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ORIGINAL ARTICLE

The aim of this retrospective study is to evaluate the efficacy and safety of posterior-only vertebral column resection (PVCR) for the treatment of angular and isolated congenital kyphosis

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Abstract
Purpose The aim of this retrospective study is to evaluate the efficacy and safety of posterior-only vertebral column resection (PVCR) for the treatment of angular and isolated congenital kyphosis.
Methods 24 patients with isolated angular congenital kyphosis treated by PVCR in our hospital were retrospectively studied. The patients' radiographs and hospital records were reviewed. Deformity in sagittal planes and global sagittal alignment were analyzed for correction and maintenance of the correction in preoperative, postoperative, and follow-up radiographs. The complications and related risk factors were analyzed.
Results The average age was 13.9 (4–40) years. Three of them were revision surgeries. Two patients have intraspinal anomalies. The mean follow-up is 56.9 (26–129) months. The mean operation time was 293.1 (170–480) min. The averaged blood loss was 993.8 (250–3000) ml. The segmental kyphosis was 87.3° before surgery, 17.6° post surgery and 20.4° at the latest the follow-up. And the sagittal vertical axis was improved from 43.1 mm to 9.2 mm. Mean total score of SRS-22 was 89.3. Complications occurred in 4 patients, including 1 screw pullout due to pseudarthrosis, 1 proximal junctional kyphosis, 1 incomplete spinal cord injury and 1 root injuries.
Conclusion Posterior-only vertebral column resection is an ideal procedure for severe rigid congenital kyphosis. However, it is still a highly technical demanding procedure. Neurological compromises still remain the biggest challenges. Sufficient height of anterior reconstruction, avoidance sacrifice of bilateral roots in the same level in the thoracic spine, avoidance of the sagittal translation of the upper and lower vertebras, intra-operative neuromonitoring, and preoperative surgical release of diastematomyelia and tethered cord may help to improve the safety.

Keywords Posterior vertebral column resection · Isolated angular congenital kyphosis · Results · Complications · Risk factors

Introduction

Most of congenital kyphosis (CK) are progressive and lead to severe rigid deformities [1, 2] (Fig. 1). Many surgical techniques have been used to deal with CK, including fusion in situ, anterior instrumentation with anterior strut grafting, Smith-Peterson osteotomy, pedicle substraction osteotomy (PSO) and posterior-only vertebral column resection (PVCR) [3–5]. PVCR has been proved to be an ideal procedure for severe angular deformities [6–9]. However, the patients in previous studies on PVCR were heterogeneous, including idiopathic, post-infectious, neuromuscular and congenital scoliosis or kyphoscoliosis, et al. [6–9]. The purpose of this paper is to share our experiences in treating isolated angular CK with PVCR.

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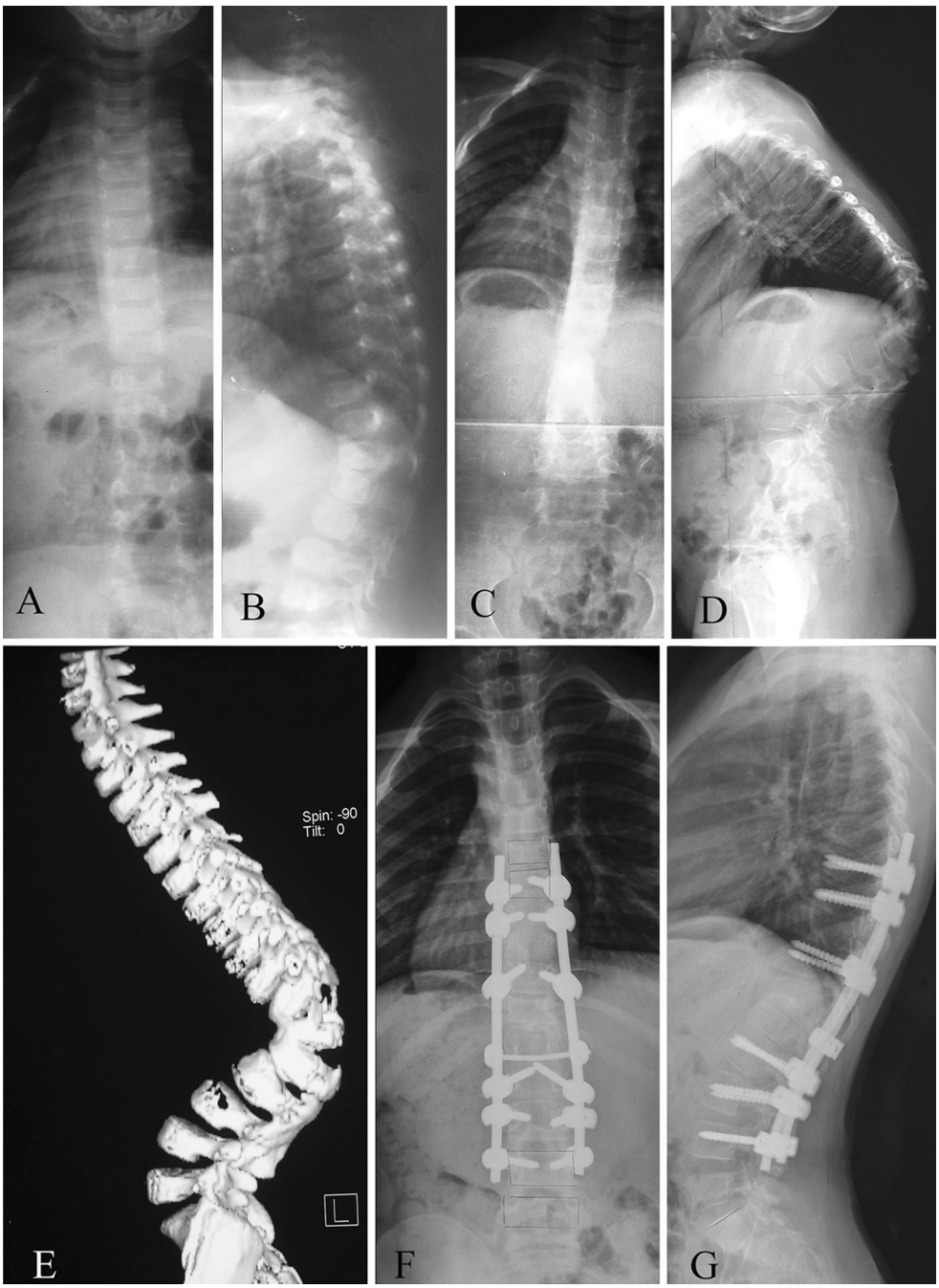

