The posterior surgical correction of congenital kyphosis and kyphoscoliosis: 23 cases with minimum 2 years follow-up

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Abstract

Purpose The purpose of this study is to review our operative experience of congenital kyphosis or kyphoscoliosis undergoing either pedicle subtraction osteotomy (PSO) or posterior vertebral column resection (pVCR) according to certain criteria we have established.

Methods From December 2003 to 2009, 23 consecutive patients of congenital kyphosis or kyphoscoliosis were treated by means of PSO or pVCR procedure in a single institution. The average preoperative kyphosis angle was 74.3°. The C7 plumb line was 12.6 mm posterior to the posterior–superior corner of S1 on average, showing negative imbalance. In the 11 cases who had accompanied scoliosis, the average preoperative scoliosis angle was 42.6°. The average Oswestry Deficiency Index (ODI) for back pain was 14.6 before surgery. Eleven patients had compromise of neurological functions.

Results After PSO or pVCR procedure, the average kyphosis angle decreased to 20.0°, and the accompanied scoliosis also decreased to 15.8°. The average follow-up time after surgery was 34.3 months. At the last follow-up, the average kyphosis corrective rate was 73.7 %, and the average scoliosis corrective rate was 61.7 %. The negative imbalance improved, with the C7 plumb line being 1.5 mm posterior to the posterior–superior corner of S1 on average. After surgery, the average ODI for back pain had 40.6 % improvement, and most patients who had neurological symptoms before surgery had varying degrees of relief.

The total satisfactory rate to corrective surgery was 91.3 %. No permanent neurological damage was observed. **Conclusions** If selected appropriately, both PSO and pVCR procedures can achieve compatible and satisfactory correction results in the surgical treatment of congenital kyphosis or kyphoscoliosis.

Keywords Posterior correction · Congenital deformity · Kyphosis · Kyphoscoliosis

Introduction

Congenital spinal deformity can be derived from failure of formation or failure of segmentation of the vertebrae. Congenital kyphosis or kyphoscoliosis results from developmental vertebral anomalies that impair longitudinal growth anterior or anterolateral to the transverse axis of vertebral rotation in the sagittal plane [13]. The developmental imbalance of the deformed vertebral segment during growth may lead to severe kyphosis, scoliosis, or kyphoscoliosis. Even after skeletal maturity, congenital spinal deformity can develop continuously. In addition to cosmetic problems, many patients have significant back pain and functional disability due to the spinal imbalance associated with the kyphosis or kyphoscoliosis [21]. Others present with neurological symptoms as a result of both direct compression and over tension of the spinal cord over the deformed region. Paraplegia may occur early but is more common during the adolescent growth spurt with rapid increase in the untreated kyphosis deformity and is described as occurring after minor trauma [23].

Surgical correction is the main treatment for significant congenital spinal deformity. Its surgical correction may be associated with significant risks and challenges. In the past

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years, many surgeons have applied a variety of surgical techniques in the correction of congenital kyphosis or kyphoscoliosis, either by a single posterior procedure [2, 6, 8, 10, 15], anterior procedure [16] or combined anterior–posterior procedure [3, 14]. Majority of these studies focused on the innovation of surgical methods, improvement of corrective efficiency and reduction of surgical complications. The making process of surgical decision on the procedure selection, however, remains a problem needs to be addressed. Nowadays, the most popular osteotomy techniques are pedicle subtraction osteotomy (PSO) [2, 7, 20] and posterior vertebral column resection (pVCR) [9, 19]. Hence, we applied these two different posterior surgical correction procedures (PSO and pVCR) in our clinical practice according to the deformity characteristics of congenital kyphosis or kyphoscoliosis, and reported the radiographic and clinical outcomes on these patients.

Materials and methods

Clinical data

From December 2003 to 2009, 23 patients (Male 17 cases, Female 6 cases) with congenital kyphosis or kyphoscoliosis underwent posterior surgical correction in our hospital. The average age was 27.1 years (range 13–61 years). Three cases of this series had a previous posterior surgical history. Fourteen cases had the kyphotic apex in thoracolumbar segment or lumbar spine (T12–L2), three cases had the kyphotic apex in lower-thoracic spine (T10–T11), four cases had the kyphotic apex in mid-thoracic spine (T5–T9), and two cases had the kyphotic apex in upper thoracic spine (T1–T4). In this series, nine cases had accompanied neurological abnormality, including split cord malformation, myelomeningocele, tethered cord, syringomyelia and spinal cord hernia. Of the 23 cases, nine suffered from lower extremity neurological symptoms, seven had back pain, two presented with both neurological symptoms and back pain, and five juvenile or adolescent patients underwent the surgery to prevent the progression of deformity. All the symptomatic cases had non-effective conservative treatment at least 6 months.

