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The effect of growing Rod treatment on coronal balance during serial lengthening surgeries in early onset scoliosis

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Abstract

Background: Gaining and maintaining spinal balance after surgery is of great importance for early onset scoliosis (EOS). However, tendency of balance on the coronal plane after growing rod surgery has not been studied before. This study evaluated the effect of growing rod treatment on coronal balance (CB) during serial lengthening surgeries in EOS.

Methods: All EOS patients treated with growing rod technique in our hospital from August 2002 to June 2014 were retrospectively reviewed. Radiographic data before the sixth lengthening surgery were measured on the posteroanterior X-ray images, including global CB (C7 plumbline-central sacral vertical line, C7PL-CSVL), regional CB (apical vertebrae-CSVL), Cobb angle of the main curve and pelvic inlet width (PIW). Global CB index and regional CB index were calculated as dividing global CB and regional CB by PIW, respectively. The changes of these parameters during repeated lengthening surgeries were analyzed.

Results: Five hundred seventy Radiographs of 67 patients, including 134 images before and after growing rod insertion surgeries and 436 images pre- and post-lengthening surgeries were measured. Global CB and global CB index did not show significant differences between every two set points during lengthening procedures ($P > 0.05$). The percentage of patients with C7PL-CSVL distance more than 20 mm roughly ranged from 30 to 45 % during the lengthening process. With regards to regional CB and main curve Cobb angles, there were significant differences between every two adjacent set points during the first five lengthening surgeries ($P < 0.05$).

Conclusions: Global CB did not significantly change during serial lengthening surgeries and C7PL-CSVL distances of greater than 20 mm comprised of over one third of patients during growing rod treatment. However, worsening regional CB and Cobb angles of the main curve during lengthening intervals were corrected by lengthening manipulation and maintained at a stable level.

Keywords: Coronal balance, Growing rod, Early onset scoliosis, Lengthening surgery

Background

The goal of surgical correction of scoliosis is to achieve a solid spinal fusion in a balanced position in both coronal and sagittal planes. Gaining and maintaining spinal balance after surgery is of great importance as apparent trunk deformity significantly correlates with patients' quality of life [1–3].

Growing rod surgery was developed to treat early onset scoliosis (EOS) with the goals of obtaining and maintaining deformity correction, achieving adequate spinal growth and allowing sufficient thoracic development [4]. Previous studies had evaluated the effect of growing rod surgery on curve correction, spinal growth as well as thoracic or lung growth [5–19]. Several studies have also evaluated the effect of growing rod treatment on the sagittal profile [20–22]. However, to our knowledge, tendency of trunk balance on the coronal plane during growing rod lengthening surgery has not been studied before.

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After growing rod insertion surgery, repeated lengthening surgeries were carried out, which would last for several years. Flynn et al. [23] studied 99 patients who completed lengthening and found that the mean duration of growing rod treatment was 5 years. Coronal profile would influence patients' quality of life not only after final fusion but also during serial lengthening surgeries. During serial lengthening procedures, long term coronal imbalance would probably influence EOS patients' quality of life. Therefore we retrospectively reviewed the radiographic data of EOS patients treated with growing rod in our hospital and conducted this study to

