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Comparison of osteotomy versus non-osteotomy approach for congenital scoliosis: a retrospective study of three surgical techniques

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Key words
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Abstract

Background: Currently, there are many reports about congenital scoliosis (CS) treatment, but there are still controversies existing with respect to selecting its surgical methods.
Methods: Retrospective analyses were conducted on 31 CS patients. The surgical treatments included the following: posterior instrumentation (10 patients; group 1), pedicle subtraction osteotomy (11 patients; group 2) and vertebral column resection (10 patients; group 3).
Results: All patients had remarkable improvements in morphology, image findings, visual analogue scale and American Spinal Injury Association classification. Groups 2 and 3 had greater preoperative sagittal Cobb's angle (25.0, 62.2 and 9.2°, respectively), greater intra-operative blood loss (604.5, 620.0 and 460.0 mL, respectively) and fewer fused segments (5.8, 6.3 and 9.2, respectively) than group 1. As compared with group 1, groups 2 and 3 had greater correction rate of coronal Cobb's angle (79.6 ± 12.8, 78.2 ± 10.1% versus 56.1 ± 11.1%), and coronal trunk inclination (77.6 ± 14.2, 85.2 ± 11.0% versus 45.0 ± 42.5%). The sagittal Cobb's angle correction rates of three groups were 67.7 ± 42.9, 79.3 ± 27.6, 84.3 ± 12.1%, respectively, which showed no significant difference ($P = 0.461$). With an average follow-up of 3.5, 3.2 and 4.0 years, the correction loss rate of coronal Cobb's angle in group 1 was higher than those of groups 2 and 3.
Conclusion: For CS patients, osteotomy procedure had less fused segments, along with a greater correction rate and lower correction loss, which were more advantageous for those with severe deformity in sagittal plane or nerve decompression requirements.

Introduction

Congenital scoliosis (CS) is defined as spinal deformity caused by vertebra formation failure or segmentation failure, and is frequently accompanying with sagittal deformity to different degrees. The incidence of CS in neonates is about 1/1000.[1] An aetiology has yet to be identified, but several studies suggested that intrauterine hypoxia and certain medications for 4–8 weeks of the embryonic stage may cause this disease.[2] As posterior instrumentation and fusion techniques develop, a one-stage posterior approach is becoming routine for CS, and the posterior approach includes posterior-instrumented correction, pedicle subtraction osteotomy (PSO) and posterior vertebral column resection (VCR). It is essential to do osteotomy (PSO or VCR) for CS patients with a sharp and serious angle, or patients accompanying with nerve roots and spinal compression, but when and how to do osteotomy were still controversial.[3] Thus, for this study, a retrospective comparison analysis was performed on the three surgical methods for CS treatment.

Methods

General information

All patients were admitted for CS. The same surgeon operated on all patients from August 2004 to June 2012. The inclusion criteria were as follows: (i) the Cobb's angle progressed >5° per year in the recent 2 years and was unresponsive to conservative treatment; and (ii) in groups 2 and 3, the vertebral osteotomy was mainly located to one vertebra. The exclusion criteria included (i) preoperative magnetic resonance imaging findings suggesting a tethered cord,

Table 1 Operative information and VAS decrease in the three groups

	Group 1	Group 2	Group 3	*P*
Age (years)	17.3 ± 2.7	19.6 ± 6.9	21.1 ± 13.1	0.888
Operative time (min)	263.5 ± 42.4	306.4 ± 45.9	306.0 ± 42.3	0.055
Blood loss (mL)	460.0 ± 73.8	604.5 ± 135.0	620.0 ± 191.8	Group 1 versus group 2, *P* = 0.027; group 1 versus group 3, *P* = 0.018
Fused segments	9.2 ± 2.5	5.8 ± 1.3	6.3 ± 1.6	Group 1 versus group 2, *P* = 0.000; group 1 versus group 3, *P* = 0.002
Preoperative VAS	2.1 ± 1.6	2.5 ± 1.5	2.9 ± 1.5	0.517
Last follow-up VAS	0.6 ± 0.7	0.5 ± 0.7	0.6 ± 0.7	0.978
VAS decrease	75.2 ± 22.1%	84.3 ± 17.1%	83.5 ± 16.4%	0.538

VAS, visual analogue scale.

syringomyelia, spina bifida or other nervous system abnormalities; (ii) severe osteoporosis; and (iii) an accompanying severe cardiopulmonary disease.

