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

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Abstract

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

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

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

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

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

INTRODUCTION

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

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

MATERIALS AND METHODS

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

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

Surgical procedures

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

Statistical analysis

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

RESULTS

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

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

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

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

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

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

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

Representative cases

A two-stage case

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

A control case

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

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

DISCUSSION

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

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

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

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

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

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

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

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

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FIGURE LEGENDS

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

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

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

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 ± 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 ± 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

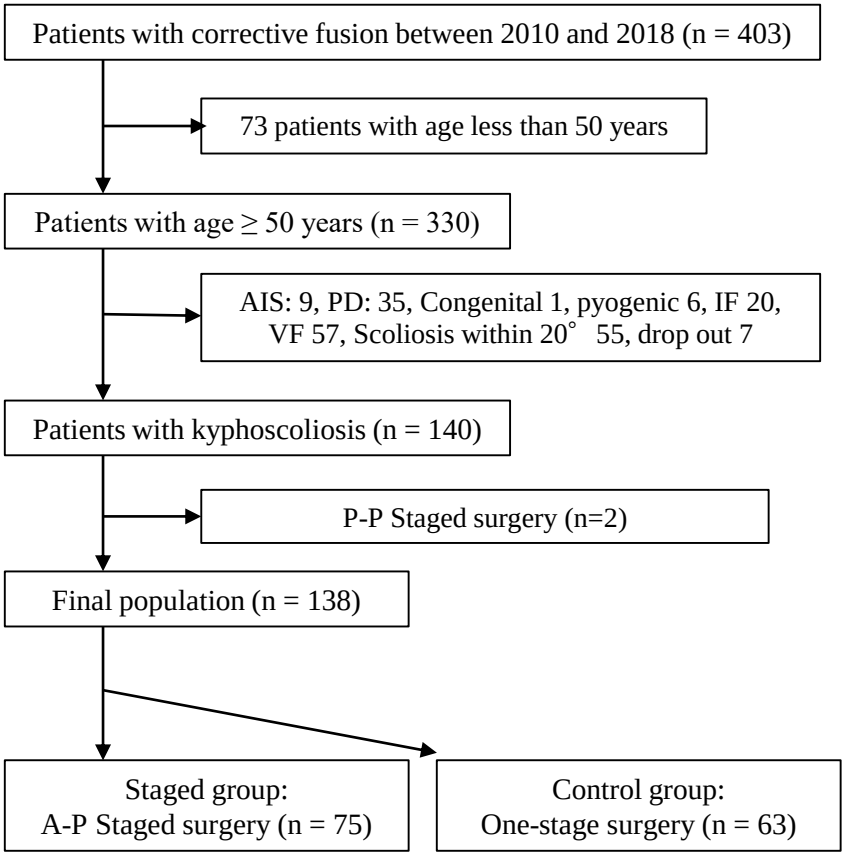

Patients with corrective fusion between 2010 and 2018 (n = 403)
73 patients with age less than 50 years
Patients with age ≥ 50 years (n = 330)
AIS: 9, PD: 35, Congenital 1, pyogenic 6, IF 20,
VF 57, Scoliosis within 20° 55, drop out 7
Patients with kyphoscoliosis (n = 140)
P-P Staged surgery (n=2)
Final population (n = 138)
Staged group:
A-P Staged surgery (n = 75)
Control group:
One-stage surgery (n = 63)