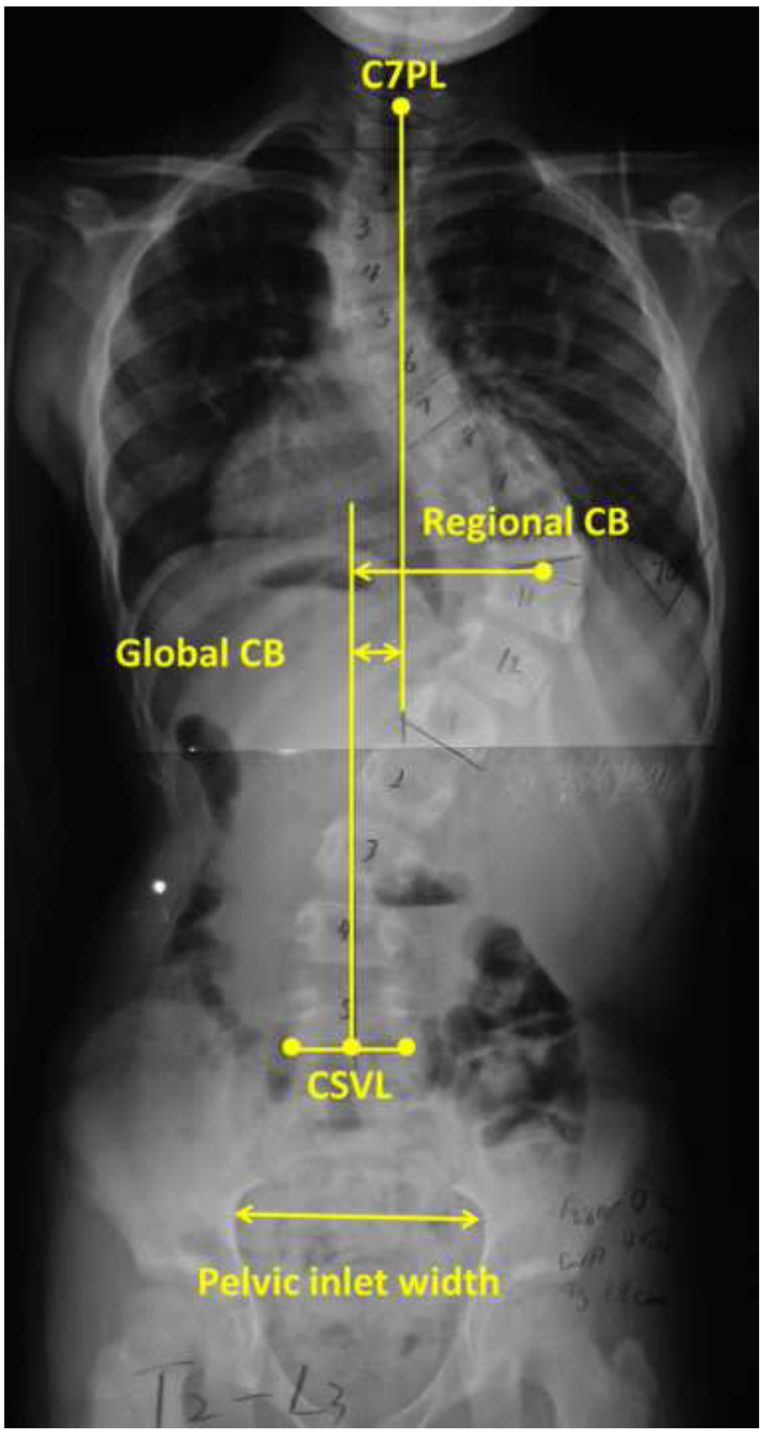

Fig. 1 Measurements of global coronal balance, regional coronal balance and pelvic inlet width

evaluate the effect of consecutive growing rod lengthening on coronal balance (CB).

Methods

Patients

All EOS patients treated with growing rods in our hospital from August 2002 to June 2014 were retrospectively reviewed. Patients who underwent at least one lengthening surgery were included. Patients with kyphoscoliosis were excluded. Since very few patients underwent more than five lengthenings, radiographic data up to and including the fifth lengthening surgery were reviewed.

If the radiographic parameters could not be measured due to technical inadequacy of the plain film, measurements and outcomes for that specific radiograph were excluded from our study. In addition, if patients underwent final fusion surgeries before the fifth lengthening surgery, radiographs after the final surgery were not measured. This study was approved by the institutional review board of Peking Union Medical College Hospital. And written informed consent was obtained from all participants in the study.

Radiographic measurements

The upright posteroanterior images before and after growing rod insertion surgery and the first five lengthening surgeries were measured, including global CB, regional CB, Cobb angle of the main curve and pelvic inlet width (PIW). Global CB was measured in millimeters as the perpendicular distance between the C7 plumbline and the central sacral vertical line (C7PL–CSVL). Regional CB was defined as the perpendicular distance between the midpoint of the apex vertebrae of the main curve and CSVL (AV-CSVL). PIW was measured at the maximal width across the inner margin of the left and right iliac bones [24] (Fig. 1). PIW is an age-independent parameter, which can be used as an individualized internal standard of growth [25]. Thus, global CB index and regional CB index were calculated as dividing global CB and dividing regional CB by PIW, respectively.

