Non-fusion and growing instrumentation in the correction of congenital spinal deformity associated with split spinal cord malformation: an early follow-up outcome

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Received: 12 May 2012/Revised: 11 January 2013/Accepted: 15 March 2013/Published online: 5 April 2013
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Abstract

Study design A retrospective case review.

Introduction To evaluate the safety and efficacy of the non-fusion technique in achieving and maintaining the proper correction for congenital spinal deformity (CSD) and allowing normal spinal growth in patients with split spinal cord malformation (SSCM).

Materials and methods Seven patients who had CSD and SSCM were adopted, with a mean age of 8 years. All the patients in this study received Halo-gravity traction (HGT) prior to expansion of the spine and instrumentation with vertical expandable titanium prosthetic rib, growing rod or their hybrid. Five of them underwent opening wedge thoracoplasty simultaneously. And the two patients with type I SSCM underwent bony spur excision in the initial surgery before corrective manipulation. Then all the patients received a lengthened operation every six months. Changes of their major curve and length of T1–S1 spine were measured, and complications, neurological status were recorded. All the patients were followed up with an average of 32.6 months.

Results Their mean major curve improved from 90.1° to 58.6° with a correction rate of 34.9 %. The T1–S1 length increased from 26.3 to 34.7 cm at final follow-up.

Especially, one of the type I SSCM patients whose neurological deterioration was found preoperatively was significantly improved.

Conclusion Preoperative Halo-gravity traction followed by non-fusion and growing instrumentation may be effective and safe for young children of CSD associated with SSCM. But it is an ongoing study and additional large multicenter studies are necessary to further assess the safety and efficacy of non-fusion and growing instrumentation.

Keywords Split spinal cord malformation · Congenital spinal deformity · One stage · Non-fusion and growing instrumentation · Halo-gravity traction

Introduction

The etiology of congenital spinal deformity (CSD) has been identified as environmental factors, genetics, vitamin deficiency, chemicals, and drugs, singly or in combination [1]. Whatever the cause is, the resulted defects can lead to a full or partial fusion and/or lack of development of the vertebrae, thoracic cage, intraspinal deformity, etc., which, in turn, can cause a progressive curvature, thoracic insufficiency syndrome and neurological deteriorate during the growth of the child [2, 3]. The criterion of surgery for the progressive CSD has been widely accepted to be an early surgical intervention to stop the progression with early spinal in situ fusion, fusion with partial correction, hemivertebra resection, vertebral column resection fusion or convex epiphysiodesis and arthrodesis without concern to the growth inhibition effects of spinal fusion on the growing spine [4, 5]. In general, care must be given not to use the distraction instrumentation to obtain correction [6].

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Split spinal cord malformation (SSCM) is a rare type of congenital spinal cord anomaly, but a common finding associated with CSD [7]. CSD associated with SSCM in young children invariably leads to severe progression of the spinal deformity and neurological deterioration without treatment [8, 9]. Non-fusion and growing instrumentation in young children with CSD can reconstruct the spinal deformity, to the largest limit, can pursue preserving the relatively symmetrical growth potential of the vertebrae, improving the volume, symmetry, and functions of the thorax, and protecting this improvement during the growth [2, 10–12]. However, it is a common belief that SSCM must be operated before any orthopedic intervention, because the spinal cord was thought to be tethered through the bony spur, fibrous adhesions, dural sleeves, and thick terminal filum, etc., [8, 13–16]. So, the safety of a non-fusion surgical treatment to improve the spinal deformity should be considered. To our knowledge, there is no study on surgical treatment using non-fusion and growing instruments for these two associated conditions.

Therefore, by a retrospective analysis of surgical and neurological outcomes, the objective of this study is to assess the safety and efficacy of the non-fusion surgical treatment for progressive CSD with coexisting SSCM.