Fig. 1 Anterior segmentation failure of vertebral bodies was detected in a girl when she was 1 year old. No treatment was given by the local hospital and she lost to the follow-up. Severe rigid congenital kyphosis (**c**, **d**, **e**) was noted 6 years later. She underwent PVCR of T12. The correction and sagittal alignment maintained well until the latest follow-up (**f**, **g**)

Materials and methods

Between 2002 and 2010, 24 consecutive patients (10 males, 14 females) diagnosed with isolated angular CK (without significant scoliosis) in our hospital were treated with PVCR by the corresponding author. Three of them underwent previous spinal surgeries for their deformities (Case 11, Case 14 and Case 16). Two patients (Case 22, Case 24) had intraspinal anomalies. Both of them developed incomplete paraplegia (ASIA C for Case 22, ASIA D for Case 24) before the surgery (Table 1). No neurological deficits were found in other cases. A retrospective review using the clinical records and the radiographic materials was performed. Surgical information and complications were recorded.

Table 1 Patients characteristics

	Sex	Age (years)	Follow-up (months)	OP-time (min)	Blood loss (ml)	Resected levels	Fusion levels	Associate diseases
1	F	12	129	360	1000	L1	T10–L4	
2	M	14	117	270	1500	T5, T6	T3–T8	
3	F	14	108	420	1200	T11	T6–L3	
4	M	5	107	320	800	L1	T11–L3	
5	M	16	87	280	900	T12	T10–L2	
6	M	14	75	270	1100	T12	T10–L2	
7	F	12	62	310	1400	L1, L2	T9–L5	
8	F	13	60	290	900	L3	L1–L5	
9	F	13	56	270	700	T12, L1	T9–L3	
10	F	22	52	270	800	T9, T11	T5–L2	
11	F	40	48	360	3000	L3, L4	T12–S1	
12	F	12	48	280	1100	T12, L1	T9–L4	
13	F	11	48	240	900	T11	T8–L3	
14	F	31	47	270	1000	T13, L1	T9–L4	
15	F	7	47	240	800	T12	T8–L4	Congenital heart disease
16	M	12	40	250	1200	T11	T7–L3	
17	M	13	36	200	600	L2	T11–L3	
18	F	15	33	340	500	L2, L3	T9–S1	
19	M	15	32	350	900	L2, L3	T12–L5	
20	M	4	28	240	300	T12	T9–L2	
21	M	11	28	480	1100	L1, L2	T10–S1	
22	F	11	27	240	600	L3	L1–L5	Diastematomyelia, tethered cord
23	F	13	26	315	1300	T12	T4–L4	
24	M	4	26	170	250	L3	T12–L5	Meningocele
Average		13.9	56.9	293.1	993.8			

All upright full-length posteroanterior and lateral radiographs were available before surgery, after surgery, at latest follow-up. Radiographs were measured in coronal and sagittal planes for Cobb's angle and sagittal vertical axis (SVA, the distance between the plumb line from central of C7 to the posterior-superior corner of S1 on lateral radiographs). All radiographic measurements were calibrated and corrected for magnification to represent actual change. Two observers measured each radiograph independently. All patients were evaluated with preoperative full-length spinal cord magnetic resonance imaging and computerized tomography. two patients have intra-spinal anomalies.

