Factors Associated With Low Back Pain In Patients With Lumbar Spinal Stenosis: A Cross-Sectional Study

Izaya Ogon (ogon.izaya@sapmed.ac.jp)
Sapporo Medical University School of Medicine
Kousuke Iba
Sapporo Medical University School of Medicine
Hiroyuki Takashima
Sapporo Medical University School of Medicine
Yoshinori Terashima
Sapporo Medical University School of Medicine
Mitsunori Yoshimoto
Sapporo Medical University School of Medicine
Makoto Emori
Sapporo Medical University School of Medicine
Atsushi Teramoto
Sapporo Medical University School of Medicine
Tsuneo Takebayashi
Sapporo Maruyama Orthopaedic Hospital
Toshihiko Yamashita
Sapporo Medical University School of Medicine

Research Article

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Abstract

Background: Low back pain (LBP) is a major symptom of lumbar spinal stenosis (LSS). To develop better treatment, it is important to assess LBP in patients with LSS. This study aimed to analyze the factors associated with LBP in patients with LSS.

Methods: This cross-sectional study included consecutive patients with LSS aged between 51 and 79 years who had symptoms in one or both legs with or without LBP. The participants were classified into two groups: the high group (LBP visual analog scale [VAS] score of 30 mm or more) and the low group (LBP VAS score of less than 30 mm). We performed multiple logistic regression analysis with the high and low groups as dependent variables and a receiver operating characteristic (ROC) analysis.

Results: A total of 80 patients with LSS were included (35 men and 45 women; mean age 64.5 years), with 47 and 30 patients in the high and low groups, respectively. Multivariate logistic regression analysis revealed that the sagittal vertical axis (SVA; + 1; odds ratio [OR], 1.029; 95% confidence interval [CI], 1.005–1.052) and pelvic incidence (PI)-lumbar lordosis (LL; + 1; OR, 1.065; 95% CI 1.019–1.168) were significantly associated with LBP. ROC analysis revealed cut-off values of 47.0 mm and 30.5° of PI-LL, respectively.

Conclusion: These cut-off values could have a high specificity and positive predictive value for LBP in patients with LSS due to spinopelvic malalignment. However, these cut-off values could also represent with a cause other than LSS due to spinopelvic malalignment.

Background

Lumbar spinal stenosis (LSS) is characterized by symptoms such as low back pain (LBP), pain and numbness in the lower extremities, and neurogenic claudication [1]. Amundsen et al. [2,3] reported that the most common symptoms in patients with LSS were back pain, including LBP (prevalence, 95%); claudication (91%); leg pain (71%); weakness (33%); and voiding disturbances (12%). Miyakoshi et al. [4] reported that the prevalence of LSS among individuals aged ≥ 50 years in a rural Japanese cohort was 10.8% and that the prevalence of LSS with chronic low back pain (CLBP) and LSS without CLBP was 67.6% and 32.4%, respectively. Therefore, LBP is considered a major symptom of LSS.

LSS is a degenerative condition that involves spinal canal narrowing due to facet joint osteoarthritis, ligamentum flavum hypertrophy, intervertebral disc bulging, and spondylolisthesis [1]. These spondylotic changes can induce LBP, which can negatively affect the patients' quality of life (QOL) [5,6]. Kobayashi et al. [6] used the Japanese Orthopaedic Association Back Pain Evaluation Questionnaire to compare the QOL of patients with LBP with and without LSS. They showed that the scores for pain-related disorder, gait disturbance, social life disturbance, and psychological disorders were significantly lower in the patients with LSS in those without LSS group. Therefore, to develop better treatments in the future, it is important to assess LBP in patients with LSS.

Recent studies have investigated the mechanism of LBP and have found that the following factors contribute to LBP: overweight [7], osteoporosis [8], spondylolisthesis [9], range of motion (ROM) [10], spinopelvic alignment [11], muscle degeneration [12-15], intervertebral disc degeneration (IVDD) [16,17], Modic changes (MC) [18], and facet joint degeneration (FJD) [19]. Based on these findings, this study aimed to analyze the factors associated with LBP in patients with LSS. The following factors were evaluated: lower extremity symptoms (LES), body mass index (BMI), bone mineral density (BMD), spondylolisthesis, ROM, spinopelvic alignment, cross-sectional area (CSA) and fat infiltration (FI) of the multifidus muscle (Mm), IVDD, MC, and FJD.