Materials and methods

We retrospectively reviewed the records of seven consecutive young children with CSD and SSCM treated by non-

fusion and growing instrumentation at one institution between 2007 and 2010. The profiles of all the patients are presented in Table 1. Inclusion criteria were young (not more than 10 years old) patients with CSD and SSCM, who were treated with long-segment instrumentation (more than 10 functional units) with at least 2 years of follow-up. All procedures were primary; no revisions were included in this series.

All parents of the patients signed the informed content and the clinical study was approved by Medical Ethics Committee in our institution. Patients accepted surgery only after a multidisciplinary evaluation involving a neurosurgery surgeon, pediatric general surgeon, and orthopedic surgeon. Medical records and radiographs were retrospectively reviewed. Anatomic diagnosis, comorbidities, process of surgery, operative outcomes, neurological status pre- and postoperative, and complications were noted (Table 2).

All patients underwent sedation and local anesthesia for application of the Halo ring. The number of pins varied from 4 to 6 that considered the patient's age; the younger patients had more pins placed. The traction was continuous and transferable between bed and wheelchair. Each child walks or exercises freely for 1–2 h to reduce the potential disuse osteoporosis that may occur. The initial traction force was 2–3 kg, the maximum traction was half of the patient's body weight, and should be tolerated by the patients until they were barely touching the wheelchair seat. In patients exposed to great neurological risk, the traction increased slowly with frequent neurological

Table 1 Data of the patients and radiographic measurement ($n = 7$)

Case	Age	Follow-up (months)	Deformity of ribs	Deformity of vertebrae	AV	Level of SSCMs	Level of spur	Radiography	Pattern and major level of curve
1	10	36	T4–5, T7–9F, R TIS	Unilateral unsegmented bars T4–7R, L5 hemivertebra	T7	L1–3	L1–2	Lower conus medullaris L5	L thoracic, T3–12
2	7	24	T9–10F, R 11Ribs, TIS	Unilateral unsegmented bars T1–9 R, T10–11	T10	T1–10	T5–8 2 spurs	Lower conus medullaris L5	L thoracic, T1–L1
3	8	24	T8–10F, 13 Ribs, R	Unilateral unsegmented bars, T8–12 R	T11	T7–L1		Lower conus medullaris S1, aorticopulmonary fistula	L thoracic, T6–L1
4	4	36	9 Ribs, R, TIS	Unilateral unsegmented bars, T6–12 R, L4	T10	L3–4			L thoracic, T6–L1
5	10	36	T4–5, 7–8F, R, TIS	Unilateral unsegmented bars, T2–4, T8–9 R	T7	T1–4		Syringomyelia	L thoracic, T1–12
6	7	30	T6–7F, R, TIS	Unilateral unsegmented bars, T6–8 R	T7	T9–L1		Lower conus medullaris L4–5, syringomyelia	L thoracic, T5–11
7	10	42	T5–6	Unilateral unsegmented bars, T3–7, T10–11,3	T10	T12–L3			L thoracic, T3–L1

TIS Thoracic insufficiency syndrome, F fused, R right, L left, AV apex vertebra

Table 2 Data of the surgery and neurological status ($n = 7$)

Case	Process of surgery	Level of instrumentation	Complication	Preoperative neurological status	Follow-up neurological status	Operative time (min)	Blood loss (ml)
1	Growing rod + veptr + spur resected + duraplasty + OWT	T1–L3, 4–10 right rib–rib		Progressive weakness and non-progressive sensory deficit	Weakness improved, no difference in sensory deficit	540	1000
2	Veptr + spur resected + duraplasty + OWT	The right second rib—L4, 3–10 right rib–rib	Rib fracture 1 device migration 1	Non-progressive atrophy in the right extremity	No difference	200	100
3	Dual growing rod	T3–L2				220	200
4	Veptr + OWT	T3–ilium, 3–5 right ribs,				130	100
5	Single growing rod + OWT	The second rib–L4	Distal laminar hooks migration			180	120
6	VEPTR + OWT	Double rib 3–L4	Rib fracture 1 device migration 3			105	100
7	Dual growing rods	T1–L4				210	400

