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Adjacent Segment Disease after Long Spinal Fusion Ending at L5 for Adult Spinal Deformity: A Retrospective Cohort Study

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Abstract

Study Design: This is a retrospective cohort study using data from the adult spinal deformity (ASD) database of a single institution. **Purpose:** To investigate the incidence of proximal junctional failure and distal junctional failure (DJF) after ASD surgery with a lower instrumented vertebra (LIV) at L5. **Overview of Literature:** Spinopelvic fixation from the lower thoracic vertebra to the pelvis is the current gold standard treatment for ASD. However, the LIV at L5 is acceptable in some cases. **Methods:** Fifty-six patients who underwent corrective surgery for ASD with LIV at L5 were included. The upper instrumented vertebra (UIV) was T7 in one patient, T9 in 14, T10 in three, T11 in four, T12 in eight, L1 in 10, and L2 in 16. Regarding clinical parameters, age, sex, curve types of Scoliosis Research Society-Schwab classification, number of levels fused, follow-up period, hip bone mallow density, revision surgery rate, and radiographic measurements were compared between the T (UIV: T7 - 10) and TL (UIV: T11 - L2) groups. **Results:** The revision surgery rate was 19.6% overall. In the T and TL groups, it was 27.8%, and 15.8%, respectively ($p = 0.305$). The rate of DJF in the T group (33.3%) was significantly higher than in the TL group (5.3%). The rate of proximal junctional kyphosis in the T group (55.6%) was higher than in the TL group (28.9%), with no significant difference. The mean global alignment, sagittal vertical axis, and C7 plumb line-central sacral vertical line were not different between both groups. **Conclusions:** ASD surgery with LIV set at L5 and UIV set at the thoracic vertebrae (T7 - T10) has a risk of adjacent segment disease.

Keywords

Adjacent Segment Disease, Adult Spinal Deformity, Spinal Long Fusion, L5, Distal Junctional Failure, Proximal Junctional Failure

1. Introduction

Spinal deformity is highly prevalent in individuals older than 65 years, affecting between 32% and 68% of the population [1] [2]. It is a major public health problem and correlates with the quality of life (QOL). A positive correlation has been observed between the range of motion (ROM) of the spine and QOL. Limited ROM in patients with adult spinal deformity (ASD) can reduce the QOL [3]. In contrast, corrective surgical procedures have been shown to improve the QOL [4] [5] [6] [7] [8]. Despite improving the QOL, long spinal arthrodesis does not always improve all postoperative activities. Light activities, such as daily basic actions, offer the possibility of showing continued postoperative improvement; however, activities of daily living (ADL) requiring relatively larger spinal mobility and strenuous activities are restricted postoperatively [9].

We seek the ideal spinal deformity correction; nonetheless, the challenge is to shorten the range of fixation, considering the decline in ROM and ADL. Spinopelvic fixation from the lower thoracic vertebra to the pelvis is currently the gold standard for treating ASD, most commonly caused by primary degenerative kyphoscoliosis [10]. Lower instrumented vertebra (LIV) at L5 is acceptable in some cases [10]. The end at L5 offers preservation of lumbosacral motion. However, the preservation may cause some adjacent segment diseases. There is a paucity of studies on the occurrence of adjacent segment diseases, such as proximal junctional failure (PJF) and distal junctional failure (DJF), due to differences in upper instrumented vertebrae (UIV) in ASD surgery with a LIV at L5. To address this knowledge gap, we aimed to investigate the incidence of PJF and DJF after ASD surgery with a LIV at L5.

2. Materials and Methods

Study design

The data used in this retrospective cohort study was retrieved from the ASD database in a single institution. The institution is a spine center that covers a population of approximately one million and documents at least one hundred spinal deformity surgeries annually. All study participants provided informed consent, and the study protocol was approved by the Institutional Review Board of our institutions.

