral angle | 39.6 (27.5–67.4) | 38.8 (17.0–61.4)                | 0.510 |

Values expressed are medians (minimum-maximum) according to Mann-Whitney U test.

**Table 2.** Lumbosacral morphological parameters by grade of disc herniation.

|                | Bulging (n=43) | Protrusion (n=63) | Extrusion (n=45) | p   |
|----------------|---------------|------------------|-----------------|-----|
| L1–L2          | 2.6 (0.0–10)  | 2.39 (-4.3 to 9.8)| 2.60 (-1.3 to 7.5) | 0.652 |
| L2–L3          | 3.9 (0.0–10.5)| 3.87 (-2.1 to 10.8)| 3.20 (0.0–9.5)  | 0.314 |
| L3–L4          | 5.7 (1.0–12.8)| 5.50 (-0.9 to 14.7)| 3.86 (-5.4 to 10.6)| 0.009 |
| L4–L5          | 8.2 (0.0–15.7)| 8.08 (0.0–15.8)   | 6.15 (0.0–13.0)  | 0.013 |
| L5–S1          | 15.9 (3.2–25.5)| 14.70 (3.3–25.1) | 13.82 (1.7–25.8) | 0.268 |
| Lumbar lordosis angle | 34.5 (18.0–64.5)| 33.34 (12.3–60.5) | 31.00 (13.9–53.7) | 0.103 |
| Lumbar sacral lordosis angle | 143.8 (128.0–164.8)| 145.00 (128.6–161.2)| 146.88 (126.3–162.9) | 0.223 |
| Sacral tilt    | 50.4 (33.0–61.8)| 50.20 (28.0–70.0) | 49.55 (31.8–65.2) | 0.765 |
| Lumbosacral angle | 39.3 (21.1–55.4)| 39.50 (26.0–61.4)| 37.89 (17.0–57.6) | 0.253 |

Values expressed are medians (minimum-maximum) according to Kruskal-Wallis test.

**Table 3.** Lumbosacral morphological parameters by the level of disc herniation.

|                | L1–L2 (n=6) | L2–L3 (n=12) | L3–L4 (n=20) | L4–L5 (n=62) | L5–S1 (n=51) | p   |
|----------------|-------------|-------------|-------------|-------------|-------------|-----|
| L1–L2          | 1.1 (-1.0 to 5.6)| 2.8 (-1.3 to 7.5)| 2.8 (0.0–4.2)| 3.0 (-4.3 to 10.0)| 2.1 (-1.1 to 8.0) | 0.077 |
| L2–L3          | 5.9 (0.8–9.6)| 3.8 (-2.1 to 7.3)| 4.7 (1.4–9.1)| 3.9 (0.0–11.3)| 3.2 (-0.5 to 9.3) | 0.100 |
| L3–L4          | 4.9 (2.5–9.1)| 4.3 (0.4–12.1)| 3.4 (-5.4 to 12)| 5.7 (-0.9 to 14.7)| 5.3 (-2.0 to 12.8) | 0.419 |
| L4–L5          | 10.2 (6.4–15.7)| 8.5 (3.0–14.3)| 9.3 (1.8–13)| 6.9 (0.0–15.8)| 7.2 (0.5–14.6) | 0.020 |
| L5–S1          | 15.1 (11.4–18.2)| 15.6 (3.8–22.9)| 15.5 (3.2–25.5)| 15.2 (6.2–25.8)| 13.5 (1.7–25.5) | 0.549 |

Values expressed are medians (minimum-maximum) according to Kruskal-Wallis test.
reduced lumbar lordosis cannot be attributed solely to LDH. Therefore, in order to distinguish the discriminative effects of LDH on sagittal alignment, it is reasonable to compare patients with LDH to patients with LBP who are free of LDH, rather than to normal subjects. Thus, in order to avoid a possible LBP-related difference in lumbar morphology, the control group consisted of patients who had LBP but were free of disc herniation instead of healthy subjects.

