Radiographic evaluation of sagittal alignment in the selection of operation method for lumbar spondylolisthesis

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Abstract

Mal-alignment in the sagittal plane after spinal decompression in lumbar spondylolisthesis causes various problems such as low back pain. Reference values (distance B below 35 mm and lumbar lordosis above 45°), obtained by reviewing the standing lateral radiograph of the spine and the pelvis were used as the index. We compared group A, in which the index was not used, and group B, in which it was used, and reviewed the relationship between the low back pain and the spinal alignment. The postoperative distance B was 49.1±50.5 mm on average in group A and 32.0±20.2 mm on average in group B, and thus group B had a satisfactory value.

The lumbar lordosis was 37.8±19.0° on average in group A and 45.2±7.8° on average in group B, and thus group B had a satisfactory angle. The postoperative low back pain was minor in group B with regard to the JOA score IA, the evaluation method of Nakai, and the pain scale of Seybold.

By using the distance B as the index, the tendency of low back pain was recognizable. Therefore, distance B can be used as one form of index in the selection of the operation method of spinal fusion, and is a useful and significant index.

Introduction

How fusion should be performed and what the best alignment should be after decompression are important in planning an operation for lumbar spondylolisthesis. Many reviews have been reported, for evaluation of sagittal alignment of lumbar vertebra, regarding local disk spondylolisthesis and local kyphosis based on the postoperative radiographs. However, only few reviews have been reported regarding the spinal alignment in cases of lumbar spondylolisthesis, and thus it is still a problem to be addressed. In our department, we have reported the usefulness of the C7 plumb line, used as an index of sagittal balance of the spine, by reviewing the standing lateral radiograph of the spine and the pelvis. Presently, our operation plans are based on the reference values (distance B below 35 mm and lumbar lordosis above 45°) of the spinal alignment obtained from the above results. We compared cases not using the index, or group A (up to 1998), and cases using the index, or group B (from 1999) and reviewed the relationship between the postoperative low back pain and the spinal alignment to clarifying the significance of the index.

Materials

We reviewed 34 cases of lumbar spondylolisthesis in which operation was performed, ranging in age from 48 to 76 years at the time of surgery (average 64.1 years), and the postoperative follow-up period being 2 years 3 months to 10 years 5 months (average 5 years 6 months). Group A (up to 1998) consisted of 8 men and 8 women, with average age of 62.8 years. With regard to the operation method, posterior lumbar interbody fusion (PLIF) was performed in 7 cases and posterolateral
fused (PLF) in 9 cases. Group B (from 1999) consisted of 8 men and 10 women, with an average age of 65.3 years. PLIF was performed in 15 cases and PLF in 3 cases.

Methods

1. Therapeutic strategy for group A

   The operation method was randomly selected without using the index.

2. Therapeutic strategy for group B

   Two types of operations were performed for group B based on the distance B and the reference value by age, obtained from the result of Matsuoka et al., on the standing lateral radiograph of the spine and the pelvis. In group B, cases in which the distance B was below 35 mm and the lumbar lordosis was above 45° were performed with PLF with instrumentation (in site fusion) after decompression. On the other hand, cases in which the distance B was above 35 mm and the lumbar lordosis was below 45° were treated with PLIF after decompression for correction purpose.

3. Radiography

   The standing lateral radiograph of the spine and the pelvis was taken in accordance with the method of measurement Jackson et al. In the Jackson method, the patients stretched their arms out at the level of their chest, held a bar to balance, and took a relaxed pose. On the contrary, in our method, the patients joined their hands over the abdominal and took a relaxed pose. The radiographic image, including the hip joint was taken with the knee and the hip joint stretched.

4. Radiographic measurement

   In the standing lateral radiograph of the spine and the pelvis, a vertical line (plumb line) was drawn from the center of the C7 vertebral body according to the measurement method of Jackson. The distance (hereinafter referred to as distance B) to the posterior superior corner of the S1 vertebra and the angle between the L1 upper edge and the S1 upper edge, or lumbar lordosis, were measured according to the Cobb method (Fig. 1).

5. Reviewed items

   For the postoperative records, we reviewed the Japanese Orthopedic Association's evaluation system for lower back syndrome (hereinafter referred to as JOA score), and the improvement rate using the Hirabayashi method. For the evaluation of low back pain, we reviewed the relationship between the distance B and the lumbar lordosis using the JOA score IA, the evaluation method of Nakai, and the pain scale of Seybold and Bayley.

