MEDICAL SCIENCE MONITOR

CLINICAL RESEARCH

e-ISSN 1643-3750
© Med Sci Monit, 2017; 23: 4981-4988
DOI: 10.12659/MSM.903795

Received: 2017.02.14
Accepted: 2017.05.09
Published: 2017.10.18

Evaluating the Rotation Correction of the Main Thoracic Curve in Severe Adolescent Idiopathic Scoliosis: Bending and Traction *vs.* Fulcrum – A Preliminary Report

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

ABCDEFG 1 **Qing-Jie Kong***
CDEF 2 **Xiao-Fei Sun***
BCDEF 1 **Yuan Wang**
CF 1 **Jing-Chuan Sun**
BDF 2 **Zi-qiang Chen**
BCD 1 **Yong Yang**
AG 1 **Jian-Gang Shi**

1 Department of Spine Surgery, The Affiliated Changzheng Hospital of The Second Military Medical University, Shanghai, P.R. China
2 Department of Orthopedic Surgery, The Affiliated Changhai Hospital of The Second Military Medical University, Shanghai, P.R. China

* These authors contributed to the work equally

Corresponding Author: Jian-gang Shi, e-mail: jiangangshi812@163.com
Source of support: Departmental sources

Background: Flexibility evaluation methods were only used to assess the changes of coronal Cobb angle in patients with adolescent idiopathic scoliosis (AIS). Little attention was attached to the vertebral rotation in these methods.

Material/Method: 21 patients with severe adolescent idiopathic scoliosis were enrolled in this study. Coronal flexibility and rotation correction were compared on the supine bending, traction and fulcrum bending radiographs. The apical vertebral body rib ratio (AVB-R), and Perdriolle rotation angles were used to measure the rotation of the main thoracic curve. Statistical analysis was performed with one-way Analysis of Variance(ANOVA). Correlations between postoperative AVB-R and AVB-R in supine bending, traction and fulcrum bending radiographs were assessed utilizing the Linear Regression.

Results: There were trends towards increased coronal flexibility in fulcrum bending versus traction versus supine bending, but there were no significant differences due to the limited sample size. And all were significantly lower than postoperative correction. The correction of AVB-R at traction and supine bending radiographs were significantly better than fulcrum bending, however, all were significantly lower than postoperative correction. Correction of Perdriolle rotation angle at traction radiograph was best among these methods. A univariant linear regression analysis showed a strong linear correlation between the postoperative AVB-R and the AVB-R in the traction radiograph.

Conclusions: As to patients with severe AIS, the coronal plane flexibility evaluated at the fulcrum bending radiograph is superior to that at the traction radiograph. This may be explained by the measurement errors induced by the better derotation capacity at the traction radiograph. Rotation correction evaluated at the traction radiograph proves better than the fulcrum bending radiographs, showing a linear correlation with the postoperative correction.

MeSH Keywords: **Atherectomy, Coronary • Range of Motion, Articular • Scoliosis**

Full-text PDF: https://www.medscimonit.com/abstract/index/idArt/903795

2862 5 5 21

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS] [Index Copernicus]

Background

Preoperative flexibility assessment plays a vital role in the selection of operative approaches, the fabrication of fusion segments, and the prediction of postoperative orthopedic effects. The supine bending radiograph, allowing easy and convenient operation, offers an important reference for the evaluation of scoliosis flexibility and the formulation of surgical plans. For patients whose Cobb angle is greater than 60 degrees, it is better to perform correction at the traction radiograph than at the supine bending radiograph [1]. Studies by Watanabe et al. showed that, for main thoracic curve with a Cobb angle equal to or more than 60 degrees, the flexibility obtained at the traction radiograph was higher than that at the bending radiograph, especially in patients below 15 with normal sagittal kyphosis, their apical vertebrae located at T4-T8/9, and their main thoracic curve involving 6 or 7 vertebrae [2]. Researchers have started to notice the advantages of conducting flexibility evaluation at the fulcrum radiograph [3]. However, there are few studies comparing the fulcrum radiograph and traction radiograph in patients whose Cobb angle is greater than 60 degrees. Hamzaoglu et al. contrasted 4 kinds of flexibility evaluation methods with regard to the fulcrum, bending, and traction radiographs, and the position where traction are applied following general anesthesia. They found that all the lateral-bending patients with a main thoracic curve Cobb angle was equal to or greater than 65 degrees obtained from these methods a lower flexibility than the postoperative correction rate. Flexibility obtained at the fulcrum radiograph was better than that at the traction radiograph, yet the best flexibility was acquired at the radiograph where traction was applied after general anesthesia [4]. Nonetheless, only 5 patients with severe scoliosis participated in this study.

