Eur Spine J (2016) 25:2368–2375
DOI 10.1007/s00586-015-3767-7

REVIEW ARTICLE

Posterior vertebral column resection in spinal deformity: a systematic review

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Received: 22 September 2014 / Revised: 10 January 2015 / Accepted: 11 January 2015 / Published online: 20 January 2015

Abstract

Purpose This study aimed to assess the amount of correction and risk of complications of posterior vertebral column resection (PVCR) in the treatment of spinal deformity.

Methods A comprehensive research was conducted in MEDLINE, EMBASE and Cochrane Database of Systematic Reviews for published articles about PVCR in spinal deformity. Data from these included studies were pooled with the help of the Review Manager software from the Cochrane Collaboration and the R software. The amount of correction of PVCR was indicated with change of coronal and sagittal Cobb angle after operation. Risk of complications was demonstrated with prevalence.

Results 7 studies, a total of 390 patients, were included for analysis. The average operative time for PVCR was 430 min and the estimated blood loss was 2,639 ml. The mean amount of correction by PVCR was 64.1° in scoliosis and 58.9° in kyphosis, accounting a correction rate of 61.2 and 63.1 %, respectively. As to coronal and sagittal imbalance, data were limited. The overall prevalence of complications of PVCR was 32 % (95 % CI 12–54 %). The most common was neurologic complications, estimated to be 8 % (95 % CI 2–16 %). And risk of spinal cord injury was 2 % (95 % CI 0–3 %). The revision rate was 6 % (95 % CI 1–13 %). Incidence of infection was pooled to be 2 % (95 % CI 1–4 %). Complication rate related with implant was 2 % (95 % CI 0–6 %).

Conclusion PVCR is a powerful surgical procedure for severe spinal deformity. However, it has the risk of excessive blood loss and major complications. Decision of PVCR should be prudent and the procedure should be performed by an experienced surgical team.

Keywords Posterior vertebral column resection · Spinal deformity · Scoliosis · Kyphosis · Complication

Introduction

Severe spinal deformity is a relatively uncommon condition which has a great impact on cosmetic appearance, pulmonary function and general health (such as pain, easy fatigue and neurologic symptoms). Surgery is usually advisable for patients with severe spinal deformity. The goals of surgery are to obtain satisfactory self-image, a sagittal and coronal balance, prevention of progression of deformity and relief of symptoms if possible. The surgical treatment of severe spinal deformity is demanding and extremely challenging. Conventional procedures such as posterior or/and anterior instrumentation and fusion afford limited correction in severe spinal deformity. Osteotomies such as Smith-Peterson osteotomy (SPO), pedicle subtraction osteotomy (PSO) and vertebral column resection (VCR) are usually considered. VCR is the most powerful operative method and reserved for severe spinal deformity which cannot be alleviated with other osteotomies.

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VCR is defined as "a 3-column circumferential vertebral osteotomy creating a segmental defect with sufficient instability to require provisional instrumentation" [1]. One or more vertebral segments are completely resected through a combined anterior and posterior approach or posterior-only approach. It derived from vertebrectomy, which was first illustrated in 1922 by MacLennan [2] as an apical resection for the treatment of severe scoliosis. In 1982, Eduardo Luque [3] performed the decancellation through an anterior fenestration without violating the segmental vessels and posterior resection, followed by spinal shortening with segmental instrumentation. Modification of the Luque technique was described by Bradford in 1987 [4]. Instead of decancellation through an anterior fenestration, the vertebral column was resected with an osteotome through a combined anterior and posterior approach. In 1997, Bradford [5] reported another series of patients. Both of Bradford's research reported a favorable correction (more than 50°, accounting a correction rate over 50 %). However, the combined anterior and posterior VCR (APVCR) is a challenging procedure for both the surgeons and patients, requiring an exhaustively lengthy operation with a great risk of major complications. It was reported to have operative time of over 12 h and blood loss of more than 5,500 ml and a high risk of complications (nearly 50 %) [5, 6].

To mitigate the technical difficulties, in 2002 Suk [7] introduced the technique of vertebral column resection through a posterior-only approach (posterior vertebral column resection, PVCR), which had been reported in the resection of spinal tumor [8]. It is a single procedure and avoids opening of the thoracic cage and pleura. It also enables manipulation under a simultaneous control of both anterior and posterior columns. Many authors reported series of PVCR sequentially. However, it remains the fact PVCR is still a major procedure and application of PVCR was controversial, mainly because of high risk of complications, its aggressiveness and technical difficulty [1, 7, 9–11]. But so far no articles predominantly concerning on this topic have been published. It is necessary to systematically review and evaluate the efficacy and safety of PVCR before more procedures are carried out.

