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L1 Slope as an Indicator of Thoracolumbar Sagittal Balance in Osteoporotic Vertebral Fractures

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Study Design: Feasibility study.

Objectives: To evaluate the association between L1 slope and thoracolumbar spinal parameters of sagittal balance in cases of osteoporotic vertebral fracture.

Summary of Literature Review: Recently, interest has emerged in the sagittal parameters of the thoracolumbar spine in cases of osteoporotic vertebral fracture.

Materials and Methods: Eighty-five patients were enrolled in this study, including 36 patients with recent osteoporotic vertebral fractures (group 1) and 49 patients who did not have vertebral fractures (group 2). Radiographic parameters including L1 slope, C7 plumb line (C7 PL), sagittal imbalance (C7 PL >50 mm), lumbar lordosis, thoracic kyphosis, pelvic tilt, S1 slope, local kyphotic angle were evaluated on standing lateral radiographs of the whole spine. We analyzed correlations between L1 slope and these parameters.

Results: Of the sagittal parameters of the spine, the mean L1 slope, C7 PL, thoracic kyphosis, lumbar lordosis, S1 slope, pelvic tilt, and local kyphotic angle were 10.43°, 92.43 mm, 29.30°, 30.31°, 25.27°, 27.27°, 9.90° in group 1 and 9.41°, 68.50 mm, 20.09°, 23.25°, 22.03°, 31.43°, 8.21° in group 2, respectively. There were significant differences in thoracic kyphosis (p=0.01) and lumbar lordosis (p=0.04) between the two groups. L1 slope was positively correlated with thoracic kyphosis (r=0.46, p=0.01), lumbar lordosis (r=0.51, p=0.01), and local kyphotic angle (r=0.29, p=0.04) in group 1.

Conclusions: These results suggest that L1 slope is a central indicator for the evaluation of thoracolumbar sagittal balance in osteoporotic vertebral fractures.

Key words: Thoracolumbar spine, Osteoporotic vertebral fracture, Sagittal parameters, L1 slope

Introduction

The incidence of osteoporotic vertebral fracture is increasing and as a result, the prevalence of the sagittal imbalance of the spine is increasing.1,2 The sagittal balance of the spine is essential not only for appearance but also for function.3 The sagittal imbalance of thoracolumbar spine increases the prevalence of osteoporotic vertebral fracture associated with lumbar extensor weakness as well as pain itself and inconvenience of life.4 Recently, there have been interested in the thoracolumbar parameters of sagittal balance in osteoporotic vertebral fractures.5-9 Many studies have reported variances of thoracic kyphosis, lumbar lordosis, and spinopelvic parameters on spinal sagittal balance.10-14 Yokoyama et al reported that the increase in cervicothoracic curvature occurring along with thoracic deformation is the basis for age-related changes in the spine.15 In contrast, the lumbosacral spine is compensated by maintaining the sagittal balance. The sagittal balance of
whole spine may deteriorate if the compensatory changes in the lumbosacral spine are insufficient.

Sagittal imbalance of whole spine needs to be evaluated in elderly patients with degenerative thoracolumbar disease, but radiological examination is not easy for patients with osteoporotic vertebral fracture due to pain itself and wearing the brace. Therefore, we introduce L1 slope for easier radiological examination. The L1 slope could be a central parameter that defines the sagittal balance of whole spine. We wondered that if the L1 slope in osteoporotic vertebral fractures was used as a simple indicator of thoracolumbar sagittal balance, it would be helpful for evaluation of the thoracolumbar sagittal balance without the whole-spine radiographic examination. The purpose of this study was evaluated an association between L1 slope and thoracolumbar spinal parameters of sagittal balance in osteoporotic vertebral fractures.

Materials and Methods

The present study was enrolled from January 2017 to December 2018 for patients with low back pain through outpatient visits to our hospital. The feasibility study was conducted in 85 patients, of whom 20 patients were men and 65 patients were women. There were 36 patients with recent osteoporotic vertebral fractures (Group 1) and 49 patients without osteoporotic vertebral fractures (Group 2). The vertebral fracture had diagnosed by simple radiograph and magnetic resonance imaging. The mean compression ratio of the vertebral fracture were 58% in two fractures of T10, 28.4% in five fractures of T11, 26.4% in nine fractures of T12, 24.3% in twelve fractures of L1, 25.8% in six fractures of L2 and 33.5% in two fractures of L3. In Group 2, 49 patients with chronic back pain had defined as a back pain in thoracic and lumbar spine area and the pain that persists for 12 weeks or longer. We excluded the patients who had acute back pain of severe trauma, spinal infection and pathologic fractures including metastatic cancer. The average age was 79±7.3 years in group1, 77±10.0 years in group 2. The body mass index (BMI) was 22.6±9.9 kg/m² in Group 1, 23.6±15.0 kg/m² in Group 2, respectively. There were no statistically significant differences in the age, sex, BMI of the two groups (p>0.05) (Table 1). This study had performed with the approval of the Institutional Review Board (KCHIRB–M–2019–034).