A SRS-22 questionnaire was used it as an outcome measure at the latest follow-up.

Surgical procedure

PVCR was performed at the apex of the deformity. The number of vertebrae to be resected was determined based on several factors including the height of the vertebrae, the severity of the deformity and kyphotic angular magnitude and the overall condition of the spinal cord at the level of the resection. All of the patients were treated with titanium pedicle screw and rod system. According to the preoperative plan, a titanium mesh cage filling with auto cancellous bone was used for anterior reconstruction if the spine should be shortened more the 2 cm. Intraoperative radiography, SEP (sensory evoked potential) and MEP (motor evoked potential) were used for all surgeries.

The patient was placed prone on a frame after general anesthesia. A midline skin incision was made after baseline spinal cord monitoring recordings and administration of intravenous antibiotic prophylaxis. Cell saver was used in all patients. After typical midline posterior spinal exposure, pedicle screws was placed. Ribs above and below the apical vertebrae were subperiosteally exposed.

During the osteotomy and correction, the mean arterial pressure were controlled no less than 75 mmHg. A temporary rod was placed before initiation of the osteotomy. On the contralateral side, all the posterior elements were excised. Then the transverse processes, the rib heads, and

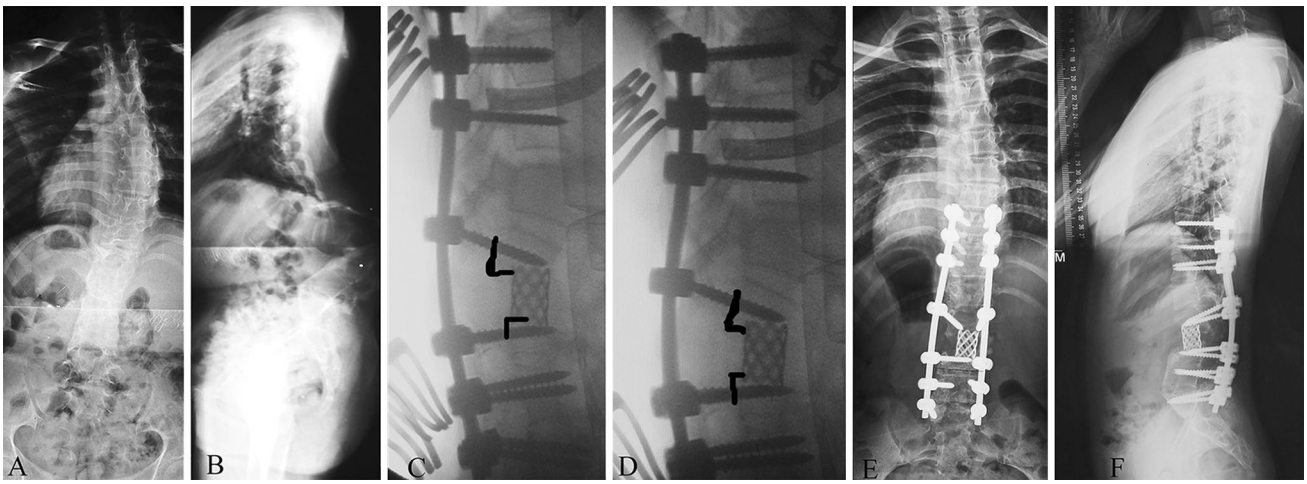

Fig. 2 Angular type III congenital kyphosis was found on a 15 years old female (**a**, **b**). During the surgery, changes of MEP signals occurred immediately after the closure of the osteotomy gap. The fluoroscopy showed significant sagittal translation (**c**). After the correction of ST (**d**), MEP signals went back to the base line. And relatively good correction was obtained (**e** and **f**)