Figure 1

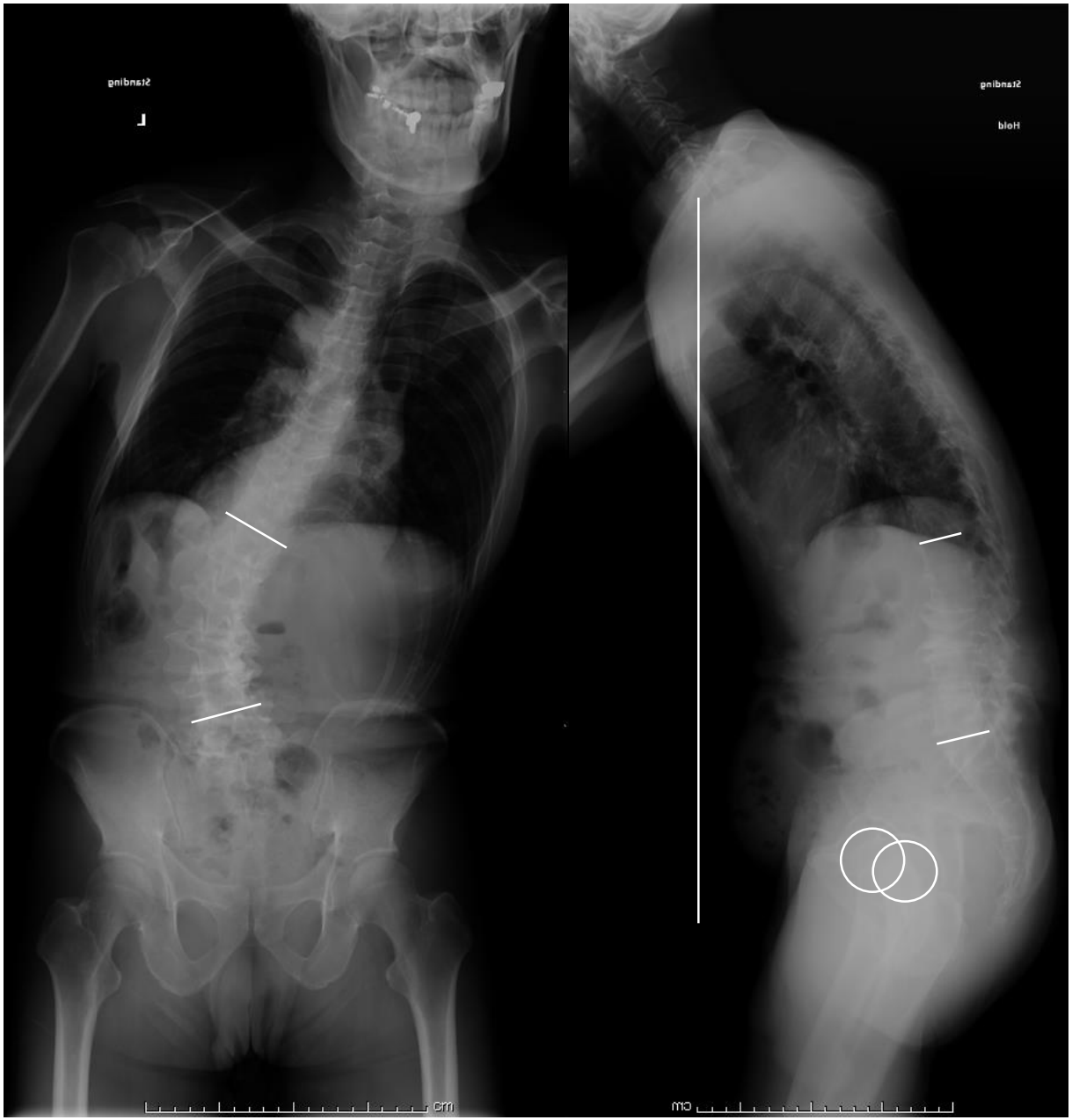