Through systematically collecting and analysis of all the articles about PVCR in the treatment of spinal deformity, the current study is to demonstrate the amount of correction of this technique for spinal deformity and concentrate on the risk of complications of PVCR.

Method

The systematic review was prepared in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) guidelines.

Literature search

The MEDLINE, EMBASE and Cochrane Database of Systematic Reviews were searched for eligible studies with the term "vertebral column resection". The search strategy was available in the appendix. No language restriction was used. Reference lists of related reviews were also searched as an addition.

Including and excluding criteria

Studies were included according to the following criteria: patients that had PVCR because of spinal deformity and had data of radiologic correction and/or complications. Patients that had PVCR for tumor or hemivertebra were excluded.

Study selection and data extraction

The titles and abstracts were screened for relevance. Relevant studies were retrieved and assessed for inclusion, using the above criteria. Data were extracted according to predetermined form. Two reviewers worked independently and any disagreements were resolved by a third reviewer if necessary.

Statistical analysis

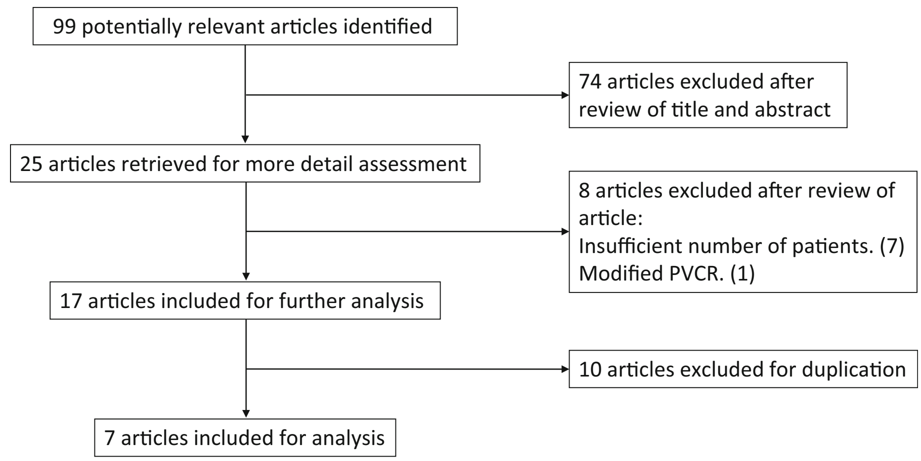
Continuous data, that is, changes of Cobb angle in coronal and sagittal plane, were synthesized with weighted mean difference. The statistical analysis was performed with the help of the Review Manager software from the Cochrane Collaboration (Version 5.2). Medians were used when mean values were unavailable. Missing standard deviations were imputed using methods reported in the Cochrane Handbook [12]. Prevalence of complications was pooled with help of the R software (Version 3.0.2).

Statistical heterogeneity among studies was evaluated using the I^2 statistic. If I^2 was less than 50 %, a fixed effect model would be employed. Otherwise, a random effect model would be suitable.

Results

The search strategy identified 99 studies. Twenty-five studies were retrieved for further evaluation. Seven studies were excluded for insufficient number of patients (less than 10 patients) and one study was excluded due to the fact that the "modified PVCR" was performed. Seventeen studies from seven institutions [7, 9–11, 13–25] were included for further analysis. To avoid overlap of patients in different studies, only one main publication from each institution

Fig. 1 Flow diagram



was retained. Thus, seven studies [7, 9, 16, 20, 21, 24, 25] (a total of 390 patients) were included finally (Fig. 1). The etiology of spinal deformity (scoliosis, kyphosis and/or kyphoscoliosis) was different. It might be congenital, idiopathic, post-traumatic or post-infectious. The average age ranged from 14 to 38.5 years. The average follow-up ranged from 2 to 9 years. Most of resected vertebrae were at thoracic or lumbar spine and the average number of vertebrae resected ranged from 1.3 to 2.8 (Table 1).

The average operative time for PVCR was 430 min and the estimated blood loss was 2,639 ml. (according to 288 patients from 6 studies).

