

Planned two-stage surgery using lateral lumbar interbody fusion and posterior corrective fusion: a retrospective study of perioperative complications

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1 **Planned two-stage surgery using lateral lumbar interbody fusion and posterior corrective fusion: a**
2 **retrospective study of perioperative complications**

3

4

5 **Abstract**

6 **Purpose:** To determine the effect of planned two-stage surgery using lateral lumbar interbody fusion (LLIF)
7 on the perioperative complication rate following corrective fusion surgery in patients with kyphoscoliosis.

8 **Methods:** Consecutive patients with degenerative scoliosis who underwent corrective fusion were divided
9 into a control group that underwent single-stage posterior-only surgery and a group that underwent planned
10 two-staged surgery with LLIF and posterior corrective fusion. We collected the patient background and
11 surgical data and assessed the perioperative complication rates. We also investigated spinopelvic parameters
12 and patient-reported outcome measurements (PROMs).

13 **Results:** One hundred and thirty-eight patients of mean age 69.8 (range, 50–84) years who met the study
14 inclusion criteria were included. The two-stage group (n=75) underwent a staged anterior-posterior surgical
15 procedure and the control group (n=63) underwent single-stage surgery. There was no significant between-
16 group difference in the incidence of perioperative complications, except for deep wound infection
17 (reoperation is necessary for surgical site infection). Revision surgery within 3 months of the initial surgery
18 was more common in the control group (n=8, 12.7%) than in the two-stage group (n=3, 4.0%). Spinopelvic
19 parameters and PROMs were significantly better in the two-stage group at 2 years postoperatively.

20 **Conclusion:** The complication rate for planned two-stage surgery was similar to that of previous posterior-
21 only single-stage surgery. However, early reoperation was less common, and the degree of spinal correction
22 and clinical results were significantly better after two-stage surgery.

23

24 **Keywords:** degenerative scoliosis, adult spinal deformity, two-stage surgery, perioperative complication,
25 spinal corrective fusion

26 **INTRODUCTION**

27 Corrective fusion surgery for adult spinal deformity (ASD) has become more common because of the rapid
28 increase in the elderly population. Surgical treatment for patients with ASD is reportedly accompanied by
29 a high incidence of perioperative complications and a high reoperation rate [1-6]. The etiology of ASD in
30 elderly patients includes degenerative scoliosis, degenerative kyphosis, and deformity following vertebral
31 body fractures. Surgery does not always produce consistent results in the elderly and may result in
32 perioperative and postoperative complications. Moreover, elderly patients often have comorbidities and
33 tolerate surgery poorly, so are prone to developing perioperative systemic complications. Therefore, effort
34 is required to reduce the perioperative complication rate in elderly patients with ASD.

35 Since 2014, to reduce surgical invasiveness and risk of complications, we have performed staged corrective
36 fusion surgery in patients with degenerative kyphoscoliosis, which is the most common cause of spinal
37 deformity in elderly patients [7]. Staged surgery includes anterior surgery (lateral lumbar interbody fusion:
38 LLIF) followed by posterior corrective fusion using pedicle screws. By dividing the operation into two
39 stages, the surgical invasiveness of each operation is reduced. However, there is concern about perioperative
40 complications due to staging [8-10], particularly deep vein thrombosis (DVT), postoperative delirium, and
41 surgical site infection [8]. Therefore, we hypothesized that the perioperative complication rate and need for
42 reoperation would be lower with staged surgery using LLIF for adult spinal deformity than with
43 conventional methods. In this study, we investigated the effect of planned two-stage surgery on the
44 perioperative complication rate following corrective fusion surgery for kyphoscoliosis. We also investigated
45 the correction of spinal alignment and clinical outcome of a staged procedure and compared the results with
46 those of posterior-only single-stage surgery.

47

48 **MATERIALS AND METHODS**

49 Data were retrospectively retrieved from a prospectively maintained database containing the operation
50 notes for 404 patients who underwent surgery for ASD at our institution between June 2010 and March

51 2018. ASD was defined as the presence of at least one of the following indicators: Cobb angle $>20^\circ$ in the
52 coronal plane, a sagittal vertical axis (SVA) >50 mm, pelvic tilt (PT) $>25^\circ$, and/or thoracic kyphosis (TK)
53 $>60^\circ$. Patients who had undergone corrective fusion surgery, had a diagnosis of kyphoscoliosis, were aged
54 >50 years, and had a minimum of 2 years of follow-up were included. Kyphoscoliosis was defined as a
55 coronal Cobb angle $>20^\circ$ at the lumbar spine. Patients with a history of adolescent idiopathic scoliosis,
56 congenital scoliosis, iatrogenic deformity, neuromuscular disease, or pyogenic spinal disease, including
57 spinal tuberculosis, were excluded, as were those who underwent staged posterior-posterior surgery. We
58 obtained the patient demographic, clinical, and surgical data and any perioperative complications from
59 medical records. The patients were divided into a control group that underwent single-stage posterior-only
60 surgery (performed before 2014 at our institution) and a two-stage group that underwent planned two-stage
61 anterior-posterior surgery. Demographic variables included age, sex, weight, height, body mass index,
62 American Society of Anesthesiologists Physical Status grade, and comorbidities. Perioperative surgical data
63 included intraoperative bleeding, operating time, number of levels fused, fusion to the pelvis, and incidence
64 of three-column osteotomy and LLIF. Perioperative complications were defined as events that required
65 medical intervention or treatment not normally provided for physical events within 3 months
66 postoperatively. However, those related to postoperative pain, such as administration of additional
67 analgesics, were not included. Imaging consisted of full-length sagittal radiographs obtained in a free-
68 standing position with the fingers on the clavicles [11]. Spinopelvic parameters, including TK, lumbar
69 lordosis (LL), SVA, pelvic incidence (PI), PT, PI-LL, and T1 pelvic angle (TPA), were measured
70 preoperatively and within 2 weeks after surgery. Patient-reported outcome measurements (PROMs) were
71 assessed using the Oswestry Disability Index (ODI) and Scoliosis Research Society–22 r (SRS-22r)
72 questionnaire preoperatively and 2 years after surgery. We investigated the perioperative complications and
73 clinical outcome according to each group.