Figure 2a

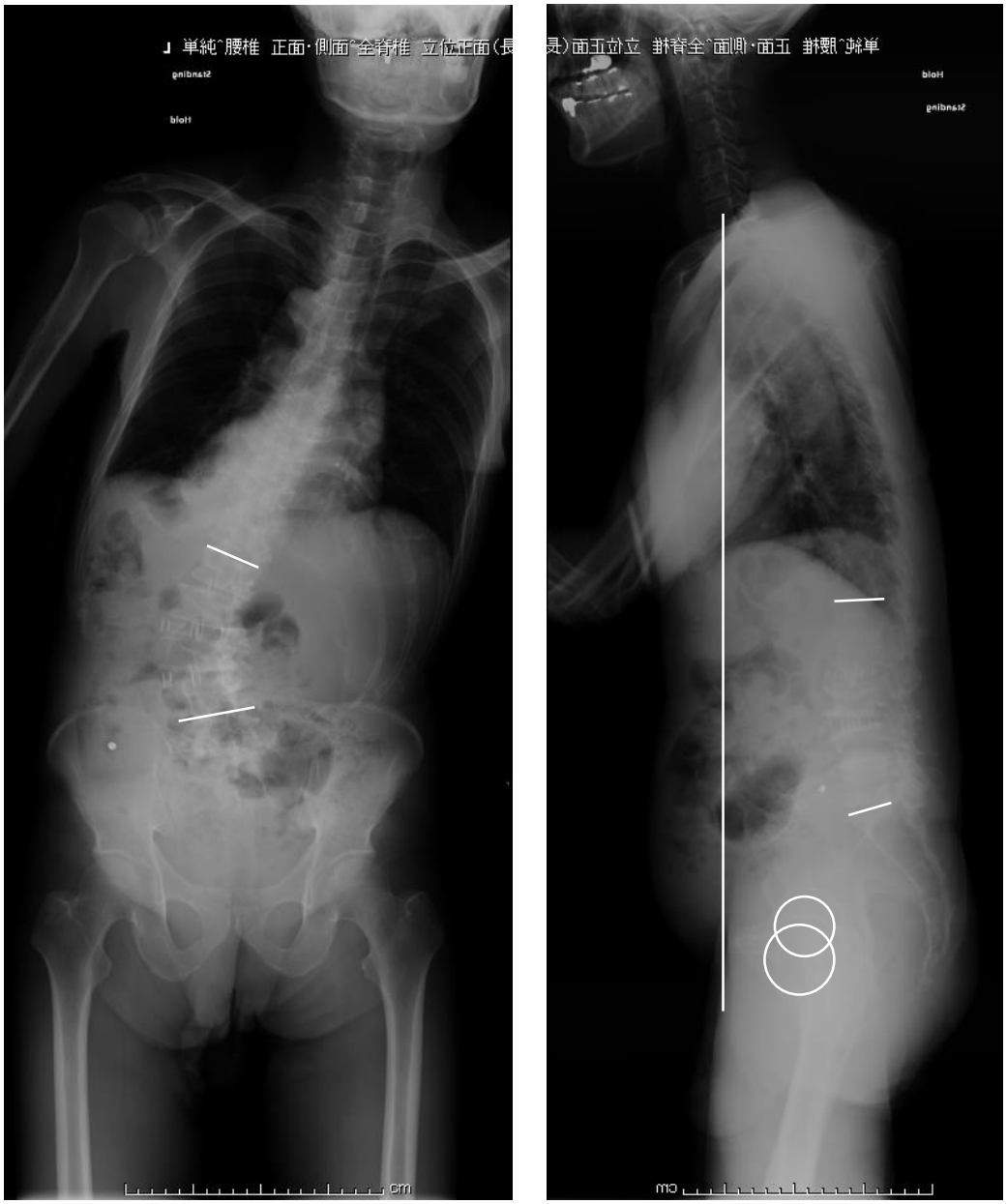


