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Treatment of Severe Kyphotic Deformity Secondary to Ankylosing Spondylitis by Staged Osteotomy in Lateral Decubitus Position: A Retrospective Study

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Research Article

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Abstract

Background: Patients are often complicated with severe kyphotic deformity (Cobb>100 °) in the advanced stage of ankylosing spondylitis (AS). Corrective osteotomy based on prone position seems to be the only effective treatment. Sometimes, it is difficult to place AS patients with severe kyphosis in a prone position even with a specially prepared folding bed.

Methods: 23 patients who underwent staged osteotomy in lateral position from October 2015 to June 2017 were analyzed. All but one patient underwent a single-level Ponte osteotomy in the first stage surgery; pedicle subtraction osteotomy was then carried out in the second stage surgery. The average follow-up was 30.8±4.6 months. The global kyphosis (GK), thoracic kyphosis (TK), lumbar lordosis (LL), the sagittal vertical axis (SVA), the osteotomized vertebra intervertebral angle (OVI), Chin-brow vertical angle (CBVA), the Oswestry Disability Index (ODI) score and the Scoliosis Research Society-22 Patient Questionnaire (SRS-22), were compared pre-and post-operation.

Results All kyphosis parameters were significantly improved (all P< 0.05). The GK was corrected from 115.0± 13.4 ° to 46.5 ± 9.0 ° postoperatively, with a mean correction of 68.5 °. The SVA was improved from 21.2 ± 5.1 cm to 5.1 ± 1.8 cm postoperatively. The CBVA was corrected from 64.1±23.2 ° to 5.7±10.6 ° postoperatively; The OVI was corrected from 9.0±2.7 ° to -20.1±5.6 ° postoperatively. There were significant improvements in the ODI and SRS-22 (all P< 0.05). 4 mild complications were observed perioperatively.

Conclusion Satisfactory correction is safely achieved by staged osteotomy in lateral decubitus position in AS patients with severe kyphosis, which can not only correct the sagittal imbalance of the spine with acceptable complications but also facilitate the placement of intraoperative position.

Background

Ankylosing spondylitis (AS) is a chronic non-specific inflammatory disease involving fibro-osseous tissues. [1, 2] Patients with advanced AS often suffer from severe rigid thoracolumbar kyphosis (Cobb>100°), leading to sagittal-plane imbalance, abnormal appearance, and impairment of horizontal visual field. In severe cases, the cardiopulmonary and digestive functions are also compromised because of compression of the thoracic and abdominal viscera. [3–6] Corrective osteotomy is the only effective treatment for AS patients with kyphosis. Several osteotomies have been reported for correction of kyphosis: Smith-Peterson osteotomy (SPO), Ponte osteotomy (PO), pedicle subtraction osteotomy (PSO), and vertebral column resection (VCR). [7–9] The above-mentioned osteotomies are all based on the prone position; however, it is difficult to place AS patients with severe kyphosis in the prone position even with a specially prepared folding bed. One-stage two-level PSO is reported to be an effective treatment for such patients. However, this procedure is technically demanding for surgeons and anesthetists, which might result in more intraoperative bleeding and a higher incidence of neurological complications. [10–12] In order to reduce the technical difficulty of correcting severe kyphosis in AS patients, and to solve the

problem of setting intraoperative position. For the first time, we have proposed the treatment of severe kyphotic deformity secondary to ankylosing spondylitis by staged osteotomy in lateral decubitus position.

Therefore, the objective of this study was to evaluate the clinical efficacy and safety of staged osteotomy in lateral decubitus position in the treatment of AS-related severe kyphosis with a minimum of 2 years follow-up.

Methods

Patients

A retrospective analysis of AS patients with severe kyphotic deformity, who underwent a single-level Ponte osteotomy in lateral position in the first-stage surgery and PSO in the second-stage from October 2015 to June 2017, was carried out. AS was diagnosed according to the modified New York standards proposed in 1984. [13] Indications for corrective surgery included: severe kyphotic appearance, inability to forward gaze, restricted daily life, and impairment of cardiopulmonary function. The inclusion criteria were as follows: (1) AS patient with the Cobb angle of thoracolumbar kyphosis> 100 °; (2) underwent staged osteotomy in lateral decubitus position; (3) a minimum of 2 years follow-up with complete clinical data; The exclusion criteria:(1) previous history of spinal surgery; (2) a severe concomitant disease, such as spinal tumors or infection. The study was approved by the ethics committee of the Third People's Hospital of Chengdu.

23 patients (20 males and 3 females) were included in the study, with an average age of 43.5±9.5 years old (range,29-67); The endpoint of follow-up was November 2019, and the mean follow-up period was 30.8±4.6 months (range,25-40).

None of the patients had neurological deficits before surgery. According to the 2005 ATS/ERS pulmonary function classification standard [14], all but one patient had impaired lung function. Table 1 summarized the patient characteristics findings in the study.