All patients performed the lateral radiograph of whole spine in a standing position that the upper limb was placed in the fist on clavicle position and the whole legs were fully extended after walking on the flat surface for 5 minutes. The radiological examination was performed in an average of 3.1 months after injury.

### Table 1. Comparison of basic data between two groups

|                  | Group 1 (n=36) | Group 2 (n=49) | p-value |
|------------------|----------------|---------------|---------|
| Age (yr)         | 79±7.3         | 77±10.0       | 0.09    |
| Gender (M:F)     | 1:2.9          | 1:3           | 0.15    |
| BMI (kg/m²)      | 22.6±9.9       | 23.6±15.0     | 0.11    |

*p<0.05, yr: year, M: male, F: female, BMI: body mass index.

Group 1: Recent osteoporotic vertebral fracture, Group 2: Not recent osteoporotic vertebral fracture.
occurrence of the osteoporotic vertebral fracture in Group 1. At this time, there was no specific influence of the fracture pain on a standing posture. The sagittal balance parameters including L1 slope, C7 plumb line, sagittal imbalance, lumbar lordosis, thoracic kyphosis, pelvic tilt, sacral slope and local kyphotic angle was measured on lateral radiograph of whole spine in a standing position using a medical imaging information system (PACS, Picture Archiving Communications System).

The following parameters were measured on lateral radiograph of whole spine in a standing position as described by Dang et al (Fig. 1).\(^{16}\) The L1 slope was the angle formed by a line drawn along the superior endplate of the L1 and a horizontal reference line. The C7–sagittal vertical axis (C7–SVA) was the distance between the C7 plumb line and the posterior corner of the sacrum. The sagittal imbalance was defined within 50 mm anteriorly and 20 mm posteriorly while the sagittal imbalanced spine was defined beyond this range.\(^{17}\) The lumbar lordosis was the angle between upper end plate of L1 and superior end plate of S1 using the Cobb method. The thoracic kyphosis was the angle between upper end plate of T3 and superior end plate of T12 using the Cobb method. The pelvic tilting was the angle formed by a line drawn between the center of the femoral head and the sacral endplate. The sacral slope was the angle formed by a line drawn along the endplate of the sacrum and a horizontal reference line.

For statistical analyses, we used PASW for WINDOWS software (version 18; SPSS Inc.). We evaluated the association among osteoporotic vertebral fractures and independent variables such as sex, age, BMI and BMD between the two groups using an independent sample T test after a normality test. Pearson correlation analysis was performed to determine the contribution to each factor. A p-value of less than 0.05 was considered statistically significant.

**Results**

Of sagittal parameters of the spine, the mean L1 slope, C7–SVA, thoracic kyphosis, lumbar lordosis, S1 slope, pelvic tilt, local kyphotic angle were 10.43±7.96 degrees, 92.43±6.29 mm, 29.30±17.46 degrees, 30.31±17.20 degrees, 25.27±10.69 degrees, 27.27±10.69 degrees, 9.90±6.23 degrees, 27.27±8.53 degrees, 31.43±7.11 degrees, 8.21±5.72 degrees in Group 1 and 9.41±4.35 degrees, 68.50±5.36 mm, 20.09±11.50 degrees, 23.25±12.04 degrees, 22.03±6.39 degrees, 22.03±6.39 degrees, 8.21±5.72 degrees in Group 2, respectively. There was significant difference of thoracic kyphosis (p=0.01) and lumbar lordosis (p=0.04) between two groups (Table 2).