A total of 31 cases (16 men; 15 women) were included and had one of the following procedures: posterior-instrumented correction (group 1; 10 patients), PSO (group 2; 11 patients) or VCR (group 3; 10 patients). The average age was 17.3, 20.3 and 22.8 years, respectively ($P = 0.888$). According to the pathological changes, group 1 included two wedge-like vertebra cases and eight unilateral segmentation failure cases; group 2 included three hemivertebra cases, six wedge-like vertebra cases, one unilateral segmentation failure case and one wedge-like vertebra with contralateral segmentation failure case; group 3 included seven hemivertebra cases, one butterfly vertebra case and two hemivertebra with contralateral segmentation failure case. Of the apex vertebra cases, nine were located in the thoracic segment (T1–T10), whereas 13 were in the thoracolumbar segment (T11–L1) and nine were in the lumbar segment (L2–L5).

Surgical methods

For each patient, the neuro-potential monitoring and cell savers were utilized intra-operatively, a posterior median incision was performed and the targeted fused vertebrae were exposed. The pedicle screws of the targeted fused segments were inserted under a C-arm image, then a unilateral pre-bent titanium rod was installed for temporary support in groups 2 and 3. In group 1, no vertebra osteotomy was conducted; in group 2, a PSO was conducted, including part of the vertebral body, pedicle and superior or inferior intervertebral disc; and in group 3, a VCR was conducted, including the entire apex vertebra and superior and inferior intervertebral discs. In groups 2 and 3, the 'eggshell' osteotomy procedures were conducted via bilateral pedicles. Then the spinal deformity was corrected using distraction on the concave side and compression on the convex side, the osteotomy surfaces of groups 2 and 3 were closed simultaneously. At last, pedicle screws were locked, an intervertebral and posterolateral spinal graft and a drainage placement were performed. An antibiotic, cefuroxime, was used post-operatively, and dexamethasone and mannitol were administered for 3–5 days. Moreover, an orthosis was worn for 3–6 months.

Evaluation method

A standing anteroposterior and lateral digital radiograph of full-length spine were performed in all groups preoperatively, post-operatively and at the last follow-up. Coronal Cobb's angle, sagittal Cobb's angle, the distance of vertical line between seventh cervical vertebra and central sacra (C7-CSL) were measured on the radiograph. The visual analogue scale (VAS) and American Spinal Injury Association (ASIA) classification were assessed preoperatively and at the last follow-up.

Statistical analysis

Statistical analysis was performed using SPSS 19.0 (SPSS Inc, Chicago, IL, USA); significance level was defined as 0.05 in two-sided probability. The one-sample Kolmogorov–Smirnov test was used for normality test, and the Levene method was used to test the homogeneity of variances. If homogeneous, one-way analysis of variance was performed for pairwise comparisons with the Least Significant Difference method. Otherwise, the rank-sum test was performed with the Kruskal–Wallis *H*-test, and Wilcoxon matched-pair signed-rank test was performed for pairwise comparisons. The Bonferroni method was used to adjust the significance level.

Results

Among all groups, four patients underwent expansion thoracoplasty, whereas three cases in group 3 utilized a titanium mesh. Follow-up ranged from 14 months to 9 years, with an average of 3.5, 3.2 and 4.0 years, respectively ($P = 0.452$).

Operative information

No significant differences existed with operation time in each group (263.5 ± 42.4, 306.4 ± 45.9, 306.0 ± 42.3, $P = 0.055$). Group 1 (464.0 ± 73.8 mL) had less intra-operative blood loss than group 2 (604.5 ± 135.0 mL) and group 3 (620.0 ± 191.8 mL) (group 1 versus group 2, $P = 0.027$; group 1 versus group 3, $P = 0.018$). Group 1 (9.2 ± 2.5) had more fused segments than group 2 (5.8 ± 1.3) and group 3 (6.3 ± 1.6) (group 1 versus group 2, $P = 0.000$; group 1 versus group 3, $P = 0.002$) (Table 1).