the proximal portion of the ribs were excised. After resection of the rib head, the parietal pleura and/or the psoas muscle were detached and reflected from the anterior aspect of the vertebral body. Segmental vessel hemorrhage was usually controlled with bipolar cauterization. In the cases in which the apical vertebra was at the thoracic level, the intercostal nerve roots may be severed on the working site and spared on the opposite site. However, all the lumbar nerve roots should be spared if the apical vertebra was in the lumbar region. After that the lateral portion of the vertebral body were removed under direct visualization. The vertebral body and the intervening discs were removed in a piecemeal fashion gradually with an osteotome, keeping a thin shell of bony posterior vertebral wall beneath the dural sack. This portion of the posterior wall lateral to the neural tube is the last portion of the vertebrae to be resected. After the osteotomy, two pre-contoured rod were connected to the screws with cantilever technique on both sides. After that, a proper titanium mesh cage filling with autograft was inserted into the resected gap unless bone to bone contact could be achieved with acceptable shortening of the spine (no more than 2 cm). The insertion of the cage might be difficult in some cases. In the thoracic spine, the vessels and roots of one side could be scarified to the approach of the cage, but they should be spared on the opposite site. In the lumbar spine, the cage was inserted with the cross section towards the space. And then we modified the position when the cage was totally inserted into the space when the roots has already been passed. Then gradually compression was used to improve the correction of the kyphosis. Attention should be paid to the sagittal translation (ST) between the cranial and caudal levels of the gap at this time (Fig. 2).

Multiple levels of Smith-peterson osteotomies above and/or below the apex may be needed to improve the correction. The location of the implants and correction of the deformity were confirmed by intraoperative radiograph. Posterolateral fusion with autograft and BMP was performed. The wound was then closed over sub-fascial drains.

The procedures of PVCR we performed were almost the same as that described by Papadopoulos EC [9].

Patient started to stand and walk 3 days after the operation. And a thoracolumbosacral orthosis was used for 3 months.

Results

No patients lost to follow-up. Three of them had histories of previous spinal surgeries. The mean age at the initial surgery was 13.9 (4–40) years. There were 14 cases of failure of vertebral body formation, 2 cases of failure of segmentation and 8 cases of mixed failures. The apex of the kyphosis was located in the thoracic spine (T1–T10) in 1 patients, in the thoracolumbar spine (T10–L2) in 17 patients, and in the lumbar spine (L3–L5) in 6 patients. An average of 1.45 vertebral segments (range 1–3) were resected, and an average of 6.08 levels were instrumented (range 4–12).The mean operation time was 293.1 (170–480) min. The averaged blood loss was 993.8 (250–3000) ml. All the patients had at least 24-month follow-up (range 26–129 months) (Table 1).

The segmental kyphosis was 87.3° before surgery, 17.6° post surgery and 20.4° at the latest the follow-up. And the sagittal vertical axis was improved from 43.1 to 9.2 mm (Table 2).

Table 2 Correction of the sagittal deformity and reconstruction of the global sagittal balance

	Pre-op	Post-op	Follow-up
Segmental kyphosis (°)	87.3 ± 21.4	17.6 ± 12.7	20.4 ± 13.1
Thoracic kyphosis (°)	2.7 ± 43.9	10.8 ± 20.8	19.4 ± 21.9
Lumbar lordosis (°)	−35.2 ± 55.7	−39.0 ± 23.9	−40.0 ± 23.4
SVA (mm)	43.1 ± 19.1	24.0 ± 10.6	9.2 ± 7.7

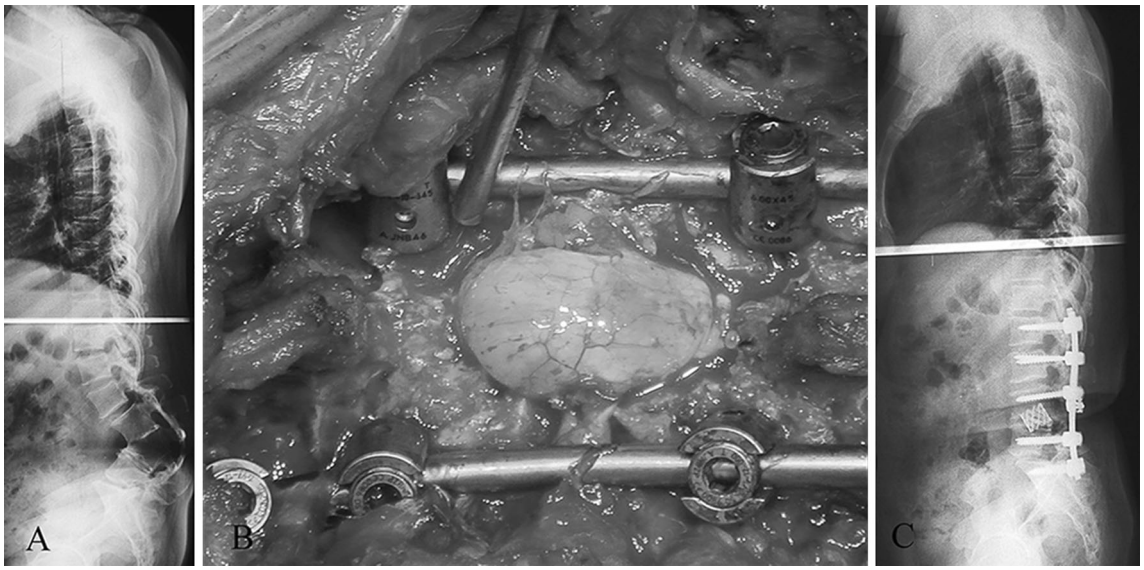

Fig. 3 40 years old female with angular type III congenital kyphosis (**a**) was treated with PVCR. Although anterior reconstruction was performed, severely buckled dura was noted after the closure of the gap (**b**). Transient root injures happened after the surgery and she completely recovered 3 months later. The height of cage might be insufficient (**c**)