AIS includes coronal, sagittal, and axial deformities. The axial rotation, which is closely associated with the patient's appearance, has attracted attentions of researchers [5,6]. Studies have shown that, coronal correction can act on the vertebral rotation through the coupling effect [7]. It is urgent to investigate how to predict the postoperative orthopedic effects of vertebral rotation and develop reasonable de rotation strategies. Thus, rotation flexibility evaluation figures prominently, especially for patients showing apparent vertebral rotation. Many flexibility evaluation methods, however, are only used to study the change of Cobb angle of coronal. Therefore, this study aims at comparing the effects of the evaluation of coronal plane and rotation flexibility conducted at the bending, fulcrum, and traction radiographs for patients with severe scoliosis patients, to provide evidence for the formulation of surgical strategies and prediction of orthopedic effects.

Material and Methods

A retrospective analysis was conducted on AIS patients who underwent surgical treatment in our hospital from January 2013 to September 2014. Inclusion criteria: Cobb angle of the main thoracic curve on the coronal plane at the standing position exceeded 60 degrees; posterior pedicle screws were used on the entire vertebrae for fixation and all operations were completed by the same surgeon; case data were complete, and the flexibility evaluation covered the bending, fulcrum bending, and traction radiographs (Figure 1); the patients and their family members consented to this study after being informed. This study was approved by the Ethics Committee. A total of 21 patients with severe scoliosis participated, including 18 women and 3 men, aged 15 (11–19) on average, their Cobb angle of the main thoracic curve averaging 72.90 degrees (60–95.72 degrees).

Radiographic measurement: All radiographic data were the average of the measurements performed by 3 physicians.

Coronal: Before surgery, the Cobb angle of main thoracic curve was measured at the standing, bending, fulcrum, and traction radiographs. Within 2 weeks after surgery, the angle was measured according to a full-length radiograph of the spine. For the fulcrum radiograph, we made reference to the method proposed by Chueng et al. [3]. Appropriately sized cylinders were placed below the ribs opposite to the thoracic scoliosis vertebra, and the shoulders of the patient were made off the desktop. Gravitational suspension traction was performed: the patient suspending himself by both hands at the orthostatic position to receive gravity-exercised traction.

Scoliosis flexibility = (Main thoracic curve Cobb angle before operation – Main thoracic curve Cobb angle in the evaluation approach)/Main thoracic curve Cobb angle before operation.

Postoperative correction rate = (Main thoracic curve Cobb angle before operation – Main thoracic curve Cobb angle after operation)/Main thoracic curve Cobb angle before operation.

Apical vertebral rotation: The Perdriolle rotation angle was measured by the Perdriolle rotation gauge with the method propounded by Perdriolle et al. [8]. AVB-R was the ratio of the distances between the apical vertebral body and the 2 chest walls [9] (Figure 2).

Perdriolle rotation angle difference = preoperative Perdriolle rotation angle – Perdriolle rotation angle in the evaluation approach.

AVB-R difference = preoperative AVB-R – AVB-R in the evaluation approach (postoperative AVB-R).

