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Effect of position on lumbar lordosis in patients with adult spinal deformity

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OBJECTIVE The purpose of this study was to evaluate the effect of position on lumbar lordosis (LL) in adult spinal deformity (ASD) patients.

METHODS The authors evaluated the radiographic data of ASD patients who underwent posterior corrective fusion surgery from the thoracic spine to L5, S1, or the ilium for the treatment of ASD of the lumbar spine. The spinopelvic parameters were measured in the standing position preoperatively. LL was also evaluated in the supine position preoperatively and in the prone position on the surgical frame. Changes in LL were compared between groups.

RESULTS Eighty-five patients were included. The average LL in standing, supine, and prone positions was 11.8°, 24.3°, and 24.0°, respectively. LL increased significantly from standing to supine or prone position ($p < 0.001$). In 80 patients (94.1%), the difference between supine LL and prone LL was within 5°. Change in LL from standing to prone position was significantly higher in the severe deformity group.

CONCLUSIONS The lordotic effect of intraoperative prone positioning was remarkable in patients with severe deformities. LL in the supine position was approximately the same as that in the prone position. Therefore, assessing preoperative supine lateral lumbar radiographs enables one to plan corrective spinal surgeries in ASD patients.

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KEYWORDS lumbar lordosis; adult spinal deformity; prone position; corrective spinal surgery

Recent studies have shown that sagittal spinopelvic alignment, including pelvic position, plays a critical role in the health-related quality of life of patients with adult spinal deformity (ASD).[4,7,12,13] Therefore, the goal of corrective surgery for ASD is to achieve and maintain optimal spinopelvic alignment. Lumbar lordosis (LL) is one of the important parameters for optimal sagittal alignment. The achievement of adequate LL is necessary for good results in corrective surgeries in spinal fusion. Additionally, LL is one of the main parameters that can be controlled by surgeons. Thus, some formulae have been developed to calculate the degree of optimal LL in corrective surgeries for ASD.[11,16]

There are some correction techniques to restore LL, such as posterior column osteotomy, pedicle subtraction osteotomy, and vertebral column resection. These osteotomy techniques have varying correcting power to achieve lordosis. Posterior column osteotomy provides about only 10° of correction per level, but it can be used at multiple levels. Pedicle subtraction osteotomy and vertebral column resection provide about 30° or more correction per level.[1,2] Optimal LL can be achieved through a combination of these techniques depending on the type of deformity.

Usually, spinopelvic parameters including LL are evaluated on standing radiographs. Thus, the correction angle that can be achieved by osteotomy is evaluated by radiographs taken in the standing position. However, since LL may be different depending on position, preoperative surgical planning for deformity correction should be based on intraoperative prone position. Although various authors

ABBREVIATIONS ASD = adult spinal deformity; LL = lumbar lordosis; PI-LL = pelvic incidence minus lumbar lordosis; PT = pelvic tilt; SVA = sagittal vertical axis; TK = thoracic kyphosis.

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FIG. 1. Left: The spinal frame image viewed from the top of the table**. Right:** Intraoperative prone position. Patients were positioned on the frame with hips and knees in slight flexion. The spinal frame consisted of 2 chest pads and 2 anterior pelvic pads.

have analyzed the effects of operative positioning on LL during surgeries for lumbar degenerative disease,[5,8–10,14,15] there are few reports about the impact of positioning on the change in LL in patients with ASD.

The purpose of this study was to investigate the impact of positioning on LL in patients with ASD to help with preoperative planning.

Methods

Patient Sample

Our study group consisted of adult patients who underwent posterior corrective fusion surgery from the thoracic spine to L5, S1, or the ilium for the treatment of ASD of the lumbar spine. The study protocol was approved by the institutional review board of Hamamatsu University School of Medicine, Shizuoka, Japan. Inclusion criteria for ASD were patients aged 40 years or older and the presence of at least one of the following measures of spinal deformity: coronal Cobb angle of 20° or greater, sagittal vertical axis (SVA) of 5 cm or more, pelvic tilt (PT) of 25° or greater, and thoracic kyphosis (TK) of 60° or greater.

The etiologies of ASD were as follows: degenerative kyphoscoliosis in 44 patients, degenerative kyphosis in 19, kyphosis with vertebral fracture in 9, neuromuscular deformity in 10, and adult idiopathic deformity in 3. Two patients had a history of spinal fusion (one level and two levels, respectively).