All the patients returned a completed Chinese version of the SRS-22 questionnaire at the latest follow-up. Mean total score was 89.3 (ranging between 55 and 101).The mean score of function, pain, self-image, mental health and satisfaction was 22, 20, 18, 20 and 9.3.

Complications

Intraoperative MEP changes occurred in 2 patients (Case 12, Case 18). And intra-operative fluoroscopy showed sagittal translation (ST) at the osteotomy site was pronounced. After the correction of ST, the MEP went back to the base line (Fig. 2). And Wake-up test of both patients were negative.

Loss of MEP occurred in one patient (Case 22) at the moment of osteotomy closure, and the Wake-up test was positive. Although preopeative MRI showed diastematomyelia and tethered cord, they were not treated surgically before the correction surgery because we thought that these deformity would not place the patients at the risk of neurological deficits during the limited shortening procedure of the spine. Although no implants mal-placement or bony compression was noted on the CT scan, laminectomy above and below was performed during the surgery. And methylprednisolone was given immediately after the wake-up test. His preoperative ASIA grade was C and deteriorate to B after the surgery. Physical therapy was given after the surgery and his ASIA grade recovered to D 6 months later.

Transient root injures happened to Case 12 and she suffered from severe radiating pain and weakness of the left leg. No implants mal-placement or bony compression were found on the CT scan. Analgesics, mecobalamin and physical therapy were given and she completely recovered 3 months later.

Although laminectomy above and below were performed on the two patients above, the severely buckled dura which may reflect that the spine was over shortened was noted on both patients above (Fig. 3).

An anticipated surgeries were performed on two patients. Rod breakage and mesh cage dislodgement due to pseudarthrosis happened to Case 19 and revision surgery was performed to enhanced the fusion. Proximal junctional kyphosis occurred in case 13 and a revision to extend the proximal fusion levels was needed.

Discussion

CK could be classified into three types: Type I, congenital failure of vertebral body formation; Type II, congenital failure of vertebral body segmentation; and Type III, mixed failure of formation and segmentation [1, 2]. Most of these deformities, especially Type I and III, are progressive and show no response to conservative treatments. The progression of the kyphosis will not only result in sagittal imbalance, but also may cause neurological deterioration. McMaster reported that in their 112 patients spontaneous spastic paraparesia occurred in 10 % [1]. And 7 of the 11 patients were type I cases. According to Winer's study, Paraparesia was seen in 12 % of the patients. And all of those patients suffered from type I CK [2]. Surgical intervention are mandatory for these progressive and severe deformities for their malignant natural histories. However, there is little evidence in the literature regarding the clinical outcomes of the surgical treatment of CK.

Several procedures has been used for the treatment of CK. In the early period of the patients, arthrosis may achieve growth arrest of the deformity and provide gradually correction during the follow-up. In 2001, Kim et al. retrospectively studied 26 cases of congenital kyphosis or kyphoscoliosis undergoing anterior and posterior arthrodesis. The correction of patients younger than 3 years was 46.9 % during 6 years and 9 months follow-up. For the patients older than 3 years, the correction was 50.8 % [3]. In 2009, Noordeen et al. reported the results of anterior instrumented fusion and strut grafting for 15 patients with congenital kyphoscoliosis. The correction of kyphosis was 43 % [10]. As techniques of transpedicular instrumentation and several posterior spinal osteotomies developed, most of surgeons choose to treat these patients with posterior procedure only. Zeng et al. reported their experiences of PVCR or PSO for 23 patients with congenital kyphosis or kyphoscoliosis. The kyphosis was corrected from 73° to 20°, and the average scoliosis corrective rate was 61.7 %. The SVA improved from 12.6 to 1.5 mm [4]. According to their study, If selected appropriately, both PSO and PVCR procedures can achieve compatible and satisfactory correction results for the treatment of congenital kyphosis or kyphoscoliosis. Ayvaz et al. chose posterior all-pedicle screw instrumentation combined with multiple chevron and concave rib osteotomies for the treatment of adolescent congenital kyphoscoliosis. The scoliosis was corrected from 66.0° to 27.5°, and the local kyphosis was corrected from 71.9° to 36.9°. They concluded that this procedure may be an alternative in the treatment of rigid congenital curves involving more than three levels or multiple curves separated by at least two segments that would otherwise require multiple vertebral resections [11]. Atici et al. treated 10 patients with isolated congenital scoliosis with PSO. After 58.8 months follow-up, the kyphosis improved from 67.7° to 31.9°, and the SVA improved from 33.1 to 14.1 mm. They considered that PSO with posterior instrumented fusion is an efficient method of surgical treatment in terms of sagittal balance restoration and deformity correction selected patients with CK [5].