Patient population

Of the 224 patients who underwent corrective surgery with multilevel posterior lumbar interbody fusion (PLIF) or lateral lumbar interbody fusion (LLIF) for ASD between 2011 and 2019, those with LIV level at L5 were selected. Our inclusion criteria for LIV level at L5 were as follows: 1) no foraminal stenosis of L5 - S1; 2) no disc herniation and gas in the disc space of L5 - S1; 3) no spondylolytic spondylolisthesis of L5; 4) no rotation of L5 - S1; and 5) no coronal imbalance of L5 - S1 [11] [12]. Additional inclusion criteria for the study comprised the following patient details: 1) patients > 50 years of age with ASD, such as de novo onset and progressive degeneration; 2) minimum follow-up duration of 24 months. Patients with ankylosing spondylitis or a history of spinal surgery were excluded from the study.

The patients included 37 women and 19 men, with a mean age of 68.7 (range, 54 - 83) years. All patients underwent all-pedicle-screw instrumentation and fusion without using a laminar or transverse process hook at the UIV. The UIV was determined according to the degree of correction over the apical vertebra of kyphosis or the upper-end vertebra of scoliosis. UIV was at T7 in 1 patient, T9 in 14, T10 in 3, T11 in 4, T12 in 8, L1 in 10, and L2 in 16.

We divided the patients into a thoracic (T) group (UIV: T7 - 10) and a thoracolumbar junction (TL) group (UIV: T11 - L2) and compared clinical parameters particularly, age, sex, curve types of Scoliosis Research Society (SRS)-Schwab classification, the number of fused levels, follow-up period, hip bone mallow density (BMD), and revision surgery rate between the two groups. This information was collected from medical records, retrospectively.

Radiographic measurements

All radiographic data consisted of full-length lateral long-cassette radiographs obtained with the patients standing with their palms on their clavicles. The time to reoperation was set as the endpoint. Images were taken preoperatively, one month postoperatively, and at the final follow-up or the endpoint. The sagittal vertical axis (SVA), C7 plumb line-central sacral vertical line (C7PL-CSVL), lumbar lordosis (LL), pelvic tilt (PT), pelvic incidence (PI), and PI minus LL (PI-LL) were evaluated. The proximal junctional angle (PJA) was defined as the caudal endplate of the UIV to the cephalad endplate of two proximal vertebrae. Proximal junctional kyphosis (PJK) was defined as a PJA greater than 20˚ and at least a 10˚ increase in PJA from the preoperative baseline value [13] [14]. Both PJF and DJF were identified as symptomatic conditions requiring any type of surgery [15].

Operative procedure

All patients underwent multilevel PLIF, or LLIF, followed by posterior surgery on the same day. Posterior surgery consisted of a standard midline approach with Schwab Grade 1 osteotomy [16] up to the UIV. Additional bone resection with Schwab Grade 2 Ponte osteotomy was performed, as necessary. Instrumentation included the use of segmental spinal pedicle screws from UIV to L5.

Statistical analysis

Continuous variables were evaluated using Student's t-test and paired t-test. Discontinuous variables were evaluated using the Mann-Whitney U test, and categorical variables were evaluated using Fisher's exact test. Statistical significance was set at $p < 0.05$. All statistical analyses were conducted using EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan) [17].

3. Results

The baseline patient characteristics are presented in **Table 1**. There were significant differences between the two groups in terms of sex (% male) (T vs. TL, 11.1% vs. 44.7%, p = 0.0162) and the number of levels fused (7.9 vs. 3.6, p < 0.001). However, age, SRS-Schwab classification curve type, follow-up period, and hip BMD were not significantly different between the two groups.

Overall, the revision surgery rate was 19.6% (n = 12). Revision surgery was carried out in 5 of 18 patients in the T group (27.8%) and 6 of 38 patients in the TL group (15.8%). There was no significant difference in the revision surgery rate between both groups (p = 0.305). **Figure 1** shows the incidence rates of PJF,

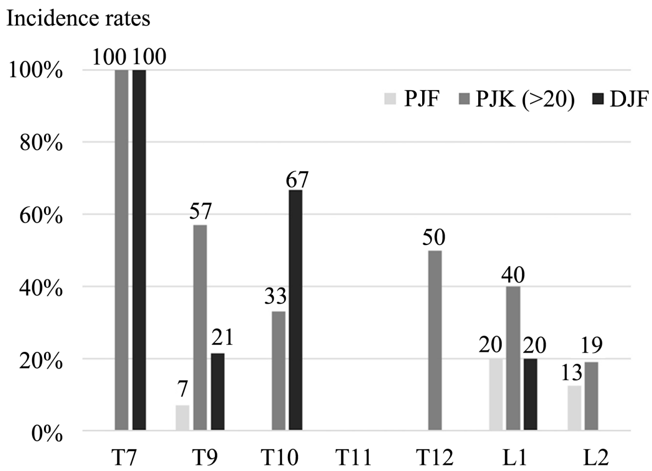

Figure 1. Incidence rates of proximal junctional failure (PJF), proximal junctional kyphosis (PJK), and distal junctional failure (DJF) for each upper instrumented vertebra (UIV).

