Anterior and posterior vertebral column resection for severe and rigid idiopathic scoliosis

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Abstract A total of 16 patients with severe and rigid idiopathic scoliosis treated by anterior and posterior vertebral column resection (APVCR) were retrospectively reviewed after a minimum follow-up of 2 years. The indication for APVCR was scoliosis more than 90° with flexibility less than 20%. The radiographic parameters were evaluated, and clinical records were reviewed. All patients underwent APVCR with posterior pedicle screw instrumentation in a two-stage surgery. The rib hump was reduced from 7.2 cm preoperatively to 1.8 cm at final follow-up (75% correction). Preoperative curves ranged from 93° to 110° Cobb angle. Coronal plane correction of the major curve averaged 67% with an average loss of correction of 1.4%. The apical vertebral translation of the major curve was corrected by 63.5%. The preoperative coronal imbalance of 0.9 cm (range 0–2.4) was improved to 0.8 cm (range 0.1–1.7) at the most recent follow-up. The preoperative sagittal imbalance of 1.0 cm (range –3.1 to 4.6) was improved to 0.9 cm (range –2.6 to 3.0) at the most recent follow-up. Complications were encountered in four patients. One patient required ventilator support for 12 h after anterior surgery. Malposition of one pedicle screw was found in one patient. Malposition of titanium mesh cage happened to two patients. There were no neurological complications, deep wound infections or pseudarthrosis. APVCR

is an effective alternative for severe and rigid idiopathic scoliosis.

Keywords Idiopathic scoliosis · Anterior fusion · Posterior fusion · Vertebral column resection · Posterior instrumentation

Introduction

The surgical treatment of severe and rigid idiopathic scoliosis is challenging [11], and only a few studies have been conducted reporting the management of it. Conventional procedures are anterior release and a posterior correction and instrumentation [4, 9, 16, 17, 22, 23] with some authors suggesting a period of halo traction after anterior release [7, 14, 15]. With this method, a correction rate of 40–50% can be achieved. Although conventional procedures can bring obvious cosmetic improvement for some patients with severe and rigid idiopathic scoliosis, better correction rate is chased by patients because of residual deformity.

In the recent years, some authors report posterior vertebral column resection (PVCR) for severe rigid scoliosis. As reported, a correction rate of 51–59% can be achieved by PVCR surgery, but it also brings a high neurological risk [2, 12, 13, 18, 20, 21].

To optimize curve correction, and to minimize the neurological risk, we performed anterior and posterior vertebral column resection (APVCR) with posterior pedicle screw instrumentation in a two-stage surgery to treat severe and rigid idiopathic scoliosis. The present study was undertaken to evaluate and report on the technique, and the results of APVCR for severe and rigid idiopathic scoliosis.

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Methods

Patients and evaluation

Between 2006 and 2008, the corresponding author used APVCR to treat 16 consecutive patients with severe and rigid idiopathic scoliosis. Inclusion criteria were idiopathic curves with Cobb angles of at least 90° and a flexibility of less than 20% on bending films. All patients were retrospectively reviewed after a minimum follow-up of 2 year (range 2.0–3.4). No patient was lost to follow-up. The clinical records were reviewed for demographic data, operating time, average blood loss, functional improvement, and complications. Ten patients had adolescent and 6 patients had adult idiopathic scoliosis. There were 8 males and 8 females. Average age at surgery was 16 years (range 10–28). The curves were classified according to the Lenke classification (Table 1).

Before operation, all patients received a careful examination. Standing anteroposterior, lateral radiographs (Fig. 1a, b) as well as supine right and left bending radiographs (Fig. 1c, d) were taken to measure the curve and flexibility. CT images of major curve were obtained to exclude deformity besides scoliosis, and magnetic resonance images of the spinal canal and its contents were obtained to find any existing abnormality.

Patient's evaluation, which included clinical (Fig. 2a–c) and radiographic analysis (Fig. 3a–d), was taken before surgery, 2 weeks after surgery, and at the most recent follow-up. Clinical analysis included rib hump and lumbar hump. The height of hump was measured using the method described by Harding [8]. Radiographic analysis consisted of Cobb angle measurements of coronal curves, apical vertebral translation, coronal balance, sagittal balance, thoracic kyphosis and lumbar lordosis. In the measurements of coronal curves, proximal thoracic curve, main thoracic curve, and thoracolumbar or lumbar curve were measured, respectively, and flexibility of curves was calculated according to Cobb angle obtained from bending film. Apical vertebral translation for thoracic curves was measured as the distance between the C7 plumb line and the center of apical vertebral body or disk. Apical vertebral translation for thoracolumbar and lumbar curves was measured as the distance between the center sacral line and the center of apical vertebral body or disk. Coronal balance was measured as the distance between the C7 plumb line and the center sacral line. Sagittal balance was measured as the distance between C7 plumb line and the posterior superior corner of S1. Thoracic kyphosis was measured by the Cobb method from the superior endplate of T5 to the lower endplate of T12, and lumbar lordosis from the superior endplate of T12 to the endplate of S1.