Only the study by Suk et al. mentioned the coronal imbalance, with the preoperative imbalance of about 30 mm and postoperative imbalance corrected to less than 10 mm. As to coronal Cobb angle, to better demonstrate the capability of PVCR, only the patients with preoperative scoliosis more than 90° were analyzed. A total of 199 patients were included. The average of preoperative Cobb angle was 104.7° and the postoperative Cobb angle was 40.6°. The average amount of scoliosis correction was 64.1°, accounting for a correction rate of 61.2 % (Fig. 2).

It was strange but none of seven studies had a sagittal imbalance of SVA larger than 40 mm. As it is usually accepted that only an SVA larger than 40 mm could be deemed a sagittal imbalance [26], we did not pool the data of SVA. With regard to kyphotic Cobb angle, 38 patients with mild preoperative kyphosis (44°) were not included in the analysis. A total of 236 patients were included. The average of preoperative kyphosis was 93.3° and the postoperative kyphosis was 34.4°. The average amount of kyphosis correction was 58.9°, accounting for a correction rate of 63.1 % (Fig. 3).

121 complications occurred in 390 patients (32 %, 95 % CI 14–54 %). The most common complication was neurologic complications, including nerve root injury, spinal cord injury, cauda equina syndrome and disorder of bowel–bladder function and deteriorated myelopathy after operation, estimated to be 8 % (36/390, 95 % CI 2–16 %). Ten cases of spinal cord injury were reported, accounting a pooled incidence of 2 % (95 % CI 0–3 %). Three cases of spinal cord injury were complete and permanent for unknown reason [7, 25]. Four transient spinal cord injury were due to instrumentation failure (two patients) [25], titanium mesh loosening (one patient) [21] and osteotomy segment shifting (one patient) [21] and recovered after appropriate maneuver. Two patients without any spinal cord monitoring failed a wake-up test [16]. One was possibly because of over-shortening of spinal cord and managed with placement of an anterior cage and decompression. The other was most likely caused by compression of the cottonoid, which was removed immediately. Both patients wake up with intact neurologic function finally. The remaining patient with complete spinal cord injury was managed with methylprednisolone after excluding mechanical compression through emergency computed tomography (CT) and magnetic resonance imaging (MRI) examination and neurologic function was completely normal in 2 weeks [20]. Prevalence of revision was 6 % (31/390, 95 % CI 1–13 %). The cause of revision was infection, implant failure, pseudarthrosis, hematoma, recurrence or progress of deformity, and neurologic complications. The most common cause of revision was infection, with an incidence of 2 % (13/390, 95 % CI 1–4 %). The risk of implant-related complications was 2 % (95 % CI 0–6 %) (Tables 2, 3).

Four studies (a total of 205 patients) clearly stated changes of intraoperative spinal cord monitoring. [9, 16, 24, 25] Three studies used both motor-evoked potentials (MEPs) and somatosensory-evoked potentials (SSEPs) and the remaining used MEPs alone. Intraoperative monitoring changes occurred in 24 patients, accounting an incidence of 10 % (95 % CI 6–15 %) (Table 3).

Table 1 Descriptive data of included studies

References	Year	*N*	Deformity	Diagnosis	Age	F:M	FU/year	Level	Vertebra resected	Fusion levels
Hamzaoglu [9]	2011	102	S, K, KS	Severe spinal deformity (idiopathic, congenital, etc.,), 56	37.6	80:22	9.3	U	1.3	U
				Osteoporotic fractures with neurologic compromise, 25						
				Healed tuberculosis with severe angular kyphosis, 12						
				Posttraumatic deformity, 9						
Lenke [16]	2010	43	S, K, KS	Severe scoliosis, 7	23.9	23:20	2.2	T3-L2	1.5	U
				Global kyphosis, 12						
				Angular kyphosis, 10						
				Combined kyphoscoliosis, 14						
Papadopoulos [25]	2013	45	K, S	Congenital, 9	14	25:20	2.3	T1-L5	2.8	10.4
				Infectious, 36						
Suk [7]	2002	70	S, K, KS	Adult scoliosis, 7	27.4	36:34	2.8	T-L	2.1	6.3
				Congenital kyphoscoliosis, 38						
				Post-infectious kyphosis, 25						
Xie [20]	2014	76	S, K, KS	Idiopathic spinal deformity, 31	17.5	39:37	4.1	T-L	1.5	U
				Non-idiopathic spinal deformity, 45						
Zeng [21]	2013	39	K	Traumatic, TB, C, Iatrogenic	38.5	U	2.6	T-L	U	U
Zhang [24]	2013	15	K	TB	35.8	6:9	3	T8-L2	1.3	7.7