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS] [Index Copernicus]

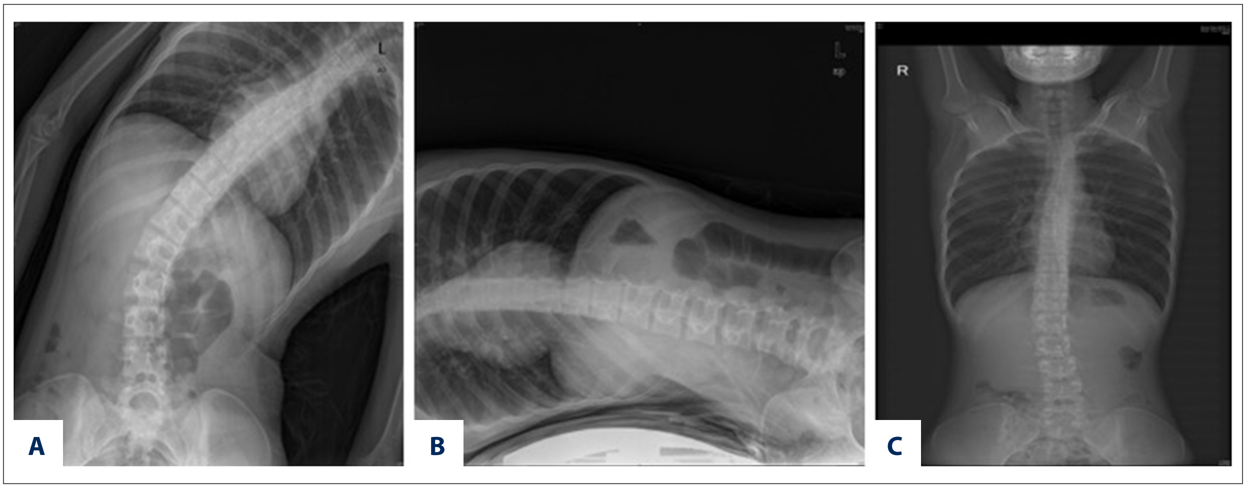

Figure 1. Different methods of flexibility evaluations, (**A**) bending radiograph; (**B**) fulcrum bending radiograph; (**C**) traction radiograph.

Figure 2. Measurement of the apical vertebral body rib ratio (AVB-R).

Statistical analysis

One-way ANOVA was used to compare the preoperative and postoperative data, as well as the data of the bending, fulcrum, and traction radiographs. Statistical analysis was conducted via SPSS 17.0 (Chicago, IL, USA). As for postoperative AVB-R and AVB-R of the 3 radiographs, a univariant linear regression analysis was conducted to figure out the correlation, and a statistical analysis was conducted via Excel (Microsoft, USA) (P<0.05 was considered statistically significant).

Results

Twenty-one patients participated in this study, including 18 females and 3 males, aged 15 (11–19) on average. Their Risser sign, main thoracic curve Cobb angle, AVB-R, and Perdriolle rotation angle averaged 3.38 (1–5), 72.90 degrees (60 degrees–95.72 degrees), 2.19 (1.46-3.05), and 31.86 degrees (20–45 degrees) respectively (Table 1).

The coronal flexibility evaluated at the bending, traction, fulcrum radiographs was lower than the real postoperative correction rate (31.15±11.07, 33.36±13.06, 38.77±15.36 *vs.* 49.42±15.88, P<0.05). Despite tendency that fulcrum radiograph >traction radiograph >bending radiograph in terms of the coronal plane flexibility, no statistically significant difference was found in between (P>0.05) (Table 2).

The postoperative improvement of AVB-R was superior to the fulcrum radiograph (0.52±0.31 *vs.* –0.11±0.28, P<0.001), the bending radiograph (0.52±0.31 *vs.* 0.29±0.21, P<0.05=), and the traction radiograph (0.52±0.31 *vs.* 0.26±0.21, P<0.05=). The effect of AVB-R correction at the traction radiograph outperformed that at the fulcrum radiograph (0.26±0.21 *vs.* –0.11±0.28, P<0.001); the effect at the bending radiograph

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS] [Index Copernicus]

Table 1. Patient profile.