Methods

The study was performed in accordance with the Declaration of Helsinki after approval by the Ethics Committee of our institution (approval number: 262-1074). All participants received written and verbal explanations of the study and provided informed consent before participation.

Participants

We enrolled consecutive patients with LSS aged between 51 and 79 years who visited our university hospital. The inclusion criteria were as follows: symptoms in one or both legs, with or without LBP, radiographic evidence of spinal stenosis or cauda equina compression, and clinical signs of nerve root affection. The exclusion criteria were as follows: infection, neoplasm, history of spinal surgery, acute trauma, history of spinal fracture, and spondylolisthesis with obvious instability, which was defined as a sagittal translation of ≥ 3 mm, segmental mobility of ≥ 20°, or posterior opening of ≥ 5° on flexion/extension radiographs. LBP was defined as pain, discomfort, and stiffness in the lower back, extending from the 12th rib to the lumbar or lumbosacral area, lasting more than three months. All participants rated their LBP on the visual analog scale (VAS; 0–100 mm). Based on the findings of previous reports, a VAS score of > 30 mm was defined as moderate or severe pain, whereas a VAS score of ≤ 30 mm was defined as no or mild pain [20,21].

Classification of LES

As described in a previous report [22], LES were classified into cauda equina, radicular pain, and mixed.

Measurement of BMI and BMD

We measured the patients' height and body weight and calculated their BMI (kg/m^2) [23]. BMD was measured at L2, L3, and L4 using a dual-energy X-ray absorptiometry scanner.

Measurement of ROM

We acquired dynamic flexion-extension radiographs of the participants in the standing position. The angle between the superior endplates of L1 and S1 was termed the ROM.

Measurement of the sagittal spinopelvic radiologic parameters

As described in a previous report, we obtained full-length spinal and pelvic radiographs of the participants in the standing position and used them to calculate several parameters [11]. The following sagittal spinal parameters were measured on sagittal-view spinal radiographs: lumbar lordosis (LL; the superior endplate of L1 to the superior endplate of S1; Fig. 1a), thoracic kyphosis (TK; the superior endplate of T4 to the inferior endplate of T12; Fig. 1a), and sagittal vertical axis (SVA; the horizontal offset from the posterosuperior edge of S1 to the center of the body of C7; Fig. 1b). The following sagittal pelvic parameters were measured on sagittal-view pelvic radiographs: sacral slope (SS; the angle between the horizontal and the superior sacral endplate; Fig. 1c), pelvic tilt (PT; the angle between the vertical axis and the line running from the midpoint of the sacral plate to the center of the femoral head axis; Fig. 1d), pelvic incidence (PI; the angle between a line perpendicular to the superior sacral endplate at its midpoint and the line connecting this point to the center of the femoral head axis; Fig. 1e), and PI-LL. Two investigators blinded to the study assessed the intraobserver and interobserver reliability of the measurements of the spinopelvic parameters (observer 1, I.O., and observer 2, H.T.). The κ values for intraobserver and interobserver reliability were as follows: LL, 0.85 and 0.91; TK, 0.89 and 0.92; SVA, 0.84 and 0.91; SS, 0.83 and 0.90; PT, 0.85 and 0.88; PI, 0.81 and 0.87; and PI-LL, 0.80 and 0.84, respectively.

Measurement of the CSA and FI of the Mm

We used the Signa HDx 1.5T magnetic resonance imaging (MRI) system (GE Healthcare, Milwaukee, WI, USA) with a spine coil to obtain T2-weighted MRI images. The CSA and FI of the Mm at the L3–L4, L4–L5, and L5-S levels were measured using axial T2-weighted MRI. CSA was assessed by manually tracing the fascial border of the Mm, as previously described [14]. We analyzed the histograms of signal intensity in the regions of interest for the areas using digitized image-processing software (Image J; National Institutes of Health, Bethesda, MD, USA). We measured the percentage area with FI using the software's pseudo-coloring tool, using which pixels representing fat tissue appeared red. We then calculated the percentage of the muscle compartment that was red. The CSA and FI data were averaged between the right and left Mms. The κ values for intraobserver and interobserver reliability were 0.88 and 0.92 for CSA and 0.82 and 0.89 for FI, respectively.