74

75 **Surgical procedures**

76 The anterior-posterior staged surgery used to correct degenerative kyphoscoliosis was as follows. First, we
77 performed LLIF of 2–4 intervertebral discs via a lateral approach. Large cages (cage height: 8mm to 12
78 mm, angle: 6° or 10°) were inserted to correct and stabilize the intervertebral bodies. The patient was
79 allowed to ambulate on the day after the first surgery, and the spine was re-evaluated for planning of the
80 second posterior operation. A week later, posterior corrective fusion with posterior lumbar interbody fusion
81 (PLIF) at L5/S1 was performed using a pedicle screw system. In the control group, dissociation (including
82 three-column osteotomy), screw placement, correction, and interbody fusion were performed in one stage
83 via a posterior approach. Smith-Petersen osteotomy and PLIF were basically performed in three to four
84 intervertebral levels of the lumbar spine. In cases with fused vertebrae or vertebral body deformity, a 3-
85 column osteotomy was also used. In both groups, iliac screws were applied for pelvic fixation and connected
86 to the rod using connectors.

87

88 **Statistical analysis**

89 Descriptive statistics, including means and standard deviations, were calculated for the demographic data.
90 Differences in spinopelvic parameters between before and after surgery were examined using paired *t*-tests.
91 Differences in demographics, surgical and spinopelvic parameters, PROMs score, comorbidities, and
92 complication rates was compared between the control group and the two-stage group using unpaired *t*-tests
93 and chi-square tests. All statistical analyses were performed using EZR (Saitama Medical Center, Jichi
94 Medical University, Saitama, Japan), which is a graphical user interface for R (The R Foundation for
95 Statistical Computing, Vienna, Austria). More precisely, it is a modified version of R tool designed to add
96 statistical functions frequently used in biostatistics [12]. A *p*-value <0.05 was considered statistically
97 significant.

98

99 **RESULTS**

100 One hundred and thirty-eight patients of mean age 69.8 (range, 50–84) years who satisfied the eligibility

101 criteria were included in the main analysis (Fig. 1). Seventy-five of these patients underwent staged
102 anterior-posterior surgery (two-stage group) and 63 underwent one-stage surgery (control group). The
103 second surgery was performed at an average of 7.3 (range, 5–14) days after the first surgery in the two-
104 stage group. Table 1 shows the patient demographics. There was no significant between-group difference
105 in demographics, comorbidities (except for cardiovascular disease), or medications.

106 The average operating time was significantly longer in the two-stage group than in the control group (Table
107 2). However, the average intraoperative blood loss was significantly less in the two-stage group than in the
108 control group. Three-column osteotomy was performed in seven patients in the control group.

109 The perioperative complication rate in each study group is shown in Table 3. Delirium was the most frequent
110 perioperative complication in both groups. The incidence of perioperative complications was not
111 significantly different between the two groups, except for deep wound infection, which was defined as
112 reoperation for surgical site infection. Revision surgery within 3 months of the initial surgery was more
113 common in the control group (n=8, 12.7%) than in the two-stage group (n=3, 4.0%); the difference was not
114 statistically significant. The reasons for revision surgery were hematoma (n=3), surgical site infection (n=3),
115 instrumentation failure (n=1), screw reinsertion (n=1), and proximal junctional failure (n=1) in the control
116 group and proximal junctional failure (n=2) and screw reinsertion (n=1) in the two-stage group.

117 In the two-stage group, ambulation was planned for day 1 after the first surgery but was delayed in some
118 patients. Forty-five patients were able to ambulate on postoperative day 1, 16 on postoperative day 2, and
119 10 on postoperative days 3–6; four patients were unable to ambulate until after the second surgery. Table 4
120 shows the incidence of perioperative complications according to the day of ambulation after surgery. The
121 overall incidence of complications was significantly lower in patients who ambulated on day 1 than in those
122 who did not ambulate until day 2 or later.

123 There was no significant between-group difference in the spinopelvic parameters preoperatively. However,

124 LL, SVA, and TPA were significantly better on the postoperative radiographs in the two-stage group (Table
125 5). PROMs at 2 years postoperatively were evaluable in 70 patients (93%) in the two-stage group and 56
126 (89%) in the control group. We found no significant difference in the mean preoperative PROMs score
127 between the two study groups. The mean ODI and SRS-22r scores were significantly improved at the 2-
128 year postoperative follow-up. However, scores on the ODI and the Function, Pain, Self-Image/Appearance,
129 and Total domains of the SRS-22r were significantly better in the two-stage group at 2 years postoperatively
130 (Table 5). Table 6 shows the radiographic parameters of the 65 patients available for the whole spine
131 radiograph after LLIF surgery. The change in LL before and after surgery was 32.7°, of which 26.9% (8.8°)
132 was corrected after LLIF. In contrast, the mean improvement in SVA before and after surgery was 68.1 mm,
133 of which 33.1 mm (48.6%) was obtained after LLIF surgery.

134

135 **Representative cases**

136 A two-stage case

137 Fig. 2 shows the whole spine radiographs obtained preoperatively, immediately after LLIF surgery, and 2
138 weeks postoperatively for a 65-year-old man with degenerative kyphoscoliosis. According to the
139 preoperative radiographs, the sagittal spinopelvic parameters were as follows: Cobb angle, 43°; LL, -4°;
140 TK, 18°; PT, 30°; PI-LL, 46°; and sagittal vertical axis, 200 mm. LLIF was performed at L2/3, L3/4, and
141 L4/5 in one-stage surgery (operating time, 116 min; blood loss, 28 ml). A week later, posterior corrective
142 fusion from T10 to the ilium was performed using pedicle screws (operating time, 336 min; blood loss, 645
143 ml). The spinopelvic parameters improved as follows: Cobb angle, 5°; LL, 50°; TK, 47°; PT, 12°; PI-LL, -
144 8°; and SVA, 0 mm. No perioperative complications were observed. At 2-year postoperative follow-up, the
145 global alignment was maintained with Cobb angle, 6°; LL, 51°; TK, 45°; PT, 30°; PI-LL, 9°; and SVA, 26
146 mm.