Table 1. Characteristics in patients at baseline in both groups.

	T group n = 18	TL group n = 38	p-value
Age (median) [range]	66.8 years [55 - 75]	69.5 years [54 - 83]	0.197
sex (% men)	11.1%	44.7%	0.0162*
Curve type (% type) (SRS-Schwab classification)	N 61% L 22%, D 17%	N 74% L 24%, D 3%	0.141
Number of levels fused (median) [range]	7.9 [7 - 10]	3.6 [3 - 6]	<0.001*
Follow-up period (median) [range]	4.7 years [2 - 7]	4.8 years [2 - 11]	0.936
Hip BMD (median) [range]	0.631 g/cm^2 [0.544 - 0.742]	0.645 g/cm^2 [0.347 - 0.909]	0.759

Bone mineral density; BMD, thoracic; T, thoracolumbar; TL. *p < 0.05 was defined as statistically significant.

PJK, and DJF for each UIV and **Table 2** shows the incidence rates in both groups. Both PJF and DJF occurred in one case in the TL group. The rate of DJF in the T group (33.3%) was significantly higher than in the TL group (5.3%). Similarly, the rate of PJK in the T group (55.6%) was higher than in the TL group (28.9%); however, there was no significant difference. The changes in the radiographic parameters are listed in **Table 3**. The global alignment (SVA and C7PL-CSVL) and spino-pelvic parameters (LL, PI, PI-LL and SS) did not significantly differ between both groups. The postoperative PT and final follow-up PT in the T group were significantly lower than those in the TL group.

4. Discussion

In this retrospective cohort study, the reoperation rate was 17.9%, and the rates of DJF and PJK in the T group, where the UIV was at T7 - T10, were significantly higher than in the TL group whose UIV was at T11 - L2 with LIV at L5. Although LL pre-surgery in the T group tended to be smaller than in the TL group, global alignment did not show a significant difference between both groups. Previous reports indicated that long fusion to L5 was carried out in selected ASD patients with favorable conditions for spinal fusion, specifically in those with less severe disability and less complex deformity; however, 50% of the patients required additional fusion to the pelvis [18]. The reoperation rate in this study was lower than that reported previously, especially in the TL group. We believe that there are some cases in which it is acceptable to stop UIV at L5.

The rate of PJF, in this study, was 5.6% in the T group and 10.5% in the TL group, which was higher than the previously reported rate (1.4%) [19]. However, the rate of PJK of 20˚ or more was 55.6% in the T group and 28.9% in the TL group, which was less than that reported previously for fixation to the pelvis (69.8%) [20]. Regarding DJF, the 22.2% and 5.3% observed in the T and TL groups, respectively was lower than previously reported rates [18]. However, the frequencies of DJF and PJK were higher in the T group. These results suggest

Table 2. The rate of revision surgery, PJF, PJK, and DJF.

	All n = 56	T group n = 18	TL group n = 38	p-value
Revision surgery rate	12 (21.4%)	7 (38.9%)	5 (13.2%)	0.305
PJF	5 (8.9%)	1 (5.6%)	4 (10.5%)	1
PJK	21 (37.5%)	10 (55.6%)	11 (28.9%)	0.0777
DJK	8 (14.3%)	6 (33.3%)	2 (5.3%)	0.0101*

Proximal junctional failure; PJF, proximal junctional kyphosis; PJK, distal junctional failure; DJF, thoracic; T, thoracolumbar; TL. *p < 0.05 was defined as statistically significant.

Table 3. Radiographic parameters.