**Table 2.** Comparison of sagittal parameters of thoracolumbar spine between two groups

|                        | Group 1(n=36) | Group 2(n=49) | p-value |
|------------------------|---------------|---------------|---------|
| L1 slope(degree)       | 10.43±7.96    | 9.41±4.35     | 0.49    |
| C7SVA (mm)             | 92.43±6.29    | 68.50±5.36    | 0.07    |
| Thoracic kyphosis (degree) | 29.30±17.46   | 20.09±11.50   | 0.01    |
| Lumbar lordosis (degree) | 30.31±17.20   | 23.25±12.04   | 0.04    |
| Sacral slope (degree)  | 25.27±10.69   | 22.03±6.39    | 0.11    |
| Pelvic tilt (degree)   | 27.27±8.53    | 31.43±7.11    | 0.50    |
| Local kyphosis (degree) | 9.90±6.23     | 8.21±5.72     | 0.12    |
| Sagittal imbalance (case) | 21           | 18            | 0.01    |

*p<0.05, C7SVA: C7-sagittal vertical axis.

**Fig. 2.** L1 slope was positively correlated with thoracic kyphosis. Pearson correlation coefficient of L1 slope (r)=0.46, p=0.01.

**Fig. 3.** L1 slope was positively correlated with lumbar lordosis. Pearson correlation coefficient of L1 slope (r)=0.51, p=0.01.
The L1 slope was positively correlated with thoracic kyphosis ($r=0.46$, $p=0.01$), lumbar lordosis ($r=0.51$, $p=0.01$) and local kyphotic angle ($r=0.29$, $p=0.04$), respectively in Group 1 (Fig. 2, 3). In Group 2, the L1 slope was positively correlated with thoracic kyphosis ($r=0.59$, $p=0.01$), lumbar lordosis ($r=0.58$, $p=0.01$) and sacral slope ($r=0.57$, $p=0.01$), respectively (Table 3). In total analysis including Group 1 and Group 2, the sagittal imbalance was associated with age ($r=0.53$, $p=0.01$) and vertebral fracture ($r=0.32$, $p=0.01$) (Table 4).

**Discussion**

In the spinal disease as osteoporotic vertebral fractures, many studies have been reported, including thoracic kyphotic angle, lumbar lordosis, and spinopelvic indicators such as sacral slope, pelvic tilt and pelvic index because it is important to understand the spinopelvic parameters and to know each other’s correlations. However, it is difficult to measure the various parameters of spinopelvic balance because patients were suffering from pain as well as it is hard to see in the radiography due to hidden by other bones and organs. Yokoyama et al reported that the L1 slope was a central parameter that defines the spinal sagittal balance. We therefore asked whether the L1 slope is related to thoracolumbar spinal parameters of sagittal balance in osteoporotic vertebral fractures.

As the age of the elderly increases, the thoracolumbar angle ratio increases. The decrease of the lumbar lordosis and sacrum inclination due to aging–related changes such as osteophyte formation or disc degeneration, resulting in a posture with the trunk bent forward. The osteoporotic vertebral fractures could be easily developed from minor trauma or back strain such as dynamic movement, especially when the trunk is bent forward and there is a sagittal imbalance. Therefore, the sagittal balance between lumbar alignment and thoracic alignment seems to be an important component to prevent occurrence of osteoporotic vertebral fracture. Yokoyama et al reported that the L1 slope as central parameter of spinal sagittal balance was the highest correlation with the C7 sagittal vertical axis. Our findings suggested that the L1 slope was positively correlated with thoracic kyphosis ($r=0.46$, $p=0.01$), lumbar lordosis ($r=0.51$, $p=0.01$), local kyphotic angle ($r=0.29$, $p=0.04$) in Group 1, respectively. However, there was no significant correlation between the L1 slope and the sagittal imbalance. The reason for difference with Yokoyama’s result is considered that the degenerative changes due to aging such as degeneration of intervertebral discs, osteophyte formation, and weakness of posterior extensor muscle have already been developed.

Despite several studies on normal range of thoracic kyphotic angle, there is a controversy over normal magnitude of thoracic curve. The normal kyphotic angle of thoracic spine in adults is ranged from 35 to 37 degrees with different results according to different investigators. But such studies were conducted in heterogeneous populations. The simple radiograph of thoracic spine is difficult to measure the thoracic kyphotic angle, as it may be hard to precisely identify the upper part criteria of the kyphotic angle because of the shoulder girdle and rib cage overlap in many cases. Various attempts to measure the lumbar lordosis have resulted in different results substantially because researchers have used different parameters. On the other hand, the L1 slope has no limitation in measurement unlike the thoracic kyphosis and no difference of parameter like the measurement parameters of lumbar lordosis. In summary, these results suggest that L1 slope which can be determined on lateral

| Table 3. Correlation between the L1 slope and spinal sagittal parameters |
|---------------------------------|-----------------|---------------|-----------------|---------------|
| Parameter                        | Group 1(n=36)   |               |               |               |
|                                 | Pearson         | p-value       | Pearson         | p-value       |
|                                 | correlation (r) |               | correlation (r) |               |
| Lumbar lordosis                 | 0.51            | 0.01          | 0.58            | 0.01          |
| Thoracic kyphosis               | 0.46            | 0.01          | 0.59            | 0.01          |
| Local kyphotic angle            | 0.29            | 0.04          | -               | -             |
| Sacral slope                    | 0.05            | 0.76          | 0.57            | 0.01          |
| Pelvic tilt                     | 0.02            | 0.90          | 0.11            | 0.53          |