	Mean	Maximum–Minimum
Age	15.00	11.00–19.00
Gender	18 (3)	–
Risser	3.38	1.00–5.00
Menstruation	2.70	0–5.00
Cobb angle of main thoracic curve	72.90	60.00–95.72
AVB-R	2.19	1.46–3.05
Perdriolle rotation angle	31.86±6.67	20.00–45.00

Table 2. Flexibility of the main thoracic curve on the coronal plane.

Bending radiograph	Traction radiograph	Fulcrum radiograph	Postoperative correction
31.15±11.07	33.36±13.06	38.77±15.36	49.42±15.88
	Bending radiograph	**Traction radiograph**	**Fulcrum radiograph**
Postoperative correction rate	<0.001	<0.001	0.016
Traction radiograph	0.61	–	0.213
Fulcrum radiograph	0.081	–	–

Table 3. Difference of AVB-R before and after operation evaluated with different methods.

Bending radiograph	Traction radiograph	Fulcrum radiograph	Postoperative correction
0.29±0.21	0.26±0.21	–0.11±0.28	0.52±0.31
	Bending radiograph	**Traction radiograph**	**Fulcrum radiograph**
Postoperative correction rate	0.004	0.002	<0.001
Traction radiograph	0.749		<0.001
Fulcrum radiograph	<0.001		

was better than at the fulcrum radiograph (0.29±0.21 *vs.* –0.11±0.28, P<0.001). However, there was no significant difference between the bending radiograph and traction radiograph (P≥0.05) (Table 3). A univariate linear regression analysis of the relationship between postoperative AVB-R and AVB-R in the 3 flexibility evaluation methods revealed a linear correlation (P<0.05=). The correlativity sequence was: bending >traction >fulcrum (R^2=0.836 *vs.* 0.809 *vs.* 0.641) (Table 4, Figures 3–5).

However, the orthopedic force at the fulcrum radiograph, directly acting on the thorax, may affect the AVB-R. In order to rule out the interference of this factor, we compared differences between the Perdriolle rotation angles and the preoperative value in the 3 flexibility evaluation methods. The improvement of Perdriolle rotation angle at the traction radiograph was better than at the bending (10.57±3.98 *vs.* 5.43±3.61, P<0.05) and fulcrum radiographs (10.57±3.98 *vs.* 5.76±5.74, P<0.05) (Table 5). After operation, the obstructing pedicle screws would result in big errors in measuring the Perdriolle rotation angle, so this study did not evaluate the improvement of postoperative Perdriolle rotation angle.

Discussions

Severe scoliosis is a big challenge in clinical research. In different studies, there are various definitions of it as the coronal plane Cobb angle ranging from 60 degrees to 90 degrees [10–12]. With the application of the entire-pedicle screw system, the scoliosis correction rate has significantly

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS] [Index Copernicus]

Table 4. Relationship between the postoperative AVB-R and the AVB-R in different flexibility evaluation methods.

Method	R^2	P	Formula
Traction radiograph	0.809	<0.001	Y=0.368+0.676X
Fulcrum radiograph	0.641	<0.001	Y=0.786+0.384X
Bending radiograph	0.836	<0.001	Y=0.519+0.605X

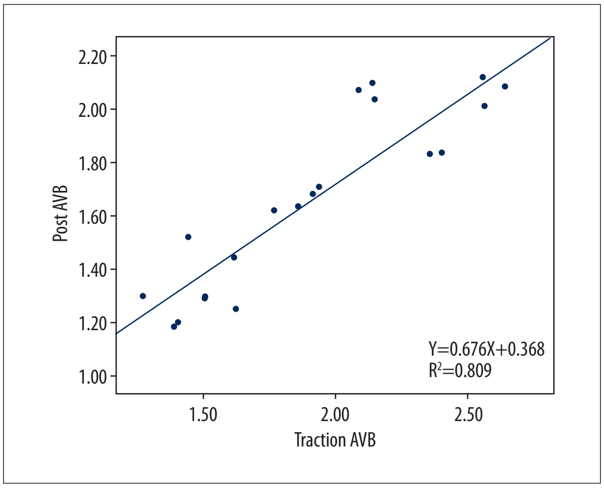

Figure 3. Relationship between Post AVB-R and Traction AVB-R.