Measurements were performed by two of authors independently using Surgimap version 1.2.1.86 (Nemaris Inc, New York, NY, USA). All the radiographs were calibrated to achieve accurate distance measurements. The alignments of all stitched films were carefully checked.

Statistical analysis

Statistical analysis was conducted using SAS software version 9.4 (SAS Institute, Inc., Cary, NC). Comparisons of global CB, regional CB, Cobb angle of the main curve, global CB index and regional CB index at adjacent set points were performed using covariance analysis. P values of less than 0.05 were considered statistically significant.

Results

A total of 67 patients, including 21 males and 46 females were included in this study. The mean age at initial growing rod insertion surgeries was 7.3 ± 2.9 years (range from 2 to 13 years). And the mean duration of growing rod treatment was 2.8 ± 1.5 years (range from 0.5 to 6 years). An average of 3.4 lengthening procedures per patient with an average interval of 0.8 years was performed. Of the 67 patients, 59 underwent dual growing rod surgery and 8 received single growing rod treatment. In terms of etiology, 52 patients were congenital (77.6 %), 4 patients were idiopathic (5.9 %), 3 patients had an underlying neuromuscular condition (4.4 %), 5 patients had neurofibromatosis(7.5 %) and 3 patients had syndromic scoliosis (4.4 %). 570 Radiographs were available for measurement, including 134 images before and after growing rod insertion surgeries and 436 images pre- and post-lengthening surgeries. The number of patients that underwent initial growing rod insertion and each subsequent lengthening is illustrated in Fig. 2.

The mean preoperative global CB of the 67 patients was 21.3 ± 17.7 mm, and C7PL-CSVL distances were greater than 20 mm in 30 patients (44.7 %) (Fig. 3) After growing rod insertion surgery, the mean global CB changed to 17.1 ± 15.2 mm, which showed significant differences ($P = 0.0382$, Table 1). The percentage of C7PL-CSVL distance greater than 20 mm also fell to 32.8 % (22/67). However, during lengthening procedures, global CB did not show significant differences between every two set points ($P > 0.05$; Table 1, Fig. 4a). The percentage of patients with C7PL-CSVL distance >20 mm also showed no regularity, approximately ranging from 30 to 45 % (Fig. 3). When normalized by PIW, global CB index did not show statistical difference both between measurements of initial surgery and between lengthening surgeries ($P > 0.05$; Table 1, Fig. 4d).

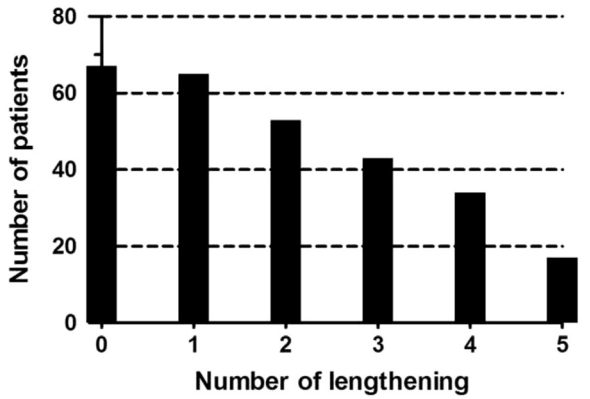

Fig. 2 Numbers of patients that underwent initial growing rod insertion and each subsequent lengthening "0" indicates growing rod insertion surgery and "1-5" indicate the first to the fifth lengthening surgery respectively