Radiographic Measurements

Standing radiographic evaluation was performed according to an established positioning protocol for obtaining lateral slot scan digital standing radiographs[6] preoperatively. Radiographic parameters included SVA, L1–S1 LL, T5–12 thoracic kyphosis (TK), pelvic tilt (PT), and pelvic incidence minus lumbar lordosis (PI-LL) by using digitized radiographs of the entire lateral spine in the standing position. LL was also evaluated in supine and prone positions. Supine LL was measured using lateral lumbar radiographs taken in the supine position preoperatively. Additionally, prone LL was measured using lateral lumbar radiographs of the spinal frame that were obtained in the prone position after induction of general anesthesia just before beginning the surgery. The spinal frame had 2 chest pads and 2 anterior pelvic pads (Fig. 1 left). All patients were positioned on the frame with hips and knees in slight flexion (Fig. 1 right). All radiographs were measured by 7 board-certified spine surgeons using the Synapse application available in the Fujifilm PACS application suite (Fujifilm Holdings).

Impact of Positioning

Change in LL in each position was analyzed. Additionally, correlation between the change in LL and spinopelvic parameters was evaluated using Spearman's correlation.

The patients were divided into 2 groups depending on preoperative PI-LL: a severe deformity group (PI-LL > 30°) and a mild deformity group (PI-LL ≤ 30°). The Mann-Whitney U-test was used to identify significant differences between the groups.

Results

Relevant Characteristics of the Study Group

Eighty-five patients met our inclusion criteria; there were 11 men and 74 women whose mean age was 70.2 years.

Radiographic Parameters of Spinopelvic Alignment

Radiographic parameters of spinal alignment are summarized in Table 1. The average SVA improved from 127 mm to 45 mm after surgery, while the average TK

TABLE 1. Spinopelvic radiographic parameters in standing position

Parameter	Preoperative Standing Radiograph
SVA (mm)	127.0 ± 89.8
LL (°)	7.8 ± 23.0
TK (°)	25.0 ± 17.6
PT (°)	35.5 ± 11.7
PI-LL (°)	43.4 ± 23.9

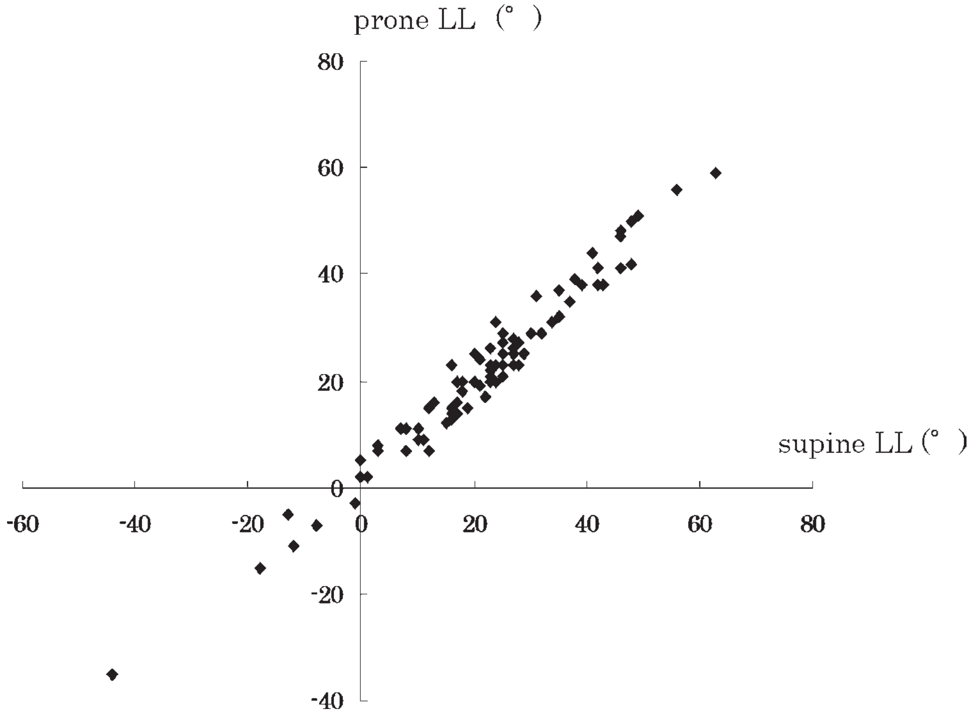

FIG. 2. Scatter plots of LL in the supine position and prone position. LL in the supine position was nearly the same as that in the prone position.

increased from 25.0° to 34.8° and the anteversion in PT improved from 35.5° to 23.9°. The average LL increased from 7.8° to 40.0°, and PI-LL improved from 43.4° to 12.0° after surgery.

