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Original Article

Cervical axis tilt phenomenon in Lenke type 1 and 2 adolescent idiopathic scoliosis

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Abstract: Purpose: To investigate the cervical axis tilt (CAT) phenomenon in Lenke 1 and 2 adolescent idiopathic scoliosis (AIS) patients, and to identify the risk factors for CAT at follow-up. Methods: Medical records of 55 Lenke 1 or 2 type AIS patients with follow-up time > 20 months were reviewed from February 2013 to February 2015. Patients were divided into case group (CAT ≥ 5°), and control group (CAT < 5°). Demographic data, preoperative and follow-up radiologic parameters were evaluated, including age, gender, Risser sign, coronal parameters, shoulder balance parameters and SRS-22. Correlation analyses between CAT at follow-up and other coronal parameters were pursued. To identify risk factors of CAT ≥ 5° at follow-up, binary logistic regression models, with forward stepwise (Conditional), were constructed by variables that were of significance in a comparison study. Result: Preoperatively, 23 patients (41.82%) exhibited CAT ≥ 5° with an average CAT of 6.83±3.60, and 32 patients (58,18%) exhibited CAT < 5° with an average CAT of 2.16±1.72. There was no difference in average age (P = 0.158), gender distribution (P = 0.446), follow-up time (P = 0.955), LIV (P = 0.366), and Lenke type curve distribution (P = 0.341) between groups. Significant difference was observed in terms of Risser sign (P = 0.041) and T1-Tilt (P = 0.023). No difference was observed in PTC (P = 0.455), and MTC (P = 0.953), TL/LC (P = 0.816), CA (P = 0.169), RSH (P = 0.976), CB (P = 0.470). At follow-up, 21 patients (38.18%) exhibited CAT ≥ 5° with an average CAT of 5.86±1.20, and 34 patients (61.82%) exhibited CAT < 5° with an average CAT of 2.15±1.56. We detected statistical difference in PTC (P = 0.002), CB (P = 0.043), and T1-Tilt (P = 0.004). No significant difference was observed in MTC (P = 0.520), TL/LC (P = 0.144), CA (P = 0.406), RSH (P = 0.316), UIV-T1 (P = 0.184). Significant correlations were detected between postoperative CAT and postoperative PTC (r = 0.377, P = 0.012), postoperative CA (r = 0.421, P = 0.001), postoperative RSH (r = 0.483, P < 0.001), and postoperative T1-Tilt (r = 0.557, P < 0.001). Binary logistic regression analysis identified that postoperative PTC (P = 0.002) was the primary contributor to postoperative CAT ≥ 5°. Conclusion: CAT was different from shoulder imbalance. The primary contributors to postoperative CAT was the postoperative PT. The CAT did not affect the SRS-22 scores.

Keywords: Adolescent idiopathic scoliosis, cervical axis tilt, Lenke 1 and 2, shoulder balance

Introduction

Adolescent idiopathic scoliosis (AIS) is a three-dimensional deformity of spine. For those individuals with severe deformity, surgical treatment is recommended to reconstruct the spinal alignment in three-dimensional planes [1]. Initially, the attentions were mainly paid to the coronal correction, for which was significantly correlated with patient's appearance and satisfaction in AIS patients [2]. Recently, sagittal alignment has been a hot issue in adolescent scoliosis [3-5], for that sagittal balance affected the clinical outcome, particularly for those elderly individuals. Since pedicle screws were employed to correct this deformity, the satisfactory radiographic correction was achieved in three-dimensional planes, and more motional segments were saved [6, 7]. However, the strong strength of pedicle screws could result in overcorrection for the main thoracic curve (MTC), which always resulted in shoulder imbalance for that the proximal thoracic curve (PTC) failed to compensate for the over correction [8].

The occurrence of shoulder imbalance varied ranging from 23% to 32% [9, 10]. Correspondingly, it was commonly accepted that shoulder balance was correlated with clavicle chest ca-

