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Factors affecting pelvic rotation in idiopathic scoliosis

Analysis of 85 cases in a single center

Yunfei Zhao, MD[a], Lin Qi, MD[b], Jun Yang, MD[b], Xiaodong Zhu, MD[a], Changwei Yang, MD[a,*], Ming Li, MD[a,*]

Abstract

Pelvic rotation (PR) is commonly seen in patients with idiopathic scoliosis (IS), but factors contributing to this phenomenon and its relationship with the surgical outcome are not well established.

This retrospective study included 85 IS patients in 2 groups: thoracic curve dominance group (group A) and lumbar curve dominance group (group B). Pre- and postoperative PR was measured on standing posteroanterior radiographs by the left/right ratio (L/R ratio) of horizontal distance between the anterior superior iliac spine (ASIS) and the inferior ilium (SI) at the sacroiliac joint on the same side in both groups. Other radiographic data, age, sex, and Risser sign of each patient were recorded to analyze their correlations with PR before and after operation.

The patients ranged in age from 10 to 35 years with a mean of 17.0±5.2 years. The mean L/R ratio of PR before operation was 0.99 (0.73–1.40) versus 0.98 (0.87–1.26) after operation. The L/R ration was beyond the range of 1±0.1 (indicating the presence of PR) in 17 (20%) patients before operation and in 14 (16.5%) patients after operation. There was no significant difference in PR between the 2 groups of patients either before ($P=0.468$) or after ($P=0.944$) surgery. The preoperative PR showed a very low correlation with Risser sign ($r=0.220$, $P=0.043$), apex vertebral rotation (AVR) in the proximal thoracic curve ($r=0.242$, $P=0.026$), and AVR in the lumbar curve ($r=0.213$, $P=0.049$), while the postoperative PR showed a very low correlation with Risser sign ($r=-0.341$, $P=0.001$) and postoperative trunk shift (TS) ($r=-0.282$, $P=0.009$). Multiple stepwise regression analysis showed that preoperative PR was affected by proximal thoracic curve AVR and lumbar curve AVR.

There was no significant difference between PR before operation and 2 years after operation. Preoperative PR was mainly correlated with Risser sign and the rotation status of the proximal thoracic curve and lumbar curve, while postoperative PR was mainly correlated with Risser sign and postoperative TS.

Abbreviations: ASIS = anterior superior iliac spine, ASIS-SI = the horizontal distance between the anterior superior iliac spine (ASIS) and the inferior ilium (SI) at the sacroiliac joint on the same side, AVR = apex vertebral rotation, C7PL = C7 plumb line, CSVL = central sacral vertical line, IS = idiopathic scoliosis, L/R ratio = left/right ratio, PR = pelvic rotation, SI = inferior ilium at the sacroiliac joint, TL/L = thoracolumbar/lumbar, TS = trunk shift.

Keywords: corrective surgery, idiopathic scoliosis, pelvic rotation, radiographic study

1. Introduction

Idiopathic scoliosis (IS) is a common form of spinal deformity, mainly characterized by spinal scoliosis at the coronal plane, thoracic hypokyphosis at the sagittal plane, and rotational deformity at the axial plane.[1,2]

IS patients are often accompanied with deformities in other parts of the body such as shoulder imbalance and trunk shift (TS). In recent years, the phenomenon of pelvic rotation (PR) in some IS patients has aroused interest of many researchers.[3–6] Some studies reported that thoracolumbar/lumbar (TL/L) apex vertebral rotation (AVR), TL/L curve flexibility, main thoracic apex rotation, and main thoracic Cobb angle were potential factors contributing to PR.[3–6] Other studies argued that PR might also be a compensation for spinal deformity, as is the case with main thoracic curve that is often accompanied with a compensatory TL/L curve.[3,4]

Compensatory TL/L curve is believed to have a great impact on surgical outcomes in patients with IS.[7,8] Although some studies reported that PR could be affected by surgery, change in surgery-associated PR and its relationship with surgical outcomes remain poorly studied. The aim of the present study was to explore factors related to PR before and after surgery, and correlation between PR and surgical outcomes.

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I agree and confirm this statement as true.

YZ, LQ, and JY have equally contributed this work.

[a] Department of Orthopedics, Changhai Hospital, The Second Military Medical University, [b] Student Brigade, The Second Military Medical University, Shanghai, China.