VEPTR Vertical expandable prosthetic titanium rib, OWT opening wedge thoracoplasty

evaluation. Patients were encouraged to stay in the wheelchair except while sleeping and exercising, when traction in bed, 30 % of body weight was used routinely. The neurological status of the patient was monitored everyday. Patients underwent halo-gravity traction (HGT) for 4–12 weeks and without anterior release. When the correction of deformity plateaued, the orthopedic surgery to the CSD was done using non-fusion and growing instrumentation, such as vertical expandable titanium prosthetic rib, and growing rod or hybrid. Neurological monitoring was mandatory in all patients.

Studies included preimplant weight-bearing anteroposterior (AP) and lateral radiographs on the entire spine with scanogram ruler included along the lateral border for convenience of measurement purposes, supine AP of the entire spine, supine side-bending films of the spine, preoperative computed tomography (CT) scan, and magnetic resonance imaging (MRI) of the entire spine. During the HGT, every 2 weeks AP radiographs of the entire spine were obtained to monitor the correction of deformity in traction state. Within 1 week of implant surgery, weight-bearing AP and lateral radiographs of the entire spine were repeated. Spine radiographs were repeated preoperatively and postoperatively under lengthening surgeries. Preimplant AP radiographs, supine side-bending radiographs, the last posttraction radiographs, postimplant radiographs, and postexpansion radiographs at last follow-up were measured, and checked by the senior author (H.R.T). Levels of curves and types of congenital anomalies were also noted.

The Cobb angles of the coronal major curves were measured and the truncal decompensation was measured as the distance in millimeters from the central sacral vertical line to C7 plumb line. The sagittal decompensation was measured as the distance in millimeters from the C7 plumb line to the anterosuperior corner of the S1 vertebrae. T1–S1 length was used to calculate the growth of the spine over the course of treatment, the distance of linearly paralleled to the C7 plumb line from the center of T1 vertically to the horizontal line which through up-endplate of S1, was separately measured by a ruler in the preoperative and the postoperative AP radiograph and the last follow-up radiograph and converted the film scanogram distance to the substantial value.

Descriptive statistics were done to determine the means and ranges.

Results

There were seven patients: six female and one male with a diagnosis of CSD associated with SSCM, type I (with bony spur) in two patients and type II (without bony spur) in five patients. Patients were all categorized as mixed defects of CSD with unilateral unsegmented bars. In addition to CSD and SSCM, comorbidities also presented: six patients had fused ribs and five of them associated with thoracic insufficiency syndrome, four patients had lower conus medullaris and two patients had syringomyelia, all patients

had no thick filum terminale. Patterns of major curve were all left thoracic curve. Besides, one patient had congenital heart disease (aorticopulmonary fistula) without need of clinical interference. Progressive weakness and non-progressive sensory deterioration in lower extremities in one of type I SSCM patient, and non-progressive atrophy in the right lower extremity in another type I SSCM patient, there was no neurological deterioration in type II patients, all patients were self-ambulatory preoperative. Mean age at the time of surgery was 8 years (range 4–10 years).

In the initial surgery, neurological surgery for SSCM was performed on the one-stage included bony spur excision and duraplasty in type I SSCM patients before corrective manipulation; no neurosurgical procedure was done to type II SSCM patients, lengthening due to distraction to all patients was performed with non-fusion and growing instrumentation, two patients in double growing rods, one patient in single growing rod, three patients in VEPTR, and one patient in hybrid of VEPTR and single growing rod.