Assessment of IVDD using T2 mapping

We performed MRI T2 mapping using a protocol described in previous studies [24-28]. Sagittal images were acquired with the patients in the supine position, and T2 maps were created on a pixel-by-pixel basis. We used the T2 values of the midsagittal section, which was centered on the lumbar midline, with an optimized 8-echo multi-spin echo sequence obtained using the Advantage Workstation (version 4.4, Functool; GE Healthcare, Milwaukee, WI, USA) with the following parameters: repetition time, 1000 ms; first echo time [TE], 14.8 ms; last TE, 118.6 ms; receiver bandwidth, ± 15.63 kHz; field of view, 22 cm; matrix, 320 × 256; slice thickness/gap, 4 mm/4 mm; number of slices, 5; number of excitations, 2; and total scan time, 8 min and 34 s. We did not use the first echo from the multi-spin to minimize the effect of

the stimulated echo. The T2 map was calculated for each pixel from the signal intensity in the respective TE using the following formula: SI (TE) = $e^{-TE/T2}$.

The intervertebral discs at L3–L4, L4–L5, and L5-S were divided into five equal areas each. We measured the mean T2 values at the first, middle, and last fifth areas, which were the anterior annulus fibrosus (AF), the center of the nucleus pulposus (NP), and the posterior AF, respectively [24-28] (Fig. 2) A total of 300 levels were evaluated. The T2 values were measured using MedCalc (version 10.2.0.0; MedCalc Software, Mariakerke, Belgium) by a PhD researcher (H.T.) with 15 years of experience in spine MRI analysis.

Assessment of MC

MC were evaluated from L1–L2 to L5–S1 and classified as none, types 1, type 2, or type 3 according to their signal patterns on T1- and T2-weighted sagittal MRI [29]. Type 1 MC were hypointense on T1-weighted images and a hyperintense on T2-weighted images. Type 2 MC were hyperintense on both T1- and T2-weighted images. Type 3 MC were hypointense on both T1- and T2-weighted images. The intraobserver and interobserver reliability were excellent, with κ values of 0.81 and 0.84, respectively.

Assessment of FJD

To evaluate FJD, we acquired axial images at three lumbar levels (L3–L4, L4–L5, and L5–S1) using computed tomography (Aquilion PRIME, Toshiba, Japan). As described in a previous report, FJD was classified into four grades: grade 0, normal; grade 1, mild degenerative disease; grade 2, moderate degenerative disease; and grade 3, severe degenerative disease [30]. If there was a difference in FJD severity between the right and left sides at the same lumbar level, the worse grade was recorded. All patients were categorized as either grade 0–1 or grade 2–3. The intraobserver and interobserver reliability were excellent, with κ values of 0.80 and 0.81, respectively.

Statistical analyses

We compared the LES, BMI, BMD, spondylolisthesis, ROM, spinopelvic alignment, CSA and FI of the Mm, IVDD, MC, and FJD between the high and low groups using the Mann–Whitney U test and chi-square test. We performed multiple logistic regression analysis with the high and low groups as dependent variables. Variables found to be associated with LBP ($p < 0.10$ in the univariate logistic regression analysis) were entered into the multivariate logistic regression models using forward selection (likelihood ratio). To determine the boundary values of the VAS score for LBP, we performed receiver operating characteristic (ROC) analysis of the significant variables. Statistical significance was set at $p < 0.05$. We used SPSS (version 27.0; IBM Corp., Armonk, NY, USA) for all statistical analyses. Numerical data were expressed as mean ± standard error of the mean.