147 A control case

148 The patient was a 75-year-old woman with degenerative kyphosis (Fig. 3). Preoperative radiographs

149 showed thoracolumbar kyphoscoliosis with a Cobb angle of 43°, LL of 1°, TK of 19°, PT of 46°, PI-LL of
150 56°, and SVA of 177 mm. We performed corrective fusion from T9 to the ilium with L2/3, L3/4, L4/5, and
151 L5/S1 posterior lumbar interbody fusion with Smith-Petersen osteotomy (operating time, 360 min; blood
152 loss; 1280 ml). The spinopelvic parameters improved as follows: Cobb angle, 5°; LL, 60°; TK, 29°; PT,
153 19°; PI-LL, -2°; and SVA, 41 mm. At 2-year postoperative follow-up, the global alignment was maintained
154 with Cobb angle, 6°; LL, 53°; TK, 45°; PT, 30°; PI-LL, 6°; and SVA, 44mm.

155

156 **DISCUSSION**

157 A high complication rate has been reported in elderly patients with degenerative scoliosis who undergo
158 corrective fusion surgery [1-6]. In this study, we found no difference in the complication rate after planned
159 two-stage surgery using LLIF following posterior surgery and that after posterior-only single-stage surgery;
160 however, the early reoperation rate was lower in patients who underwent two-stage surgery. Notably, the
161 surgical targets in this study had almost the same demographic characteristics, comorbidities, spinopelvic
162 parameters, and PROMs before surgery.

163 Planned two-stage surgery has been performed for various complex spinal deformities [13-16].
164 Perioperative complication rates are high for surgical procedures that involve a long operating time and
165 substantial blood loss. Therefore, complications can be reduced by dividing the surgery into two stages and
166 reducing the surgical invasiveness of each procedure [17]. However, it is controversial whether the
167 complication rate increases with staged surgery. Previous reports indicate that the complication rate is
168 higher with planned two-stage surgery that includes anterior and posterior spinal fusion than with single-
169 stage surgery, including an anterior and posterior approach [9,10]. Maddox et al. recently found no
170 difference in the complication rate between an intent-to-treat group with adult scoliosis who underwent a
171 staged procedure and a group that underwent a single-stage posterior-only procedure [18]. However, when
172 Passias et al. compared the intraoperative and perioperative complication rates of staged and simultaneous
173 procedures for correction of ASD using propensity score matching, they found a significantly higher

174 incidence of perioperative complications requiring revision in their staged surgery group [19]. Several
175 papers have reported an increased risk of perioperative complications after staged surgery, particularly
176 thrombosis. Patients undergoing major spine reconstructive surgery are at significant risk for thrombosis,
177 including DVT and pulmonary embolism, especially older patients who undergo combined anterior-
178 posterior surgery. Edwards et al. assessed the incidence of DVT associated with single-stage versus multi-
179 stage posterior-only complex spinal surgeries and concluded that DVT was eight times more likely after
180 multi-stage surgery than after single-stage surgery [20]. Arzeno et al. reported no difference in infection
181 rates but observed an increase in thrombotic events in their staged group that underwent surgery for ASD
182 using a combined anterior-posterior approach [21]. In contrast, Dearborn et al. found no significant
183 difference in the incidence of DVT on ultrasound between patients who underwent same-day surgery and
184 those in whom surgery was staged [8]. There was no significant difference in the perioperative complication
185 rate or thrombosis between the two-stage and control groups in our study. The lower thrombosis rate might
186 be explained by the fact that we performed anterior surgery using LLIF, which is less invasive with a short
187 operating time and less blood loss.

188 In the case of planned two-stage surgery, the interval between each surgery should be carefully considered.
189 Hassanzadeh et al. examined the occurrence of complications depending on whether the interval between
190 operations was longer than 21 days in patients with ASD who underwent combined anterior-posterior
191 procedures. Staging the procedure in two hospitalizations 21 or more days apart resulted in less combined
192 estimated blood loss and fewer major complications [22]. Arzeno et al. compared the complications
193 associated with planned two-stage surgery that included a short interval of 3 days with those of same-day
194 surgery. Multivariate analysis allowing individual case risk adjustment did not find a significant increase in
195 the hospital stay or the complication rate, except for thrombotic events, in the staged group [21]. In our
196 study, the second operation was performed 7 days after the first. The incidence of postoperative infection
197 tended to be higher in the one-stage surgery group and was attributed to surgical invasiveness. Another
198 potential contributor to the risk of complications associated with two-stage surgery is the duration of bed

199 rest after the first surgery. We found that the incidence of complications was significantly lower in patients
200 who could ambulate on the first postoperative day. Therefore, when the surgery is staged, it seems important
201 to consider the operative procedures and implement measures to mobilize the patient immediately after the
202 first surgery.

203 It has been reported that LLIF is a minimally invasive procedure for spinal deformity and provides good
204 correction. Particularly good results have been reported for adult spinal deformities [23-26]. Bae et al.
205 reported that patients' quality of life was significantly better after LLIF followed by posterior spinal fusion
206 than after anterior interbody fusion followed by posterior spinal fusion or posterior-only surgery [23]. In
207 their study, revision rates and the numbers of patients with pseudoarthrosis, hardware prominence, and other
208 perioperative complications were similar between the study groups. A systematic review of studies that
209 compared the complication rates of minimally invasive transforaminal interbody fusion and LLIF by Joseph
210 et al. found no significant difference in medical complication or reoperation rates [27]. They found that
211 rates of sensory and temporary or permanent neurological symptoms were higher with LLIF and that
212 intraoperative and wound complication rates were lower than those with minimally invasive transforaminal
213 interbody fusion. Phillips et al. demonstrated favorable clinical and radiographic results with LLIF and that
214 the complication rate was lower than that reported with traditional surgical reconstruction in patients with
215 degenerative scoliosis [26]. Given that LLIF is performed in the first stage of surgery when using our
216 method, it is probable that good results would be obtained with fewer complications even in planned
217 second-stage surgery.