[*] Correspondence: Changwei Yang and Ming Li, Department of Orthopedics, Changhai Hospital, The Second Military Medical University, Shanghai, China (e-mail: changwei_y@qq.com [CY] and limingchspine@126.com [ML]).

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2. Data and methods

2.1. General data

The research protocol was approved by the Ethics Committee of Changhai Hospital (Shanghai, China). All IS patients who were admitted in Changhai Hospital between January 2010 and January 2013 were recruited as the subjects of primary selection in this retrospective study.

Inclusion criteria were IS patients who received posterior pedicle screw implantation; patients with a right-thoracic or left-lumbar curve pattern; patients with a main curve magnitude of 40° to 70°; and patients with a minimum follow-up period of 24 months after surgery.

Exclusion criteria were patients with the possibility of having non-IS; patients with a history of spinal surgery before admission; patients with pelvic deformities due to pelvic diseases such as tumors or congenital hip dysplasia; patients with an apparent leg length discrepancy >2 cm; patients who once experienced trauma or surgery that may affect the normal configuration of the pelvis.

2.2. Surgical procedures

Surgical correction was performed with the posterior pedicle screw system (Expedium, DePuy Synthes, Raynhum, USA) under general anesthesia-controlled hypotension. After implantation of the pedicle screw and corrective rod on the concave side (for main thoracic curve, convex side for main lumbar curve) by using the rod rotation and translation techniques, the supportive rod was implanted on the other side, and at the same time autogenous bone grafting with an allogenic bone[9] was performed.

2.3. Imaging examination and grouping

Posteroanterior full-length X-ray radiography of the whole spine was performed in a standard position before surgery and during the 2-year follow-up period after surgery in all IS patients, on which coronal Cobb angle, the degree of Nash-Moe rotation of the apical vertebra and Risser sign were measured. Coronal balance was represented as the horizontal distance between the central sacral vertical line (CSVL) and C7 plumb line (C7PL), and a C7PL presents on the left or right side of the CSVL was designated as the negative or positive value, respectively. TS was measured on the standing posteroanterior X-ray radiographs. First, the apical vertebra of thoracic curve was determined, and then a horizontal line (ab) was drawn through its central point, where points a and b represent the crossover point between the horizontal reference line across the central point of the apical vertebra of the thoracic curve and the left and right boundary of the bony thorax, respectively. The midpoint of the a–b line is c, through which a vertical line was made as the vertical trunk reference line. TS was referred to as the distance (mm) between the vertical trunk reference line and CSVL. Displacement of TS to the right side of CSVL was recorded as the positive value, and that to the left side was recorded as the negative value. Horizontal PR was measured as described.[10] First, the horizontal distance between the anterior superior iliac spine (ASIS) and the inferior ilium (SI) at the sacroiliac joint on the same side was measured on the whole-spine posteroanterior view of X-ray radiography, and then the left/right (L/R) ratio of ASIS-SI was used to represent the degree of horizontal PR (Fig. 1). An L/R ratio of ASIS-SI smaller than 1 indicated right PR in the cephalad view, and vice versa. An