Results

A total of 80 patients (mean age 64.5 ± 1.8 years; range, 41–79 years) satisfied the inclusion criteria. As shown in Table 1, the high group included 47 patients (67.1%; 21 men, 26 women), and the low group included 33 patients (32.9%; 11 men and 12 women). The mean VAS scores of the high and low groups were 62.6 ± 2.0 mm and 17.0 ± 1.1 mm ($p < 0.01$), respectively. The mean ages of the high and low groups were 65.1 ± 1.6 years and 63.7 ± 1.9 years, respectively, but the difference was not statistically significant ($p = 0.71$). The mean BMIs of the high and low groups were 23.2 ± 0.7 kg/m^2 and 24.6 ± 0.9 kg/m^2, respectively, but the difference was not statistically significant ($p = 0.38$). There was no significant difference in the type of LES between the high and low groups; 19 and 15 patients had cauda equina LES, 18 and 10 had radicular pain, and 10 and 8 had mixed LES, respectively. Moreover, there was no significant difference in BMD between the two groups (1.03 ± 0.04 g/cm^2 vs. 1.11 ± 0.09 g/cm^2, $p = 0.40$). Eleven (23.4%) and 7 (21.2%) patients in the high and low groups, respectively, had spondylolisthesis, but the difference was not statistically significant ($p = 0.82$). The mean ROMs of the high and low groups were 41.2° ± 3.3° and 43.5° ± 4.1°, respectively, but the difference was not statistically significant ($p = 0.47$).

The spinopelvic parameters of the high and low groups were as follows: TK, 26.1° ± 1.3° and 28.9° ± 2.2°; LL, 31.5° ± 2.9° and 39.5° ± 3.3°; SVA, 56.1 ± 6.7mm and 29.8 ± 6.1mm; SS, 27.5° ± 1.4° and 31.1° ± 1.3°; PT, 19.7° ± 1.4° and 17.8° ± 1.1°; PI, 47.2° ± 1.6° and 48.9° ± 2.0°; and PI-LL, 15.7° ± 1.1° and 9.4° ± 0.9°, respectively. There were statistically significant differences in SVA, and PI-LL between the two groups (LL, $p < 0.01$; SVA, $p < 0.01$; PI-LL, $p < 0.01$).

In the high group, the CSA and FI of the Mm were 392.6 ± 37.1 mm^2 and 12.6% ± 1.5%, at the L3–L4 level, 421.5 ± 37.1 mm^2 and 19.1% ± 2.1% at the L4–L5 level, and 443.8 ± 42.3 mm^2 and 19.9% ± 1.9 %, respectively, at the L5–S1 level. In the low group, the CSA and FI of the Mm were 421.5 ± 39.9 mm^2 and 11.4% ± 1.2 % at the L3–L4 level, 438.1 ± 40.4 mm^2 and 16.4% ± 1.7 % at the L4–L5 level, and 424.7 ± 40.1 mm^2 and 17.5% ± 1.8 % at the L5–S1 level, respectively. There were no significant between-group differences in CSA and FI.

In the high group, the T2 values of the anterior AF, NP, and posterior AF were 60.9 ± 1.8 ms, 64.2 ± 3.0 ms, and 55.9 ± 1.9 ms at the L3–L4 level; 58.1 ± 2.1 ms, 59.7 ± 3.0 ms, and 51.3 ± 1.5 ms at the L4–L5 level; and 59.5 ± 2.0 ms, 62.1 ± 2.7 ms, and 55.2 ± 1.9 ms at the L5–S1 level, respectively. In the low group, the T2 values of the anterior AF, NP, and posterior AF were 61.7 ± 1.3 ms, 62.6 ± 1.5 ms, and 56.8 ± 1.4 ms at the L3–L4 level; 59.1 ± 3.0 ms, 60.2 ± 2.4 ms, and 58.2 ± 2.1 ms at the L4–L5 level; and 59.0 ± 2.3 ms, 59.6 ± 2.1 ms, and 56.6 ± 1.8 ms at the L5–S1 level, respectively. There was a significant between-group difference in the T2 value of the posterior AF at the L4–L5 level ($p < 0.01$).

MC were observed in 14 patients (type 1, 3 patients; type 2, 10 patients; and type 3, 1 patient) in the high group and 10 patients (type 1, 1 patient; type 2, 9 patients; and type 3, 0 patients) in the low group. There was no significant difference in the frequency pf occurrence of MC between the two groups.

In the high group, grade 0–1 and grade 2–3 FJD was observed in 31 and 16 patients at the L3–L4 level; 17 and 30 patients at the L4–L5 level; and 22 and 25 patients at the L5–S1 level, respectively. In the low group, grade 0–1 and grade 2–3 FJD was observed in 19 and 14 patients at the L3–L4 level; 13 and 20 patients at the L4–L5 level; and 15 and 18 patients at the L5–S1 level, respectively. There was no significant difference in the frequency pf occurrence of FJD between the two groups.