Results

The reviewed items were clinically evaluated using Student’s t-test. A p-value of less than 0.05 was taken to indicate a statistically significant difference.

In group A, the JOA score improved from a preoperative average of 14.3 ± 2.91 points to a postoperative

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Table 1 Therapeutic strategy

| Cases in which distance B was below 35 mm and the lumbar lordosis was above 45° were performed with PLF with instrumentation (in site fusion) |
| Cases in which distance B was above 35 mm and the lumbar lordosis was below 45° were performed with PLIF with instrumentation (correction purpose) |

Two types of operations were performed for group B based on the distance B and the reference value by age in the standing lateral radiograph of the spine and the pelvis. In group B, cases in which the distance B was below 35 mm and the lumbar lordosis was above 45° were performed with PLF with instrumentation after decompression. In the other hand, cases in which the distance B was above 35 mm and the lumbar lordosis was below 45° were performed with PLIF after decompression for correction purpose.
In group A, the JOA score improved from preoperative average of 14.3±2.91 points to postoperative average of 21.6±5.38 points, with improvement rate of 56.2%. In group B, the JOA score improved from preoperative average of 16.1±3.80 points to postoperative average of 23.2±2.54 points, with improvement rate of 59.4%. Thus, no statistically significant difference was recognized between the two groups.

The distance B was corrected to 49.1±50.5 mm on average in group A and 32.0±20.2 mm on average in group B and thus group B was corrected to a satisfactory value close to the value of index.

The lumbar lordosis was 37.8°±19.0° on average in group A and 45.2°±7.8° on average in group B, and thus group B had a satisfactory lumbar lordosis. No statistically significant difference was recognized between the two groups.

Table 2 Postoperative results (JOA score)

<table>
<thead>
<tr>
<th>JOA Score</th>
<th>GA</th>
<th>BG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre op</td>
<td>14.3±2.91</td>
<td>16.1±3.80</td>
</tr>
<tr>
<td>Post op</td>
<td>21.6±5.38</td>
<td>23.2±2.54</td>
</tr>
<tr>
<td>Rate of improvement:</td>
<td>56.2%</td>
<td>59.4%</td>
</tr>
</tbody>
</table>

Table 3 Distance B of group A and group B

<table>
<thead>
<tr>
<th>Distance B (mm)</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre op</td>
<td>49.1±50.5</td>
<td>32.0±20.2</td>
</tr>
<tr>
<td>Post op</td>
<td>37.8±19.0</td>
<td>45.2±7.8</td>
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</tbody>
</table>

Table 4 Lumbar lordosis L of group A and group B

<table>
<thead>
<tr>
<th>Lumbar Lordosis (°)</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre op</td>
<td>37.8±19.0</td>
<td>45.2±7.8</td>
</tr>
<tr>
<td>Post op</td>
<td>37.8±19.0</td>
<td>45.2±7.8</td>
</tr>
</tbody>
</table>

average of 21.6±5.38 points, with an improvement rate of 56.2%. In group B, the JOA score improved from a preoperative average of 16.1±3.80 points to a postoperative average of 23.2±2.54 points, an improvement rate of 59.4%. Thus, no statistically significant difference was recognized between the two groups (Table 2).

The distance B was corrected to 49.1±50.5 mm on average in group A and 32.0±20.2 mm on average in group B which was close to our index value (Table 3). The lumbar lordosis was 37.8°±19.0° on average in group A and 45.2°±7.8° on average in group B, and thus group B had a satisfactory lumbar lordosis. Again, no statistically significant difference was recognized between the two groups (Table 4). With regard to the postoperative low back pain, the JOA score IA was 1.9±0.85 points in group A, and 2.2±0.51 points in group B. In the evaluation method of Nakai (converted to excellent: 3 points, good: 2 points, fair: 1 point, poor: 0 point), group A scored 1.8±0.83 points, and group B scored 2.2±0.65 points. In the pain scale of Seybold and Bayley, group A scored 1.5±1.09 points, and group B scored 1.2±0.88 points. In all the reviewed items, no statistically significant difference was recognized between the two groups but postoperative low back pain was less in group B.