Surgical procedure

There were two surgical techniques for this cohort of 23 patients. A pedicle subtraction osteotomy (PSO) was performed in nine cases that had a kyphosis angle less than 70° , and the size of deformed vertebrae was big enough to be part preserved after osteotomy. For these patients, the osteotomy space could be directly closed. The average kyphosis angle of the nine cases was 56.2° (range 48° – 66°).

A posterior vertebral column resection (pVCR) was performed in 14 cases who had a kyphosis angle over 70° , or the size of deformed vertebrae was too small to be preserved during osteotomy even when the kyphosis angle was less than 70° . For these patients, a satisfactory correction could not be achieved by directly closing of the osteotomy space. The average kyphosis angle of the 14 cases was 85.9° (range 60° – 138°) (Fig. 1).

Normal blood pressure was maintained during the operation to reduce the risk of spinal cord ischemia. Intra-operative monitoring of spinal cord function, including somatosensory evoked potential (SEP) and motor evoked potential (MEP) were routinely applied during surgery.

Radiographic evaluation

The standing full-length spine radiographs before surgery and at post-operative follow-up were examined routinely. The kyphosis angle was measured, and sagittal plane balance was evaluated in each case. Overall sagittal plane balance was measured as the horizontal distance from the C7 plumb line to the posterior–superior corner of S1 or sacral promontorium. If the C7 plumb line fell between the posterior–superior corner of S1 and the sacral promontorium, that indicated a well-balanced condition. Positive sagittal imbalance was described as the C7 plumb line falling anterior to the sacral promontorium. Negative sagittal imbalance was considered when the C7 plumb line fell posterior to the posterior–superior corner of S1. There were 11 patients who had accompanied scoliosis, which was also measured as important parameter in the film.

Clinical evaluation

Back pain of the patients was measured with the Oswestry Deficiency Index (ODI) before surgery and at follow-up. The neurological function assessments were evaluated using the Frankel grading system. The Patient Satisfactory Index (PSI) was used to evaluate the satisfaction rate with surgery.

Results

The average preoperative kyphosis angle was 74.3° (range 48° – 138°). In the 11 cases who had accompanied scoliosis, the average preoperative scoliosis angle was 42.6° (range 12° – 112°). The C7 plumb line was 12.6 mm posterior to posterior–superior corner of S1 on average (range -88 to 60 mm). Negative sagittal imbalance was evidenced in 10 cases, with 47.0 mm of posterior shift of C7 plumb line on average. The sagittal plane balance was well maintained in eight cases. Positive sagittal imbalance was found in five

Fig. 1 The illustration of two surgical procedures. **a** The pedicle subtraction osteotomy (PSO). **b** The posterior vertebral column resection (pVCR)

cases, with 35.9 mm of anterior shift of C7 plumb line on average (Table 1).

Before surgery, the average ODI for back pain was 14.6 in all patients, including the patients who had no back pain. The average ODI was 10.0, 18.1 and 15.0 in well-balanced, negative sagittal imbalance and positive sagittal imbalance cases, respectively. There was no statistical difference between the ODI of patients in different balance conditions ($P > 0.1$). The preoperative Frankel grade for neurological functions was shown in Table 2. In 14 patients who had kyphosis apex in thoracolumbar segment or lumbar spine, only three cases suffered from neurological symptoms,

whereas of the nine patients who had kyphosis apex in thoracic spine, eight complained of neurological symptoms.

The average follow-up time was 34.3 months (range 24–62 months) after surgery in all patients. The improvement of deformity immediately after surgery and at last follow-up was shown in Table 1 (Fig. 2). At the last follow-up time, the C7 plumb line was 1.5 mm posterior to posterior–superior corner of S1 on average (range –36 to 38 mm). The patients with negative sagittal imbalance decreased to four cases, with 27.0 mm of posterior shift of C7 plumb line on average, and was improved significantly compared to pre-operation ($P < 0.05$). The well sagittal

Table 1 The deformity parameters before surgery, immediately after surgery and at last follow-up in 23 patients

	Kyphosis		Scoliosis		Sagittal balance ($n = 23$)		
	Angle (°)	Corrective rate (%)	Angle (°)	Corrective rate (%)	Negative	Well	Positive
Before surgery	74.3	–	42.6	–	10	8	5
Immediately after surgery	20	75.1	15.8	67.2	–	–	–
At last follow-up	21.0	73.7	16.9	61.7	4	16	3

Table 2 The Frankel grade of the patients before surgery and at last follow-up

	Frankel grade		
	E	D	C
Before surgery	12	6	5
At last follow-up	16	6	1

balance increased to 16 cases. The patients with positive sagittal imbalance decreased to three cases, with 24.5 mm of anterior shift of C7 plumb line on average.