Table 2 shows the results of the multiple logistic regression analysis performed with the high and low groups as dependent variables. SVA was significantly associated with LBP (+ 1; odds ratio [OR], 1.028; 95% confidence interval [CI], 1.004–1.052), and this association remained significant after adjusting for other significant variables (+ 1; OR, 1.029; 95% CI, 1.005–1.052). PI-LL was significantly associated with LBP (+ 1; OR, 1.064; 95% CI, 1.017–1.167), and this association remained significant after adjusting for other significant variables (+ 1; OR, 1.065; 95% CI, 1.019–1.168).

The cut-off values obtained via ROC analysis of SVA and PI-LL are shown in Figure 3. The cut-off value, sensitivity, specificity, and area under the curve (AUC) for SVA were 47 mm, 55.3%, 83.3%, and 0.675, respectively (Fig. 3a). The cut-off value, sensitivity, specificity, and AUC for PI-LL were 30.5°, 31.9%, 96.7%, and 0.629, respectively (Fig. 3b).

Discussion

SVA and PI-LL are radiographic parameters that have been found to be associated with disability due to LBP in adults with spinal deformities [11]. Ogura et al. [31] classified patients with LSS into two groups based on an SVA cut-off of 50 mm and compared their LBP numerical rating scale (NRS) scores. The mean NRS scores in the group with an SVA ≥ 50 mm and in the group with an SVA < 50 mm were 6.6 and 5.6, respectively. Furthermore, the group with an SVA ≥ 50mm had more sever LBP than the group with an SVA < 50 mm, although this difference was not statistically significant (p = 0.058), Gao et al. [32] showed that patients with LSS and degenerative scoliosis with a PI-LL greater than 20° had significantly higher Oswestry Disability Index scores, which indicated greater disability due to LBP, than those with a PI-LL less than 20°. Miyakoshi et al. [4] reported that patients with LSS with LBP were more likely to have a kyphotic lumbar spinal alignment and a stooped posture than those with LSS without LBP. These findings are consistent with the result of this study, indicating that SVA and PI-LL are associated with LBP in LSS.

Patients with LSS present with a forward-bending posture [33] because lumbar extension increases epidural pressure, worsening leg symptoms [34]. Suzuki et al. [33] reported that the SVA of patients with cauda equina symptoms in the lower extremities (57.6 ± 37.5 mm) was substantially larger than that of patients with lower extremity radicular pain (40.3 ± 42.3 mm), while Matsuoka et al. [35] reported that both these groups of patients showed a longer SVA than the corresponding age-appropriate standard value (18.6 mm at 50–59 years, 26.2 mm at 60–69 years, and 33.8 mm at 70–79 years). They also reported that patients with cauda equina symptoms had a smaller LL (18.8° ± 13.2°) than those with radicular pain (22.4° ± 14.0°), although the difference was not significant. Kobayashi et al. [36] reported

that in both these types of patients, the LL was smaller than the normal range (mean LL, 28.1°; mean age, 62 years). Fujii et al. [37] showed that the mean symptom severity assessed using the Zurich Claudication Questionnaire decreased from 2.5 preoperatively to 1.7 postoperatively, the mean SVA decreased from 49.1 mm preoperatively to 28.6 mm postoperatively, and the mean PI-LL decreased from 12 mm preoperatively to 6 mm postoperatively in patients with LSS who underwent recapping laminoplasty. The high SVA and PI-LL seen in this study could be due to the presence of a forward-bending posture, which reduced LES and caused LBP regardless of the LES type. We analyzed the relationship of LES with SVA and PI-LL and found that patients with more severe or more advanced LES had a greater SVA and PI-LL than those with less severe or less advanced LES, and this should be confirmed in future studies.