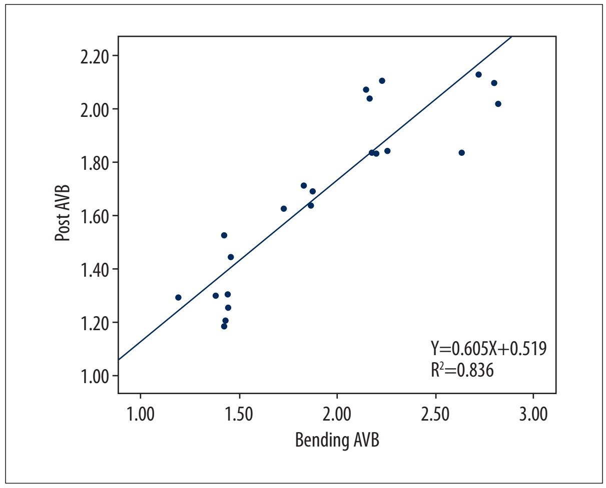

Figure 5. Relationship between Post AVB-R and Bending AVB-R.

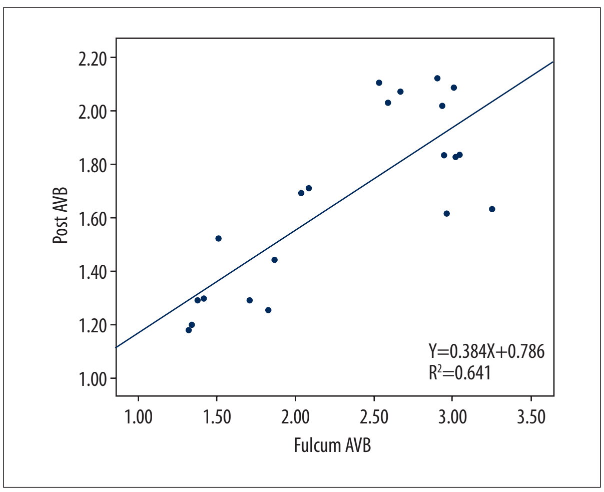

Figure 4. Relationship between Post AVB-R and Fulcrum AVB-R.

improved [13], so some researchers consider it necessary to raise the diagnostic standard of severe scoliosis. In a study by Lao et al., all the cases of severe scoliosis were characterized by a Cobb angle exceeding 100 degrees [14]. Winter et al., however, believed that scoliosis was a three-dimensional deformity; it was meaningless to focus on only the correction rate of the coronal plane; the sagittal, rotation, and the improvement of pulmonary function in particular, constituted important aims of scoliosis treatment [13]. The use of the entire-pedicle screw system, however, has not noticeably improved the pulmonary function of scoliosis patients [13]. Studies reveal that patients with a small Cobb angel may suffer an impaired pulmonary function [15]. Therefore, in order to call attention to the correction of sagittal and rotational deformities of scoliosis patients and improve their livelihood, this study defines the severe scoliosis as the coronal plane Cobb angel being greater than 60 degrees.

Table 5. Difference of Perdriolle rotation angles before and after operation evaluated with different methods.

Bending radiograph	Traction radiograph	Fulcrum radiograph
5.43±3.61	10.57±3.98	5.76±5.74
	Bending radiograph	**Traction radiograph**
Fulcrum radiograph	0.813	0.001
Traction radiograph	0.001	–

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS] [Index Copernicus]