Vertebral column resection (VCR) is an osteotomy of three columns, allowing for translation and shortening of the spine to correct multiplanar deformities. It was traditionally performed via a separate anterior and posterior approach to the spinal column [12–16]. PVCR has been proved to be an ideal procedure for severe rigid spinal deformities since Suk first reported [6, 16]. Lenke retrospectively studied their 35 patients undergoing PVCR for severe rigid spinal deformities. The patients were divided into five groups: severe scoliosis, global kyphosis, angular kyphosis, kyphoscoliosis and congenital scoliosis. The correction rate of these five groups was as follows: 51, 55, 58, 54 and 60 % [7]. Wang reported on the clinical outcome of their modified PVCR on 13 adult patients with congenital kyphoscoliosis in 2008. The correction of scoliosis 57 % (79.7°–33.7°) and the correction of kyphosis was 62.7 %(85.9°–32.0°) [12]. Recently, Papadopoulos reported on the results of PVCR in the treatment of severe rigid kyphosis in a series of 45 patients (post-infectious 36, congenital 9). Average preoperative local kyphosis was 108° and corrected to 60° postoperatively. The SVA improved from 3.45 to 3.1 cm [9]. However, the etiologies of patients involved in previous studies are heterogeneous. So far there were no evidence regarding PVCR for the treatment of severe isolated CK. In the current study, 24 patients with severe isolated congenital kyphosis treated with PVCR by the same surgeon were retrospectively studied. The correction rate of segmental kyphosis was 76.6 % (87.3°–20.4°). And the sagittal vertical axis was improved from 43.1 mm to 9.2 mm. Both the correction of the local deformities and reconstruction of global sagittal alignment were relatively satisfied.

However, as an aggressive and technical demanding procedure, PVCR has always been a challenge for its complications, especially neurological deficits. According to previous literatures, the rate of neurological complications of PVCR ranged from 6.98 to 17.15 % [6–9, 16]. Suk et al. reported 2 complete cord injuries in 70 patients. They postulated that these injuries were associated with disrupt of the blood supply of the cord [6]. In Lenke's study, no permanent cord injuries occurred. They suggested that intra-operative MEP monitoring, proper arterial pressure and the use of high-speed burr may be helpful to avoid the neurological compromises [7]. Recently, Papadopoulos reported that complete cord injury occurred in 1 (2.2 %) out of 45 patients.

Root injuries happened to 2 patients (4.4 %); one was permanent and the other was transient. They thought that protect of blood supply of the cord and correction of the kyphotic deformity by sequential rod exchange or in situ bending rather than cantilever technique may help to decrease the risk of neurological complications [9]. After reviewing their 76 patients undergoing PVCR for severe spine deformities, Xie et al. thought that preexisting neurologic dysfunction, associated with intraspinal and brain stem anomalies, scoliosis associated with thoracic hyperkyphosis and level of vertebral column resected were independent risk factors for neurologic deficits during PVCR procedure [17]. According to Hui's [18] and Jeszenszky's [19] experiences, preoperative Halo-vest traction might contribute to improving the neurological safety during PVCR. Zeng thought that protect of the blood supply of the spinal cord was important to decrease the risk of neurological complications as the disastrous result of spinal cord ischemia was equal to that of direct injury. Thus maintainence of normal or elevated blood pressure during the surgery was recommended [20]. The incidence of neurologic complications was relatively low (8.3 %) in the current study. We thought that preoperative surgical release of the intraspinal anomalies which could tether the cord, delicate procedures during the surgery, use of a temporary rod to provide stability during the osteotomy, avoidance sacrifice of bilateral roots in the same level in the thoracic spine, application of intra-operative spinal cord monitoring, control of the blood pressure during the osteotomy and correction, avoidance of ST and sufficient anterior reconstruction to avoid over shortening might contribute to the low incidence of neurologic complications.