The upper foundation anchors were hooks in one patient, VEPTR in 3 (Fig. 1), all screws in two (Fig. 2), hybrid with hooks and VEPTR in one, the upper level was at T1 in two, T2 in two, and T3 in three. The lower foundation anchors were hooks in three, screws in three, VEPTR ilium hook in one, the lower level of instrumentation ended at L2 in one, L3 in one, L4 in four, and ilium in one patient. Location of the instrumentation was subfascial. Standard concave mid-thoracic opening wedge thoracoplasty with rib-to-rib VEPTR in four patients and without instrumentation in one patient. The mean initial operation time was 226.4 min (range 105–540 min) and the mean blood loss was 288.6 ml (range 100–1,000 ml). The patients were observed for a minimum of 24 months after initial surgical treatment with an average of 32.6 months follow-up (range 24–42 months). During the treatment period (initial surgery to final follow-up), the average number of lengthenings were 5 (range 4–6) per patients with an average interval of 6.2 months (range 5.5–8 months), the average

Fig. 1 A 7-year-old female patient with CSD and type I SSCM and TIS. **a, b** Preoperative radiographs show 105° left thoracic curve. **c** Side bending 92°. **d, e** Preoperative CT and MRI sections show a bony spur at T5–8. **f, g** Immediate postoperative AP and Lat X-rays

shows: corrected by VEPTR between right rib 2–L4 and right 3–10 ribs. **h, i** Final follow-up radiograph shows 90° reliquus curve. **j** Preoperative, and **k** 2 years after operation

Fig. 2 An 8-year-old female patient with CSD associated with type II SSCMTR. **a, b** Preoperative radiograph shows 60° left thoracic curve. **c** Side bending 45°. **d** Preoperative CT section shows unilateral unsegmented bars between right T8–12. **e** MRI sections show a type

II SSCM. **f, g** Immediate postoperative AP and Lat X-rays shows: corrected by double growing rods between T3–L2. **h, i** Final follow-up lateral radiograph shows 33° residual curve. **j** Preoperative, and **k** 2 years after operation

instrumentation spanned 14.7 (range 12–16) vertebral levels. The progressive neurological deterioration in one of the type I SSCM patient was improved after HGT; non-progressive atrophy and sensory deterioration were still unchanged at the time of the latest follow-up. Meanwhile, five patients of CSD with type II SSCM remained asymptomatic at the time of the latest follow-up.

The mean major coronal curves were corrected from an average of 90.1° (range 60°–133°) pre-initial surgery to 56.9° (range 32°–93°) post-initial surgery with a correction rate of 39.6 % (Table 3); At final follow-up, the mean Cobb angle was 58.6° (range 30°–90°) with the correction rates of 34.9 %. The T1–S1 length increased from 26.3 cm (range 22.0–30.2 cm) pre-initial to 30.7 (range 26.0–32.7 cm) cm after HGT and 31.4 cm (range 27.9–33.4 cm) post-initial (elongation) and 34.7 cm (range 29.6–37.3 cm) at latest follow-up (Table 4). In addition to initial orthopedic surgery, the length of T1–S1 elongated average 5.1 cm (range

3.1–8.1 cm), the growth over the remaining elongation treatment period was 3.2 cm (range 1.7–4.2 cm) with an average of 1.17 cm/year (range 0.6–1.5 cm/year). Thus, so far, these patients have a total average T1–S1 length increased of 8.3 cm (range 4.8–12.2 cm) from pre-initial to latest follow-up, 61.4 % of this growth is attributed to HGT and initial elongation and 38.6 % to continued growth.

No complication occurred during the course of traction (Table 2). Of the seven patients, four had no complication from the surgery of expansion to the latest follow-up, the other two patients, patient 2 and 6 experienced fortuitously rib fracture in the initial surgery, respectively, and was resected at a more upper level. Asymptomatic proximal migration of the rib cradle happened in a total of four times: complete migration of the VEPTR rib cradle through the osseous rib happened at 1, 1.5, and 2 years after implant surgery in patient 6 and at 0.5 year after implant surgery in patient 2. These complete migrations were

Table 3 Radiography measurements of the major coronal curve (degrees)