N number of patients, *S* scoliosis, *K* kyphosis, *KS* kyphoscoliosis, *F:M* ratio of female/male, *FU* follow-up

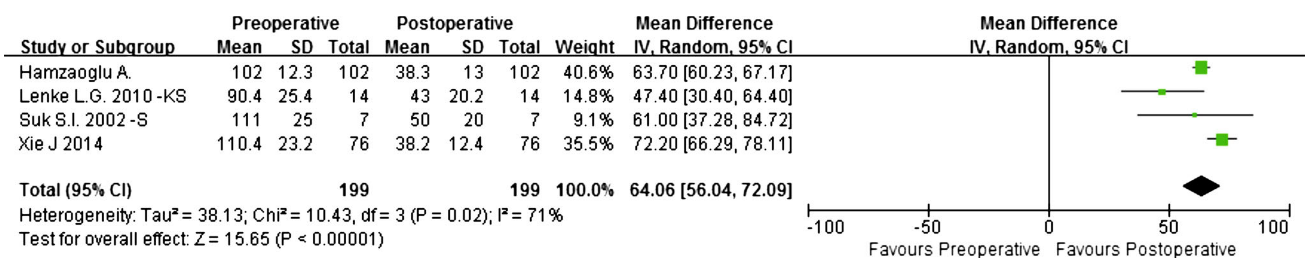


Fig. 2 Change of coronal Cobb angle after PVCR

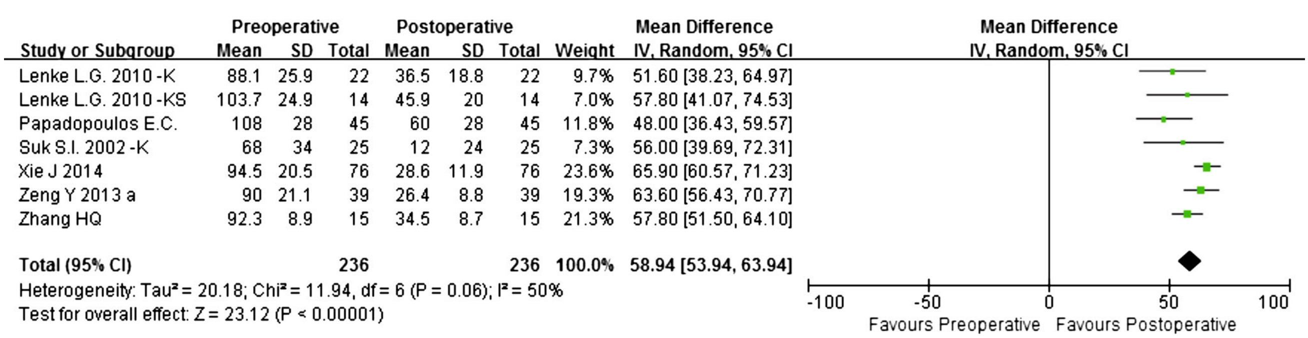


Fig. 3 Change of sagittal Cobb angle after PVCR

Table 2 Incidence of complications

	Overall	Neurologic complications	Spinal cord injury	Revision	Infection	Implant
PVCR (%)	32 (14, 54)	8 (2, 16)	2 (0, 3)	6 (1, 13)	2 (1, 4)	2 (0, 6)
Posterior instrumentation (%)	5.1	0.32	0.21	–	1.35	0.64

Table 3 Detail of neurologic complications and NMEP changes

References	Neurologic complications	Detail	Neurologic monitoring	NMEP changes	Detail
Hamzaoglu [9]	2	2 nerve root injury	MEP	6	4 translation 2 compression of spinal cord
Lenke [16]	5	2 SCI (L2, anterior cage. T10-11, removal of cottonoid. Recover) 1 numbness in bilateral lower limb 1 left quad palsy 1 decreased strength of left quad	MEP, SEP	7	3 translation 2 over-shortening 1 compressed by cottonoid 1 unknown
Papadopoulos [25]	9	1 SCI (Unknown reason) 2 transient SCI (instrumentation failure. Revision. Recover.) 2 nerve root injury 2 bowel–bladder disturbance 2 deteriorated myelopathy	MEP, SEP	10	1 SCI 1 compressed by cross-link
Suk [7]	12	2 SCI (Unknown reason) 4 root injury. 6 hematomas with cauda equina syndrome	SEP	–	–
Xie [20]	1	1 complete SCI 8 h after operation Methylprednisolone. Recover	Data unavailable	–	–
Zeng [21]	7	2 transient SCI (Mesh loosen, segment shifting. Revision. Recover) 5 nerve root injury	Data unextractable	–	–
Zhang [24]	0	None	MEP, SEP	1	
Total	36			24	