Figure 2b

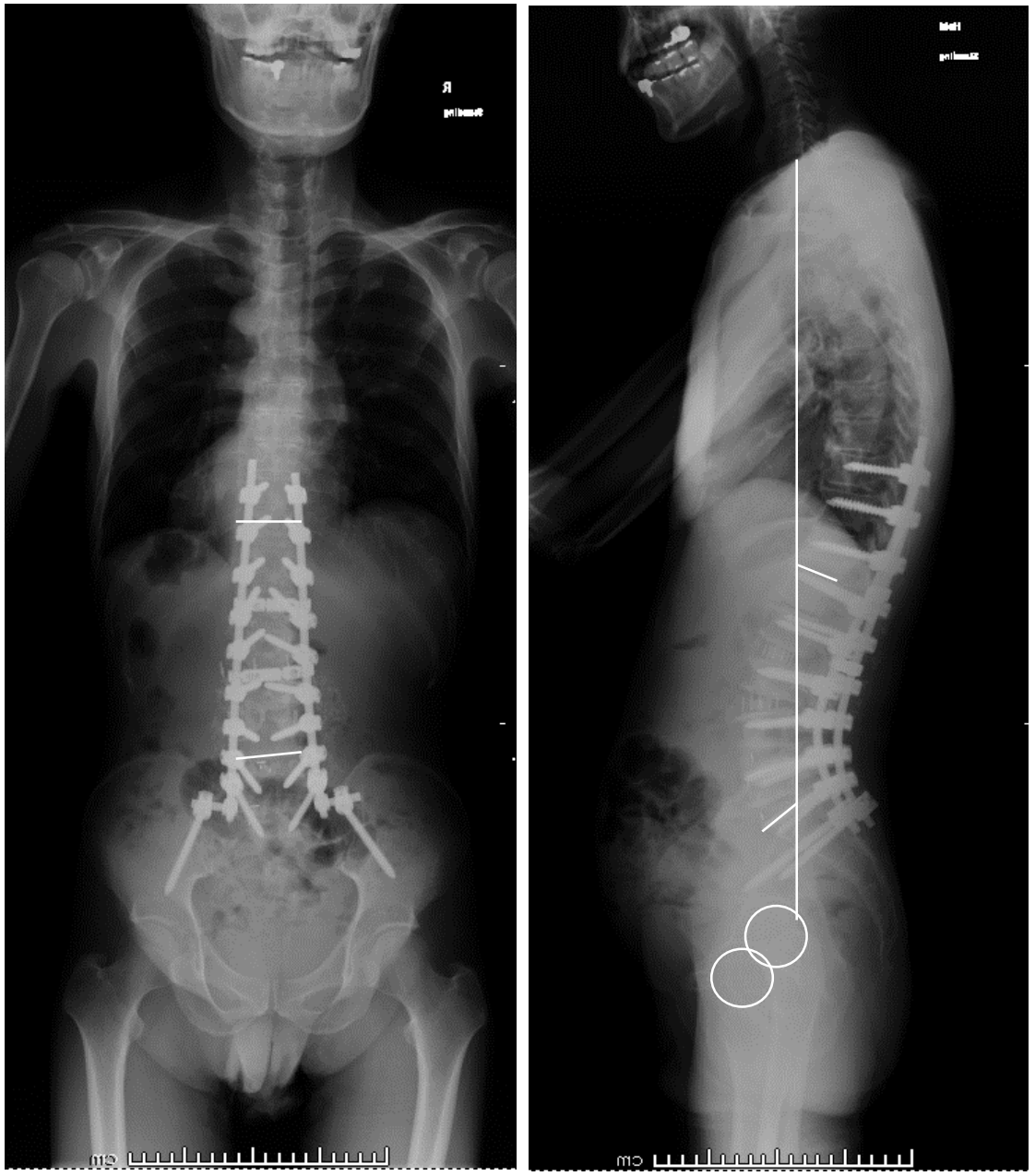