Coronal deformity

No significant differences existed regarding coronal Cobb's angle preoperatively in each group. But group 1 (21.0 ± 11.4°) had a significant larger post-operative coronal angle than group 2

Table 2 Correction of deformity and coronal imbalance in the three groups

	Group 1	Group 2	Group 3	*P*
Preoperative coronal curve (°)	46.8 ± 18.2	36.4 ± 15.3	46.6 ± 18.9	0.382
Post-operative coronal curve (°)	21.0 ± 11.4	7.7 ± 3.8	10.8 ± 8.9	Group 1 versus group 2, $P = 0.001$; group 1 versus group 3, $P = 0.013$
Coronal curve correction	56.1 ± 11.1%	79.6 ± 12.8%	78.2 ± 10.1%	Group 1 versus group 2, $P = 0.000$; group 1 versus group 3, $P = 0.000$
Coronal curve loss (° per year)	2.1 ± 0.9	0.4 ± 0.3	0.6 ± 0.7	Group 1 versus group 2, $P = 0.000$; group 1 versus group 3, $P = 0.001$
Preoperative sagittal curve (°)	9.2 (0 to 23.0)	25.0 (–21.0 to 54.0)	62.2 (33.8 to 100.0)	Group 3 versus group 1, $P < 0.000$; group 3 versus group 2, $P = 0.002$
Post-operative sagittal curve (°)	0.3 (–5.3 to 5.9)	–1.4 (–12.0 to 9.2)	8.8 (–0.8 to 18.4)	0.178
Sagittal curve correction	67.7 ± 42.9%	79.3 ± 27.6%	84.3 ± 12.1%	0.461
Sagittal curve loss (° per year)	0.5 ± 0.2	0.6 ± 0.5	0.7 ± 0.5	0.743
Preoperative C7-CSL (mm)	20.1 ± 7.7	19.1 ± 11.2	21.8 ± 8.7	0.911
Post-operative C7-CSL (mm)	11.1 ± 9.5	3.5 ± 3.1	2.9 ± 2.0	Group 1 versus group 2, $P = 0.000$; group 1 versus group 3, $P = 0.001$
C7-CSL correction	45.0 ± 42.5%	77.6 ± 14.2%	85.2 ± 11.0%	Group 1 versus group 2, $P = 0.009$; group 1 versus group 3, $P = 0.002$
C7-CSL loss (mm/year)	0.1 ± 0.4	0.1 ± 0.4	0.1 ± 0.7	0.852