Change in LL by Patient Positioning

The average LL angles in standing, supine, and prone positions were 7.8°, 22.1°, and 22.0°, respectively. The change in LL increased significantly by change in position from standing to supine or prone ($p < 0.001$). Prone LL was approximately equal to supine LL (Fig. 2). In 80 of 85 cases (94.1%), the difference between supine LL and prone LL was within 5° (Fig. 3).

Comparison Between Preoperative Severe and Mild Deformity Groups

There were 60 patients in the severe deformity group (PI-LL > 30°) and 25 patients in the mild deformity group (PI-LL ≤ 30°). The change in LL according to each position in the two groups is summarized in Table 2.

In the severe deformity group, standing LL, supine LL, and prone LL were −0.5°, 18.1°, and 18.3°, respectively.

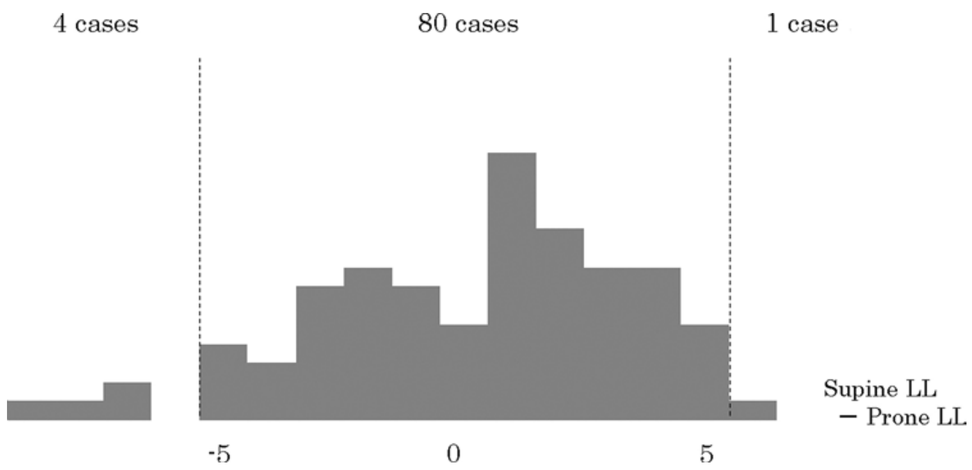

FIG. 3. Distribution of the difference between supine LL and prone LL (supine LL minus prone LL). In 80 of 85 patients (94.1%), the difference between supine LL and prone LL was within 5°.

TABLE 2. LL in standing, supine, and prone positions

Position	All Patients	Severe Deformity (PI-LL >30)	Mild Deformity (PI-LL ≤30)	p Value (severe vs mild)
Standing LL (°)	7.8 ± 23.0	−0.5 ± 21.1	27.8 ± 13.4	<0.001
Supine LL (°)	22.1 ± 17.0	18.1 ± 16.3	32.0 ± 14.5	0.002
Prone LL (°)	22.0 ± 15.8	18.3 ± 15.0	30.9 ± 14.2	0.004
Change in LL				
Standing to supine (°)	14.3 ± 15.1	18.5 ± 15.1	4.2 ± 9.3	<0.001
Standing to prone (°)	14.2 ± 15.2	18.8 ± 15.0	3.1 ± 8.8	<0.001
Supine to prone (°)	−0.1 ± 3.3	−0.3 ± 3.4	1.1 ± 3.0	0.11

The changes in LL from standing to supine and prone positions were 18.5° and 18.8°, respectively. In the mild deformity group, standing LL, supine LL, and prone LL were 27.8°, 32.0°, and 30.9°, respectively. The changes in LL from standing to supine and prone positions were 4.2° and 3.1°, respectively. The changes in LL from standing to supine and prone positions in the severe deformity group were significantly greater than those in the mild deformity group ($p < 0.001$).

Comparison Between Each Etiology

The change in LL according to each position by each etiology is summarized in Table 3. The lordotic effect of change to supine and prone position in adult scoliosis was very small. The cases of neuromuscular deformity had the most lordotic effect in change to supine and prone position. However, LL in the supine position was approximately the same as that in the prone position in any etiology.

Discussion

This study investigated the impact of position on LL in patients with ASD. The lordotic effect of the intraoperative prone position was remarkable in patients with severe deformities. Furthermore, LL in the supine position was approximately equal to LL in the prone position.