Preoperative flexibility evaluation is of vital importance to the selection of operative approaches, the fabrication of fusion segments, and the prediction of postoperative orthopedic effects. At present, no method is generally recognized by scholars as a "golden doctrine" of flexibility evaluation. The supine bending radiograph, allowing easy and convenient operation, offers an important reference for the evaluation of scoliosis flexibility and the formulation of surgical plans [1]. Studies have shown that for patients whose Cobb angle exceeds 60 degrees, the effect of correction was better at the traction radiograph than at the supine bending radiograph [1,2]. Studies by Watanabe et al. indicated that those whose main thoracic curve Cobb angle was equal to or larger than 60 degrees could obtain higher flexibility at the traction radiograph than at the bending radiograph. This was particularly true in patients below 15 years old with normal sagittal kyphosis, their apical vertebrae located at T4–T8/9, and their main thoracic curve involving 6 or 7 vertebrae [2]. The researchers constructed a mechanical model to explain this result and concluded that the longitudinal orthopedic force applied was superior to the cross-sectional one for severe scoliosis patients. This finding has also been proved in related studies [16]. However, Watanabe et al. did not conduct a comparative analysis of the fulcrum and traction radiographs as well as the real postoperative correction rate. Hamzaoglu et al. contrasted 4 kinds of flexibility evaluation methods at the traction, fulcrum, bending, and after-general-anesthesia traction radiographs and found that all the lateral-bending patients whose main thoracic curve Cobb angle exceeded 65 degrees obtained from these methods a lower flexibility than the postoperative correction rate. Flexibility obtained at the fulcrum radiograph was better than that at the traction radiograph, yet the best flexibility was acquired at the position where traction was applied after general anesthesia [4]. Nonetheless, this study employed supine traction, which was performed by a spine surgeon in the head, neck, and lower limbs of patients using unquantifiable traction force (possibly smaller than the orthopedic force at the fulcrum radiograph). This study compared coronal flexibility at the bending, traction, and fulcrum radiographs, as well as the real correction rate after operation. The results showed that flexibility measured by each of the 3 methods was lower than the real postoperative correction rate ($P<0.05$). There appeared a tendency of fulcrum radiograph >traction radiograph >bending radiograph, yet no statistically significant difference was found among them. This may be attributable to the small sample size. It should be noted that the after-general-anesthesia orthopedic effect was better at the traction radiograph than at the fulcrum radiograph when the interference of muscles and soft tissues was ruled out. This was echoed by studies of Rodrigues et al. [17] Therefore, the orthopedic force applied in the longitudinal direction can still be regarded as superior to that in the cross-sectional direction. The reason why the flexibility achieved at the normal traction radiograph is not so good as at the fulcrum radiograph may be that the actual orthopedic force applied to the spine is smaller than the applied external force due to muscle tension during the process of traction. To achieve the same effect as after-general-anesthesia traction, it is imperative to increase the external force, which may injure the soft tissue.

CT is the most accurate method of evaluating vertebral rotation. Yet it costs a lot, increases radiation exposure, and requires supine position photographing, which will surely affect the accuracy of results due to posture changes [18,19]. Apical vertebral body rib ratio (AVB-R) is one of the methods of vertebral rotation evaluation. Research by Kuklo et al. suggested that the rotation degree measured by AVB-R and CT had a strong correlation with the correction rate [9]. In this study, AVB-R improvement at the traction radiograph was superior to that at the fulcrum radiograph ($P<0.05$), but there was no significant difference between it and the bending radiograph. AVB-R values were indirectly obtained by thorax measurement. The orthopedic force at the fulcrum radiograph directly acting on the thorax may affect the result. To rule out the interference of this factor, we used Perdriolle method to compare the derotation results of the 3 methods, and the results showed that difference between the traction radiograph and preoperative Perdriolle rotation angle was greater than that at the fulcrum and bending radiographs ($P<0.05$). Lamarre et al. [20]. devised an underarm suspension device for in-suspension traction of scoliosis patients. Compared with the bending radiograph, the traction radiograph could produce a better derotation effect. This is consistent with the existing researches. Hence, it could be concluded that traction may provide the best derotation orthopedic force. In patients featuring obvious rotational malformation, the plane with the maximum actual bending angle is not at the antero-posterior position; instead, it tilts to the convex. Compared with the fulcrum radiograph, the traction radiograph promises better derotation orthopedic effects, and that is the position where the plane with maximum bending angle is closer to the coronal plane or even overlaps with it. In this situation, even though the 2 evaluation methods can achieve the same orthopedic effect, the main thoracic curve angle at the antero-posterior traction radiograph is larger than that at the fulcrum radiograph. However, Perdriolle rotation angle was not completely consistent with the AVB-R measurement result, because of the inherent defect in the 2 measurement methods.