Radiographic and Clinical Assessment

The patient data of the radiologic and clinical parameters were collected and evaluated preoperatively, postoperatively, and at last follow-up. All radiographic measurements were performed on standing full-length spine lateral radiographs by an independent spine surgeon, which included: (1) global kyphosis (GK): defined as the angle between the maximally tilted upper and lower endplate of vertebral; (2) thoracic kyphosis (TK): the angle between the superior endplate of T5 and the inferior endplate of T12; (3) lumbar lordosis(LL): the angle between the superior endplate of T12 and S1; a positive value of the aforementioned angle indicated kyphosis ;(4) sagittal vertical axis (SVA): defined as the distance between

the C7 plumb line and the posterosuperior corner of S1, if the C7 plumb line was anterior to the posterosuperior corner of S1, the value was positive.[15]

In the first-stage, 22 patients underwent a single-level Ponte osteotomy in the lateral position. The correction results of the first-stage surgery were evaluated by the osteotomized vertebra intervertebral angle (OVI), a positive value indicated kyphosis. (Fig. 1A, B)

Chin-brow vertical angle (CBVA) was measured using standing lateral photographs of the patients, which is defined as the angle between a line from the chin to brow and its plumb line (Fig. 1C).[16]

Clinical efficacy assessments included the Oswestry Disability Index (ODI) score and the Scoliosis Research Society-22 Patient Questionnaire (SRS-22). [17-18]

Surgical technique

(1) First-stage osteotomy in the lateral position, except for one patient who underwent L1 PSO because of extremely severe kyphosis, the others underwent a single-level Ponte osteotomy. After general anesthesia, the patient was positioned laterally on an individualized foam pad, which could well support the patient's head, thorax, hip, and lower limb of the lateral side, and then was fixed with medical tape (Fig. 2A, B). The posterior elements were exposed as far as the transverse process (Fig. 2C). Pedicle screws were implanted bilaterally. Since the screw was implanted in the lateral position, the inherent habit of screw instrumentation in the prone position should be changed. In order to avoid any uncontrolled sagittal translation during osteotomy, a unilateral temporary rod was installed first. The Ponte osteotomy from pedicle to pedicle was then performed.[19] The correction was done by gradually closing the osteotomy gap by slowly pushing the front of the thigh backward and pressing the osteotomy site (Fig. 3).

(2) Second-stage PSO, based on the method of Wang [20], was performed two weeks after the first-stage surgery. All but one patient underwent a second-stage procedure in the prone position. All surgeries were performed by the corresponding author under multimodal neuroelectrophysiology monitoring (Fig. 2 E, F).

Statistical Analysis

Statistical analysis was performed with the use of SPSS 18.0 (SPSS Inc, Chicago, IL, USA). All radiologic and clinical parameters were measured by a senior spinal surgeon who was not involved in the surgery. Each parameter was measured three times and averaged. All measurement data were expressed as mean ±standard deviation (SD). We used the one-way ANOVA analysis to compare the data of GK, TK, LL, OVA, SVA, CBVA, ODI, and SRS-22 score preoperatively, postoperatively, and at the last follow-up. Statistical significance was indicated at $P<0.05$.

Results

Surgical Results

All patients showed significant improvement of stooped and downward-looking posture after surgery. Table 2 summarized the surgical characteristics findings. The average operation interval between primary and secondary surgery was (23.5 ± 6.8) days.

In the first-stage surgery, the PO level: L3-4 in16 cases (72.7%) (Table 2). The average surgical time was (207±34) minutes, and the blood loss was (773±247) ml (Table 3).

In the second-stage PSO procedure, the average surgical time was (244 ± 45) minutes, and the blood loss was (1189 ± 434) mL (Table 3); PSO level: 15 cases (68.2%) L1. 4 cases with the pseudarthrosis underwent PSO through pseudarthrosis. One case with the pseudarthrosis at L3/4 level underwent PSO above the pseudarthrosis. Final fusion segments: T9-L5 and T9-S1 were the most common fusion with 7 cases each. In our study, the instrumentation range was usually 4 levels above and 3 levels below the osteotomy vertebra (56.5%).

Radiologic and Chin Brow–Vertical Angle Results

After surgery, all kyphosis parameters were significantly improved, substantially restoring the sagittal balance of the spine (all $P < 0.05$). No patient showed loss of correction at the last follow-up (all P□0.05) (Table 4). The GK was (115.0 ± 13.4) ° before surgery, which was corrected to (46.5 ± 9.0) ° postoperatively, and (47.5 ± 8.8) ° at the last follow-up, with a mean correction of 68.5 ° and 67.5 °, respectively. The mean SVA was improved from (21.2 ± 5.1) cm preoperatively to (5.1 ± 1.8) cm postoperatively, with an average correction of 16.1 cm.