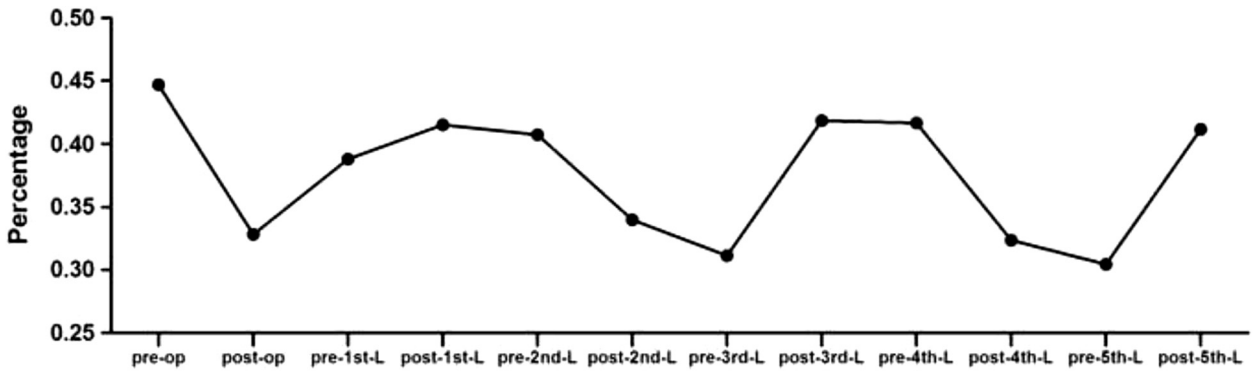

Fig. 3 Percentage of patients with C7PL-CSVL distance greater than 20 mm during growing rod treatment

With regards to regional CB, there were significant differences between every two adjacent set points of initial surgeries and the first five lengthening surgeries, which was more obvious before and after initial surgeries with the mean AV-CSVL distance changing from 64.5 ± 30.5 mm to 29.4 ± 22.2 mm ($P < 0.05$; Table 1, Fig. 4b). However, they fluctuated at a certain range during the following lengthening surgeries, which illustrated as a wavy curve in Fig. 4b. Regional CB index also showed significant differences before and after initial growing rod insertion surgeries, after initial surgeries and before first lengthening as well as before and after first lengthening ($P < 0.05$; Table 1, Fig. 4e). Although the wavy curve changes still existed during subsequent lengthening surgeries, no statistical difference was observed ($P > 0.05$; Table 1, Fig. 4e).

The mean preoperative Cobb angle of the main curve was 72.3° ± 20.9°, ranging from 32°to 135°, which was corrected to an average of 37.2° ± 13.6° after initial surgeries ($P < 0.05$). Then a wavy change was also observed during the following lengthening surgeries, which manifested an increase during lengthening intervals and a decrease after lengthening manipulations (Table 1, Fig. 4c).

Twenty implant-related complications occurred in 12 out of 67 patients, including 7 hook dislodgements, 7 screw pullouts and 6 rod breakages. All these complications were corrected during subsequent planned elective lengthening procedures. No patients experienced wound infection or other medical complications.

Discussion

Other than deformity correction and maintaining spinal and thoracic growth, CB of EOS patients is also an important aspect during growing rod treatment. Normally this problem can be easily ignored, considering CB during lengthening surgeries is temporary and does not represent the final result. However, the whole growing rod treatment usually lasts for many years [6, 23]. Coronal imbalance during this long period would probably influence EOS patients' quality of life [26]. In this study, through analyzing the radiographic data of 67 EOS

Table 1 Comparison of CB during serial growing rod lengthening procedures in EOS patients

Comparison	*P* value				
	Global CB	Regional CB	Cobb angle	Global CB index	Regional CB index
Pre-op vs. post-op	**0.0382**	**<.0001**	**<.0001**	**0.0361**	**<.0001**
Post-op vs. pre-1st-L	0.2732	**<.0001**	**<.0001**	0.5564	**<.0001**
Pre-1st-L vs. post-1st-L	0.5651	**0.0004**	**<.0001**	0.5237	**<.0001**
Post-1st-L vs. pre-2nd-L	0.1694	**0.0268**	**<.0001**	0.1653	0.1291
Pre-2nd-L vs. post-2nd-L	0.0762	**0.0080**	**<.0001**	0.0579	**0.0119**
Post-2nd-L vs. pre-3rd-L	0.2604	**0.0025**	**<.0001**	0.4004	**0.0162**
Pre-3rd-L vs. post-3rd-L	0.8247	**0.0006**	**<.0001**	0.9603	**0.0005**
Post-3rd-L vs. pre-4th-L	0.7842	**0.0101**	**<.0001**	0.7810	0.0886
Pre-4th-L vs. post-4th-L	0.3001	0.1113	**0.0003**	0.2641	0.1171
Post-4th-L vs. pre-5th-L	0.5719	**0.0134**	**0.0002**	0.6989	0.0565
Pre-5th-L vs. post-5th-L	0.3782	**0.0362**	**0.0008**	0.3825	0.0679