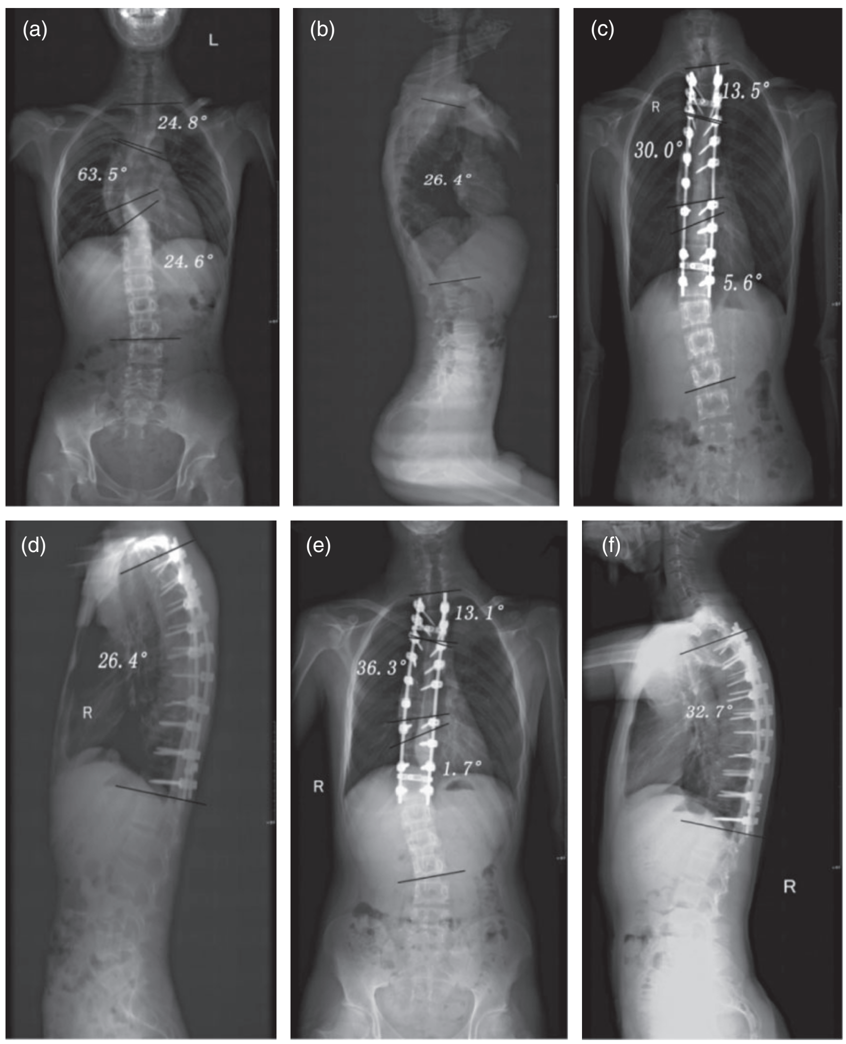

Fig. 1. Radiographs of a 14-year-old man. (a,b) A wedge-like T10 vertebra and a right 10th rib defect; the preoperative scoliosis Cobb's angle was 63.5°, with a thoracic kyphosis Cobb's angle of 26.4°. (c,d) He underwent posterior instrumentation with a T3–T12 fusion, the scoliosis Cobb's angle was 30.0° with a correction rate of 52.8%, and the thoracic kyphosis Cobb's angle was 26.4°. (e,f) Three years after surgery, the scoliosis Cobb's angle was 36.3°, with a progression of 2.1° per year, and the thoracic kyphosis Cobb angle was 32.7°, with a progression of 2.1° per year.