Figure 2c

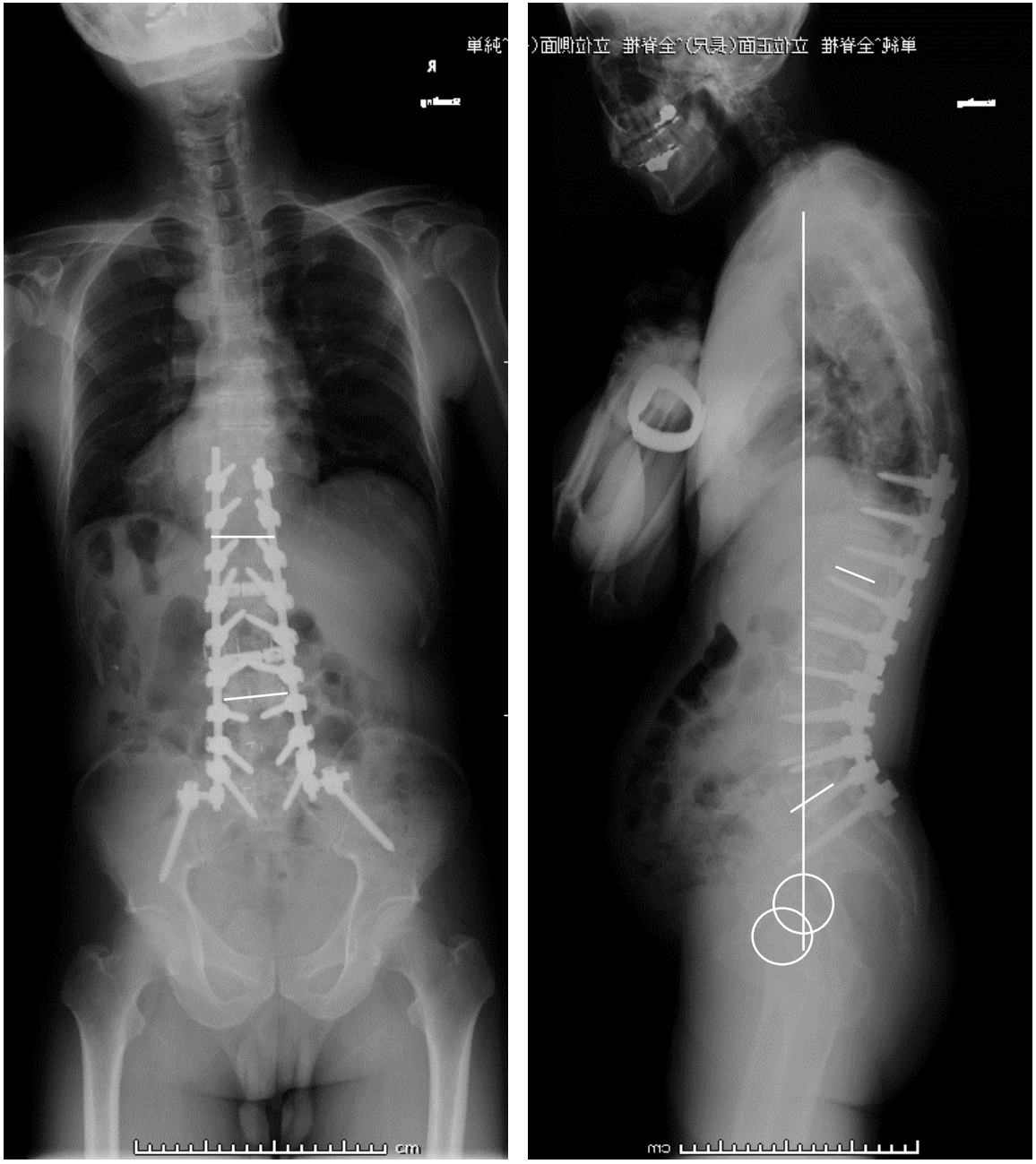