218 This study has several limitations that stem mainly from its retrospective single-center design, the small
219 number of patients included, and reliance on data from medical charts. Furthermore, only historical controls
220 were available for comparison. However, there was no difference in patient demographics, comorbidities,
221 spinopelvic parameters, or PROMs scores between our study groups. Further prospective multicenter
222 studies are necessary to clarify the effect of staged surgery in patients with ASD.

223 In conclusion, the complications of planned two-stage surgery including LLIF and posterior corrective
224 fusion, were similar to those of conventional posterior-only single-stage surgery. Although there was no
225 significant between-group difference in background factors, spinopelvic parameters, or PROMs scores
226 before surgery, the incidence of complications was significantly lower among patients who could start
227 ambulating on the day after surgery. Operative procedures and implementing measures to mobilize as soon
228 as possible after the first surgery seem to be important in patients with ASD in whom second-stage surgery
229 is planned.

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327 **FIGURE LEGENDS**

328

329 **Fig. 1** Number of patients enrolled in the study. One hundred and fifteen patients were excluded because of
330 adolescent idiopathic scoliosis (n=9), Parkinson's disease (n=35), congenital disease (n=1), pyogenic disease
331 (n=6), an iatrogenic condition (n=20), scoliosis with a Cobb angle $<20^\circ$ (n=55), or loss to follow-up (n=7).

332

333 **Fig. 2** Whole spine radiographs for a representative case of two-stage surgery. (a) Before surgery, (b)
334 immediately after initial surgery, (c) 2 weeks after the second surgery, and (d) 2 years after surgery

335

336 **Fig. 3** Whole spine radiographs for a representative case of control. (a) Before surgery, (b) 2 weeks after the
337 surgery, and (c) 2 years after surgery

338

339

Table 1. Demographics of control and two-stage group

	Control	Two-stage	p value
N	63	75	
Demographics			
Age (years)	69.5 ± 7.3	70.2 ± 6.8	0.582
Sex (Woman/Man)	54/9	65/10	-
Height (cm)	149.0 ± 6.9	149.9 ± 8.3	0.514
Weight (kg)	49.1 ± 9.7	51.7 ± 9.9	0.129
BMI (kg/cm ²)	22.0 ± 3.3	23.0 ± 3.8	0.112
ASA-PS (stage1/2/3)	6/52/5	8/64/3	0.474
Alcohol drinking	10 (15.9%)	16 (21.3%)	0.514
Smoking	8 (12.7%)	4 (5.3%)	0.142
Co-morbidities			
Hypertension	30 (47.6%)	38 (50.7%)	0.736
Diabetes mellitus	11 (17.5%)	7 (9.3%)	0.206
Renal failure	4 (6.3%)	6 (9.0%)	0.755
Respiratory	9 (14.3%)	5 (6.6%)	0.14
Cardiovascular	12 (19.0%)	3 (4.0%)	*0.004
Collagen disease	3 (4.8%)	4 (5.3%)	1
At least one co-morbidity	46 (73.0%)	64 (85.3%)	0.09
Medicines			
Steroid drug	3 (4.8%)	4 (5.3%)	1
Anticoagulant or Antiplatelet	7 (11.1%)	7 (9.3%)	0.782
Immunosuppressant	1 (1.6%)	3 (4.0%)	0.625

Data are presented as mean value ± standard deviation or number (percent).

BMI, body mass index; ASA-PS, American Society of Anesthesiologists physical status;

*Statistically significant

Table 2. Surgical parameters

		Control	Two-stage	p value
N		63	75	
Operation time (min)	1st		132.9 ± 35.2	
	2nd		301.1 ± 74.0	
	Total	392.0 ± 68.7	434.0 ± 78.6	*0.001
Intraoperative bleeding (ml)	1st		70.6 ± 113.1	
	2nd		885.5 ± 543.5	
	Total	1816.8 ± 1203.8	956.1 ± 594.8	*<0.001
Over 3000ml bleeding		7 (11.1%)	1 (1.3%)	*0.023
3-CO		7	0	*<0.001
LLIF		0	75	*<0.001
Fusion segment		8.0 ± 1.9	8.4 ± 2.5	0.333
LLIF segment		0	2.5 (1-4)	
PLIF segment		3.3 (0-5)	1.2 (0-2)	

Data are presented as mean value ± standard deviation or number (percent) or mean value (min-max).
 3-CO, 3-column osteotomy; LLIF, lateral lumbar interbody fusion; PLIF, posterior lumbar interbody fusion

*Statistically significant

Table 3. Perioperative complications

	Control	Two-stage	p-value
N	63	75	
Perioperative Complications			
Delirium	10 (15.9%)	11 (14.7%)	1
SSI	7 (11.1%)	4 (5.3%)	0.345
SSI (deep)	4 (6.3%)	0	*0.041
DVT/PE	1 (1.6%)	3 (4.0%)	0.625
Cardiovascular	0	1 (1.3%)	1
Respiratory	0	2 (2.7%)	0.5
Digestive	3 (4.8%)	3 (4.0%)	1
Urinary	4 (6.3%)	3 (4.0%)	1
Others	3 (4.8%)	3 (3.9%)	702
At least 1 complication	26 (41.3%)	29 (38.7%)	0.862
Neurological	6 (9.5%)	12 (15.6%)	0.321
Reoperation within 3M	8 (12.7%)	3 (4.0%)	0.111

Data are presented as mean value \pm standard deviation or number (percent) of cases.