Table 1 Data on the patients

Patients <i>n</i>	Age/sex	Lenke Classification	Resected vertebra	Anterior release length	Posterior fusion length	Materials for anterior fusion	Screw number	Op. time (min)	Blood loss (ml)	Complications
1	13/F	2A+	T9	T8–T11	T2–L4	Rib	11	460	2,000	Ventilator support (12 h)
2	12/F	4A+	T9	T7–T12	T3–L4	Rib	14	480	2,200	
3	20/M	4B+	T11	T9–L1	T2–L3	Rib	14	540	2,900	
4	11/F	4CN	T8	T7–T11	T3–L3	ATC	12	460	2,250	
5	18/M	4AN	T9	T7–T11	T2–L2	ATC	14	500	2,700	Malposition of pedicle screw
6	13/M	2A+	T7	T5–T9	T2–L1	ATC	14	440	1,500	
7	15/F	2BN	T10	T9–T12	T2–L3	ATC	15	420	1,100	
8	18/M	2B+	T9	T6–T11	T2–L3	ATC	14	540	3,100	
9	12/M	2AN	T9	T7–T11	T3–L2	ATC	13	480	2,000	Malposition of ATC
10	28/F	2BN	T11	T8–L2	T2–L3	ATC	17	460	2,000	
11	14/M	4CN	T7	T5–T8	T2–L4	ATC	15	500	1,800	
12	10/F	3AN	T8	T6–T9	T2–L2	ATC	15	400	800	
13	19/M	2B+	T9	T7–T11	T2–L3	ATC	14	440	1,400	Malposition of ATC
14	24/M	3A+	T8	T7–T11	T3–L2	ATC	15	470	2,100	
15	13/F	4B–	T9	T6–T10	T3–L3	ATC	13	420	1,300	
16	14/F	2BN	T10	T8–T12	T2–L3	ATC	14	450	1,500

Fig. 1 a–d A 20-year-old male with severe and rigid idiopathic thoracic scoliosis type Lenke 4B+ and a 99° Cobb angle corrected in bending films to 80°

Surgical techniques

All surgeries were performed by the corresponding author under somatosensory-evoked potential monitoring.

The surgical technique included a staged anterior and posterior approach. The first stage consisted of an approach on the convex side of the area to be resected through a thoracic or thoracoabdominal incision. The rib conforming to the uppermost level of the spine to be approached was exposed and removed to be used as bone graft. After identifying the apical vertebrae, the segmental vessels were ligated and the intervertebral disks adjacent to the apical vertebrae were fully excised back to the posterior longitudinal ligament. The apical vertebrae are then removed in piecemeal fashion. After resection of the convex pedicle and part of the concave pedicle, Gelfoam was put to protect the underlying dura. Additional disks adjacent to the resection levels were also removed to provide adequate anterior release. The resected rib or titanium cage filled with morselized bone graft from the resected vertebrae was packed into the resected area. After chest tubes were placed as indicated, a routine closure was carried out.

Fig. 2 Clinical pictures of patient 3 preoperatively (a), 2 weeks postoperatively (b) and 2 years after operation (c)

Fig. 3 a, b The patient underwent APVCR of T11 and posterior instrumentation from T2–L3. Postoperatively, the Cobb angle was corrected from 99° to 30° with an acceptable sagittal kyphosis. **c, d** At the 24-month follow-up no relevant loss of correction in the thoracic curve was observed

When the patient's medical status had stabilized, the posterior procedure was performed. With the spine exposed posteriorly, pedicle screws were inserted segmentally, except for the resected levels. Care must be taken when implanting the pedicles because trajectories may be grossly altered in multiple dimensions by the deformity. A temporary rod contoured to the shape of the deformity was applied on one side. After the posterior elements of the previously anteriorly resected vertebrae were removed, another temporary rod was inserted to the working side and securely locked to the screws. The temporary rod was removed and the same sequence of resection was performed on the remaining vertebra. Using persuasion and rod derotation, the deformity was corrected, and the temporary rods were replaced by contoured permanent rods. After the cross-link was tightened, the wound was irrigated copiously. Decortication was done to all levels of planned fusion and bone graft was placed along the spine for posterior fusion. The wound was then closed in layers over subfascial drains. After posterior surgery, a wake-up test was performed in all patients.