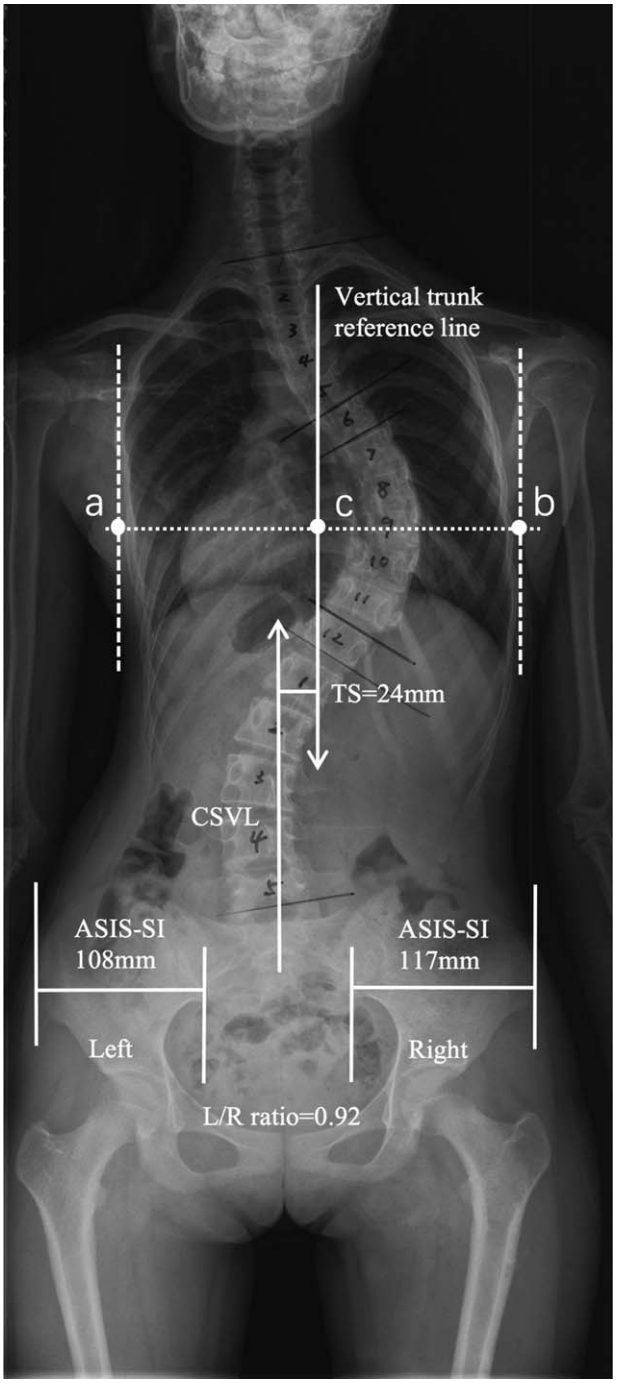

Figure 1. A standing posterior–anterior radiograph of a 14-year-old girl with thoracic curve dominance illustrating the measurements of L/R ratio of ASIS-SI and TS. ASIS = anterior-superior iliac spine, L/R ratio = left/right ratio, SI = inferior ilium at the sacroiliac joint, TS = trunk shift.

L/R ratio within the range of 1 ± 0.1 was defined as physiologic symmetry of the pelvis without the presence of horizontal PR or only minimal rotation. The IS patients were further classified into 2 groups: group A of thoracic curve dominance (equivalent to Lenke I–III) and group B of lumbar curve dominance (equivalent to Lenke V–VI). All imaging data were obtained twice by 2 doctors independently, with the interval between the 2 measurements no <2 weeks. The mean value of the 2 measurements from the 2 doctors was used for analysis.

2.4. Statistical analysis

All statistical analyses were performed with SPSS 17.0. Pre- and postoperative PR values were compared using paired *t* test. All parameters between groups A and B were analyzed by independent sample *t* test. Correlations between the pre- and postoperative L/R ration and other imaging parameters were analyzed by Pearson correlation analysis. Multiple stepwise regression analysis was performed to screen factors contributing to preoperative PR. Values of $P<0.05$ were considered statistically significant.

3. Results

3.1. General data

Included in this study were 85 IS patients who met the inclusion criteria, including 71 females and 14 males who ranged in age from 10 to 35 years with a mean of 17.0 ± 5.2 years (Table 1). The range of Risser sign was 0–V. According to Lenke classification, there were 38 cases of type I, 9 cases of type II, and 3 cases of type III in group A (n = 50) versus 27 cases of type V and 6 cases of type VI in group B (n = 33). The remaining 2 cases were type IV.

3.2. Occurrence of the PR phenomenon

Of the 85 IS patients included, the mean L/R ratio of PR was 0.99 (range 0.73–1.40) before surgery versus 0.98 (range 0.87–1.26) after surgery. The L/R ration was beyond 1 ± 0.1 (indicating the presence of PR) in 17 (20%) patients before surgery versus 14 (16.5%) patients after surgery. The details are indicated in Table 2. Of the 85 IS patients, left PR (L/R ratio >1) and right PR (L/R ratio <1) occurred in 33 and 52 patients before surgery, respectively. There was no significant difference in the degree of PR before and after surgery ($P=0.764$).

3.3. L/R ratio of PR in different groups

The L/R ratio of PR in groups A and B, before and after operation was listed in Table 3. There was no significant difference in PR between the 2 groups either before ($P=0.468$) or after surgery ($P=0.944$) (Table 3).

Table 1

Main parameters of the IS patients.