SSI, surgical site infection; DVT/PE, deep vein thrombosis / pulmonary embolism; M, months

*Statistically significant

Table 4. Perioperative complications in early and late ambulation groups

	Ambulation Day1	Ambulation Day2 or more	p-value
N	45	30	
Perioperative Complications			
Delirium	5 (11.1%)	6 (20.0%)	0.330
SSI	2 (4.4%)	2 (6.7%)	1
DVT/PE	1 (2.2%)	2 (6.7%)	0.560
Cardiovascular	1 (2.2%)	0	1
Respiratory	2 (4.4%)	0	0.514
Digestive	0	3 (10.0%)	0.060
Urinary	1 (2.2%)	3 (10.0%)	0.295
Others	5 (11.1%)	1 (3.3%)	0.392
Neurological	6 (13.3%)	6 (20.0%)	0.321
Total	17 (37.8%)	19 (63.3%)	*0.036
Reoperation within 3 months	2 (4.4%)	1 (3.3%)	1

There is duplication.

Data are presented as mean value \pm standard deviation or number (percent) of cases.

SSI, surgical site infection; DVT/PE, deep vein thrombosis / pulmonary embolism; M, months

*Statistically significant

Table 5. Spino-pelvic parameters and PROMs

Spino-pelvic parameters	Control	Two-stage	
Pre Operaton			
LL (°)	12.1± 21.4	13.2 ± 14.2	0.736
TK (°)	21.1 ± 16.3	22.5 ± 15.3	0.599
PT (°)	34.4 ± 11.3	34.4 ± 9.3	0.991
PI (°)	51.5 ± 11.6	51.0 ± 11.7	0.796
PI-LL (°)	39.4 ± 20.5	37.9 ± 18.6	0.629
SVA (mm)	105.5 ± 70.4	107.7 ± 58.1	0.84
TPA (°)	36.6 ± 15.0	36.8 ± 12.6	0.902
Cobb (°)	32.9 ± 22.0	36.2 ± 15.5	0.314
Post Operation			
LL (°)	38.4 ± 13.8	46.9 ± 11.5	*<0.001
TK (°)	32.5 ± 13.2	35.4 ± 11.1	0.164
PT (°)	22.7 ± 9.5	19.9 ± 9.0	0.091
PI (°)	50.5 ± 114	51.7 ± 10.7	0.552
PI-LL (°)	12.4 ± 14.5	4.7 ± 12.0	*0.001
SVA (mm)	52.5 ± 50.8	33.4 ± 41.7	*0.018
TPA (°)	21.6± 9.9	17.2 ± 8.4	*0.006
Cobb (°)	11.0 ± 9.4	11.4 ± 7.3	0.745
PROMs			
Pre Operaton			
ODI (%)	47.2 ± 16.7	43.5 ± 15.8	0.191
Function	2.58 ± 0.85	2.62 ± 0.68	0.778
Pain	2.75 ± 0.77	2.95± 0.82	0.145
SRS-22r Mental Health	2.50 ± 0.98	2.66 ± 0.79	0.319
Self-Image	2.17 ± 0.82	2.06 ± 0.65	0.364
Sub Total	2.49 ± 0.69	2.56 ± 0.53	0.511
2 Years Post Operation			
ODI (%)	36.2 ± 18.9	25.2 ± 19.6	*0.002
SRS-22r Function	3.04 ± 0.89	3.35 ± 0.78	*0.037

Pain	3.56 ± 0.94	3.98 ± 0.82	*0.009
Mental Health	3.11 ± 0.94	3.48 ± 0.98	*0.033
Self-Image	3.17 ± 0.79	3.40 ± 0.75	0.097
Satisfaction	3.42 ± 0.96	3.61 ± 0.84	0.239
Total	3.24 ± 0.71	3.55 ± 0.71	*0.015

Data are presented as mean value ± standard deviation.

LL, lumbar lordosis; TK, thoracic kyphosis; PI, pelvic incidence; PT, pelvic tilt; SVA, sagittal vertical axis; TPA, T1 pelvic angle; PROMs, patient report outcome measurements; ODI, Oswestry disability index; SRS, scoliosis research society

*Statistically significant

Table 6. Radiographic parameters of 65 patients in two-stage group

	Pre Operation	After LLIF	Post Operation
LL (°)	13.3 ± 13.7	22.1 ± 13.7	45.7 ± 11.5
TK (°)	23.2 ± 15.6	23.5 ± 14.3	35.2 ± 11.6
PT (°)	34.4 ± 9.7	28.3 ± 10.4	20.6 ± 9.5
PI (°)	50.6 ± 12.2	47.3 ± 10.3	51.7 ± 10.6
PI-LL (°)	37.2 ± 16.7	25.2 ± 13.7	6.0 ± 12.8
SVA (mm)	102.6 ± 57.0	69.5 ± 45.7	34.5 ± 44.0
Cobb (°)	35.9 ± 15.4	29.2 ± 13.6	11.3 ± 7.2

Data are presented as mean value ± standard deviation.

LLIF, lateral lumbar interbody fusion; LL, lumbar lordosis; TK, thoracic kyphosis; PI, pelvic incidence; PT, pelvic tilt; SVA, sagittal vertical axis