The OVI before surgery was (9.0±2.7) °, which significantly corrected to -(20.1±5.6) ° postoperatively, and -(19.6±5.7) ° at the last follow-up (P□0.01), with a mean correction of 29.1 ° and 28.6 °, respectively.

The mean CBVA of the patients before surgery was (64.1±23.2) °, which significantly improved to (5.7±10.6) ° postoperatively, and(6.3±10.7)° at the last follow-up(P□0.01).

Two typical cases were presented in Fig.4 and 5: One is a 39-year male with severe c-shaped thoracolumbar kyphosis, who underwent L3 Ponte osteotomy and L1 PSO in two stages. The GK was corrected from preoperative126 ° to 55 ° at the last follow-up; The other is a 35-year “folded patient” with extremely severe kyphosis and ankylosing of the hip joint, who underwent L1 and L4 PSO in two stages, and the final total hip replacement surgery. The GK was corrected from 158 ° to 62 °.

Clinical Assessment

The average ODI score of the patients before surgery was 34.7±10.1, which was significantly reduced to 15.6±6.6 postoperatively and 15.2±7.0 points at the last follow-up, respectively(P□0.01). (Fig. 6) After

surgery, there were significant improvements in the quality of life of all patients; The four components of SRS-22 were significantly improved postoperatively (all P <0.05). (Table 5).

Complications

No neurological deficit or vascular injury or other severe complications were recorded. Overall, 4 complications were identified in 46 operations in 23 patients (8.7%). In the first-stage surgery, 1 patient occurred a superficial infection and was cured by increasing the frequency of dressing change; the complication incidence was 4.3% (1/23). In the second-stage surgery, 3 patients occurred cerebrospinal fluid leakage after surgery and were managed by prolonged drainage time with a pressure dressing; the complication incidence of the second-stage surgery was 13.0% (3/23).

Discussion

The kyphotic deformity caused by AS can impair the ability to look forward and lie flat, which might compromise cardiopulmonary and digestive function in severe cases. [21, 22] Osteotomy surgery can not only correct the sagittal imbalance of the spine but also improve cardiopulmonary and digestive function. [5, 23, 24] At present, several corrective osteotomies were reported for the treatment of AS-related kyphosis: SPO, PSO, Ponte, and VCR, among which SPO and PSO are the most widely used procedure. SPO is a posterior chevron-shaped osteotomy that obtains 10 ° correction with a single level. [7, 25] Ponte osteotomy and SPO are often mistakenly used in scientific articles. The notable differences between the two osteotomies are in Schwab's Osteotomy Classification and the range of resections. An adequate resection of laminae was required in Ponte osteotomy to correct thoracolumbar kyphosis by substantially shortening the posterior column.[19] PSO is a closing wedge osteotomy without lengthening the anterior column, which will accomplish approximately 30° to 40° correction. [8, 12, 26] Neither single-level osteotomy is sufficient to correct severe thoracolumbar kyphotic deformities. One-stage two-level PSO, which can achieve almost 100° correction,is thought to be an effective treatment of AS-related severe kyphosis. However, such a procedure is technically demanding, and requires longer operating time as well as greater blood loss, which increases surgical difficulty and risk. [27, 28] Therefore, we suggest staged osteotomy surgeries to treat AS-related severe and rigid kyphosis. Zhong et al,[29] reported that the mean blood loss was 2560±1109ml in 10 severe kyphotic AS patients, who were treated with one-stage two-level PSO. Zhang et al,[26] also reported that the mean blood loss was 3311±523ml in 9 severe kyphotic AS patients treated with one-stage procedure. In our study, the total blood loss in staged osteotomies was 1998±613ml, which was less than one-stage two-level PSO. Additionally, patients with severe kyphosis usually cannot tolerate one-stage two-level osteotomies because of poor physical and nutrition conditions. Thus, we believe that staged surgery is a relatively safe way in the treatment of severe kyphosis in AS patients, which reduces the surgical difficulty and risk.

In the first-stage, 22 patients underwent a single-level Ponte osteotomy in the lateral position, which is Grade 2 osteotomy in Schwab's Osteotomy Classification. We performed the Ponte osteotomy from

pedicle to pedicle (Fig. 3), which achieved a mean correction of 29.1 °. The correction is mainly obtained by shortening the posterior column and lengthening the anterior column, which might lead to injury of the major vessels, particularly the abdominal aorta. [30] However, no major vascular injury was recorded in our study. This may be due to the fact that the preoperative CT angiography showed no abdominal aorta calcification in all cases; thus, the elastic aorta could well accommodate to elongation of the spine while the correction procedure. According to our experience, the width of osteotomy is safe within 25mm in Ponte osteotomy.