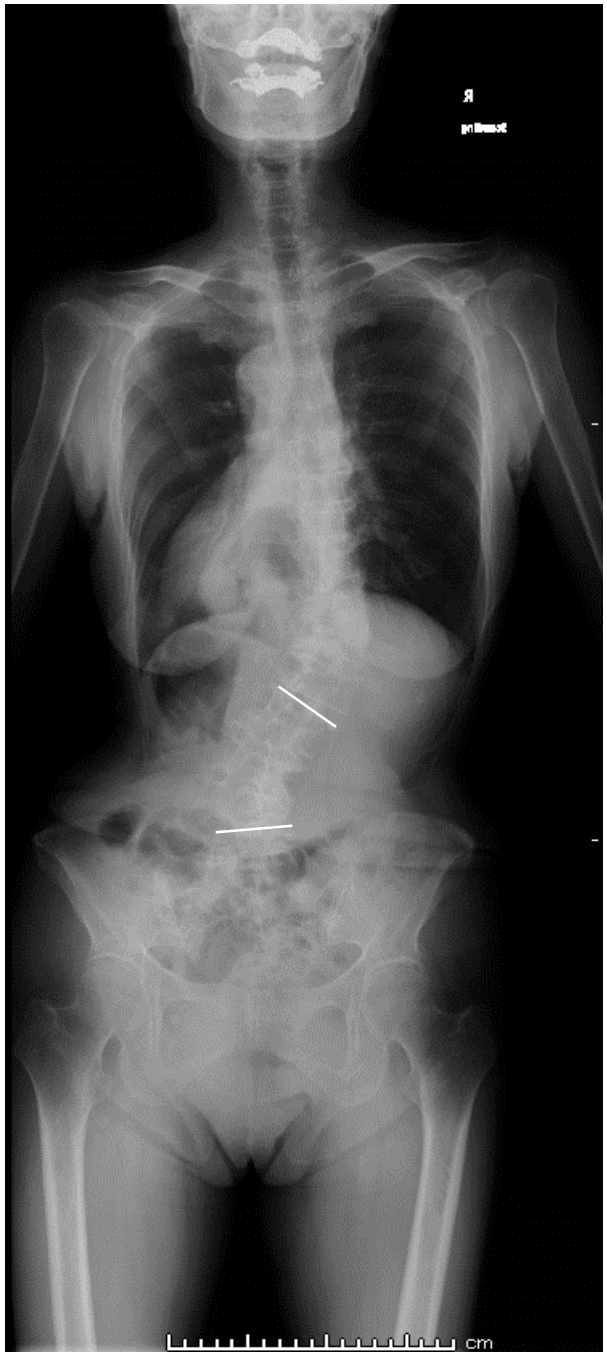