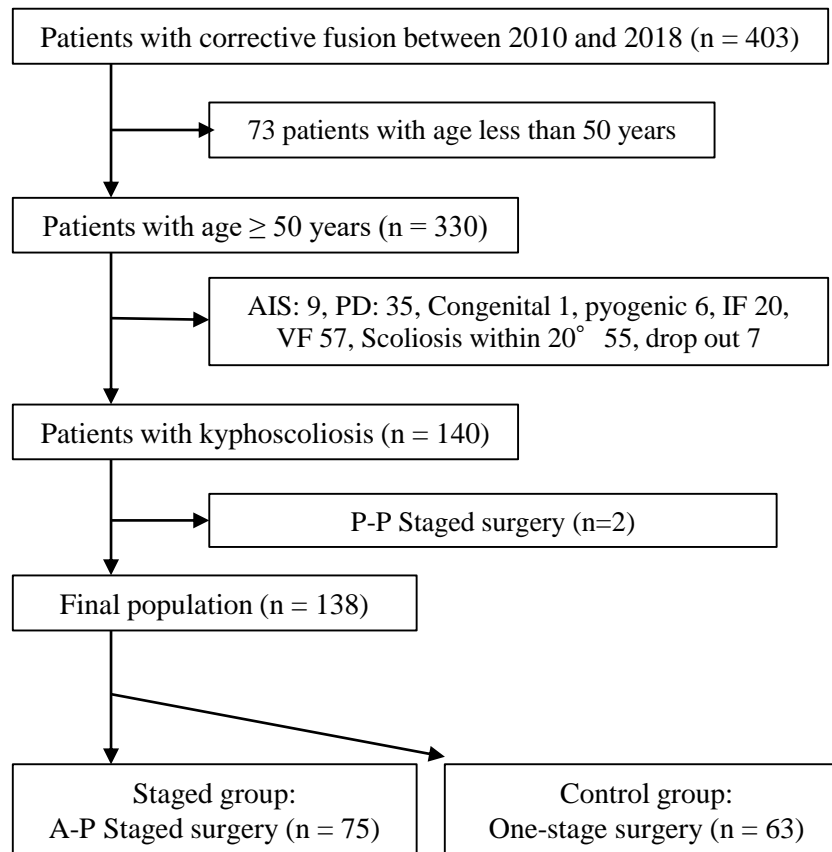


Figure 1



Figure 2a



Figure 2b

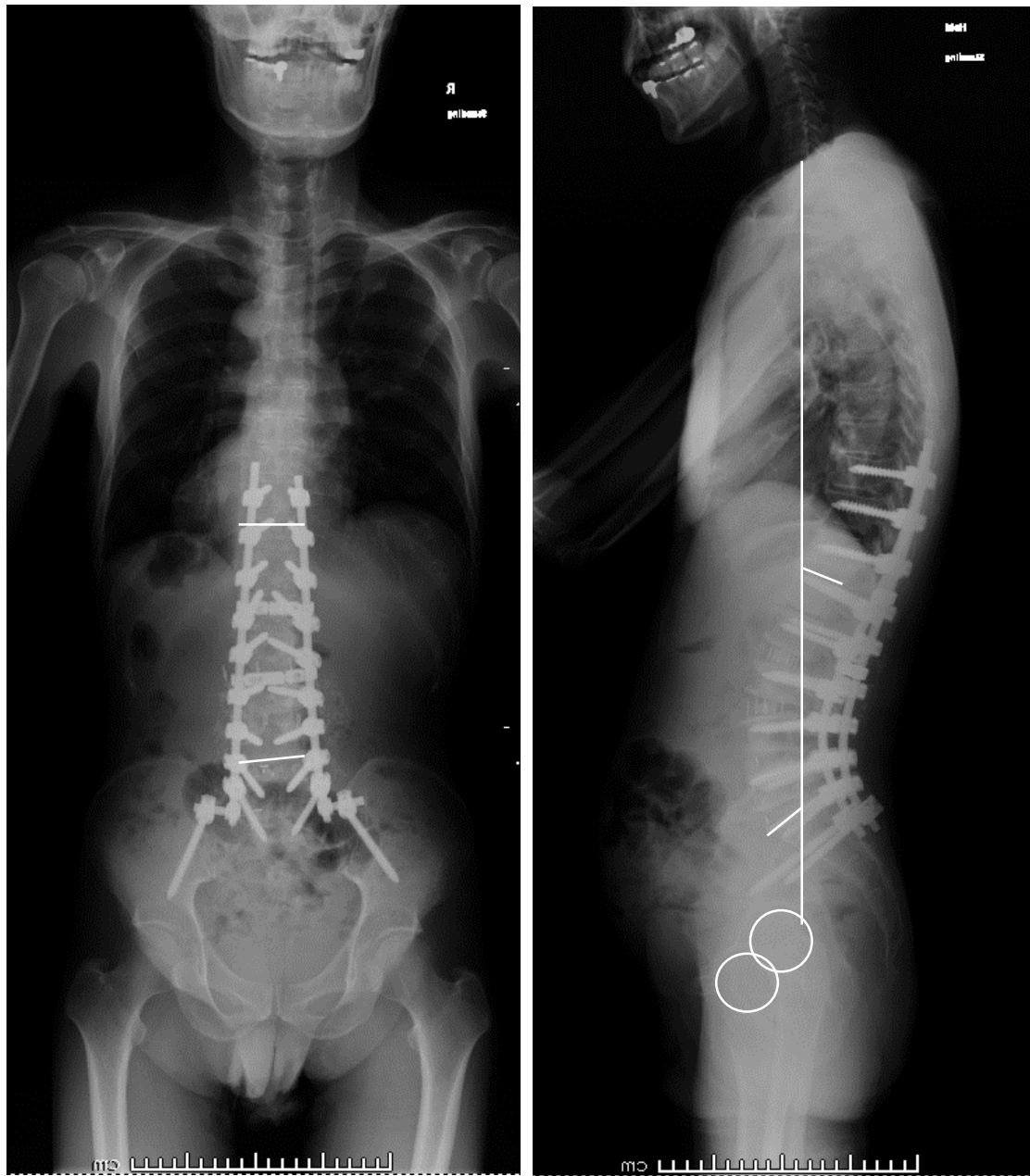