The patients were allowed to sit up in bed 48 h after surgery. Two weeks after surgery, patients were allowed to ambulate in a custom-made thoracolumbosacral orthosis. The orthosis was kept for 6 months and removed if radiograph after 6 months did not show any sign of pseudarthrosis.

Results

Surgery was performed in two stages in all patients. The removed apical vertebrae were all in thoracic region. The average number of anteriorly removed disks was 3.9 (range 3–5). The anterior column reconstruction was performed with rib graft in 3 patients and insertion of titanium mesh in the rest 13 patients. Average posterior fusion length was 13.5 vertebrae (range 12–15). The average number of screw used in posterior surgery was 14 (range 11–17). Mean operating time was 466 min, with a blood loss of 1,916 mL (Table 1).

The rib hump was reduced from 7.2 cm preoperatively to 1.8 cm at final follow-up (75% correction). The lumbar hump was corrected from 3.8 cm to 0.6 cm at final follow-up (84% correction).

The preoperative main thoracic curve of $99.3^\circ \pm 5.5^\circ$ (range 93° – 110°) with a flexibility of $12.5 \pm 5.0\%$ was corrected to $32.9^\circ \pm 12.3^\circ$ (range 15° – 52°) at immediate postoperative assessment, showing a 67.0% scoliosis correction. At the most recent follow-up, the main thoracic

curve was $34.3^\circ \pm 12.1^\circ$ (range 17° – 55°), showing a 65.6% scoliosis correction compared to the preoperative curve measurement and only a 1.4% loss of correction compared to the immediate postoperative curve measurement. The correction rate of the proximal thoracic curve was 53.9% at immediate postoperative assessment and 49.5% at the most recent follow-up. The correction rate of the thoracolumbar or lumbar curve was 68.5% at immediate postoperative assessment and 64.4% at the most recent follow-up.

The preoperative apical vertebral translation of main thoracic curve was 7.6 cm (range 5.7–10.7), and improved to 2.6 cm (range 0.3–4.6) at immediate postoperative assessment. At the most recent follow-up, it was 2.8 cm (range 1.0–5.1). The correction rate of apical vertebral translation of the proximal thoracic curve was 55.6% at immediate postoperative assessment and 51.7% at the most recent follow-up. The correction rate of apical vertebral translation of the thoracolumbar or lumbar curve was 65.5% at immediate postoperative assessment and 60.2% at the most recent follow-up (Figs. 2, 3; Table 2).

The preoperative coronal imbalance of 0.9 cm (range 0–2.4) was improved to 0.7 cm (range 0.1–1.6) at immediate postoperative assessment and 0.8 cm (range 0.1–1.7) at the most recent follow-up. The preoperative sagittal imbalance of 1.0 cm (range –3.1 to 4.6) was improved to 0.8 cm (range –2.0 to 2.3) at immediate postoperative assessment and 0.9 cm (range –2.6 to 3.0) at the most recent follow-up (Figs. 2, 3; Table 2).

Table 2 Radiographic data of patients

	Preop (range)	IMPO (range)	IM corr (%)	Final follow-up (range)	Final corr (%)	LOC (%)
Proximal thoracic curve						
Magnitude ($^\circ$)	45.9 ± 13.0 (20–65)	21.5 ± 10.7 (4–38)	53.9	23.2 ± 10.7 (5–38)	49.5	4.4
Flexibility (%)	29.0 ± 21.9 (3.9–76.7)					
AVT (cm)	1.3 ± 0.7 (0.4–2.9)	0.5 ± 0.2 (0.1–0.7)	55.6	0.5 ± 0.2 (0.2–0.8)	51.7	3.9
Main thoracic curve						
Magnitude ($^\circ$)	99.3 ± 5.5 (93–110)	32.9 ± 12.3 (15–52)	67.0	34.3 ± 12.1 (17–55)	65.6	1.4
Flexibility (%)	12.5 ± 5.0 (2.7–20.0)					
AVT (cm)	7.6 ± 1.8 (5.7–10.7)	2.6 ± 1.3 (0.3–4.6)	66.0	2.8 ± 1.4 (1.0–5.1)	63.5	2.5
Thoracolumbar/lumbar curve						
Magnitude ($^\circ$)	50.3 ± 20.7 (20–99)	17.3 ± 14.8 (2–50)	68.5	19.0 ± 15.0 (0–50)	64.4	4.1
Flexibility (%)	44.1 ± 15.3 (3.3–65.5)					
AVT (cm)	1.4 ± 1.4 (0.1–5.7)	0.6 ± 0.6 (0–2.0)	65.5	0.6 ± 0.6 (0–2.1)	60.2	5.3
Coronal imbalance (cm)	0.9 ± 0.7 (0–2.4)	0.7 ± 0.5 (0.1–1.6)		0.8 ± 0.5 (0.1–1.7)		
Sagittal imbalance (cm)	1.0 ± 2.1 (–3.1 to 4.6)	0.8 ± 1.2 (–2.0 to 2.3)		0.9 ± 1.6 (–2.6 to 3.0)		
T5–T12 Kyphosis ($^\circ$)	46.0 ± 23.5 (6–85)	27.7 ± 7.9 (17–40)		30.8 ± 8.1 (20–45)		
T12–S1 Lordosis ($^\circ$)	-56.0 ± 14.5 (–80 to –32)	-46.7 ± 8.6 (–60 to –31)		-49.7 ± 6.4 (–62 to –40)		