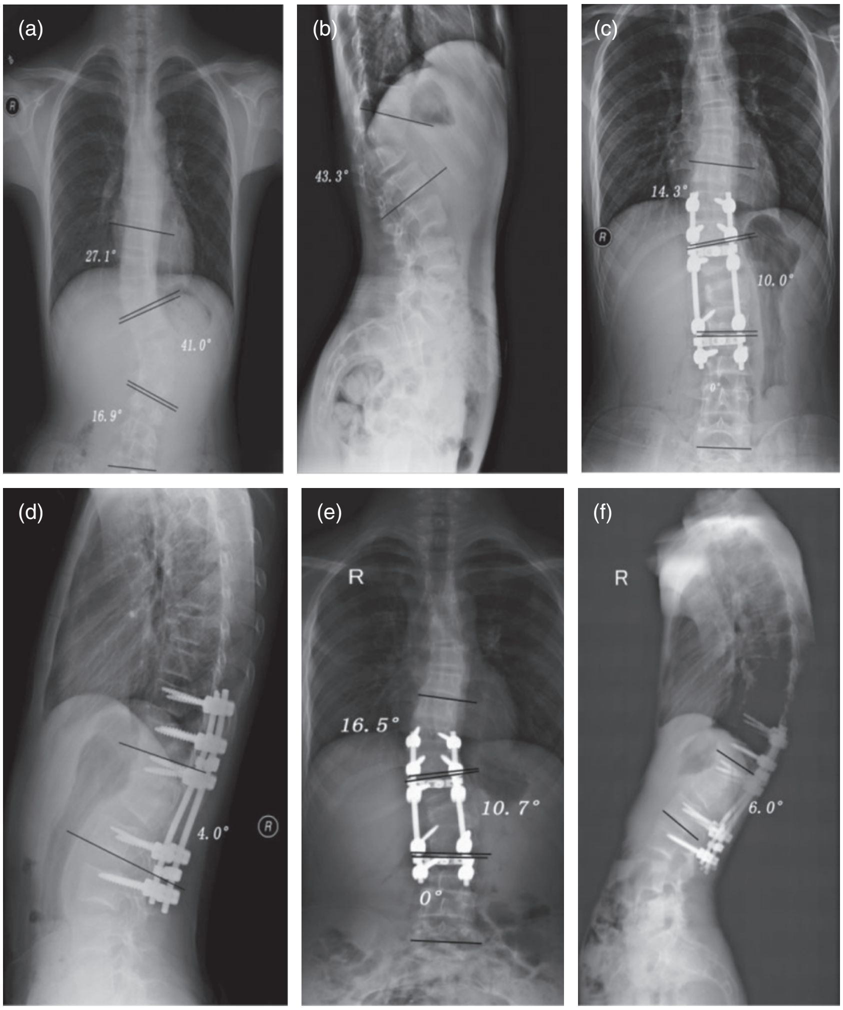

Fig. 2. Radiographs of a 15-year-old man. (a,b) A wedge-like L1 vertebra, with a preoperative scoliosis Cobb's angle of 41.0° and a thoracolumbar kyphosis Cobb's angle of 43.3°. (c,d) He underwent L1 pedicle subtraction osteotomy and a T10–L3 fusion, the scoliosis Cobb's angle is 10.0°, with a correction rate of 75.6%, and thoracolumbar kyphosis Cobb's angle is 4.0°. (e,f) Four-and-a-half years after surgery, the scoliosis Cobb's angle was 10.7°, with a thoracolumbar kyphosis Cobb's angle of 6.0°, without evident progression.

(7.7 ± 3.8°) and group 3 (10.8 ± 8.9°) (group 1 versus group 2, $P = 0.001$; group 1 versus group 3, $P = 0.013$). The correction rates of coronal angle were 56.1 ± 11.1, 79.6 ± 12.8 and 78.2 ± 10.1%, respectively (group 1 versus group 2, $P = 0.000$; group 1 versus group 3, $P = 0.000$). During the follow-up period, the coronal curve loss rate in group 1 (2.1° per year) was higher than that of group 2 (0.4° per year) and group 3 (0.6° per year) (group 1 versus group 2, $P = 0.000$; group 1 versus group 3, $P = 0.001$) (Table 2).

Sagittal deformity

Group 2 (25.0, −21.0 to 54.0°) and group 3 (62.2, 33.8–100.0°) had larger preoperative sagittal Cobb's angle than group 1 (9.2, 0–23.0°) (group 3 versus group 1, $P < 0.000$; group 3 versus group 2, $P = 0.002$). The post-operative sagittal Cobb's angles of three groups were 0.3 (−5.3 to 5.9), −1.4 (−12.0 to 9.2) and 8.8 (−0.8 to 18.4), respectively ($P = 0.178$). Group 1 (67.7 ± 42.9%) had less correction rate in sagittal Cobb's angle than group 2 (79.3 ± 27.6%) and group 3 (84.3 ± 12.1%), but showed no significant difference ($P = 0.461$). The correction loss of each group also showed no significant difference ($P = 0.743$) (Table 2).

Trunk imbalance

No significant difference existed in the preoperative C7-CSL (20.1 ± 7.7, 19.1 ± 11.2, 21.8 ± 8.7 mm, $P = 0.911$), but group 1 (11.1 ± 9.5°) had larger post-operative C7-CSL than group 2 (3.5 ± 3.1°) and group 3 (2.9 ± 2.0°) (group 1 versus group 2, $P = 0.000$; group 1 versus group 3, $P = 0.001$). Group 2 (77.6 ± 14.2%) and group 3 (85.2 ± 11.0%) had larger C7-CSL correction rates than group 1 (45.0 ± 42.5%) (group 1 versus group 2, $P = 0.009$; group 1 versus group 3, $P = 0.002$). The correction loss of each group showed no significant difference ($P = 0.852$) (Table 2).

VAS and ASIA classification

No significant differences were found in the VAS preoperatively (2.1 ± 1.6, 2.5 ± 1.5, 2.9 ± 1.5, $P = 0.517$) and at the last follow-up (0.6 ± 0.7, 0.5 ± 0.7, 0.6 ± 0.7, $P = 0.978$). The pain relief rates of each group were 75.2 ± 22.1, 84.3 ± 17.1 and 83.5 ± 16.4%, respectively ($P = 0.538$) (Table 1). One patient of group 2 and two patients of group 3 were type D of ASIA classification preoperatively, but all patients were improved to type E post-operatively.