In the breakdown of postoperative low back pain, the breakdown of the JOA score IA were 3 points: 25.0%, 2 points: 50.0% and 1 point: 25.0% for group A, and 3 points: 22.0%, 2 points: 72.2%, and 1 point: 5.6% for group B.

(3)
In the distribution of the distance B and the low back pain, there were cases in which low back pain still remained even when the distance B was at the value of index and the alignment was satisfactory. In the evaluation method of Nakai, 4 cases in the satisfactory range having the distance B between 28 mm and 34 mm were all performed with instrumentation fusion across 2 disks; and 3 cases of which were PLIF performed cases and 1 case was a PLF performed case.

In the evaluation method of Nakai, the breakdown of group A was excellent: 31.5%, good: 43.5%, and fair: 25.0%, whereas the breakdown of group B was excellent: 33.3%, good: 34.4%, and fair: 33.3%. In the pain scale of Seybold and Bayley, the breakdown of group A was 0: 12.5%, 1: 50.0%, 2: 18.7%, 3: 12.5%, and 4: 6.3%; whereas the breakdown of group B was 0: 16.7%, 1: 55.5%, 2: 16.7%, and 3: 11.1%. Thus, the proportion of postoperative low back pain was smaller in group B than in group A.

In the distribution of the distance B and the low back pain, there were cases in which low back pain still remained even when the distance B was at the value of the index and the alignment was satisfactory. In the evaluation method of Nakai, 4 cases in the “fair” range with distance B between 28 mm and 34 mm were all performed with instrumentation fusion across 2 disks; 3 cases of which were PLIF cases and 1 was a PLF case (Table 5).

**Table 5** Evaluation method of Nakai and distance B

<table>
<thead>
<tr>
<th>distance B (mm)</th>
<th>excellent</th>
<th>good</th>
<th>fair</th>
<th>poor</th>
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<tbody>
<tr>
<td>20</td>
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<tr>
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<td></td>
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<tr>
<td>180</td>
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</table>

In the distribution of the distance B and the low back pain, there were cases in which low back pain still remained even when the distance B was at the value of index and the alignment was satisfactory. In the evaluation method of Nakai, 4 cases in the satisfactory range having the distance B between 28 mm and 34 mm were all performed with instrumentation fusion across 2 disks; and 3 cases of which were PLIF performed cases and 1 case was a PLF performed case.

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In the distribution of the distance B and the low back pain, there were cases in which low back pain still remained even when the distance B was at the value of the index and the alignment was satisfactory. In the evaluation method of Nakai, 4 cases in the “fair” range with distance B between 28 mm and 34 mm were all performed with instrumentation fusion across 2 disks; 3 cases of which were PLIF cases and 1 was a PLF case (Table 5).

**Discussion**

The symptoms of lumbar spondylolisthesis can be improved by decompression. However, postoperative low back pain and structural problems such as injury between adjacent disks, advancement of spondylolisthesis and local kyphosis after fusion, are considered as important factors that affect the postoperative condition. Many regional reviews have been reported on the lumbar vertebrae but only a few on total spinal alignment. In our series, we performed the operation using an index and reviewed the influence of the alignment in terms of low back pain.

Matsuoka of our department measured the distance B on the standing lateral radiographic image of the total spine in 493 cases without low back pain, and reported that there was a positive correlation between age and distance B using regression analysis. From the regression analysis, the reference value of the distance B by age was calculated. In the 1999 congress of the Japanese Orthopedic Association, we reported, using the non-negative saddle point method, that in the cases of lumbar spondylolisthesis to which operation was performed, cases with Jackson’s distance B between 28 mm and 34 mm tend to have less low back pain. Concerning the relationship between the C7 plumb line and the low back pain, Jackson et al. reported that in two thirds of asymptomatic adults, the C7 plumb line passes through an anterior point 2.5 cm from the posterior superior corner of the S1 vertebra. Sarwahi et al. defined a condition in which the plumb line passes through an anterior point 2 cm or more from the posterior superior corner of the S1 vertebra as sagittal imbalance; and Booth et al. defined a condition in which the plumb line passes through an anterior point 5 cm or more from the posterior superior corner of the S1 vertebra as flat back deformity. Kostuik reviewed cases treated with Harrington operations and postoperatively followed them up for a long period of time, and reported that low back pain develops from a decrease in physiological lordosis. Uchida et al. also reported that many postoperative low back pains are recognized in cases in which lordosis decreased after fusion using the pedicle screw system on the lumbar vertebrae. The authors reported that in the relationship between the postoperative low back pain and the sagittal balance, postoperative low back pain tends to be recognized less in cases in which the C7 plumb line passes through an anterior point 2.8 cm from the posterior superior corner of the S1 vertebra. Kawakami et al. reported from the postoperative records of spondylolisthesis that when a
plumb line drawn from L1 is used, the operation result were significantly more poor when the distance from the L1 plumb line (LASD) was less than 3.5 cm and thus concluded that alignment of lumbar has some influences on the postoperative results.