Bold numbers were considered statistically significant ($P > 0.05$)

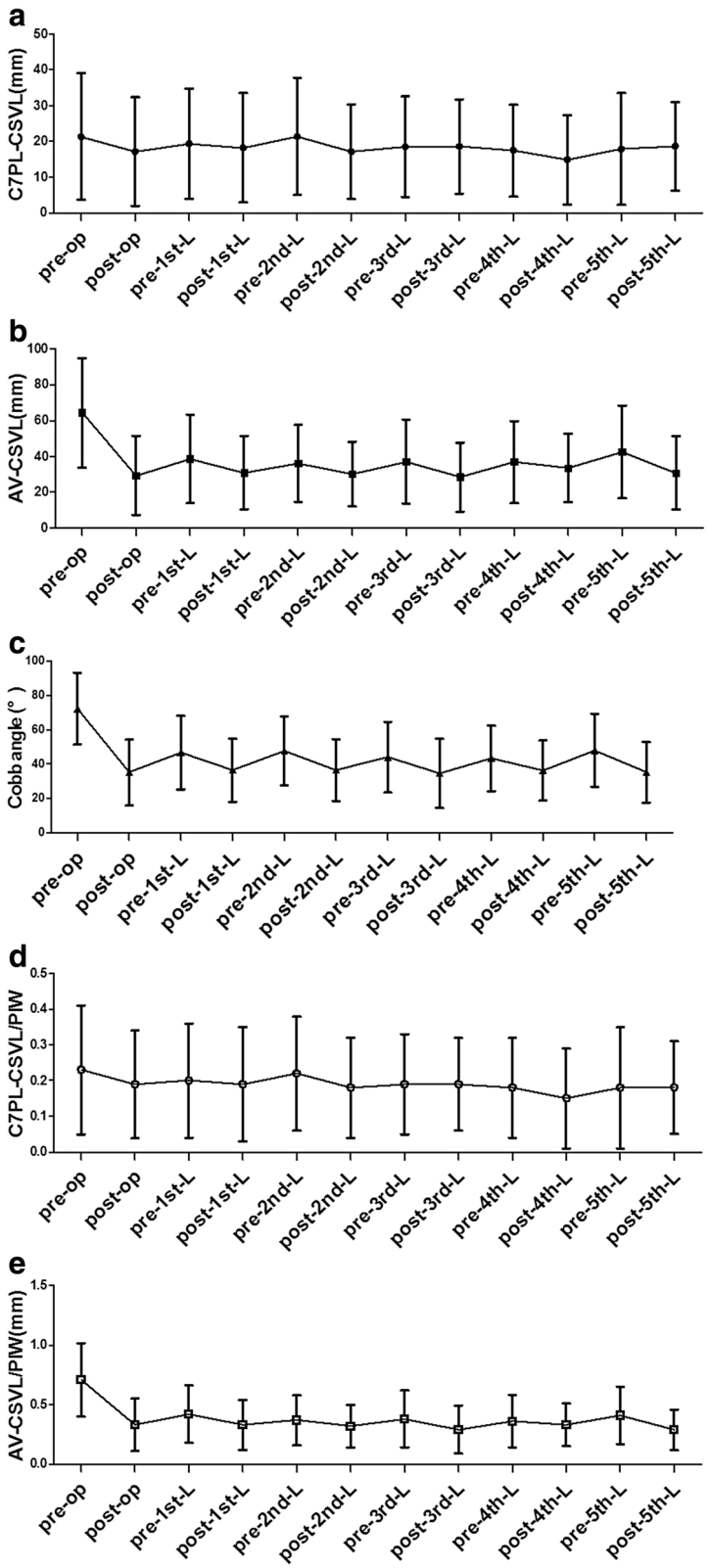

Fig. 4 Changes in CB of initial surgeries and consecutive lengthening surgeries in EOS patients

patients treated by growing rod technique, we found that global CB was maintained during serial lengthening procedures whereas worsened regional CB during lengthening intervals was corrected by lengthening manipulations.