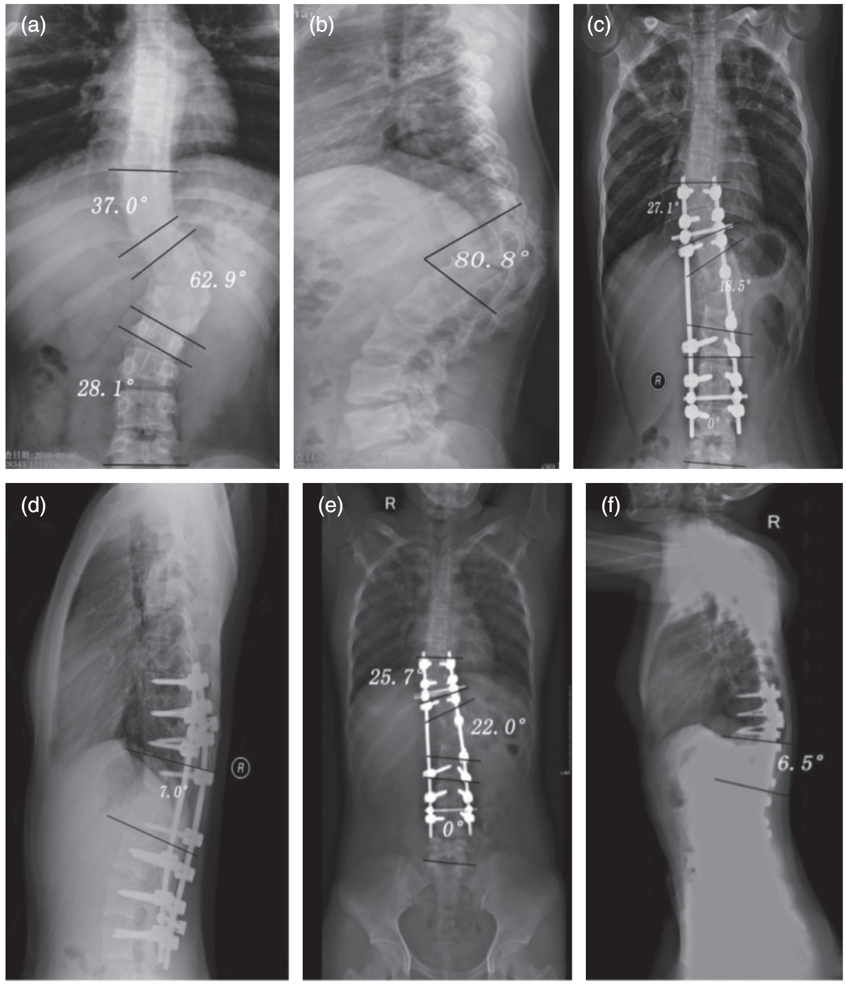

Fig. 3. Radiographs of a 14-year-old woman. (a,b) T12–L1 hemivertebra, with a preoperative scoliosis Cobb's angle of 62.9° and thoracolumbar kyphosis Cobb's angle of 80.8°. (c,d) She underwent posterior hemivertebra resection, with a T9–L4 fusion, the scoliosis Cobb's angle is 18.5°, with a correction rate of 70.6%, and thoracolumbar kyphosis Cobb's angle is 7.0°. (e,f) Three years after surgery, the scoliosis Cobb's angle was 22.0°, with a thoracolumbar kyphosis Cobb's angle of 6.5°, without evident progression.

Complications

In the three groups, the complications were as follows: group 1, one patient had delayed wound healing; group 2, one patient had unilateral lower extremity paraesthesia post-operatively and one patient had back pain at the last follow-up; and group 3, one patient had a massive blood loss intra-operatively (1000 mL), one patient had cerebrospinal fluid (CSF) leakage and one patient had unilateral lower extremity numbness post-operatively. Both above-mentioned paraesthesia patients were relieved 3–5 days after administration of glucocorticoid, mannitol and nerve growth factor. As for the CSF leakage patient, artificial dura mater was utilized during surgery, as well as the Trendelenburg position in post-operative care with intermittent clamping of the drainage tube. The CSF leakage stopped on the third post-operative day.