It is difficult to place AS patients with severe kyphosis in a prone position, which often requires a specially prepared reverse “V” shaped folding bed. In some cases, patients cannot even undergo corrective surgery in a prone position because of the attachment of chest and abdomen. (Fig. 5) Blindness as a complication, possibly caused by local extrusion and ischemic optic neuropathy, was not uncommon during the operation of spinal surgery in the prone position.[31] Qian et al,[32] reported that brachial plexus palsy may occur due to local compression and excessive abduction of the shoulder during the spinal osteotomy in the prone position. In this study, we performed first-stage osteotomy in the lateral position for the first time, which not only solved the problem of setting intraoperative position but also avoided the complications of postoperative blindness and brachial plexus palsy. The complication incidence of the first-stage lateral surgery was 4.3%, which was lower than the average complication rate (13.4%) of osteotomy reported by Qian et al. [33]

In this study, GK, TK, LL, SVA, and CBVA were used to evaluate the sagittal balance of the spine. Our results showed all parameters were significantly improved after surgery and at the last follow-up. Qian et al,[33] explored the feasibility of single-stage skipping two-level PSO in 10 patients with AS-related severe kyphosis (Cobb> 100 °). Their results showed that GK, LL, and SVA were corrected from 113.4 °, 41.9° and 25.2cm preoperatively to 71.6 °, -44.1°and 5.8cm postoperatively respectively. Zhong et al,[29] showed that the kyphosis angle, CBVA and SVA were improved from 92.0°, 37.6° and 24.1cm preoperatively to 30.0°, –0.6°and 7.5cm postoperatively respectively. In our study, the kyphosis angle correction is similar to previous studies, but superior in SVA restoration.

In this study, 23 patients underwent a total of 46 operations in two stages. The complication rate of the first-stage, second-stage, and the total were 4.3%, 13%, and 8.7% respectively. Because of the adhesive lesions between the dura and the ligamentum flavum, facet, or lamina, cerebrospinal fluid leak is the most common complication. [34] Additionally, postoperative blindness and brachial plexus paralysis are avoided due to the lateral position.

Limitations

The present study also has limitations. The sample size was relatively small. Also, retrospective studies suffer from several inherent limitations, such as selection bias and data availability. The sagittal alignment parameters of the spine were evaluated in this study (GK, TK, LL, SVA), however, the

spinopelvic alignment parameters such as pelvic incidence, pelvic tilt, and sacral slope were not fully assessed because of the quality of X-ray imaging.

Conclusion

Satisfactory correction is safely achieved by staged osteotomy in lateral decubitus position in AS patients with severe kyphosis (Cobb > 100°), which can not only correct the sagittal imbalance of the spine with acceptable complications but also facilitate the placement of intraoperative position.

Abbreviations

AS: Ankylosing spondylitis

GK: The global kyphosis

TK: Thoracic kyphosis

LL: Lumbar lordosis

SVA: Sagittal vertical axis

OVI: The osteotomized vertebra intervertebral angle

CBVA: Chin-brow vertical angle

ODI: The Oswestry Disability Index

SRS-22: Score and the Scoliosis Research Society-22 Patient Questionnaire

SPO: Smith-Peterson osteotomy

PO: Ponte osteotomy

PSO: Pedicle subtraction osteotomy

VCR: vertebral column resection

Declarations

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Availability of data and materials

The data and materials contributing to this article may be made available upon request by sending an e-mail to the first author.

Authors’ contributions

RZ, YJL put forward the concept of the study, designed the study, prepared the manuscript. ZJH contributed to the data acquisition and statistical analysis. DZ contributed to the follow-up data acquisition and quality control of data. FW analyzed the image data and interpretation. QHH edited the manuscript and draw the illustrated photo. XDJ wrote original draft. ZZ wrote review &editing. All authors have read and approved the final version of the manuscript.

Ethics approval and consent to participate

The study protocol was approved by the ethics committee of the Third People’s Hospital of Chengdu of Orthopedics. The patients gave their written informed consent for the study.

Consent for publication

The photos of the patient involved in the study were approved by the patient with the written informed consent for e-publication.

Competing interests

The authors declare that they have no competing interests.

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Tables

Table 1

Patient characteristics.