Axial rotation is associated with coronal malformation, so the accurate prediction of postoperative derotation effect is of great significance in the development of surgical plans. The degree of vertebral rotation can be assessed by several methods. the Nash-Moe method is a classification indicator of low accuracy. The degree of vertebral rotation of severe scoliosis patients assessed by Nash-Moe method is often higher than

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS] [Index Copernicus]

the actual degree [9,21]. The Perdriolle method, adopting a torsion meter for evaluation, is quite subjective [9]. Additionally, for patients using the entire-pedicle screw fixation system, their postoperative X-ray pedicle, sheltered by the internal fixer, interferes with the evaluation of postoperative rotation. CT is costly, and supine position photographing will affect the accuracy of the result [18,19]. In addition, there are other indexes for indirect evaluation of vertebral rotation: rib hump (RH), a picalrib spread difference(ARSD), and apical vertebral body rib ratio (AVB-R) [9]. RH needs to be measured on lateral-position radiographs and thus increases patient exposure to radiation. ARSD and AVB-R can be obtained on antero-posterior radiographs, but the measurement of ARSD is complex. In the study by Kuklo et al., ARSD has only a weak correlation with the rotation degrees and correction rates measured by CT [9]. Therefore, AVB-R is a simple and reliable method of measuring the rotation, but it cannot point out the correlation between preoperative evaluation and real postoperative rotation. In this study, AVB-R improvement by each of the 3 evaluation methods was significantly inferior to postoperative real correction effect. Among the 3 positions, traction radiograph achieved the best AVB-R improvement. The linear regression analysis indicated that postoperative AVB-R had a strong linear correlation with traction and bending radiographs (R^2 >0.8). Thus, AVB-R at the traction radiograph is the best method to predict postoperative rotation condition. Vertebral rotation may cause great changes to the "rotation flexibility" if it is defined as: preoperative standing AVB-R – AVB-R in the evaluation method)/preoperative standing position AVB-R. For better accuracy of the evaluation, the "rotation flexibility" is defined as the difference between the preoperative standing position AVB-R and AVB-R in the evaluation method. Accordingly, the rotation correction rate=preoperative standing position AVB-R- postoperative AVB-R. Among the 3 evaluation methods, the traction and bending radiographs are superior to the fulcrum radiograph. A comprehensive comparison proved the "rotation flexibility" measured at the traction radiograph to be the best. A linear regression analysis showed that there was a strong linear correlation between the postoperative "rotation correction rate" and the "rotation flexibility" measured at the traction radiograph (R^2=0.832).

As there were only 21 subjects researched in this study, it is just a preliminary report. Therefore, further studies are required to include a larger number of patients with severe AIS and come to a conclusion with higher level of evidence based medicine.

Conclusions

For patients with severe AIS, although the result of the coronal plane flexibility evaluation conducted at the fulcrum radiograph is better than at the traction radiograph, this may be attributed to the measurement errors caused by the better derotation orthopedic capability of the traction radiograph. The rotation flexibility evaluation at the traction radiograph has a better result than at the fulcrum and bending radiographs, showing a linear correlation with the postoperative rotation correction rate. To conclude, it is the best to evaluate the rotation flexibility at the traction radiograph. This is likely to become an important way to decipher the biomechanical properties of scoliosis, to offer guidance for the development of surgical plans, and to predict postoperative orthopedic effects.