	T group n = 18	TL group n = 38	p-value
	mean (range)		
SVA			
Pre-op	78.4 (−25 - 137)	69.9 (−59 - 232)	0.5819
1-month post-op	21.9 (−22 - 79)	33.4 (−32 - 90)	0.23
final follow-up	59.3 (−9 - 158)	66.7 (−22 - 157)	0.5887
C7PL-CSVL			
Pre-op	14.2 (0 - 90)	20.9 (1 - 38)	0.21
1-month post-op	15.9 (0 - 38)	11.2 (0 - 46)	0.1308
final follow-up	9.2 (0 - 39)	10.3 (0 - 55)	0.7648
LL			
Pre-op	11.7 (−14 - 56)	21.6 (−32 - 47)	0.0848
1-month post-op	43.3 (12 - 65)	38.7 (2 - 70)	0.231
final follow-up	38.3 (13 - 61)	36.4 (2 - 60)	0.5937
PT			
Pre-op	27.8 (10 - 56)	28.5 (13 - 47)	0.82
1-month post-op	18.0 (4 - 50)	24.3 (5 - 46)	0.0367*
final follow-up	18.5 (7 - 51)	26.2 (7 - 48)	0.009374*
PI			
Pre-op	45.0 (31 - 70)	49.1 (24 - 70)	0.16
1-month post-op	45.2 (31 - 70)	49.3 (24 - 70)	0.164
final follow-up	45.7 (32 - 70)	49.5 (24 - 70)	0.1933
PI-LL			
Pre-op	33.5 (2 - 75)	27.4 (−25 - 62)	0.269
1-month post-op	2.9 (−28 - 32)	10.5 (−19 - 46)	0.35
final follow-up	7.3 (−17 - 32)	13.1 (−18 - 39)	0.134
SS			
Pre-op	18.1 (3 - 32)	20.7 (−7 - 36)	0.367
1-month post-op	27.4 (6 - 40)	25.7 (9 - 49)	0.463
final follow-up	23.8 (4 - 36)	20.7 (7 - 40)	0.1309

Sagittal vertical axis; SVA, C7 plumb line-central sacral vertical line; C7PL-CSVL, lumbar lordosis; LL, pelvic tilt; PT, pelvic incidence; PI, sacral slope; SS, thoracic; T, thoracolumbar; TL. *p-value of <0.05 was defined as statistically significant.

that when stopping LIV at L5, it may be effective to select patients in whom UIV can be restricted to the thoracolumbar junctional region (T11 - L2).

Ending at L5 preserved lumbosacral motion. L5 - S1 joint has an approximate ROM of 17˚ in the sagittal axis [21]. This joint has the largest ROM in lumbar lesions, and the impact of a limited ROM due to fusion on ADL is significant. Reportedly, there is no difference in the lumbar stiffness disability index (LSDI) between fixation to L5 and sacrum in ASD [22]. However, it has been reported that ADL which cannot be measured by LSDI, such as nail clipping and use of squat toilets, are restricted after thoracolumbosacroiliac arthrodesis [9]. Long-range fixation to the pelvis increases the burden on the sacroiliac joint, resulting in sacroiliac joint disorders [23]. Therefore, based on these facts, we believe that it is desirable to preserve spinal mobility during the initial surgery rather than to uniformly fix the spine from the thoracic region to the pelvis in the treatment of ASD.

This study had several limitations. First, patient-reported outcomes (PRO) were not included. This study was a retrospective cohort study which limited participants based on reoperation rate and radiological evaluation. Nonetheless, future evaluations, such as randomized controlled trials including PRO and ADL, are required.

Second, the sample size of patients in the T group was relatively small, and the number of women in the T group was higher than that in the TL group. Additionally, this study was set solely in a single center. Another limitation was the UIV selection, which was determined according to the degree of correction over the apical vertebra of kyphosis or the upper-end vertebra of scoliosis. Furthermore, the BMD of both groups did not show significant differences.

5. Conclusion

In conclusion, we observed that, in ASD surgery, if the LIV is set at L5 and the UIV is set at the thoracic vertebrae (T7 - T10) there is a risk of adjacent segment disease. However, when the long fusion is stopped at L5 in patients with ASD, it may be a good option for cases where correction is possible up to the thoracolumbar junction (UIV: T11 - L2).

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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