Case	Pre-coronal major curve	Side-bending coronal		After HGT-coronal		Postoperative coronal		Final follow-up coronal	
		Major curve	Correction	Major curve	Correction	Major curve	Correction	Major curve	Correction
1	133	107	19.5	98	26.3	93	34.6	87	32.3
2	105	92	12.4	80	23.8	85	19.0	90	14.2
3	60	45	25.0	38	36.7	32	46.7	34	45.0
4	62	40	35.5	40	35.5	36	41.9	38	38.7
5	114	98	14.0	92	19.3	72	36.8	74	35.1
6	82	60	26.8	55	32.9	45	45.1	58	29.3
7	75	58	22.7	55	26.7	35	53.3	30	60.0
Mean	90.1	71.4	22.3	65.4	28.7	56.9	39.6	58.6	36.4

Table 4 Radiography measurements of the length of T1–S1

Case	Length of T1–S1 pre-initial (cm)	Length of T1–S1 after HGT (cm)	Length of T1–S1 post-initial (cm)	Length of T1–S1 followed-up (cm)	Length times	Follow-up (months)
1	25.2	31.5	32.7	35.0	6	36
2	24.8	28.7	27.9	29.6	4	24
3	30.2	32.7	33.4	37.1	4	24
4	22.0	26.0	27.9	31.9	5	36
5	25.1	32.3	33.2	37.3	6	36
6	28.3	31.7	32.2	35.5	5	30
7	28.5	31.8	32.6	36.8	5	42
Mean	26.3	30.7	31.4	34.7	5	32.6

diagnosed fortuitously on preoperative radiographs of scheduled VEPTR expansion procedures and resealed the cradle at the original rib level around the reformed osseous rib. The distal laminar hooks migration happened in patient 5 at 0.5 year after initial surgery, the hooks were resealed at the scheduled expansion procedures. There was no complication in the dual rod construction.

Discussion

The treatment of rigid and severe CSD associated with SSCM in young children is a surgical challenge [17]; Rapid correction of severe CSD can increase the risk of neurological compromise, especially when the patient has comorbidities, such as SSCM. The aim of surgery for these patients is to control asymmetry growth, to diminish the size of the curve, to restore trunk balance, to delay the time of the definitive fusion surgery while improving the vertical height of spine and avoiding thoracic insufficiency syndrome, neurological deteriorations, etc. [1–6].

Moderate correction and fusion has generally been recommended to achieve global balance, alternatively, an untethering procedure preceding the CSD correction has been advocated [8, 9, 16]. However, in young children (less

than 8–10 years old) as it is concerning to the growth inhibition effects of spinal fusion on the spine, the short length of spine may lead to thoracic insufficiency syndrome and a short trunk. So, when the severe and progressive curves at early age are treated, and normalizing spinal growth without neurological deterioration should be considered.

The neurological deterioration possesses significant risks in the orthopedic surgery. There is no uniform advice on how best to manage severe CSD with SSCM, our study provides additional data regarding how to use HGT in these patients with a decompensating scoliosis preoperatively, and how to resect bony spur in type I SSCM patients and then the deformity being corrected successfully with non-fusion and growing instruments simultaneously.

Halo-gravity traction

Previous published reports indicate that preoperative HGT can improve the flexibility of the spine, improve pulmonary function, stress the spinal cord in a patient who is awake and can verbalize any impending neurological deteriorations, and reduce neurological risks with gradual traction on a decompensating scoliosis due to reducing the tension placed on the cord through slight curve reduction [18, 19].

HGT is usually tolerated rather well than other techniques of traction. In Bouchoucha's study [20], after HGT, the main curve in the coronal plane improved from 95° to 67°, a gain of 28° or 30 %. The curve in the sagittal plane improved from 96° to 78°, a gain of 18° or 19 %. In Sink's report [18], the Cobb angle improved 35 % from an average 84° before traction to 55° pre-fusion, Trunk decompensation improved in all patients.