AVT apical vertebral translation, *Final corr* correction rate of final follow-up, *IM corr* immediate postoperative correction rate, *IMPO* immediate postoperative, *LOC* loss of correction, *Preop* preoperative

The preoperative thoracic kyphosis of $46.0^\circ \pm 23.5^\circ$ (range 6° – 85°) was corrected to $27.7^\circ \pm 7.9^\circ$ (range 17° – 40°) at immediate postoperative assessment and $30.8^\circ \pm 8.1^\circ$ (range 20° – 45°) at the most recent follow-up. The preoperative lumbar lordosis of $-56.0^\circ \pm 14.5^\circ$ (range -80° to -32°) was corrected to $-46.7^\circ \pm 8.6^\circ$ (range -60° to -31°) at immediate postoperative assessment and $-49.7^\circ \pm 6.4^\circ$ (range -62° to -40°) at the most recent follow-up.

Complications were encountered in four patients. One patient required ventilator support for 12 h after anterior surgery. Malposition of one pedicle screw, which showed as doubtful medial cortical wall violation on posterior–anterior radiograph and definite superior cortical wall violation on lateral radiograph, was found in one patient. But fortunately, the patient did not have any neurologic compromise. Malposition of titanium mesh cage, which showed as leaning on posterior–anterior radiograph, happened to two patients. No surgical revision required in these patients. There were no neurological complications or any deep wound infections. No complication of instrumentation was found at the final follow up.

Discussion

The surgical treatment of severe and rigid idiopathic scoliosis is quite challenging for a surgeon. Most commonly performed procedure is posterior instrumentation combined with an anterior release [3, 4, 9, 16, 17, 22, 23]. Shen et al. published a series of 24 cases with a preoperative Cobb angle of 98.8° and a Cobb angle of 68.0° on preoperative bending films. With anterior release and posterior hooks and pedicle screws, they achieved a final curve correction of 58.6% [16]. Some authors advocate application of halo traction in the perioperative time period [7, 14, 15]. Rinella et al. reported a series of 33 patients with severe scoliosis and kyphosis were treated by perioperative halo-gravity traction and anterior and posterior surgery. Seven of them had idiopathic scoliosis with major curve more than 90° . The preoperative average major curve of 107.3° was corrected to 52.1° , showing a 51.4% scoliosis correction [15]. In order to achieve a better correction in a safer way, Tokunaga et al. performed vertebral decancellation for 21 patients with severe scoliosis. The preoperative average major curve of 107° was corrected to 58° , showing a 46% scoliosis correction [22]. To optimize curve correction and to eliminate both patient discomfort and a prolonged hospital stay resulting from halo traction, Bullmann et al. used combined anterior and posterior instrumentation to treat 33 patients with severe and rigid idiopathic scoliosis. The preoperative average major curve of 93° was corrected to 31° , showing a 67% scoliosis correction [3].

Along with wide use of pedicle screws, exclusive posterior instrumentation without an additional anterior release to treat severe scoliosis was reported [5, 6, 10]. Kuklo et al. reported 20 patients with idiopathic scoliosis, and a Cobb angle of more than 90° and a mean flexibility of 29% on bending films. With posterior segmental pedicle screw instrumentation, a correction of 68% was achieved. Only in three cases, an anterior release was done prior to posterior instrumentation [10]. In a study including 54 consecutive patients with AIS and curves $>90^\circ$, Dobbs et al. compared the result of anterior/posterior spinal fusion (hooks and screws) with a posterior spinal fusion alone (an all-pedicle screw construct). He concluded that a posterior-only approach with the use of an all-pedicle screw construct has the advantage of providing the same correction as an anterior/posterior spinal fusion. In 34 patients treated by posterior spinal fusion alone, the preoperative average major curve of 94.3° was corrected to 51.1° , showing a 44% scoliosis correction [6].