Case	Gender	Age(y)	Apical	Pseudarthrosis	Pulmonary function	Hip function	Follow-up(m)
1	M	42	T12/L1	T12/L1	Severe	Bilateral NR	40
2	F	41	T12	0	Moderate	Right NR	25
3	M	43	T8/9	0	Moderately severe	Left AK	25
4	M	41	L1	0	Very severe	Bilateral NR	33
5	F	67	T12	T12/L1	Very severe	Right NR	28
6	M	33	T12	0	Moderate	Left AK	26
7	M	37	T12/L1	0	Very severe	Bilateral AK	26
8	M	35	T10	T11/T12	Mild	Bilateral AK	32
9	M	48	L1	L3/4	Moderate	Right NR	32
10	M	33	T12/L1	0	Moderate	Right NR	36
11	M	51	T10/T11	0	Moderate	Bilateral NR	32
12	M	44	T12	T12/L1	Moderate	Bilateral NR	31
13	M	40	L2	0	Moderate	Bilateral NR	40
14	M	29	T11	0	Moderate	Normal	29
15	M	39	T12	0	Mild	Bilateral NR	30
16	M	55	T12	0	Severe	Bilateral AK	26
17	F	58	T11/12	0	Mild	Bilateral NR	32
18	M	40	T11/12	0	Normal	Bilateral NR	34
19	M	37	T10/T11	0	Moderate	Bilateral NR	38
20	M	45	T12	0	Severe	Right NR	25
21	M	33	T12	0	Moderately severe	Left AK	31

22	M	56	T12	0	Mild	Bilateral NR	27
23	M	54	T12	0	Moderate	Left NR	30
NR: indicates significantly narrowing of hip joint; AK indicates ankylosing of hip joint							

Table 2

Surgical characteristics.

	First stage				Second stage			
Case	OT(m)	BL (mL)	PO Level	OP Interval □d□	OT (m)	BL (ml)	PSO Level	Fusion Level
1	275	900	L3-4	22	222	1100	L1	T9-S1
2	200	550	L3-4	24	236	950	L1	T9-L5
3	165	500	L3-4	19	210	2100	T8	T4-L5
4	225	1200	L3-4	23	195	800	L1	T9-L5
5	170	500	L3-4	23	225	900	L1	T9-L5
6	150	600	L3-4	26	310	1000	T12	T8-L5
7	320	1600	N	42	375	2600	L4	T9-S1
8	175	800	L3-4	40	205	900	T12	T8-S1
9	230	500	L3-4	16	270	1000	L1	T9-L5
10	200	1000	L3-4	33	232	1500	L1	T6-S1
11	255	700	L3-4	21	285	1300	L1	T9-L5
12	235	1100	L2-3	21	290	1400	T12	T8-L5
13	200	650	L2-3	19	270	1000	L1	T9-L5
14	210	1200	L3-4	21	200	1200	L1	T9-S1
15	255	800	L3-4	19	255	1200	L1	T9-S1
16	190	700	L3-4	20	272	1000	L1	T9-S1
17	205	800	L2-3	22	170	1300	T12	T8-L5
18	210	1000	L3-4	21	230	1100	L1	T9-S1
19	150	400	L3-4	21	265	1500	T12	T8-S1
20	210	750	L3-4	22	243	1100	L1	T9-S1
21	245	950	L1-2	30	230	900	T12	T8-S1
22	175	400	L2-3	22	215	600	L1	T8-L5
23	230	1000	L2-3	14	205	900	L1	T9-L5

OT indicates operation time, min; BL, blood loss, mL; OP, operation.

N indicates not applicable, this patient underwent L1 PSO at first stage surgery.

PSO indicates pedicle subtraction osteotomy; PO, expanded Ponte osteotomy.

Table 3

intraoperative parameters.

Parameters	First-stage	Second-stage	Total
Operation time, min	212±41	244±45	456±71
Blood loss, mL	809±297	1189±434	1998±613

Table 4

The comparison of sagittal parameters of spine preoperatively, postoperatively, and at the latest follow-up.

Parameters	Pre-op	Post-op	Final	*P*
GK (°)	115.0±13.4	46.5±9.0	47.5±8.8	0.001
TK (°)	60.2±18.9	43.7±11.8	44.9±13.4	0.001
LL (°)	40.7±24.3	-41.8±13.4	-41.4±13.2	0.001
SVA (cm)	21.2±5.1	5.1±1.8	5.0±2.0	0.001
CBVA (°)	64.1±23.2	5.7±10.6	6.3±10.7	0.001
OVI(°)	9.0±2.7	-20.1±5.6	-19.6±5.7	0.001
GK indicates global kyphosis; TK, thoracic kyphosis; LL, lumbar lordosis; SVA, sagittal vertical axis; CBVA, chin-brow vertical angle. OVA, osteotomized vertebra intervertebral angle. *P indicates Post-op or Final versus Pre-op.*				

Table 5

The comparison of SRS-22 score preoperatively, postoperatively, and at the latest follow-up.

Variables	Pre-op	Post-op	Final	*P*
Pain	13.7±3.1	21.8±2.4	22.6±1.8	0.001
Mental health	14.5±3.8	21.4±1.9	22.0±2.1	0.001
Self-image	9.8±3.7	19.5±3.0	20.3±2.2	0.001
Function/activity	15.7±4.2	19.4±3.0	19.5±3.1	0.001
Satisfaction with surgery	N	8.9±1.1	9.4±1.0	N
N indicates not applicable. P indicates Post-op or Final versus Pre-op.				