Park [19] reported on 20 scoliosis patients who underwent HGT for a mean of 4 weeks, the curve correction was 27 and 31 % in bending and in final HGT radiographs. We found that in our cases flexibility of HGT radiographs was 27.8 and 23.2 % on side-bending radiographs, just a little less than Park reported. However, we noted neurological deterioration improved in one patient post HGT when the rigid curves were slightly reduced. The efficacy of HGT might attribute to different spinal deformity conditions, flexibility, duration, and evaluations. HGT should not be expected to significantly improve severe curves without a prior anterior and/or posterior release, but it can be used as a prior appropriate procedure to non-fusion and growing instrumentation.

Non-fusion and growing instrumentation in surgical correction of severe CSD

Normal growth of the spine varies as a function of age. In a healthy child, longitudinal growth of the T1–S1 spinal segment is estimated to be 0.9 cm/year between the ages of 5 and 10; it increases to 1.8 cm/year during the adolescent growth spurt [11]. However, in young children, CSD can cause a progressive scoliosis and/or kyphosis, thoracic insufficiency syndrome, and progressive neurological deteriorate sometimes. Today, management for young children with CSD has changed in recent years with a large variety of instruments being applied based on surgical options to the surgeon's traditional choices of casting, bracing, and fusion. There are two deformity reconstruction methods in the treatment of young children with CSD: growing rod technique and vertical expandable prosthetic titanium rib (VEPTR) with or without expansion thoracoplasty. Growing rod technique should be used in patients where the primary problem is the vertebral column. If the patient has rib fusions and/or TIS, in other words, if the primary problem involves the thoracic cage, expanded thoracoplasty and VEPTR should be an appropriate option [2]. The current study was conducted to determine whether non-fusion and growing instruments can safely obtain correction of the deformity with CSD and SSCM and maintain it for a long term.

Harrington originally reported the growing rod technique in 1962. Moe [21] subsequently reported the

technique of “subcutaneous rods” for the treatment of progressive curves in young children. Klemme [22] reported on a group of progressive scoliosis children, main curve improved from a mean of 67° at initial instrumentation to 47° at definitive fusion. The measured growth of the instrumented segments averaged 3.1 cm over a mean treatment period of 3.1 years. Mineiro [23] studied 11 children who were treated by consecutive distraction of subcutaneous rods, with a mean Cobb angle of 74°, approximately 5 years after surgery, one patient showed no deterioration of the curve and nine patients showed a 32° improvement in the magnitude of the original curvature. Spinal growth as measured in the instrumented area occurred in all 11 patients and ranged from 0.5 to 4.5 cm. A recent study conducted by Akbarnia [24] retrospectively evaluated 23 patients who underwent dual growing rods instrumentation; the mean scoliosis improved from 82° to 38° after initial surgery and was 36° at the last follow-up or post-final fusion. T1–S1 length increased from 23.01 cm to 28.00 cm after initial surgery, finally, 32.65 cm at last follow-up or post-final fusion with an average T1–S1 length increase of 1.21 cm per year. It was concluded that growing rods with consecutive distraction allows correction of progressive CSD that failed to respond to non-operative management.

VEPTR is designed to treat thoracic deformities resulting from absent and/or fused ribs in congenital and syndromic conditions [10]. Restoring this “fourth dimension” and thereby maximizing the potential for pulmonary development is emerging as an important goal in the treatment of CSD, particularly for those patients with congenital spine and rib anomalies. In Campbell's study [11], the patients showed significant growth of the concave side of the thoracic spine and the convex side compared with the baseline lengths. Eleven patients with an unsegmented bar had an average 7.3 % increase in the length of the bar.

In our patients, the mean major coronal curves were corrected from an average of 90.1° pre-initial surgery to 58.6° at latest follow-up with the correction rates of 34.9 %. The initial elongation obtained at the first surgery constitutes a major portion (61.4 %) of the total increase in T1–S1 height. The growth per year after the initial elongation is 1.17 cm and more than the normal growth of the spine. This suggests that non-fusion and growing instrumentation is effective and can maintain the proper correction obtained from HGT and initial surgery and provide adequate stability while allowing spinal growth consecutive. It can increase the duration of treatment period to the final fusion. The lengthening intervals are approximately every 6 months and should be on schedule, bone and soft tissue exposures should be kept to absolute minimum.