* $r$: Pearson correlation coefficient of L1 slope.

| Table 4. Correlation between the sagittal imbalance and parameters |
|---------------------------------------------------------------|
| Pearson correlation coefficient of sagittal imbalance (r) | p-value |
| Age                                                          | 0.539   | 0.01    |
| L1 slope                                                      | -0.13   | 0.22    |
| Recent osteoporotic vertebral fracture                       | 0.320   | 0.01    |

*p<0.05.
radiograph of thoracolumbar spine in a standing position is a useful indicator for assessing the sagittal balance of whole spine in osteoporotic vertebral fractures.

There are some limitations in this study. First, the number of sample groups was small, so the characteristics of the entire population were limited. Second, this study is a cross-sectional study. Third, the vertebral fractures of this study had thoracolumbar area mainly. However, the sagittal alignment could be differed depending on thoracic, thoraco-lumbar, and lumbar fracture sites. To obtain a more specific result, a prospective study is needed with a large number of subjects. Fourth, there was a possibility of the change of variables, such as pelvic tilt, sacral slope, TK, LL, and sagittal balance resulting from influence of the fracture itself because lateral plain radiograph of the whole spine was taken at average of 3.1 months after the fracture. However, despite these limitations, this study identifies potential areas for future research. An additional study to reveal the actual relationship between the L1 slope and thoracolumbar spinal parameters of sagittal balance is therefore necessary in osteoporotic vertebral fractures.

Conclusions

The L1 slope which can be determined with lateral radiographs of thoracolumbar spine in the standing position without performing whole-spine radiographs, is a useful parameter for assessing whole-spine sagittal balance in osteoporotic vertebral fractures. These results suggest that L1 slope is a central indicator for evaluation of the thoracolumbar sagittal balance in osteoporotic vertebral fractures.

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골다공증 척추골절에서 흉요추 시상균형의 지표로서 제1요추 경사

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연구 계획: 타당성조사
목적: 골다공증 척추골절에서 제1요추경사와 흉요추의 시상균형지표와 관련성을 평가하고자 하였다.

연구 문헌의 요약: 최근 골다공증 척추골절에서 흉요추의 시상균형지표에 대한 관심이 증가하고 있다.

대상 및 방법: 골다공증 척추골절이 발생한 36명의 환자(그룹 1), 척추골절이 발생하지 않았던 49명의 환자(그룹 2), 총 85명의 환자를 연구대상으로 하였다. 척추전장기립측면 단순방사선검사에서 방사선지표로 제1요추경사, 제7경추수선, 시상불안정성(제7경추수선 50 mm), 요추전만각, 흉추후만각, 골반기울기, 천추경사, 국소후만각을 측정하였고, 제1요추경사와 방사선지표들의 상관관계를 분석하였다.

결과: 척추의 방사선지표인 제1요추경사, 제7경추수선, 흉추후만각, 요추전만각, 천추경사, 골반기울기, 국소후만각이 그룹 1에서 10.43도, 92.43 mm, 29.30도, 30.31도, 25.27도, 27.27도, 9.90도, 그룹 2에서 9.41도, 68.50 mm, 20.09도, 23.25도, 22.03도, 31.43 도, 8.21도로 각각 확인되었다. 양군간의 흉추후만각(p=0.01), 요추전만각(p=0.04)에서 통계학적으로 유의한 차이를 보였다. 제1요추경사는 흉추후만각(r=0.46, p=0.01), 요추전만각(r=0.51, p=0.01), 국소후만각(r=0.29, p=0.04)과 양의 상관관계를 보였다.

결론: 제1요추경사는 골다공증 척추골절환자에서 흉요추의 시상균형을 평가하는 지표의 하나로 사용될 수 있으리라 사료된다.

색인 단어: 흉요추, 골다공증척추골절, 시상균형지표, 제1요추경사

약칭 제목: 흉요추 시상균형으로 제1요추경사

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