Figure 2c

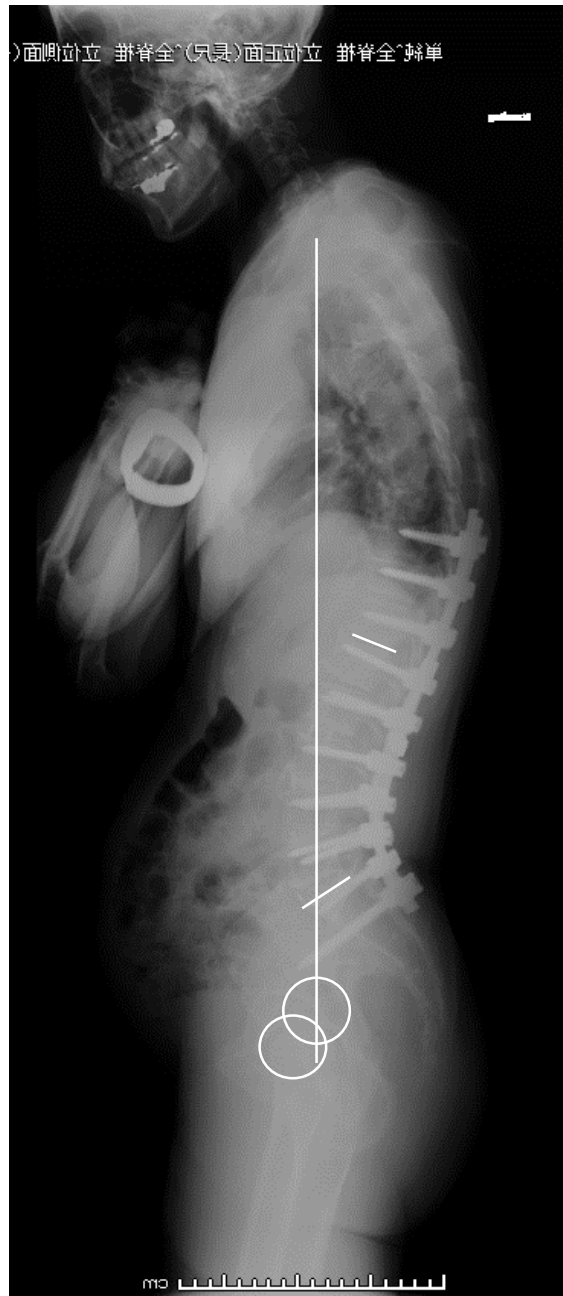
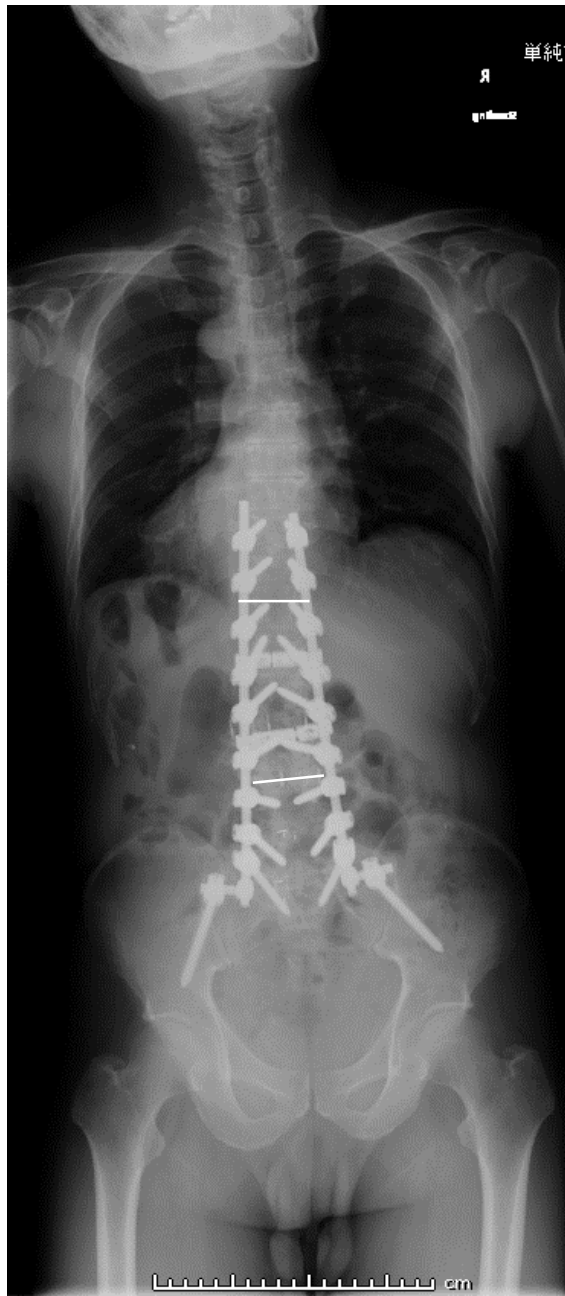