Non-fusion and growing instrumentation in surgical correction of SSCM

The release of tethering structures of the SSCM before applying any correction forces to the spinal column is a widely accepted guideline because tethering has a risk of causing neurological compromise after surgical correction and instrumentation [7, 8, 13–16, 25]. However, there is some controversy. Yamada [26] have broadened the stretch-induced functional disorder to diastematomyelia, this correlation was misinterpreted and overrated, and actually, the certain neurological conditions such as type II SSCM are referred to TCS and to correlate them to the stretch-induced changes in oxidative metabolism. Therefore, there are also assumptions [27, 28] declared that type II SSCM usually does not cause tethering and that neurosurgical intervention may be avoided, whereas excision of the bony spur is recommended in type I SSCM in most literatures.

To our knowledge, there is no study on surgical treatment of non-fusion technique for CSD patients associated with SSCM homeochronous. Campbell [29] has reported five patients with spinal cord tether, four had released of their tethers before VEPTR surgery, and one patient developed a tether post-VEPTR surgery that required a release again. In our cases, four patients had a lower spinal cord ended level and two patients had syringomyelia, there was no thick filum terminale found in MRI. In the type I SSCM patients, bony spur was resected and duraplasty was done in the corrective surgery before the correction manipulation. In the type II SSCM patients, no neurosurgical procedure was done before the correction of the deformity, the deformity was corrected successfully with non-fusion and growing instrumentation, and in an averaged 32.6 months follow-up, we routinely lengthen the construct at an interval of approximate 6 months, there was no any new neurological deterioration.

Although there are rib fractures and/or upper or distal instrumentation migrated fortuitously, there is no tragedy in the complications. Inclusion criterion of patients should be identified clearly through long-term follow-up studies and larger samples are required. Clear explanation of advantages and disadvantages of the surgery to the patients' parents is mandatory before the treatment is begun, they should know well once impending neurological deterioration is found, the expansion would be halted and neurosurgical procedure for untethering spinal cord would be done soon.

Conclusion

The treatment for patient with CSD and SSCM should follow individual and specific principles, early recognition

is very important. Bony spur should be resected in patients with type I SSCM in the corrective surgery before correction manipulation, no neurosurgical procedure was necessary in patients with type II SSCM. Non-fusion and growing instrumentation may be safe and effective in the patient of CSD with SSCM after HGT. It can maintain the correction obtained from HGT and initial surgery and provide adequate stability while allowing spinal growth consecutive, so it can extend the growth duration of treated children and has an acceptable rate of complication. However, the complications are still considerable, and patient has a risk that may develop a TCS post-non-fusion surgery that need long-term neurological review and require release if a new neurological deterioration is found. This is an ongoing study and additional large multicenter studies are necessary to further to assess the safety and efficacy of non-fusion and growing instrumentation, and further delineate the risk-benefit ratio of this treatment in this rare condition.

Key Points

Using HGT in young children with CSD and SSCM may judge whether the patient could safely afford the effective improvement of the spine deformity without neurological deterioration by non-fusion and growing instrumentation.

The non-fusion and growing instrumentation may provide a satisfactory option to effectively improve the spinal deformity by the appropriate correction after bony spur excision in patient of CSD with type I SSCM, and the same in patient of CSD with type II SSCM without neurological procedure.

Clear explanation of advantages and disadvantages of the treatment to the patients' parents is mandatory.

Acknowledgments We thank Shi-Lei Zhang and Min Li for their collection data. This work was supported by the New Clinical Technology Foundation of Xijing Hospital (Grants No. XJZT10Y07).

Conflict of interest None.

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