In the recent years, PVCR was introduced to treat severe scoliosis [2, 12, 13, 18, 20, 21]. Suk et al. reported a series of 16 patients with severe scoliosis treated by PVCR. The preoperative average major curve of 109° was corrected to 45.6° , showing a 59% scoliosis correction [20]. Lenke et al. published their results of PVCR for severe spinal deformity. 10 of 43 patients with severe scoliosis or kyphoscoliosis received PVCR surgery. The preoperative average major curve of 115.5° was corrected to 46.9° , showing a 61.9% scoliosis correction [13].

In our study, the preoperative main thoracic curve of 99.3° with flexibility of 12.5% was corrected to 34.3° at the most recent follow-up assessment, showing a 65.6% scoliosis correction. The correction rate was better than that achieved in conventional anterior and posterior surgery, and similar to that obtained from posterior surgery with all all-pedicle screw construct or PVCR surgery. Bradford et al. was the first to introduce APVCR to treat severe spinal deformity. In a series of 24 patients with rigid coronal decompensation, the average preoperative scoliosis was 103° corrected by 52% [1]. The difference in correction rate between Bradford's study and ours may be attributed to the instrumentations. Luque instrumentations were used in Bradford's study, while pedicle screws, which could provide superior biomechanical properties, were applied in our study. In addition, in Bradford's study, 18 of 24 patients had undergone previous spinal surgeries. It may bring difficulties to scoliosis correction.

Another benefit to our protocol was lower number of implanted pedicle screws. As described above, Kuklo et al. treated 20 patients with severe idiopathic scoliosis by posterior segmental pedicle screw instrumentation and achieved a correction of 68%. The average screw number was 20.4 [10]. In another study about severe and rigid

neuromuscular scoliosis, the average screw number reached 29.6 [19]. In our study, screw implanted in posterior surgery averaged 14 and the correction rate reached 65.6%. This benefit was quite important, especially in developing country, because the economic situation of such patients was usually not good enough to afford mint cost of instrumentations.

Compared to PVCR surgery reported in the literature, APVCR seems to be much safer. Suk et al. reported 1 of 16 patients with severe scoliosis treated by PVCR encountered complete paralysis. The preoperative neurologic status of the patient was Frankel C [20]. Lenke et al. reported that 7 of 43 patients (18%) lost intraoperative neurogenic monitoring evoked potential data during correction with data returning to baseline after prompt surgical intervention and 2 patients had transient nerve root palsies [13]. In our study, although three patients had complications related to instrumentations, no neurologic compromise or pseudarthrosis was found. Actually, to resect the apical vertebra by APVCR is much easier than PVCR. During APVCR surgery, the vertebral body is removed under direct observation. The operation space is much bigger than that of PVCR and the bleeding resulting from resection of vertebral body is easier to control. The insertion of titanium mesh cages or ribs during anterior surgery can make sure that the spine will not be excessively shortened when closing the resected region in the posterior surgery.

Although with the advantages described above, APVCR surgery is not perfect. As listed in the literature, APVCR will compromise pulmonary function and means longer hospital stay time [12, 13, 20]. In addition, great care must be taken to control the position of anterior reconstruction materials in APVCR, because the correction manipulation of posterior surgery, which brings not only the translation but also the rotation of spine, may cause movement of anterior reconstruction materials. In our study, malposition of titanium mesh cage happened to two patients. The rate of cage migration was relatively high (15%). These two cases were found in the early stage of the study. Aiming at avoiding such problems, following measures were taken: First, in the anterior surgery, cages, whose height was a little higher than the space resulting from the apex resection, were applied to ensure tight connection between cage and spinal column. Second, when the correction manipulation was applied to the region of the apex, a clamp was used to palpate the cage, and try to keep the relative position of the cage and spinal column unchanged with modest force. Great care was taken to avoid spinal cord injury. After these two measures were applied, no cage migration happened.

In a word, APVCR is an effective alternative for severe and rigid idiopathic scoliosis. Although it is safer

than PVCR in theory, APVCR is still technically demanding and should be performed by an experienced surgical team.

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