Lumbar sagittal morphology in LDH is a “chicken and egg” issue. It is hard to discriminate the morphological alterations which contribute to disc herniation from the compensatory postural changes due to LDH itself. There are a limited number of studies that allow for comparison with our results. Rajnics et al.\cite{10} reported that sacral slope, lumbar angle, and lumbar lordosis were smaller in the LDH group than in normal subjects, which represented a straight sagittal shape of the spine in patients with LDH. They noted that straighter spine might lead to an increase in the compressive forces, one of the possible contributors of disc herniation.\cite{10} However, the reverse might also explain the situation—the loss of lordosis might be attributed to the presence of LDH. Sciatic stimulation, along with the tonic contraction of the lumbopelvic muscles in patients with LDH, was also suggested to have an effect on lumbar sagittal balance. Thus, loss of lumbar lordosis might be a result of the protective mechanisms generated to avoid increased tension of the sciatic nerve.\cite{8} Barrey et al.\cite{15} found that sacral slope and lumbar lordosis were similar in patients with LDH and lumbar degenerative disc disease but smaller than those in controls. They suggested that discopathy might result in a structural loss of lordosis. On the other hand, analgesic flexion posture as a consequence of disc disease might in turn contribute to a postural decrease in lumbar lordosis.\cite{15} However, contradicting the results of these limited studies and our hypothesis, no relation was found between lumbar sagittal alignment and LDH in the current study. The above-mentioned studies on LDH all used healthy subjects as controls.\cite{8–10} Therefore, the difference in lumbar alignment between the experimental and control groups might be attributed to the absence of LBP in controls, which was not the case in the present study. The control group of the current study included patients free of LDH but suffering from LBP, which would be a potential cause of altered lumbar alignment. Alteration in lumbar lordosis in patients with LBP was suggested to be linked with abdominal and back muscle activities, as well as pelvic/back ligament functions.\cite{6} Supporting this hypothesis, Youdas et al.\cite{16} found that patients with LBP had weaker abdominal muscles than those without LBP. Furthermore, they underlined the decreased range of motion in lumbar extension, which was found to be associated with lumbar lordosis, in patients with LBP.\cite{16}

Although the results regarding sagittal alignment were similar in patients with LDH and controls, the angle between L4 and L5 vertebrae in patients with LDH was statistically smaller than that of controls. One potential reason for this difference might be that the majority of disc herniations occur at the level of L4-L5. Another reasonable explanation is the greater shear force at the lower lumbar region in patients suffering from LBP. It has been suggested that extreme values of sacral inclination are common in LBP. Increased dorsal inclination and/or decreased cranial inclination trying to mirror reduced lower lumbar lordosis might generate greater tear and shear forces inside the intervertebral discs of the lower lumbar region.\cite{17}

In the present study, the narrowest IDA for each level (with the exception of L2-L3) belonged to patients with disc herniations at that level. Previous studies regarding LDH were primarily concerned with vertebral endplate shape, including diameter and architecture.\cite{18,19} One recent study evaluated concave angle of vertebral endplate, finding that concave angle of vertebral endplate increased with the increase in the incidence of LDH, but the difference was not statistically significant.\cite{20} Been et al.\cite{21} evaluated the geometry of vertebral bodies and intervertebral discs in patients with spondyloyis and spondylolisthesis.
Lumbar spinal morphology showed less lordotic wedging of intervertebral discs in patients with degenerative spondylothesis.[21] Given the fact that lumbar degenerative disease is related with less lordotic disc wedging, small IDA at the level of disc herniation in the current study could be attributed to the kyphotic wedging of the discs in relation to degenerative disc disease.

There are a number of limitations of this study. Firstly, since it was difficult to find patients with solely LDH and no lumbar degenerative disc diseases, it was not feasible to discriminate the effect of LDH on lumbosacral morphology independent of the contribution of disc degeneration. Secondly, because of the retrospective design of the study, data regarding anthropometric measurements (body weight and height) and clinical variables (pain intensity, symptom duration, etc.) could not be obtained.

In conclusion, patients with LBP exhibited similar lumbar alignment measures, regardless of the presence of disc herniation. However, disc herniation was related with smaller IDA at the affected levels. Prospective studies in which clinical parameters will be taken into account should be designed in order to obtain more reliable and accurate results in patients with LBP.

Conflicts of Interest: No conflicts declared.

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