The average ODI for back pain was 8.7 at last follow-up after surgery, with an improvement of 40.6 % compared to preoperative ODI. The neurological functions were improved in some patients at the last follow-up (Table 2).

Fig. 2 Male, 13 years old, congenital kyphosis, failure of segmentation of L1–L3. **a** The PA and lateral radiographs demonstrated the preoperative deformity, the kyphotic angle was 103°; **b** The preoperative CT showed failure of segmentation of L1–L3; **c** The preoperative MRI showed compression of neurological element at the kyphosis apex; **d** A split cord malformation was evident in preoperative MRI; **e** The patient underwent posterior surgical

correction by posterior vertebral column resection (pVCR). These images performed 7 days after surgery demonstrated adequate correction of kyphosis to 30°; **f** In 30 months after surgery, the kyphotic angle was well kept, with a corrective rate of 70.9 %; **g** The CT in 30 months after surgery showed the good fusion of bone graft in anterior column space at the site of the pVCR osteotomy

The PSI was evaluated at last follow-up. Sixteen cases were completely satisfied and five cases were partially satisfied with the surgical results, with a satisfactory rate of 91.3 %, and a complete satisfaction rate of 69.6 %.

After surgery, both of the PSO and pVCR procedure groups had good deformity correction. The radiological and clinical results of different surgical procedures were shown in Tables 3, 4, and 5. The PSO group had relative worse ODI before surgery, and both of the two groups had similar ODI at last follow-up. The Frankel grading was improved in some patients of both groups at last follow-up.

As to the complications, there was one case (T11–T12 hemi-vertebrae) who had injury of right L1 nerve root during surgery. The patient complained weakness of lifting strength in right thigh, which recovered after rehabilitative exercise. Another patient (T5–T7 incomplete separation) suffered with transient postoperative paralysis as a result of spinal cord ischemia, which was probably from massive blood loss and prolonged hypotension during surgery. A change in neurologic function was detected by both intra-operative SEP and MEP. The patients were treated with positive dehydration, methylprednisolone and neurotrophic medicines immediately after the surgery, and his neurological functions improved in 3 months. The third patient (T6 malformation and spinal cord hernia) had the fixed rod

broken of both side and recurrent kyphosis due to non-union of bone graft in osteotomy space in four and a half years after the surgery. The patient underwent a revision surgery to achieve kyphosis correction and fusion again. All of these patients belonged to the group of pVCR procedure.

Discussion

The surgical objective for congenital kyphosis or kyphoscoliosis is decompression of neurological elements and correction of the deformity. A circumferential decompression is recommended to remove the apical region of the deformity which compromises the spinal cord or cauda equina, and followed by correction of the deformity. For severe kyphosis derived from failure of formation of the vertebrae, the resection of apical region of the deformity is often performed by pVCR procedure. Whereas, for a mild deformity such as partly wedge vertebrae or failure of segmentation, the PSO procedure may be enough to achieve satisfactory results. In the current series, the patients were divided into two groups according to their kyphosis severity and the shape characteristics of apical segment, and corresponding procedures were performed.

Table 3 The kyphosis angle and scoliosis angle of different surgical procedures before surgery, immediately after surgery and at last follow-up

	Kyphotic angle (°)			Scoliosis angle (°)		
	BS	AS (CR)	F/U (CR)	BS	AS (CR)	F/U (CR)
PSO (<i>n</i> = 9)	56.2 ± 5.9	11.3 ± 14.3 (81.0 %)	12.0 ± 14.9 (80.0 %)	42 ^a	4 ^a (90.5 %)	4 ^a (90.5 %)
pVCR (<i>n</i> = 14)	85.9 ± 21.1	25.6 ± 13.6 (71.3 %)	26.9 ± 12.9 (69.6 %)	42.7 ± 33.3	17.0 ± 14.9 (64.8 %)	18.2 ± 14.4 (58.8 %)

BS before surgery, AS Immediately after surgery, F/U At last follow-up, CR corrective rate

^a Only one case was in the group

Table 4 The sagittal balance of different surgical procedures before surgery and at last follow-up