Global CB, defined as C7PL-CSVL distance, was affected by several factors, including compensative changes of uninvolved segments cephalad to the upper instrumented vertebrae and caudad to the lower instrumented vertebrae, aggravating tendencies of the main curve due to the Hueter-Volkmann law and inherent etiologies, restriction of involved segments by growing rod constructs, and regular lengthening manipulations [27]. Although C7PL-CSVL distance significantly decreased immediately after growing rod insertion surgery,the overall effect of these aforementioned factors ensured that global CB was generally stable throughout serial lengthening procedures in our study.

Normally, global coronal imbalance is defined as C7PL-CSVL distance greater than 20 mm in adolescent idiopathic scoliosis [3, 28, 29]. Using this definition, we might underestimate coronal imbalance in EOS patients considering their smaller size than in adolescents. Nevertheless, the percentage of C7PL-CSVL distance greater than 20 mm was also analyzed. It turned out comparatively, there were a greater proportion of patients with C7PL-CSVL distance more than 20 mm during growing rod treatment, and the effect of growing rod manipulation on global CB during repeated lengthenings was very limited. However, we speculated that global CB would probably improve after final fusion surgery [30].

Regional CB, defined by AV-CSVL distance in this study, was also affected by similar factors as global CB, except compensative changes of uninvolved segments that were cephalad to the upper instrumented vertebrae. We hypothesized that worsening of the main curve during lengthening intervals might play a vital role, because in this study we found that regional CB was aggravated during lengthening intervals and growing rod lengthening manipulation significantly reversed it. However, regional CB index did not show statistical difference between every two set point measurements after the first lengthening surgeries. Thus, spinal growth might also have some effects on regional CB, which should be studied further in the future.

As expected, Cobb angle of the main curve was increased during lengthening intervals because of aggravating tendencies of the curve itself and restriction of growing rod constructs. Lengthening manipulations reversed the deterioration and maintained it in a stable level.

There were some limitations in this study. First, the enrolled patients have different etiologies with varying magnitude of the main curve Cobb angle (ranging from 32° to 135°), which might influence the statistical results of change tendencies of global CB and regional CB during consecutive lengthening procedures. In addition, only the first five lengthening radiographic data was analyzed due to the small number of patients that received more than five lengthening surgeries [19]. However, we could still analyze the effect of growing rod treatment on CB during subsequent lengthenings based on the findings of this study. Finally, complications, especially implant-related complications, could also affect global and regional CB. We did not exclude these patients or the specific surgeries, thus the results of this study reflected the overall effect of growing rod treatment on CB, and not just lengthening manipulations.

Conclusions

In conclusion, through analyzing 570 radiographic data of 67 EOS patients treated with growing rod technique, we found that global CB did not significantly change during serial lengthening surgeries and approximately 30–45 % patients had C7PL-CSVL distance greater than 20 mm. Regional CB and Cobb angle of the main curve worsened during lengthening intervals, both of which were corrected by lengthening manipulation and thereby maintained at a stable level.

Ethics approval and consent to participate

This study was approved by the institutional review board of Peking Union Medical College Hospital. And written informed consent was obtained from all participants in the study.

Consent for publication

Not applicable.

Availability of data and materials

The dataset supporting the conclusions of this article is available on request to the corresponding author.

Abbreviations

AV-CSVL: Apical vertebrae-central sacral vertical line; C7PL-CSVL: C7 plumbline-central sacral vertical line; CB: Coronal balance; EOS: Early onset scoliosis; PIW: Pelvic inlet width.

Competing interests

The authors declare that they have no competing interests. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

Authors' contributions

WJL participated in the planning of the study, acquisition of data, data analysis and drafted the manuscript. ZJS participated in design of the study, data analysis and revision the manuscript. SGG participated in design of the study and revision the manuscript. GXQ, JGZ, JXS, YPW, HZ and SGL were involved in the planning and methodological consideration. YZ conceived the study, and participated in its design and coordination and helped to draft the manuscript. All authors read and approved the final manuscript.

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