Figure 2d

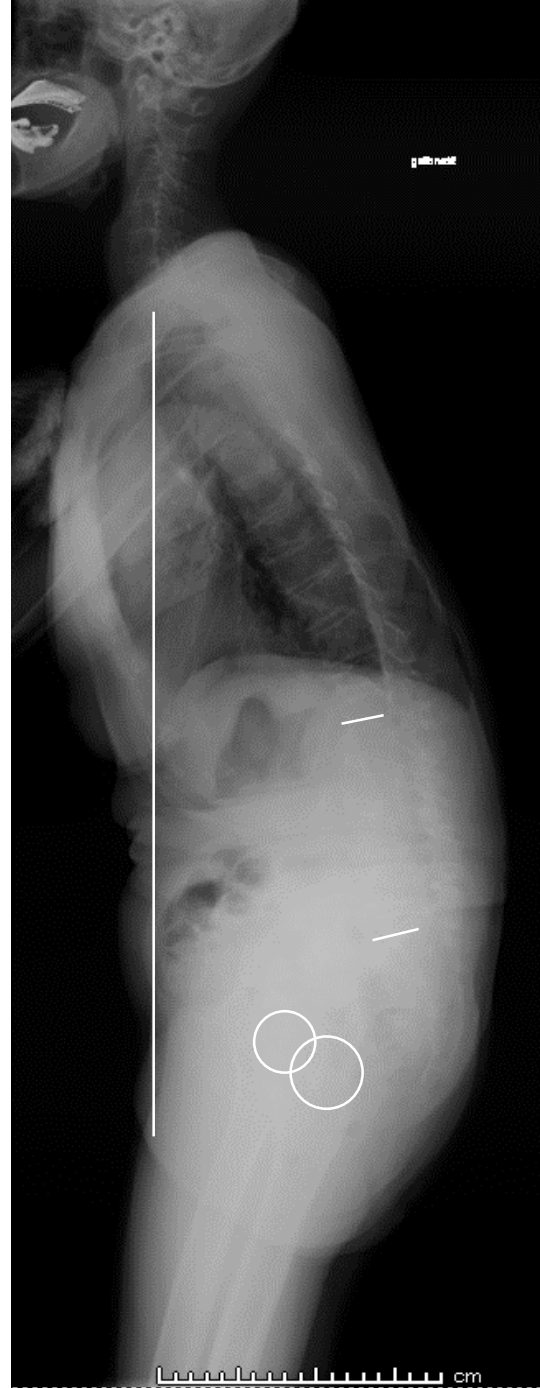
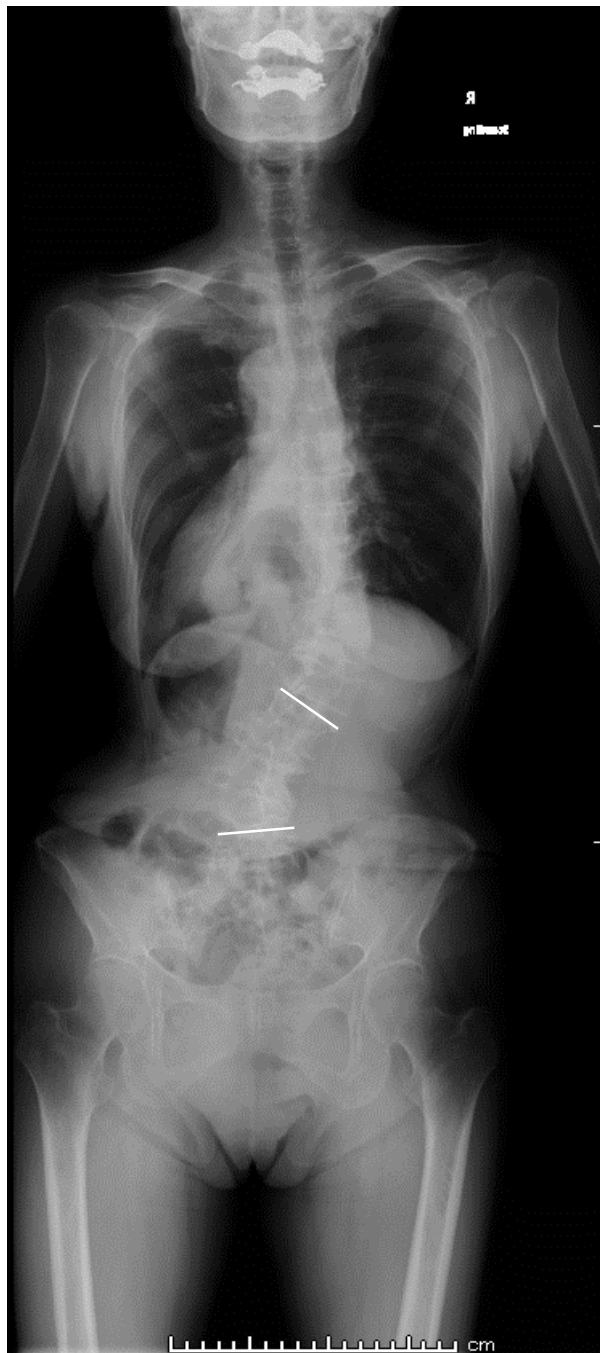


Figure 3a

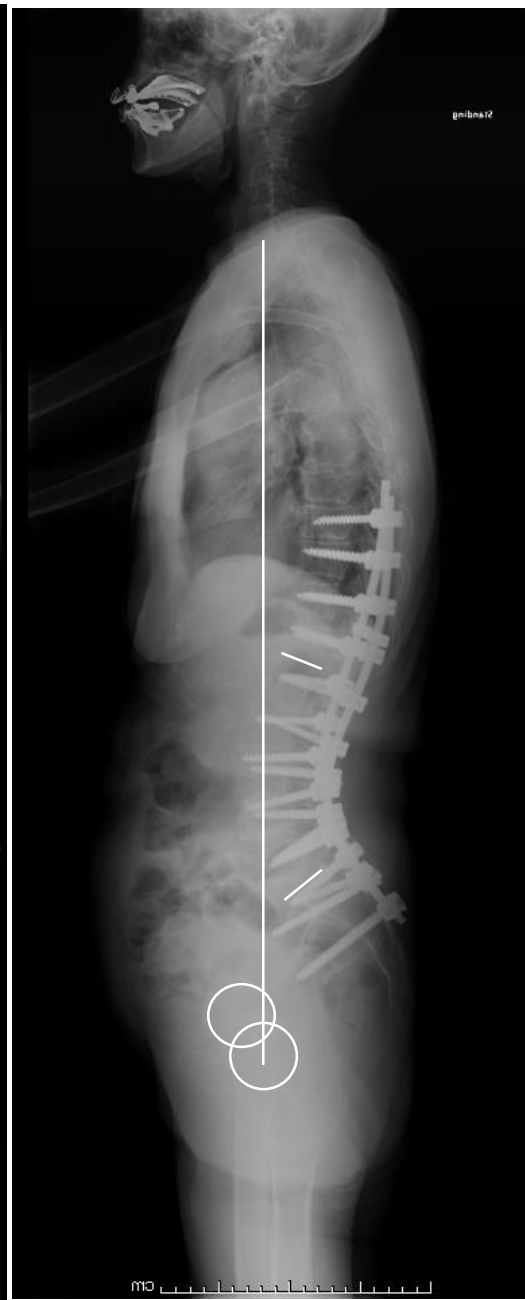


Figure 3b



Figure 3c