Previous studies concerning the impact of prone positioning on LL are summarized in Table 4.[3,5,8–10,14,15] All the studies, except those by Fei et al. and Harimaya et al., investigated patients who underwent spinal surgery for degenerative lumbar disorders and not for deformities. In degenerative diseases, LL in the prone position had decreased or slightly increased compared with that seen in the standing position. Otherwise, LL in the prone position increased significantly compared with that in the standing position in our patients with ASD. In particular, in the severe deformity group, the lordotic effect of the intraoperative prone position was remarkable. Thus, it is important to evaluate and understand spinal alignment in not only the standing position but also the intraoperative prone position.

Harimaya et al. and Fei et al. reported changes in LL in patients with spinal deformity in upright, supine, and prone positions.[3,5] LL angles in the upright, supine, and intraoperative prone positions were 38.1°, 46.0°, and 46.2° in Harimaya's report and 23.5°, 25.5°, and 24.6° in Fei's report, respectively. Supine LL was almost the same as prone LL in both reports. In 94.1% of our patients, the difference between supine LL and prone LL was within 5°. Thus, intraoperative prone LL could be approximated by preoperative supine LL. Therefore, we believe that the assessment of preoperative supine lateral lumbar radiographs will help in the planning of corrective spinal surgeries in patients with ASD.

Several limitations of this study should be acknowledged. First, this study included various etiologies of spinal deformity. Although lumbar flexibility may differ depending on etiology, this result will be applicable in various etiologies. However, a larger sample size is required since the sample size was too small to analyze in more detail by each etiology. Additionally, the apex of the deformity also varied. Although in most cases the main deformity was in the lumbar region, it was difficult to determine the apex of deformity in flat lumbar and whole kyphosis cases. However, one advantage of this study was that LL in the prone position was found to be the same as LL in the supine position in various ASD

TABLE 3. LL in standing, supine, and prone positions by each etiology

	Kyphoscoliosis	Kyphosis	Vertebral Fracture	Neuromuscular	Adult Scoliosis
No. of patients	44	19	9	10	3
Standing LL (°)	11.2 ± 22.1	5.1 ± 15.4	9.1 ± 24.3	−8.2 ± 32.8	27.3 ± 15.3
Supine LL (°)	25.5 ± 15.0	20.3 ± 9.3	21.2 ± 23.5	10.1 ± 24.9	27.0 ± 19.5
Prone LL (°)	25.2 ± 14.2	19.7 ± 9.7	21.2 ± 20.7	10.9 ± 22.4	28.7 ± 18.6
Change in LL					
Standing to supine (°)	15.2 ± 13.0	15.3 ± 13.0	12.1 ± 22.3	18.3 ± 22.5	−0.3 ± 5.9
Standing to prone (°)	14.2 ± 12.8	14.6 ± 13.5	12.1 ± 21.3	19.1 ± 22.7	1.3 ± 3.8
Supine to prone (°)	−0.3 ± 3.4	−0.6 ± 3.1	0.0 ± 3.3	0.8 ± 3.9	1.6 ± 2.5

TABLE 4. LL in standing and prone positions in previous reports

Authors & Year	Average Age (yrs)	Standing LL (°)	Prone LL (°)
Tan et al., 1994	35.7	55.6	28.3
Peterson et al., 1995	46.5	61.7	62.8
Tribus et al., 1999	NR	51	37
Lee et al., 2008	58.3	48.1	39
Harimaya et al., 2009	57.4	38.1	46.2
Lee et al., 2016	67.8	43.5	48.8
Fei et al., 2017	63.8	23.5	24.6
Present series	70.2	7.8	22
Severe deformity	70.7	−0.5	18.8
Mild deformity	69.2	27.8	30.9

NR = not reported.

cases. Furthermore, although different spinal frames might affect LL in the prone position, we only evaluated one type of frame, and validation using various frames will be required.

Conclusions

The lordotic effect of the intraoperative prone position was greater in patients with severe deformities. LL in the prone position was approximately equal to LL in the supine position; in 80 of 85 cases (94.1%) the difference was within 5°. Therefore, assessment of preoperative supine lateral lumbar radiographs will help in the planning of corrective spinal surgeries in patients with ASD.

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Disclosures

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Author Contributions

Conception and design: Yasuda, Hasegawa, Yamato, Togawa, Kobayashi, Matsuyama. Acquisition of data: all authors. Analysis and interpretation of data: all authors. Drafting the article: Yasuda. Critically revising the article: Yasuda. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Yasuda. Statistical analysis: Yasuda. Administrative/technical/material support: Yasuda. Study supervision: Matsuyama.

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