Parameters	Mean ± SD
Age	17.00 ± 5.16
PTC Cobb angle, °	19.55 ± 12.63
PTC Cobb angle, ° (2 y after surgery)	13.76 ± 9.28
PTC AVR, °	0.52 ± 0.68
PTC AVR, ° (2 y after surgery)	0.13 ± 0.34
TC Cobb angle, °	38.90 ± 13.81
TC Cobb angle, ° (2 y after surgery)	15.96 ± 9.55
TC AVR	1.21 ± 0.80
TC AVR (2 y after surgery)	0.33 ± 0.605
LC Cobb angle, °	34.67 ± 13.71
LC Cobb angle, ° (2 y after surgery)	12.88 ± 7.88
LC AVR	1.40 ± 1.00
LC AVR (2 y after surgery)	0.31 ± 0.58
Coronal balance, mm	6.04 ± 18.33
LC AVR, mm (2 y after surgery)	4.45 ± 11.76
Trunk shift, mm	2.14 ± 18.21
Trunk shift, mm (2 y after surgery)	5.05 ± 11.32
Pelvic rotation	0.99 ± 0.09
Pelvic rotation (2 y after surgery)	0.98 ± 0.07

AVR = apex vertebrae rotation, IS = idiopathic scoliosis, LC = lumbar curve, PTC = proximal thoracic curve, SD = standard deviation, TC = thoracic curve.

Table 2

Distribution of the L/R ratio before and after surgery.

Group	Before surgery, n (%)	After surgery, n (%)
<0.9	9 (11%)	9 (10.6%)
0.9–1.1	68 (80%)	71 (83.5%)
>1.1	8 (9%)	5 (5.9%)

L/R ratio = left/right ratio.

3.4. Correlations between pre/postoperative PR and other parameters

Pearson correlation analysis showed that there was a very low association between preoperative PR and Risser sign ($r=0.220$, $P=0.043$), AVR of the proximal thoracic curve ($r=0.242$, $P=0.026$), and AVR of the lumbar curve ($r=0.213$, $P=0.049$), and that there was a very low association between postoperative PR and Risser sign ($r=-0.341$, $P=0.001$) and TS after surgery ($r=-0.282$, $P=0.009$) (Table 4). Multiple stepwise regression analysis showed that proximal thoracic curve AVR and lumbar curve AVR were factors contributing to preoperative PR.

4. Discussion

4.1. Phenomenon of PR in IS patients

Many studies have reported the phenomenon of PR and tried to analyze and explain it.[3–6,10] Lucas et al[10] used X-ray bony anatomic landmarks to make a quantitative assessment of PR and found that using the left and right hipbone width ratio or L/R ratio of ASIS-SI to assess PR could reduce the effect of the sacral horizontal angle. They also found that the L/R ratio was almost linearly correlated with the degree of PR when the PR angle was within 20°, which is the situation seen in most clinical cases. Using this method, Gum et al[4] found that most IS patients had right PR with a mean L/R ratio of 0.95. Using the computer technology, Stylianides and Pasha[5,6] made 3D assessments on the pelvis of IS patients. Stylianides et al[5] classified their patients to a moderate IS group and a severe IS group, and used able-bodied females as control group. They found that the distance from right ASIS and the right widest tip of the iliac crest to SI in severe IS group was significantly larger than that in moderate IS group and control group. While in Pasha's study,[6] they classified patients to a right main thoracic curve group and a left TL/L curve group, and found that the occurrence rate of right PR was as high as 84% in main thoracic curve group versus 55% in TL/L curve group. In the present study, we used the same method as Gum[4] and found that the mean preoperative L/R ratio was 0.99 (range 0.73–1.40; 0.97 ± 0.08 in thoracic curve dominance group and 0.99 ± 0.09 in lumbar curve dominance group), which is significantly different

Table 3

Mean value of the L/R ratio before and after surgery in the 2 groups.

	Group A	Group B	*P*
n	50 (58.8%)	33 (38.8%)	
Pelvic rotation (before surgery)	0.97 ± 0.08	0.99 ± 0.09	0.468
Pelvic rotation (after surgery)	0.98 ± 0.07	0.99 ± 0.07	0.944

L/R ratio = left/right ratio.

Table 4

Correlations between pre/postoperative pelvic rotation and other parameters.