Figure 2d



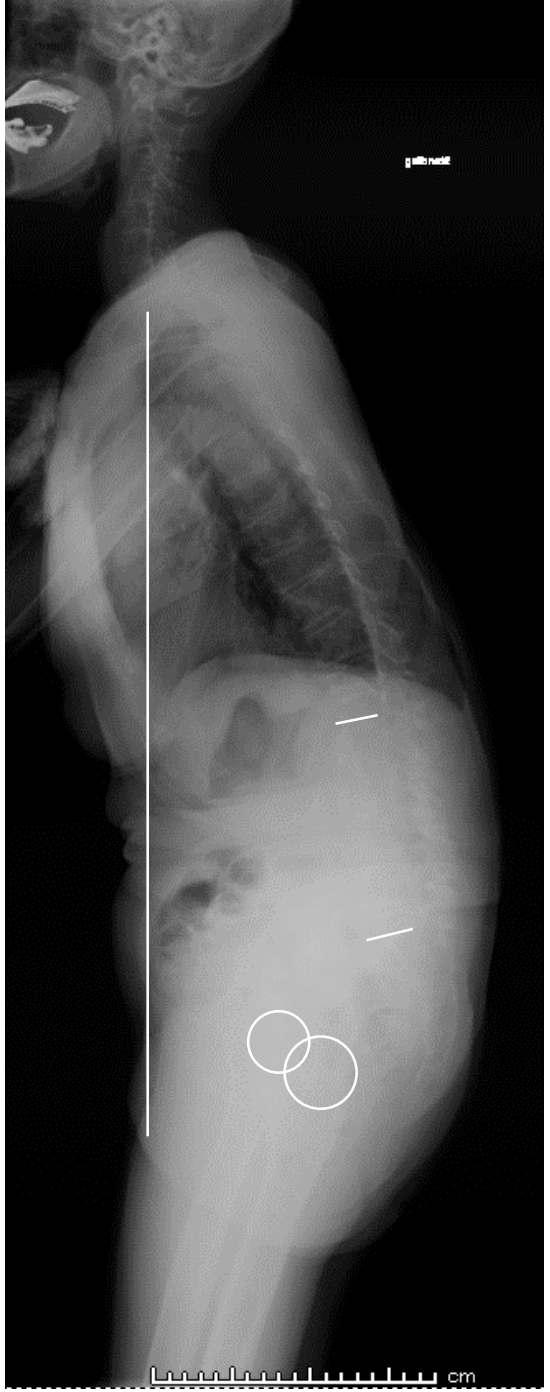


Figure 3a