References:

1. Polly DJ, Sturm PF: Traction versus supine side bending. Which technique best determines curve flexibility? Spine (Phila Pa 1976), 1998; 23: 804–8
2. Watanabe K, Kawakami N, Nishiwaki Y et al: Traction versus supine side-bending radiographs in determining flexibility: What factors influence these techniques? Spine (Phila Pa 1976), 2007; 32: 2604–9
3. Cheung KM, Luk KD: Prediction of correction of scoliosis with use of the fulcrum bending radiograph. J Bone Joint Surg Am, 1997; 79: 1144–50
4. Hamzaoglu A, Talu U, Tezer M et al: Assessment of curve flexibility in adolescent idiopathic scoliosis. Spine (Phila Pa 1976), 2005; 30: 1637–42
5. Suk SI, Lee CK, Kim WJ et al: Segmental pedicle screw fixation in the treatment of thoracic idiopathic scoliosis. Spine (Phila Pa 1976), 1995; 20: 1399–405
6. Willers U, Transfeldt EE, Hedlund R: The segmental effect of Cotrel-Dubousset instrumentation on vertebral rotation, rib hump and the thoracic cage in idiopathic scoliosis. Eur Spine J, 1996; 5: 387–93
7. Luk KD, Cheung WY, Wong Y et al: The predictive value of the fulcrum bending radiograph in spontaneous apical vertebral derotation in adolescent idiopathic scoliosis. Spine (Phila Pa 1976), 2012; 37: E922–26
8. Perdriolle R, Vidal J: Thoracic idiopathic scoliosis curve evaluation and prognosis. Spine, 1985; 10: 785–91
9. Kuklo TR, Potter BK, Lenke LG: Vertebral rotation and thoracic torsion in adolescent idiopathic scoliosis: What is the best radiographic correlate? J Spinal Disord Tech, 2005; 18: 139–47
10. Dobbs MB, Lenke LG, Kim YJ et al: Anterior/posterior spinal instrumentation versus posterior instrumentation alone for the treatment of adolescent idiopathic scoliotic curves more than 90 degrees. Spine (Phila Pa 1976), 2006; 31: 2386–91
11. Crostelli M, Mazza O, Mariani M, Mascello D: Treatment of severe scoliosis with posterior-only approach arthrodesis and all-pedicle screw instrumentation. Eur Spine J, 2013; 22(Suppl. 6): S808–14
12. Greiner KA: Adolescent idiopathic scoliosis: Radiologic decision-making. Am Fam Physician, 2002; 65: 1817–22
13. Winter RB, Lonstein JE, Denis F: How much correction is enough? Spine (Phila Pa 1976), 2007; 32: 2641–43
14. Lao L, Weng X, Qiu G, Shen J: The role of preoperative pulmonary function tests in the surgical treatment of extremely severe scoliosis. J Orthop Surg Res, 2013; 8: 32
15. Newton PO, Faro FD, Gollogly S et al: Results of preoperative pulmonary function testing of adolescents with idiopathic scoliosis. A study of six hundred and thirty-one patients. J Bone Joint Surg Am, 2005; 87: 1937–46
16. Hefti F: Pathogenesis and biomechanics of adolescent idiopathic scoliosis (AIS). J Child Orthop, 2013; 7: 17–24
17. Rodrigues LM, Ueno FH, Gotfryd AO et al: Comparison between different radiographic methods for evaluating the flexibility of scoliosis curves. Acta Ortop Bras, 2014; 22: 78–81

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS] [Index Copernicus]

18. Yazici M, Acaroglu ER, Alanay A et al: Measurement of vertebral rotation in standing versus supine position in adolescent idiopathic scoliosis. J Pediatr Orthop, 2001; 21: 252–56
19. Potter BK, Kuklo TR, Lenke LG: Radiographic outcomes of anterior spinal fusion versus posterior spinal fusion with thoracic pedicle screws for treatment of Lenke Type I adolescent idiopathic scoliosis curves. Spine (Phila Pa 1976), 2005; 30: 1859–66
20. Lamarre ME, Parent S, Labelle H et al: Assessment of spinal flexibility in adolescent idiopathic scoliosis: Suspension versus side-bending radiography. Spine (Phila Pa 1976), 2009; 34: 591–97
21. Nash CJ, Moe JH: A study of vertebral rotation. J Bone Joint Surg Am, 1969; 51: 223–29

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS] [Index Copernicus]