We previously reported that the T2 value of the posterior AF at the L4–L5 level was lower in the CLBP group than in the control group. Furthermore, we found that VAS scores were significantly negatively correlated with the T2 value of the posterior AF [16]. One possible mechanism of discogenic LBP is growth of the afferent fibers that surround the posterior AF into the disc. Here, there was a significant between-group difference in the T2 values of the posterior AF at L4–L5 level. However, multiple logistic regression analysis showed that the T2 values of the posterior AF at the L4–L5 level was not independently associated with LBP. Ogura et al. [31] reported that, in patients with LSS who underwent lumbar spinous process–splitting laminectomy, the mean SVA decreased from 42.5 mm preoperatively to 35.6 mm postoperatively, the mean PI-LL decreased from 14.9° preoperatively to 12.7° postoperatively, and the mean improvement in LBP NRS score was 3.3. These results imply that LBP in patients with LSS who have a stooped posture could improve with lumbar decompression without fusion. This is consistent with our findings, which show that LBP in patients with LSS is associated with global sagittal alignment, rather than local degeneration such as IVDD. The cut-offs of 47.0 mm for SVA and 30.5° for PI-LL determined through ROC analysis had a high specificity and positive predictive value for LBP in LSS due to spinopelvic malalignment. However, these cut-off values may also represent LBP in patients with LSS due to causes other than spinopelvic malalignment, such as IVDD. These causes of LBP should be investigated,

This study has some limitations. First, it was a cross-sectional study, not a longitudinal study, and we were therefore unable to analyze causal relationships. Second, we did not analyze the duration of the disease, relationship between spinopelvic alignment and LES, and impact of psychosocial factors.

Conclusions

We compared LES, BMD, spondylolisthesis, ROM, spinopelvic alignment, CSA and FI of the Mm, IVDD, MC, and FJD between patients with high and low LBP who had LSS. The mean SVA was 56.1 mm and 29.8 mm ($p < 0.01$) and the mean PI-LL was 15.7° and 9.4° ($p < 0.01$) in the high and low groups, respectively. Multivariate logistic regression analysis revealed that SVA (+ 1; OR, 1.029; 95% CI, 1.005–1.052) and PI-LL (+ 1; OR, 1.065; 95% CI, 1.019–1.168) were significantly associated with LBP. The cut-off values of 47.0 mm for SVA and 30.5° for PI-LL determined thorough ROC analysis had a high specificity and

positive predictive value for LBP in LSS due to spinopelvic malalignment. However, these cut-off values may also represent LBP in patients with LSS due to causes other than spinopelvic malalignment, such as IVDD. These causes of LBP should be investigated.

Abbreviations

LSS: lumbar spinal stenosis

LBP: low back pain

CLBP: chronic low back pain

QOL: quality of life

ROM: range of motion

IVDD: intervertebral disc degeneration

MC: Modic changes

FJD: facet joint degeneration

LES: lower extremity symptoms

BMI: body mass index

BMD: bone nieral density

CSA: cross-sectional area

FI: fat infiltration

Mm: multifidus muscle

LL: lumbar lordosis

TK: thoracic kyphosis

SVA: sagittal vertical axis

SS: sacral slope

PT: pelvic tilt

PI: pelvic incidence

MRI: magnetic resonance imaging

TE: echo time

AF: annulus fibrous

NP: nucleus pulposus

OR: odds ratio

CI: confidence interval

AUC: area under the curve

NRS: numerical rating scale

Declarations

Disclosures

Ethics approval and consent to participate

The study was performed in accordance with the Declaration of Helsinki after approval by the Ethics Committee of our institution (approval number: 262-1074). All participants received written and verbal explanations of the study and provided informed consent before participation.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available due to limitations of ethical approval involving the patient data and anonymity but are available from the corresponding author on reasonable request.

Competing interests

The authors report no conflicts of interest concerning the materials or methods used in this study or the findings reported in this paper.

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None.

Authors' contributions

Coordination of study conduction IO. Study design IO, HT. Data collection IO, HT. Statistical analysis IO. Data interpretation KI, HT. Clinical consultant KI, YT, MY, ME, AT, TT, TY. Manuscript preparation IO. Critical review of the manuscript KI, HT, YT, MY. Approval of the final draft ME, AT, TT, TY. The authors read and approved the final manuscript.

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Authors' information

[1]Department of Orthopaedic Surgery, Sapporo Medical University School of Medicine, 291, South-1, West-16, Chuo-ku, Sapporo, 060-8543, Japan

[2] Department of Orthopaedic Surgery, Sapporo Maruyama Orthopaedic Hospital, 1-3, North-7, West-27, Chuo-ku, Sapporo, 060-0007, Japan

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Tables

Due to technical limitations, tables 1 and 2 are only available as a download in the Supplemental Files section.