Figures

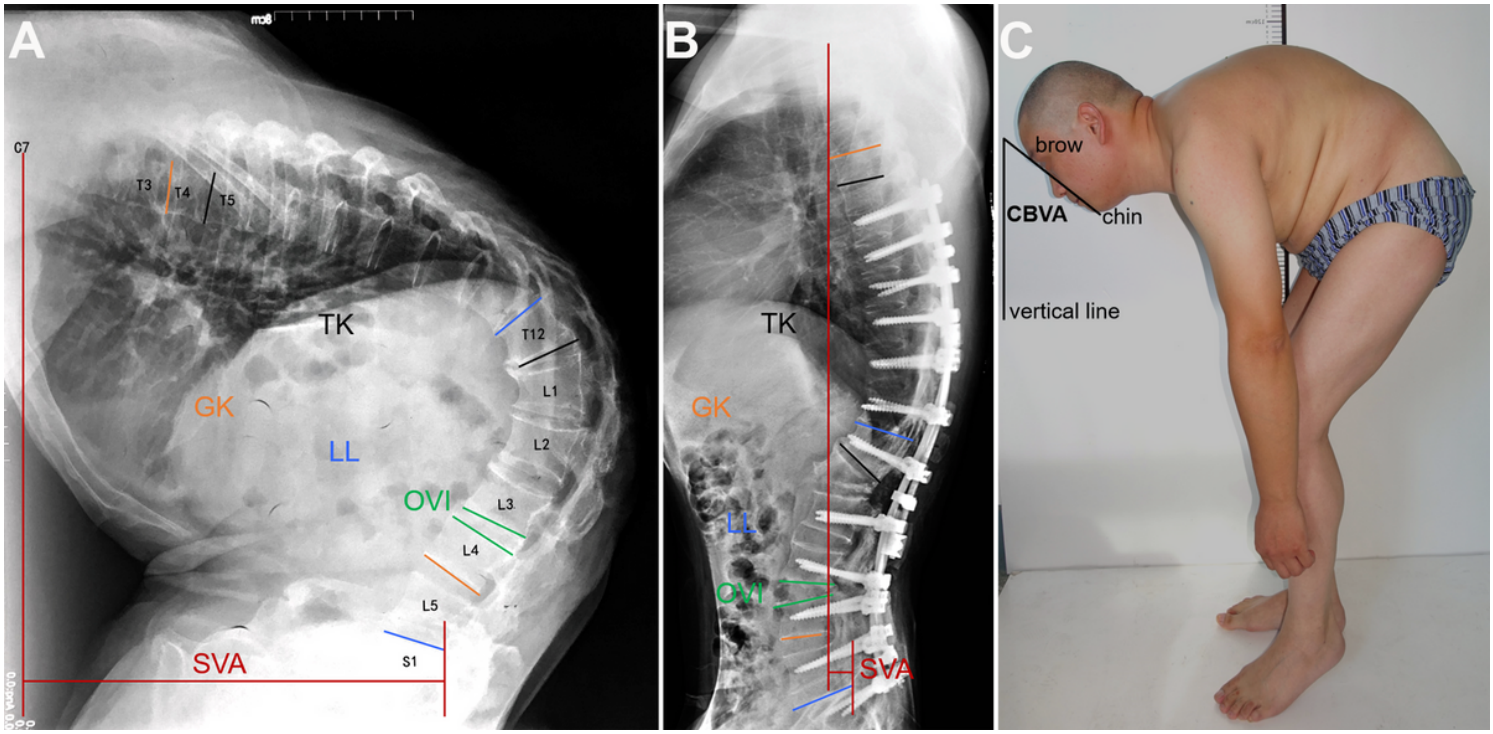

Figure 1

The diagrams of radiographic parameter measurements pre-and post-operation (A, B). The diagram of Chin-brow vertical angle (CBVA) measurement(C).

Figure 2

The placement of lateral position (A, B). The first-stage L3 Ponte osteotomy in lateral position pre- and post-osteotomy procedure (C, D). The second-stage L1 PSO in the prone position (E, F). Red arrows showed the correction process was done by slowly pushing the front of the thigh backward and pressing the osteotomy site simultaneously. White arrows indicated the closed osteotomy gap.