Furthermore, Furufu et al.\(^3\) reported that many satisfactory result were recognized in cases in which the spinal alignment including the thoracic vertebrae and lumbar vertebrae and lumbar sacral part was satisfactory. Yamamoto\(^4\) suggested that the appearance of spondylolisthesis is related to the spinal alignment, and thus treated spinal deformity in an aim to prevent further progression of postoperative spondylolisthesis. The total spinal sagittal balance is thus believed to be necessary in addition to obtaining a satisfactory thoracic kyphosis and lumbar lordosis.

In our series, cases with better results in extent and the frequency of low back pain were found in group B than in group A. The traction stress of lumbar posterior elements due to lumbar kyphosis is thought to cause low back pain, and thus an appropriate lumbar lordosis and spinal alignment are believed to be essential. However, there were cases in which low back pain still remained even when the distance B was at the index value and the alignment was satisfactory. Therefore, mal-alignment is not the only cause of low back pain, and there are many other causes such as intervertebral disks and facet joints. Nevertheless, low back pain was recognized less in cases with satisfactory alignment, and thus alignment can be considered as an essential factor for spinal fusion after decompression. Therefore, the index can be considered useful and significant.

**Conclusion**

1. There are various causes for low back pain, one of which is mal-alignment of the spine. In the series, we reviewed the relationship between the spinal alignment and postoperative low back pain using the distance B as an index.

2. The tendency of low back pain was reviewed using the distance B as an index. The distance B can be considered as one index in the selection of operation methods of spinal fusion and is a useful and significant index.

**References**


( 5 )
腰椎変性すべり症の術式選択における Sagittal alignment の意義

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【要旨】腰椎変性すべり症における脊椎除圧固定後の矢状面の不良 alignment は様々な問題を生ずる。しかし、その適切な矢状面 alignment の指標は未解決の問題である。教室では立位全脊柱側面X線像の検討から脊椎矢状面バランスの指標として、C7プラムラインの有用性を報告した。この結果より得られた脊椎 alignment の基準値 (距離 B 35 mm 以下と腰椎前弯角 45°以上) を指標として、指標を用いる以前の症例を A 群 (1998 年以前) 16 例、指標を用いた以後の症例を B 群 (1999 年以降) 16 例より、遺残腰痛をマーカーに脊椎 alignment がどのような影響を与えるか検討した。術後成績は JOA score にて、A 群は平均 21.6 点、B 群は平均 23.2 点で両群間に統計的有意差はなかった。

術後距離 B は A 群は平均 49.1±50.5 mm、B 群は平均 32.0±20.2 mm と我々の指標精度値に準拠した。

腰椎前弯角は A 群は平均 37.8°±19.6°、B 群は平均 45.2°±7.8° と B 群は良好な前弯角に保たれていたが、両群間に統計的有意差は認められなかった。

術後遺残腰痛は、JOA score la では A 群 1.9±0.85 点、B 群 2.2±0.51 点、中井の評価法では (優 3 点、良 2 点、可 1 点、不応 0 点に換算) A 群 1.8±0.83 点、B 群 2.2±0.65 点、Seybold のベインスケールの評価では A 群 1.5±1.09、B 群 1.2±0.88 であった。いずれの項目においても統計学的有意差は認めなかったが B において術後遺残腰痛は軽減であった。

遺残腰痛の原因は多岐にわたるが、脊椎の alignment 不良もその要因の一つと考えられる。距離 B を指標にすることにより、遺残腰痛が少ない傾向がみられ、距離 B は脊椎固定術の術式選択において一つの指標となり、有用と考える。