Figures

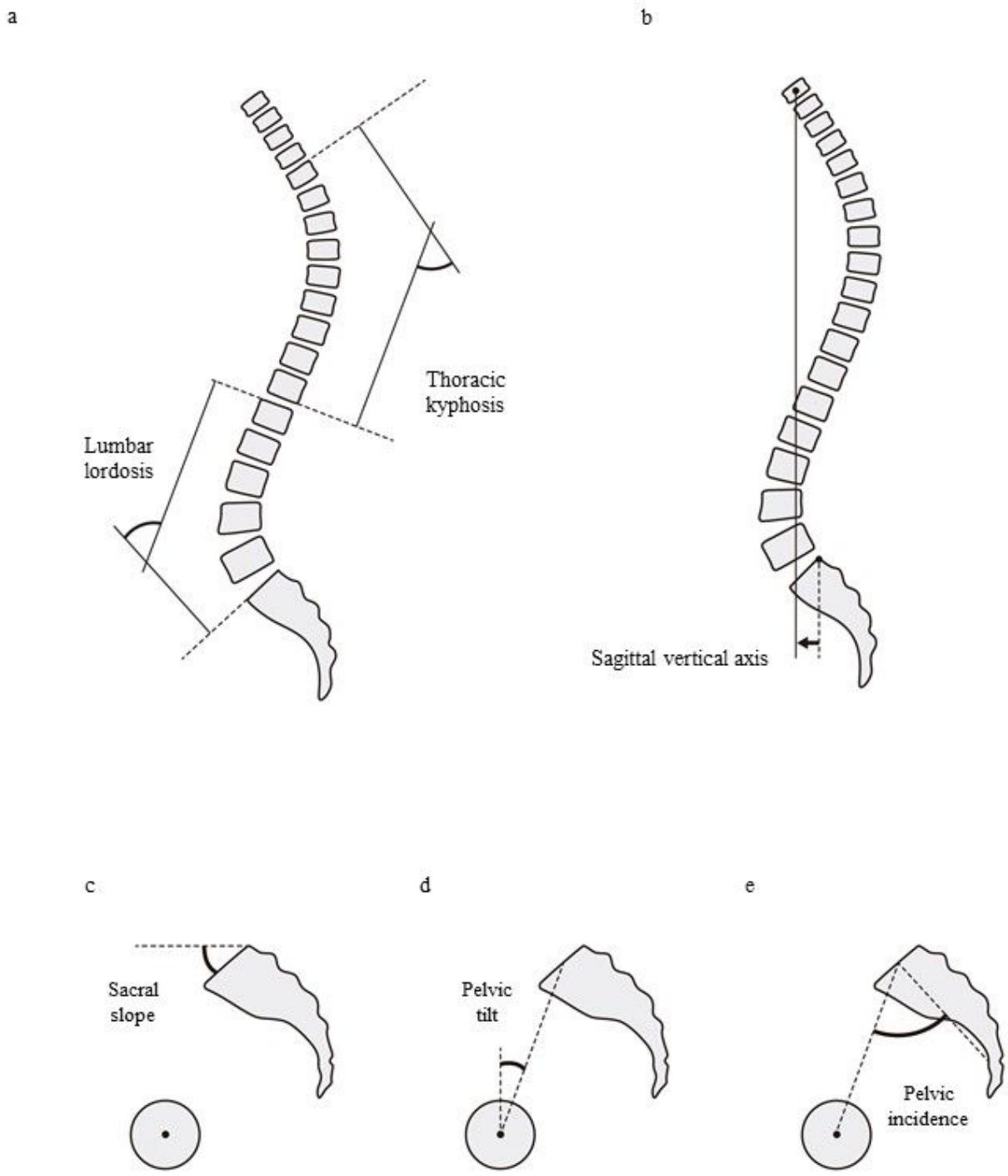

Figure 1

Measurement of the sagittal spinopelvic parameters (a) Lumbar lordosis is measured from the superior endplate of L1 to the superior endplate of S1, and thoracic kyphosis is measured from the superior endplate of T4 to the inferior endplate of T12. (b) Sagittal vertical axis (SVA) is the horizontal offset from the posterosuperior edge of S1 to the body of C7. (c) Sacral slope is the angle between the horizontal and the superior sacral endplate. (d) Pelvic tilt is the angle between the vertical axis and the line running from

the midpoint of the sacral plate to the center of the femoral head axis. (e) Pelvic incidence is the angle between a line perpendicular to the superior sacral endplate at its midpoint and the line connecting this point to the center of the femoral head axis.