Parameters	Pre-*r*	Pre-*P*	Post-*r*	Post-*P*
Age	0.109	0.320	−0.049	0.655
Risser sign	0.220*	0.043	−0.341*	0.001
PTC Cobb angle (before surgery)	0.173	0.114	0.087	0.428
PTC Cobb angle (after surgery)			0.125	0.254
PTC AVR (before surgery)	0.242*	0.026	0.108	0.325
PTC AVR (after surgery)			−0.050	0.647
TC Cobb angle (before surgery)	0.102	0.354	0.022	0.839
TC Cobb angle (after surgery)			0.056	0.612
TC AVR (before surgery)	0.003	0.982	−0.026	0.815
TC AVR (after surgery)			0.065	0.553
LC Cobb angle (before surgery)	0.088	0.423	0.142	0.194
LC Cobb angle (after surgery)			−0.011	0.923
LC AVR (before surgery)	0.213*	0.049	−0.025	0.823
LC AVR (after surgery)			−0.053	0.630
Coronal balance (before surgery)	−0.007	0.948	−0.099	0.369
Coronal balance (after surgery)			−0.185	0.089
Trunk shift (before surgery)	−0.105	0.341	−0.176	0.106
Trunk shift (after surgery)			−0.282*	0.009

Correlation analysis using Pearson method.

AVR = apex vertebrae rotation, LC = lumbar curve, PTC = proximal thoracic curve, TC = thoracic curve.

* $P < 0.05$.

from that reported by Gum et al.[4] The reason may be that the mean degree of scoliotic deformation is different between the patients of the 2 studies. The mean preoperative main curve Cobb angle in our study was significantly smaller than that reported by Gum et al. To exclude measurement bias and physiologic PR, we defined the presence of PR when the L/R ratio was <0.9 or >1.1, based on which we concluded that the preoperative occurrence of PR was about 20%.

4.2. Correlation analysis between PR and IS

It was found in our study that there was a low association between the preoperative L/R ratio and AVR of both proximal thoracic and lumbar curves. These findings were different from Wang's.[3] We failed to find any significant correlation between AVR of the main thoracic curve and PR, probably due to the different curve types of patients in the 2 studies. It is difficult to explain the significant positive correlation between proximal thoracic curve AVR and the preoperative L/R ratio. The reason may be that there exists a coordinated relationship between the cranial end (near main thoracic curve) and the caudal end (pelvis) to compensate with the rotation imbalance either from the main thoracic curve or lumbar curve at the horizontal level. It would be an interesting phenomenon if this postulation could be further confirmed.

4.3. Impact of correction surgery on PR

Although our study showed no significant difference in the L/R ratio before and after surgery, the respective distribution diagrams indicate that the postoperative L/R ratio is slightly inclined to the left, suggesting that the correction surgery to some extent increased right rotation of the pelvis, which is consistent with the study of Asher et al.[11] In the present study, we mainly used the rod derotation method for surgical correction. Whether in surgery for main thoracic curve or lumbar curve, the derotation rod is always rotated in a clockwise direction (in the cephalad view). Meanwhile studies[12–14] have demonstrated that the correction force may have impact on the nonfusion vertebrae, and likewise the clockwise correction force may increase right rotation of the pelvis.

The lumbar curve becomes more rigid when the Risser sign increases, and the more rigid the lumbar curve is, the more likely it will transmit the correction force to the pelvis. For this reason, the impact of the correction force on the pelvis of patients with younger bone age will not be as large as that on patients with older bone age, which may explain the negative correlation between the postoperative L/R ratio and the Risser sign.

In addition, Asher's study[11] showed that right trunk inclination in the coronal plane was increased in IS group of patients with increased right PR after surgery as compared with patients with no increased right PR, which is consistent with the finding of the present study. It was found in another study[15] that preoperative PR might be related to postoperative loss of balance in the coronal plane. All these conclusions seem to suggest that axial balance may affect coronal balance, though more research is needed to elucidate the intrinsic association between them.

There some limitations in this study that could be addressed in the future. First, it is a retrospective single-center study, and therefore the conclusions drawn in this study could be influenced by the retrospective nature. Second, the sample size is not large enough and the authors pooled adolescent IS together with adult IS, but as the maximal and mean age was 35 and 17 years, respectively, the degenerative factors in this study could be minimal. Third, we did not use 3D measurements of the spine, but based on the result of our literature review, the differences in spinal parameters between 2D and 3D are mainly centralized on the sagittal plane such as thoracic kyphosis and lumbar lordosis.[16] Finally, although there was an increasing trend of PR after surgery, the authors did not find significant correlations between surgery and PR. This may due to the relatively small sample size.

In summary, we observed the occurrence rate of PR in IS patients and postulated that PR may be an axial compensation to IS. In addition, preoperative PR was mainly affected by the rotation status of proximal thoracic curve and lumbar curve, and postoperative PR was related to Risser sign and TS.

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