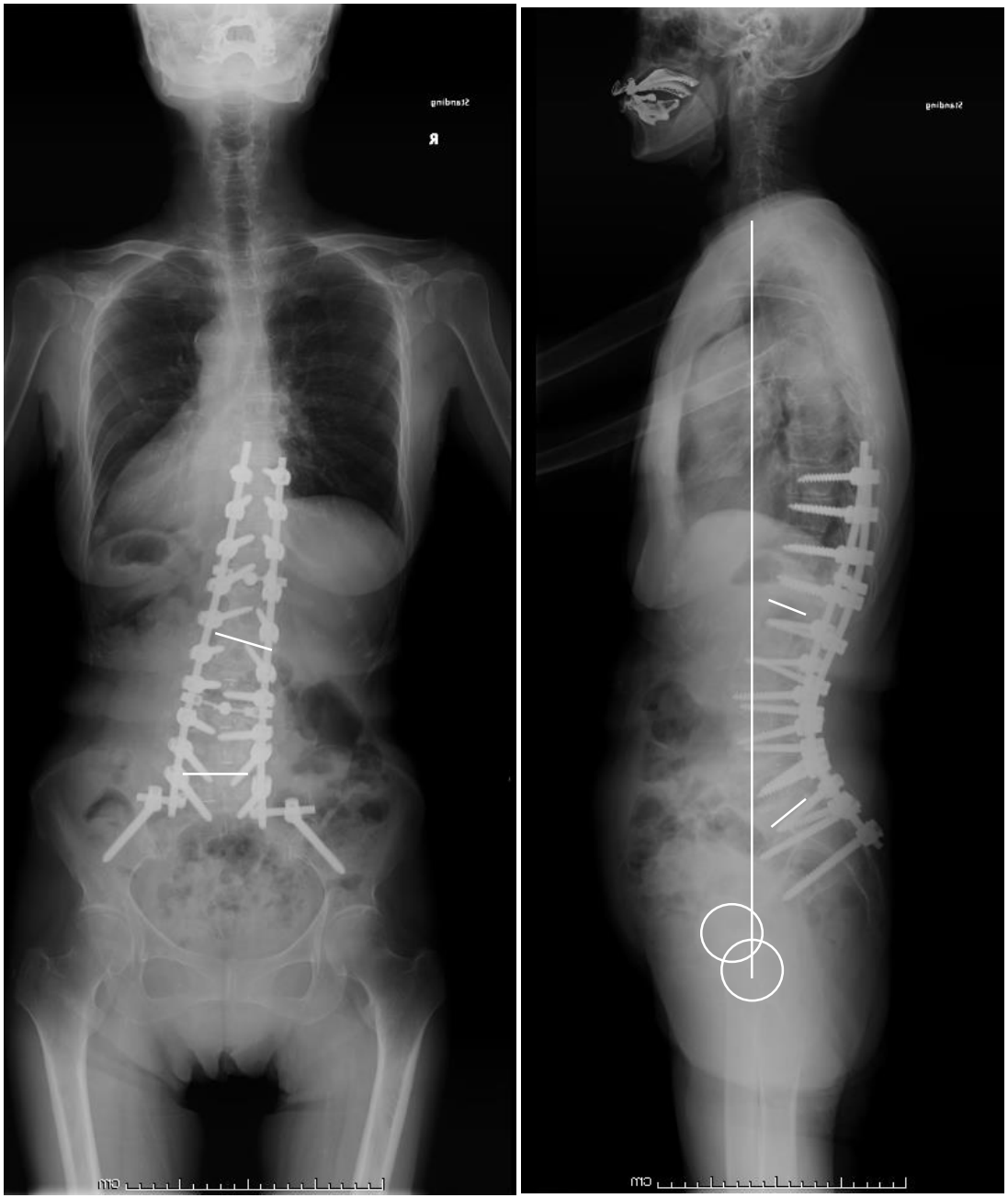


Figure 3b

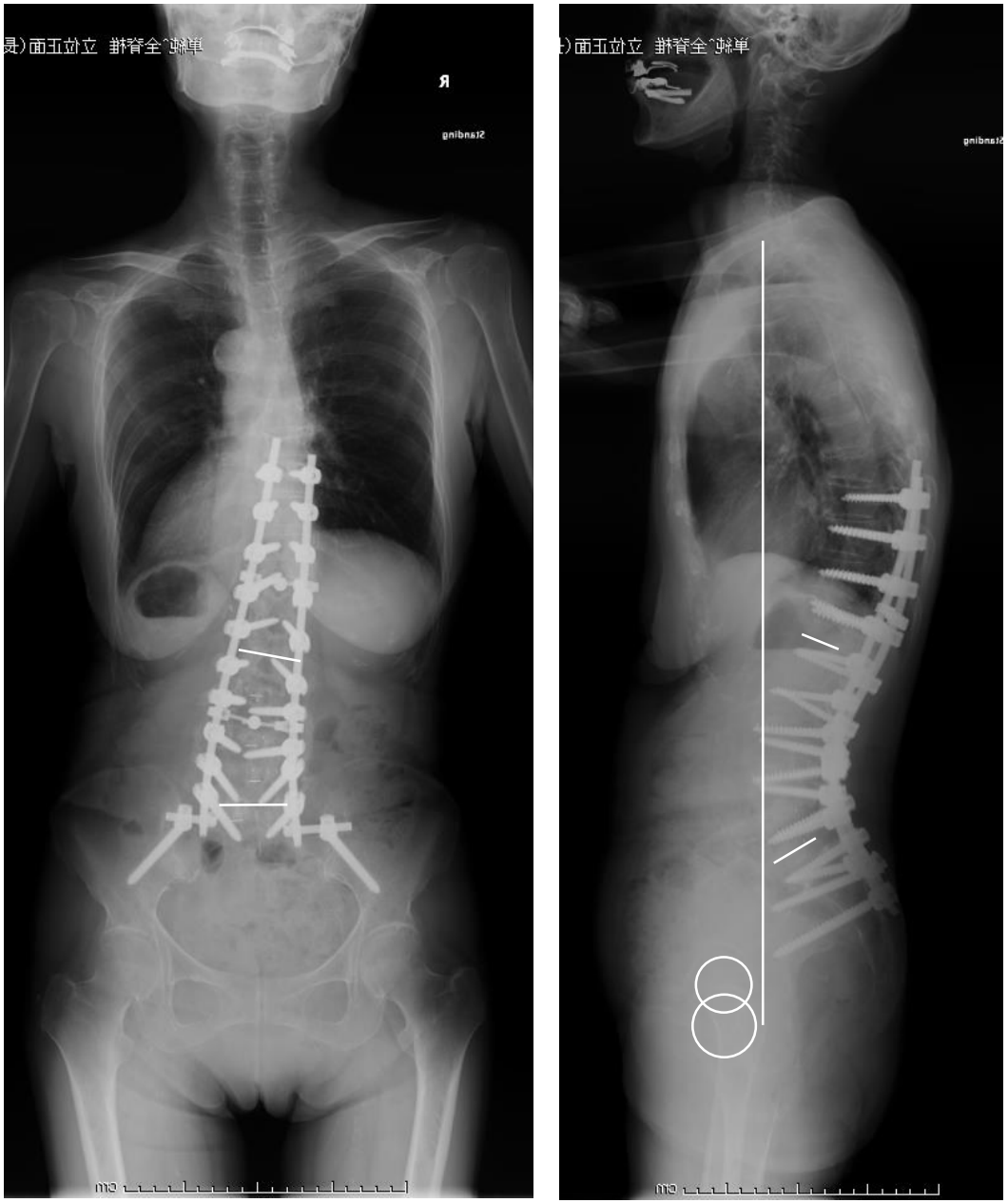


Figure 3c