Discussion

Treatment of severe spinal deformity has always been challenging. The surgery for correction of severe deformity occurs in 3 stages [27]: anchor placement, spine mobilization and correction. Most surgeons preferred pedicle screws for anchor placement. And in correction, the key is maintenance of spinal stability. As to spine mobilization, the strategy could be described with a pyramid [27]: interspinous ligament and ligamentum flavum release, complete wide facetectomy, anterior release and rib resection, vertebral body decancellation, PSO (pedicle subtraction osteotomy) and VCR (vertebral column resection). Theoretically, VCR is the most powerful mobilization strategy. However, for its high risk of complications as well as its aggressiveness and technical difficulty, VCR is reserved for severe spinal deformity which cannot be alleviated with other strategies. VCR was first performed through a combined anterior–posterior approach. To mitigate the technical difficulties, PVCR was introduced by Suk [7] in 2002 as an effective alternative for moderate to severe deformity with limited flexibility. Many authors had sequentially reported application of PVCR. However, no systematic review about PVCR in the correction of spinal deformity had been published.

In the current study, a systematic research of the literature was conducted and seven studies (a total of 390 patients) were included for analysis. Although claimed to be devised to reduce the technical difficulties, PVCR was still a challenging procedure. The average operative time for PVCR was 430 min and the estimated blood loss was 2,639 ml. But the effect of correction was excellent. Correction of scoliosis was 64.1° and correction of kyphosis was 58.9° in severe spinal deformity, accounting for a correction rate of 61.2 and 63.1 %, respectively. This represents a much better correction when compared with the published correction values of 30–40° for pedicle subtraction osteotomy [28]. In fact, PVCR is a complete destabilizing osteotomy of the spine, the amount of correction is only limited by the spinal cord. But it should be noted that none of the seven studies concentrated on trunk balance, especially sagittal balance, which had close relationship with quality of life. We have noted only one study [11], which was not included in our analysis for duplication of patients, had significant preoperative sagittal imbalance and the correction rate was reported to be 74 %. Due to lack of data, sagittal evaluation with other parameters such as pelvic tilt (PT) and pelvic incidence minus lumbar lordosis (PI-LL) was impossible.

The overall prevalence of complications was pooled to be 32 %. The risk of complications was much higher than posterior instrumentation and fusion in the treatment of adolescent idiopathic scoliosis (5.2 %, data from 4,369 patients in the Morbidity and Mortality database of the Scoliosis Research Society) [29]. One major concern of PVCR is neurologic complications. In the current study, thirty-six cases of neurologic complications, ten of which were spinal cord injury, were observed in 390 patients (8 % for neurologic complications and 2 % for spinal cord injury). With no doubt, the risk of neurologic complications and spinal cord injury was really high while the overall incidence following posterior surgical treatment for adolescent idiopathic scoliosis (AIS) was reported to be 0.32 and 0.21 %, respectively [29] (Table 2). However, it seemed that the neurologic risk of PVCR was not more than PSO. Buchowski et al. [30] reported the incidence of neurologic complications to be 11.1 % in 108 patients and Kim et al. [28] reported to be 10.7 % in 140 patients. And Kelly et al. [31] reported the incidence of neurologic complications to be similar between PSO and VCR (113 PSO and 19 VCR, 15.8 versus 8.8 %, $p = 0.348$). In fact, despite being much more challenging in the respect of technique, the spinal cord and nerve roots were under direct vision during the PVCR procedure and compression or direct injury could be well averted [25].

Lenke et al. [1] had conducted a research mainly focusing on the complications of VCR. 120 patients treated with PVCR and 27 patients with APVCR were analyzed. Operative time average 545 min and estimated blood loss averaged 1,610 ml. The overall complication rate was 59 and 27 % of patients had an intraoperative neurologic event (spinal cord monitoring change or failed wake-up test). The risk of neurologic complications was estimated to be 11.6 % (17 patients) and seven patients had spinal cord injury (4.8 %). Lenke et al. had reported a much higher rate of overall complications and spinal cord monitoring changes. It might be due to different definition. For example, in Lenke LG's study, excessive bleeding (>2L) was also counted as complication. And any change was recorded in the research of Lenke et al. while the four studies included in our research mainly recorded changes not related to anesthesia or hypotension. The risk of neurologic complications and spinal cord injury was also a little higher than that of our research.