In our series, no complete cord injuries occurred. One patient (Case 22) with pre-operative neurological deficits (ASIA C) aggravated (ASIA B) after the surgery, and recovered to ASIA D 6 months later. Another patient developed transient root injury (Case 12) after the surgery and completely recovered 6 months later. To review the surgeries, signs of over shortening were detected in both patients. Shortening of the cord is considered safe, but too much shortening (>2 cm) may be dangerous. Although anterior reconstruction with a mesh cage was performed on both of the patients above, severe dura bucking, which may increase the pressure in the dural sac, was noted after the correction. We considered that the height of the cage might be insufficient. The probable cord edema due to kinking during the surgery together with increased pressure in the dural sac can result in disrupt of the blood supply of the cord. Then neurological compromises may develop. Thus sufficient anterior reconstruction with a proper cage is mandatory to help avoid this phenomenon after PVCR. Besides, O'Shaughnessy reported that the neurological deficits without cord compression and implants malplacement might successfully treated with cord decompression duraplasty [21]. Spiro et al. pointed out that extensive laminectomy should be performed immediately when the diminution or loss of signal occurred during the surgery [22].

During closure of the osteotomy gap, ST of the upper and lower vertebras may occur and result in compression of the cord especially when more than one levels were resected. It should be corrected in time to avoid permanent injuries of the cord. Intra-operative fluroscopy could help to detect ST. According to our experiences, ST could be controlled if pedicle screws were used on the adjacent levels above and below the vertebras to be resected. During the surgery, re-position of the mesh cage may be needed to correct the ST. In the current study, ST was found in 2 cases with changes of MEP signals. And after the correction of ST, the MEP signals went back to the base line. And the Wake-up test was negative.

Either PSO or PVCR could be chosen for the treatment of kyphosis. Actually we usually choose PSO for patients with relatively global kyphosis. Good correction of angular congenital kyphosis needs translation of the spine, which could be only obtained by VCR. Furthermore, unlike kyphosis due to other etiologies, most of congenital deformities were due to formation failures, the vertebra bodies around the apex were small with lots of cartilages, even muti-levels PSOs could not provide enough correction. And PVCR could be an ideal procedure for these patients. In the current study, all of the 24 patients with severe and rigid angular kyphosis were treated with PVCR. For patients with intra-spinal anomalies, Zeng et al. suggested that as PSO and PVCR would shorten the spine, surgical treatment of these anomalies before the correction was not necessary [4]. However, in our series, the pre-operative neurological deficits of a patient (case 22) with diastematomyelia and tethered cord aggravated after the surgery. During the surgery we confirmed that all implants were in ideal position and there was no bony compression at the osteotomy site. So conservative treatment was given. And his ASIA grade recovered from B to D 6 months after the surgery. For another patient (Case 24), We surgically treated the meningocele within the levels of PVCR concurrently during the correction surgery before the osteotomy. Then T12 was resected and the correction was satisfied (98°–20°). No neurological deficits developed after the surgery and her pre-operative incomplete paraplegia completely recovered 3 months later. We postulated that although it may be safe to normal cord, transient kinking may even cause injuries to the cord with anomalies during the correction when the translation of the spine occurred after PVCR, especially in patients with preoperative neurological deficits. Based on this hypothesis, we suggest that staged or concurrent surgical release of intra-spinal anomalies, which can tether the cord, should be performed before the PVCR for the correction of severe rigid congenital kyphosis, especially for

patients with preoperative neurological deficits. Recently, Hui et al. shared their experiences in the successful treatment of a patient with congenital scoliosis and type I split spinal cord malformation with preoperative Halo-vest traction and PVCR. They thought that preoperative halo-vest traction might be helpful to decrease the risk of neurological deficits of PVCR for these patients [18]. However, until now there were no studies with lager patient sample on this topic.

Implants failures occurred 5.7–8.9 % of the patients in the previous studies [6–9, 16, 17, 20]. Most of them were due to pseudarthrosis. Dislodgement of the cage may even cause disastrous cord injury. The reason might be that the bone graft in the cage was not strong enough to provide enough structural support. The use of brace after PVCR has been reported in previous studies [7, 9]. And we noted that implants failures occurred in our patients undergoing spinal osteotomies during the early period after the surgery even when a stable fixation has been achieved in the surgery. According to our experiences, a temporary postoperative plastic brace may be helpful to enhance the post-operative stability until bony fusion was achieved. In our series, Rod breakage and mesh cage dislodgement due to pseudarthrosis happened to one patient. This may result from excessive posterior bone resection and resultant instability. During the posterior revision surgery, no bony fusion across the osteotomy site was detected. We took the cage out, and performed debridement of the pseudarthrosis to the bleeding bone. Then sufficient cancellous bone graft from the ilium was used for anterior reconstruction with a cage and posterior-lateral fusion. To decrease the risk of pseudarthrosis, we suggest that the anterior cage should be filled with sufficient auto cancellous bone. The upper and lower endplates should be well prepared until the bleeding bone could be observed. And the decortication of the posterior elements is essential. A rib "bridge" from the dorsal aspect of the decorticated lamina above to the decorticated lamina below could create the bone coverage for dural protection as well as to provide a posterior onlay fusion [7].