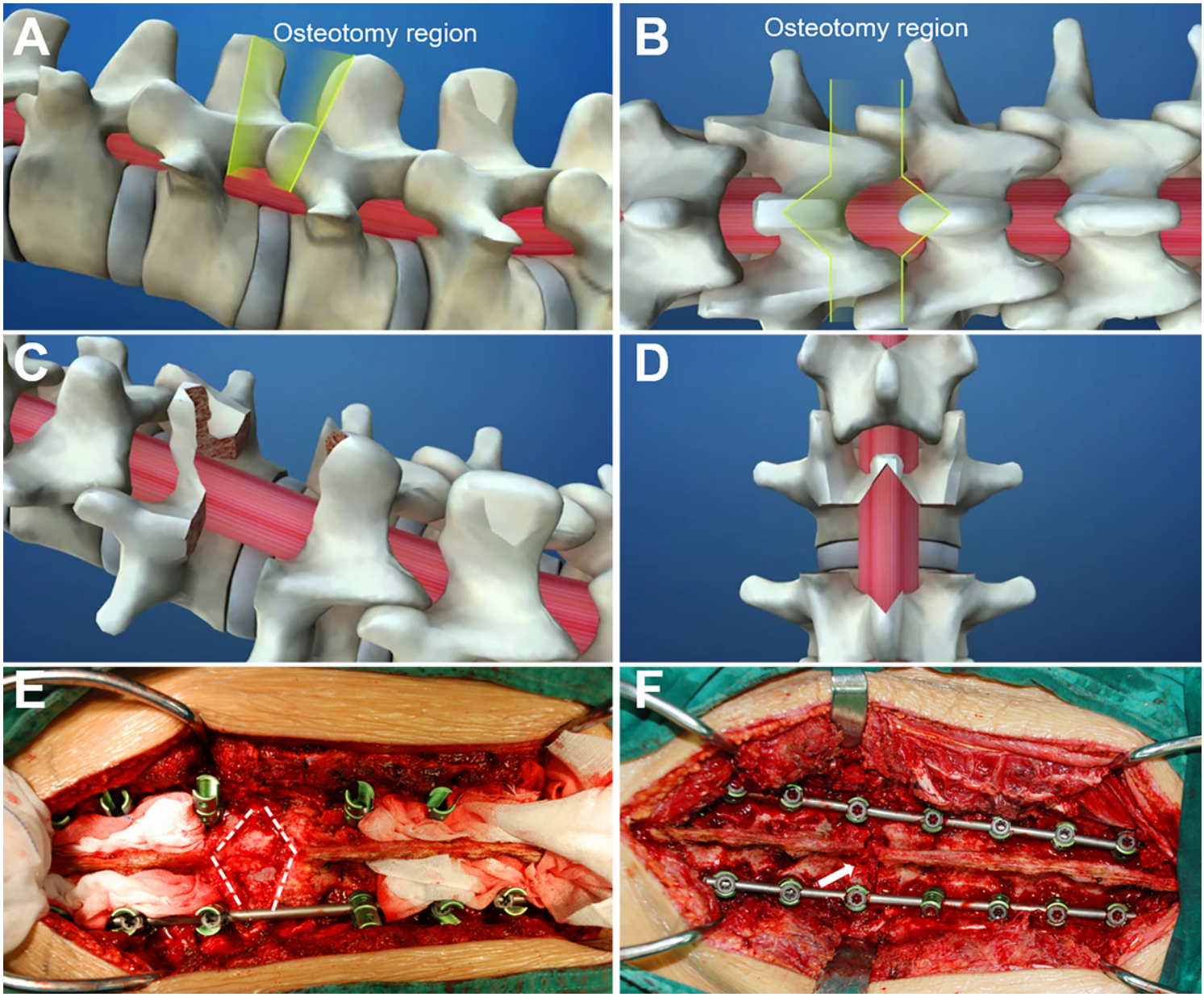

Figure 3

Illustration of the Ponte osteotomy from pedicle to pedicle. The ideal osteotomy region (A-D). A unilateral temporary rod was installed after screw instrumentation, white dotted lines showed the actual region of Ponte osteotomy, approximately a quadrangle shape (E). White arrows indicate the closed osteotomy gap after PO (F).

Figure 4

Male, 39 years old; A, B showed lateral position; C, D showed pre- and post-first-stage Ponte osteotomy, the arrow indicated L3 was the osteotomy level; E, F showed radiograph before surgery. G, H showed postoperative X-ray. I, J showed 26 months postoperative X-ray. K-N showed the preoperative and postoperative appearance. The preoperative kyphosis of the patient was significantly improved after surgery and the correction effect was not lost over time.