	Before surgery				At last follow-up			
	Average	Negative	Well	Positive	Average	Negative	Well	Positive
PSO (<i>n</i> = 9)	−28.6 ± 36.2	7	0	2	−1.7 ± 21.1	3	5	1
pVCR (<i>n</i> = 14)	−2.3 ± 35.4	3	8	3	−1.4 ± 10.7	1	12	1

Table 5 The clinical evaluation of different surgical procedures

	ODI		Frankel grade (no. cases)						PSI (%)
	BS	F/U (IR)	E		D		C		
			BS	F/U	BS	F/U	BS	F/U	
PSO (<i>n</i> = 9)	18.3 ± 11.6	9.1 ± 7.3 (50.3 %)	6	7	1	2	2	0	100
pVCR (<i>n</i> = 14)	12.1 ± 12.7	8.4 ± 12.5 (30.6 %)	6	9	5	4	3	1	85.7

BS Before surgery, F/U At last follow-up, IR Improving rate

Both the PSO and the pVCR groups got good radiological and clinical results after surgery, and the improvement of patients in the two groups was comparative.

The sagittal balance of spine plays an important role to the clinical evaluation. Booth et al. [4] performed corrective surgery for flat back deformity, which was positive sagittal imbalance of the spine related to scoliosis or ankylosing spondylitis. He found that the surgical results had significant relationship with the improvement of sagittal imbalance. The patients who had a poor sagittal contour correction were less satisfied with their surgical results. Steven et al. [18] made a study of positive spinal imbalance, with majority of the patients had scoliosis or Scheuermann's disease, and none of them had a negative imbalance. He reported that the ODI for pain exacerbated with more severe sagittal imbalance, and the functional deficiency are more significant in lumbar kyphosis patients. The congenital kyphosis or kyphoscoliosis is a type of focal deformity. Some patients keep normal sagittal spine balance with a compensatory lumbar hyperlordosis matching to the kyphosis. Unfortunately, most of the cases have a negative sagittal imbalance, which is different from the ankylosing spondylitis or Scheuermann's disease. The formation of negative sagittal imbalance is due to secondary lumbar hyperlordosis and thoracic hypokyphosis derived from focal kyphosis. The patients display no forward tendency of trunk beside local kyphosis deformity. After a successful surgery, along with the correction of kyphosis, the compensatory lumbar hyperlordosis and thoracic hypokyphosis will be also adjusted, which can improve the total spine balance. If the kyphosis cannot be compensated by the curvature change of the lumbar and thoracic spine, the patient will have a forward tendency of the trunk and consequently have a positive sagittal imbalance, which can be directly improved by the corrective surgery. In our series, majority of the patients with negative or positive sagittal imbalance had a well balance after corrective surgery. Along with the improvement of sagittal balance, the back pain of the patients were also relieved significantly.

In congenital kyphosis or kyphoscoliosis, the vertebral deformity has already existed from birth, which deteriorates following growth. In some patients, the neurological element can adapt to the compromise gradually during the long-term development of deformity, and the neurological functions can be kept integrate [13, 23]. In our series, less than 50 % (11/23) of cases had different degree of neurological symptoms, and most of them had the kyphosis apex in thoracic spine. The spinal cord in the upper and middle thoracic area has the poorest collateral circulation, the so called "watershed" area of the blood supply, which makes the neurological element more fragile to the compression and longitudinal over tension [11]. After the corrective

surgery, majority of the patients with neurological symptoms had different degree of relief.

The potential neurological abnormality should be noticed before corrective surgery. Patients should be evaluated for intraspinal anomalies, as 20–40 % of the congenital spinal deformities are associated with these anomalies [5, 12, 22]. If the patient has neurological abnormality such as split cord malformation, myelomeningocele or tethered cord, the significant correction of deformity should be careful to avoid the potential compromise of neurological function. Prahinski et al. [17] suggested congenital deformities associated with intraspinal pathologies should be treated firstly by an initial surgical treatment of intramedullary pathology, and secondary surgical treatment of the deformity at a separate stage 1–2 weeks or 1–2 months later. Other scholar believed that the same stage of the management of the intramedullary pathologies and the correction of deformity was eligible [1]. In our series, 9/23 cases had neurological abnormality. Despite of different kind of anomalies, the corrective surgeries in these 9 patients achieved good results without neurological compromise. We believe a careful manipulation and continuous monitoring of spinal cord function are crucial to keep neurological intact. In addition, a kyphosis correction which lead to spinal cord shortening can effectively relieve the over tension of a tethered cord.

Conflict of interest None.

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