Other complications such as infections and penumothorax were not found in this series. However, the number of our patients is too small to draw conclusions. Further studies on more patients are needed.

Conclusion

Posterior only vertebral column resection an ideal procedure for severe rigid isolated congenital kyphosis and it could acquire satisfied correction. More than one vertebrectomies are often needed for angular deformity. However, it is highly technical demanding. Neurological complications still remain the biggest challenges. Sufficient height of anterior reconstruction, avoidance sacrifice of bilateral roots in the same level in the thoracic spine, avoidance of the ST of the upper and lower vertebras, intra-operative neuromonitoring, and surgical release of the intra-spinal anomalies which can tether the cord may help to improve the safety.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interests related to this work.

References

1. McMaster MJ, Singh H (1999) Natural history of congenital kyphosis and kyphoscoliosis. A study of one hundred and twelve patients. J Bone Joint Surg Am 81:1367–1383
2. Winter RB, Moe JH, Wang JF (1973) Congenital kyphosis. Its natural history and treatment as observed in a study of one hundred and thirty patients. J Bone Joint Surg Am 55:223–256
3. Kim YJ, Otsuka NY, Flynn JM et al (2001) Surgical treatment of congenital kyphosis. Spine 26(20):2251–2257
4. Zeng Y, Chen ZQ, Qi Q et al (2013) The posterior surgical correction of congenital kyphosis and kyphoscoliosis: 23 cases with minimum 2 years follow-up. Eur Spine J 22:372–378
5. Yunus Atici, Sokucu S, Uzumcugil O et al (2013) The results of closing wedge osteotomy with posterior instrumented fusion for the surgical treatment of congenital kyphosis. Eur Spine J 22(6):1368–1374
6. Suk SI, Kim JH, Kim WJ et al (2002) Posterior vertebral column resection for severe spinal deformities. Spine 27:2374–2382
7. Lenke LG, O'Leary PT, Bridwell KH (2009) Posterior vertebral column resection for severe pediatric deformity. Spine 34(20):2213–2221
8. Hamzaoglu A, Alanay A, Ozturk C et al (2011) Posterior vertebral column resection in severe spinal deformities. Spine 36:E340–E344
9. Papadopoulos E, Boachie-Adjei O, Hess WF et al (2013) Early outcomes and complications of posterior vertebral column resection. Spine J 15:983–991
10. Noordeen MHH, Garrido E, Tucker SK et al (2009) The surgical treatment of congenital kyphosis. Spine 34(17):1808–1814
11. Ayvaz M, Olgun ZD, Dimirkiran HG et al (2014) Posterior all-pedicle screw instrumentation combined with multiple chevron and concave rib osteotomies in the treatment of adolescent congenital kyphoscoliosis. Spine J 14:11–19
12. Wang Y, Zhang Y, Zhang X et al (2008) A single posterior approach for multilevel modified vertebral column resection in adults with severe rigid congenital kyphoscoliosis: a retrospective study of 13 cases. Eur Spine J 17:361–372
13. Leatherman KD, Dickson RA (1979) Two-stage corrective surgery for congenital deformities of the spine. J Bone Joint Surg Br 61:324–328
14. Bradford DS (1987) Vertebral column resection. Printed abstract from the Association of Bone and Joint Surgeons Annual Meeting. Orthop Trans 11:502
15. Boachie-Adjei O, Bradford DS (1991) Vertebral column resection and arthrodesis for complex spinal deformities. J Spinal Disord 4:193–202

16. Suk SI, Chung ER, Kim JH et al (2005) Posterior vertebral column resection for severe rigid scoliosis. Spine 30:1682–1687
17. Xie JM, Zhang Y, Wang YS et al (2014) The risk factors of neurologic deficits of one-stage posterior vertebral column resection for patients with severe and rigid spinal deformities. Eur Spine J 23:149–156
18. Hui H, Zhang ZX, Yang TM et al (2014) Vertebral column resection for complex congenital kyphoscoliosis and type I split spinal cord malformation. Eur Spine J 23:1158–1163
19. Jeszenszky D, Haschtmann D, Kleinstuck FS et al (2014) Posterior vertebral column resection in early onset spinal deformities. Eur Spine J 23:198–208
20. Zeng Y, Chen Z, Guo Z et al (2013) Complications of correction for focal kyphosis after posterior osteotomy and the corresponding management. J Spinal Disord Tech 26(7):367–374
21. O'Shaughnessy BA, Koski TR, Ondra SL (2008) Reversal of neurological deterioration after vertebral column resection by spinal cord untethering and duraplasty. Spine 32:E50–E54
22. Spiro AS, Rupprecht M, Stenger P et al (2013) Surgical treatment of severe congenital thoracolumbar kyphosis through a single posterior approach. Bone Jt J 95-B(11):1527–1532