PVCR was introduced to ease the technical difficulty of APVCR. Theoretically, PVCR has a number of advantages over anterior–posterior VCR: reduction of operative time and blood loss, maintenance of spinal stability throughout the whole procedure, more reliable reconstruction of spinal column, less postoperative morbidity, and more effective correction [7, 10]. In this study, we had tried to compare PVCR with APVCR (Table 4). The two earlier studies by Bradford et al. demonstrated that APVCR had much more operative time, blood loss and complications but less correction than PVCR. However, recently Ren et al. [32] reported dramatically declined blood loss (1,712.5 ml) and operative time (552.2 min) with APVCR. What is more, complications were encountered in only 2 of the 26 patients and there were no neurologic complications. Similarly, in the Lenke et al's research [1], PVCR was compared with APVCR directly. Operative time was less in PVCR (639 min versus 486 min, $p = 0.004$) but there was no significant difference in blood loss (1,450 ml versus 1,000 ml, $p = 0.079$). No significant difference was observed between PVCR and APVCR in complications.

Table 4 Previous studies of APVCR

	n	Blood loss/ml	Operative time/min	Correction	Complications	Neurologic complications
Bradford	16	5,850	726	50 % correction in scoliosis (from 108° to 54°)	14 complications in 7 patients	12.5 %
Bradford	24	5,500	730	52.4 % correction in scoliosis (from 103° to 49°) 82.4 % correction in coronal imbalance (from 8.5 to 1.5 cm) 38 % correction in kyphosis (from 79° to 49°) 87.5 % correction in sagittal imbalance (from 8 to 1 cm)	31 complications in 14 patients	12.5 %
Ren C	43	1,713	552	67.3 % correction in scoliosis (from 101° to 33°)	2 complications	0

With these limited and inconsistent data, it was hard to prove any clear advantage over PVCR or APVCR. However, APVCR had fallen out of favor for several factors. Anterior transthoracic procedures were challenging for most orthopedists and proved to have detrimental effects on pulmonary function [33–37]. And it was difficult to approach the concavity of the angular kyphosis in deformities greater than 60° [25]. Correction by pure distraction of the anterior column might also cause severe stretching of the spinal cord.

One advantage of PVCR was believed to preserve the pulmonary function. However, we failed to provide any evidence for or against this opinion due to lack of data. Bumpass DB [13] recently reported that only pediatric patients experienced significant but slight improvements in pulmonary function after PVCR. And compared with combined anterior and posterior approach without vertebrectomy, PVCR did not show a clear advantage. In fact, PVCR often needs bilateral costotransversectomies and removal of medial ribs. And it had been reported that any disruption of chest cage might have a negative effect on pulmonary function [33, 35, 36, 38]. So preservation of pulmonary function with PVCR was suspectable.

Overall, PVCR provides powerful and definite correction in spinal deformities. But it should be kept in mind that the procedure itself is of great risk, including excessive blood loss and high complication rates, especially neurologic complications. And the procedure is aggressive and technically difficult in nature, creating a complete deficit of all the 3 columns of the spine and an extreme instability during operation. All the authors suggested that decision of PVCR should be prudent and performed by an experienced team. Preoperative halo-gravity traction, followed by posterior correction and instrumentation, might decrease the needs for PVCR. Traction can increase the flexibility of the spine and chest and improve pulmonary function. It is important to realize that most severe spine deformity will demonstrate significant improvement radiographically and clinically following traction, especially in pediatric patients. It was well tolerated and satisfying correction could be expected. The benefits of preoperative traction plus posterior correction and instrumentation had been documented by Sponseller et al. [39], Koptan et al. [40] and Park et al. [41].

Several limitations exist in our study. First, the etiology of spinal deformity was different. There is risk of bias in pooling data from studies with clinical heterogeneity. Second, data of clinical outcomes, such as SF-36, SRS-22, were not available in nearly all studies. Third, most patients have relatively good coronal and sagittal balance. In addition, spino-pelvic parameters are not recorded in the original studies.

Conclusion

PVCR is a powerful surgical procedure for severe spinal deformity. However, it has the risk of excessive blood loss and major complications. Decision of PVCR should be prudent and the procedure should be performed by an experienced surgical team.

Acknowledgments No funds were received in support of this work.

Conflict of interest No conflict of interest.

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