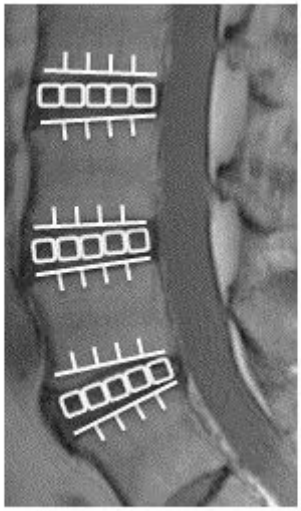

Figure 2

The intervertebral discs at L3–L4, L4–L5, and L5–S1 were divided into five equal areas each, with the first, middle, and last fifth areas being the anterior annulus fibrosus (AF), the center of the nucleus pulposus, and the posterior AF, respectively.

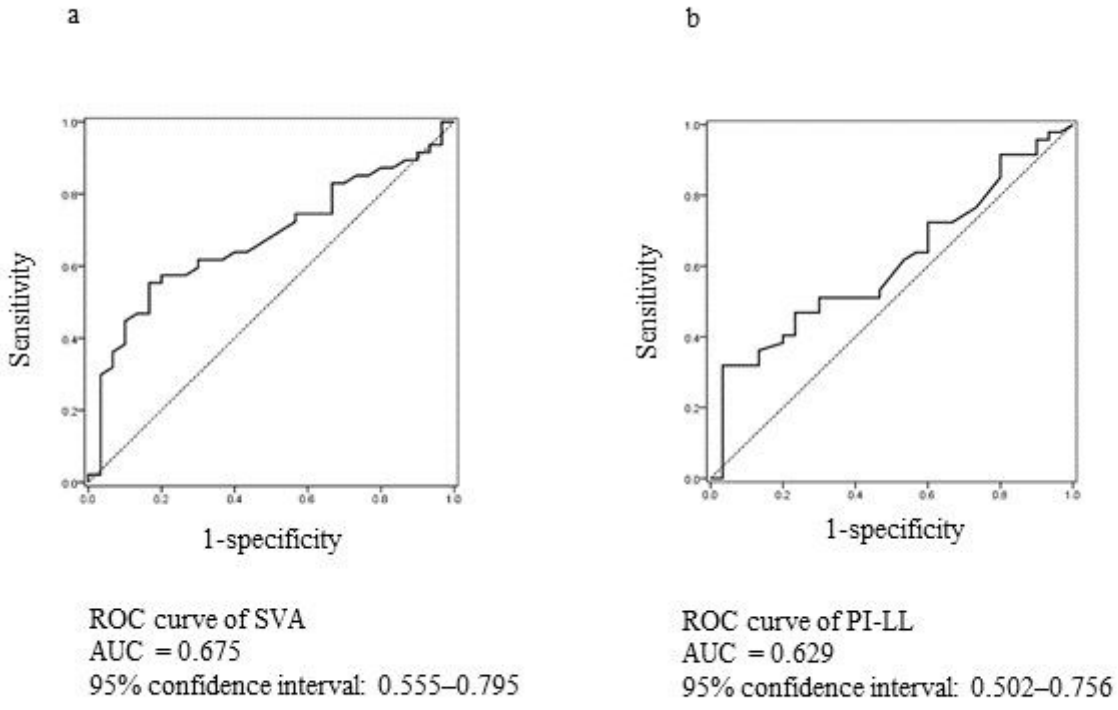

Figure 3

The receiver operating characteristic (ROC) curves of sagittal vertical axis (SVA) and pelvic incidence-lumbar lordosis (PI-LL). (a) The cut-off value for SVA was 47.0 mm. (b) The cut-off value for PI-LL was 30.5°. AUC: area under the curve

Supplementary Files

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