Discussion

Surgical treatment of CS

Surgery is an important method for treating CS, aiming to correct deformity, relieve pain, relieve neurological symptoms and prevent progressive deformity. On the basis of the purpose and operative approach, CS operations can be divided into preventive surgery, non-fusion surgery and orthopaedic surgery. Preventive and non-fusion surgeries are effective for mild deformity patients, but their effects are limited according to many researchers.[4–6] From the Harrington and Luque techniques to the Cotrel–Dubousset system, spinal fixation has developed from two-dimensional to three-dimensional fixation. Meanwhile, an osteotomy is performed with a facet joint release to the Smith–Petersen osteotomy, PSO and VCR. So far, an osteotomy combined with a posterior pedicle screw/rod system is becoming an important approach for treating CS.

Advantages of PSO and VCR in CS treatment

This study compared the clinical effects, image finding evaluation and long-term follow-up of three surgical methods. All patients demonstrated remarkable improvement with respect to morphology and clinical symptoms. Sagittal curve, coronal curve and coronal imbalance correction rates in groups 2 and 3 were significantly higher than those of group 1. After a follow-up period, the coronal correction loss rate in groups 2 and 3 was lower than that of group 1.

Most group 1 patients had a gradual and sweeping deformity such as wedge-like vertebra or unilateral segmentation disorder. The deformed vertebra was not resected, which had limited deformity correction. Sarlak *et al*.[7] and Yaszay *et al*.[8] reported 40–50%

correction rate for treating CS patients in this technique. In this study, the fused segment was longer than those of similar studies, so the coronal curve and imbalance correction rates were much higher (Fig. 1). However, the intervertebral end plates, growing point of vertebrae, were not destroyed, and the scoliosis angle was able to progress over 1–5° per year.[9] Thus, the coronal Cobb's angle correction loss rate in group 1 was much higher than those in the osteotomy groups.

A vertebra osteotomy is mainly performed for a sharp and focal CS with formation failure or an accompanying contralateral segmentation disorder. Except for coronal deformity, an osteotomy is able to correct sagittal deformity meanwhile. The preoperative sagittal angles in groups 2 and 3 patients were 25 and 62.2°, significantly larger than non-osteotomy group, and the physiological sagittal curvature of the spine was primarily restored post-operatively and at the last follow-up. Besides, during surgery, spinal cord and nerve roots around apex vertebra could be exposed clearly and decompressed multidimensionally, so it was well suited for patients with nerve decompression requirements. In this study, >80% improvement of VAS scores in groups 2 and 3 were achieved; moreover, one patient of group 2 and two patients of group 3 were improved from type D to E per the ASIA classification post-operatively.

For the group 2 patients, PSO was often performed for wedge-like vertebra. If a PSO was localized in the apex vertebra, a 25–30° correction could be obtained (Fig. 2).[10] However, VCR is mostly performed for serious rigid kyphoscoliosis, especially for one or more hemivertebra patients.[11] Zeng *et al.*[12] and Ozturk *et al.*[13] reported about 60% correction rate in sagittal and coronal plane of this surgery. In this study, the correction rates of spinal deformity and trunk imbalance were much higher than in previous studies (Fig. 3). It might be because most patients in this study had a hemivertebra deformity, and their preoperative scoliosis angle was smaller than that of the prior studies.

Nerve injury in spinal osteotomy surgery

In this study, two patients had post-operative lower extremity numbness. In group 3, one patient had CSF leakage and one had back pain. Regarding nerve injury prevention, we concluded: (i) try to avoid an osteotomy above T10 because the spinal canal is narrow here; (ii) intra-operative neuro-potential monitoring and wake-up tests should be performed; (iii) osteotomy and nerve decompression should be performed under direct clear view, and the osteotomy surface should be closed with spinal cord and nerve protection; (iv) when the height of intervertebral space after osteotomy was more than 2 cm, a titanium mesh should be used for support.

Comments

This study performed a retrospective analysis of CS patients who underwent three operative procedures. One surgeon performed all operations, with high comparability. The drawback of this study was the subject heterogeneity. The patients were divided into different groups based on deformity type and severity, and a direct comparison of the three groups could increase selection bias. Also, further investigation is necessary with more cases and a longer follow-up.

Conclusions

Less blood loss and neurological complications occurred with posterior instrumentation. PSO and VCR shared the advantages of a shorter segment fusion, greater correction degree and lower correction loss rate, as well as more advantages for CS patients with severe deformities in the sagittal plane or nerve decompression requirements.

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