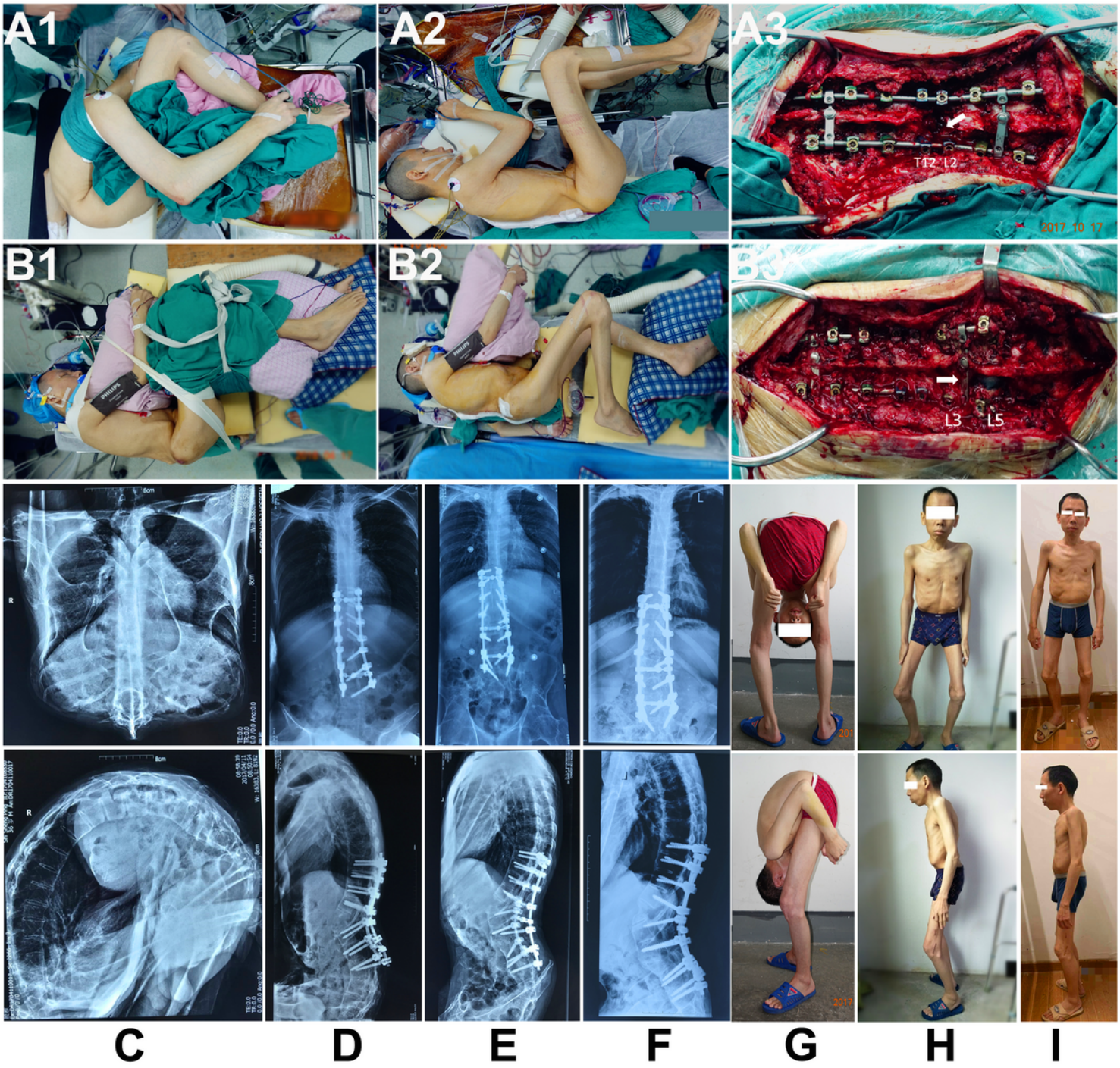

Figure 5

A 35-year-old man with a complete folded spine, who cannot undergo corrective surgery in a prone position. A1-A3 showed the first stage L1 PSO in lateral position; B1-B3 showed the second stage L4 PSO in lateral position. C-F showed preoperative, post-first-stage osteotomy, post-second-stage osteotomy and at the final follow-up radiographs. G-I showed preoperative, immediate postoperative, and 31 months postoperative appearances. White arrows indicated osteotomy level.

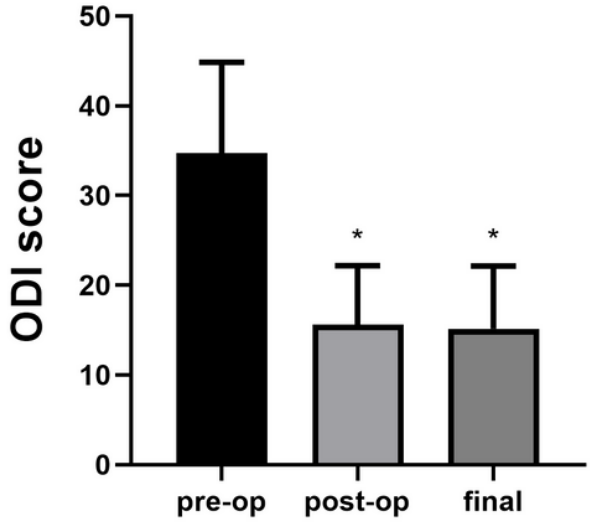

Figure 6

The comparisons of ODI score among pre-operation, post-operation, and final follow-up. * Indicated P<0.05 comparing with preoperative values.