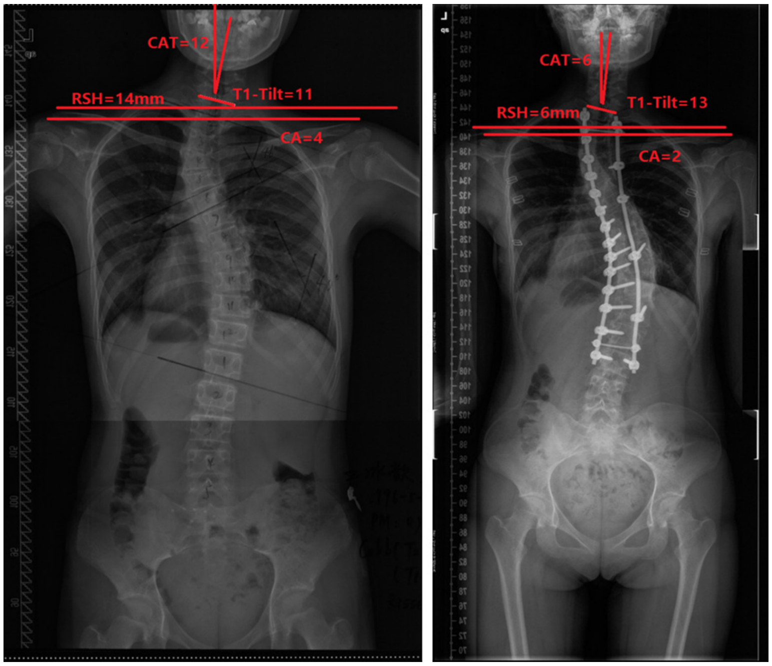

Figure 1. A 16-year old Lenke 1 AIS patient demonstrated CAT. Preoperatively CAT = 12°, T1-Tilt = 11, RSH = 14 mm, and CA = 4°; Post-operatively CAT = 6°, T1-Tilt = 13, RSH = 6 mm, and CA = 2°.

ge angle difference, coracoid height difference (CHD), clavicle angle (CA), radiologic shoulder height (RSH), and preoperative PT cobb angle. In addition, the upper instrumented vertebrae (UIV) was frequently selected based on preoperative shoulder balance (T2 for higher left shoulder, T3 for level shoulder, and T4 for higher right shoulder) [11, 12]. Based on this guideline, the balance shoulder was frequently achieved after surgery for those Lenke 1 and 2 AIS patients. However, there was no adequate studies focused on cervical axis tilt (CAT) and its resultant neck tilt phenomenon. Neck tilt was frequently observed both preoperatively and after surgery. Previously, it was reported that neck tilt was not the same phenomenon of shoulder imbalance. There was no strong correlation between neck tilt and clinical shoulder imbalance [13]. Clinical neck tilt grading was correlated with CAT and T1-Tilt, while clinical shoulder grading was correlated with CHD, RSH, and CA. In addition, those individuals with neck tilt could be shoulder balance or imbalance [13]. Furthermore, it was reported that shoulder balance was highly associated with Health-related quality of life (HRQoL) [14]. However, there was no relevant report on neck tilt or CAT.

Therefore, we performed this study to investigate the phenomenon of CAT in Lenke 1 and 2 AIS patients both preoperatively and at follow-up, and to assess its influence in coronal parameters, to identify the potential risk factors of CAT at follow-up.

Materials and methods

In the study, 55 patients with Lenke 1 or 2 AIS were included, all of which received correction surgery with posterior pedicle screws from February 2013 to February 2015. The following items were the inclusion criteria: (a) Lenke type 1 or 2 AIS patients with an age from 11 to 19 years; (b) MT Cobb > 40°; (c) One-stage posterior pedicle screw instrumentation was performed by the same treatment group; (d) Sufficient full spine X-ray films preoperatively and at follow-up; and (e) The follow-up time > 20 months. The cervical axis tilt (CAT) was used to quantitatively evaluate the neck tilt. According to CAT, patients were divided into two groups. The CAT was defined as the angle between the line from the center of C7 to the center of C2 and plumb line [13]. Patients with a CAT less than 5° were included in the control group, whereas patients with a CAT greater than or equal to 5° were included in the case group. **Figure 1** was a representative example and also schematic for measurement. This study was approved by the institutional review board in our institution.

Radiologic and clinical assessment

Preoperatively, and at follow-up X-ray films were assessed by experienced radiology technologist. The following parameters were measured on coronal radiographic films: (a) CAT (the angle between the line from the center of C7 to the center of C2 and plumb line), (b) T1-Tilt (the angle T1 between the superior endplate of T1 and a horizontal line), (c) Clavicle angle (CA), (d) Radiologic shoulder height difference (RSH), (e) Coronal balance (CB), (f) Proximal thoracic cobb angle (PTC), (g) Main thoracic cobb angle (MTC),

Table 1. Preoperative and follow-up values of the coronal radiographic parameters and SRS-22 score in AIS Patients (n = 55)

Variables	Preoperative	Follow-up	T value	*P* value
PTC (°)	24.78±9.20	16.40±7.87	9.527	< 0.001
MTC (°)	45.14±7.61	17.00±8.90	30.454	< 0.001
TL/LC (°)	27.74±11.41	11.91±7.20	13.015	< 0.001
Coronal balance (mm)	-1.44±15.64	-2.60±10.45	3.068	0.002
CA (°)	-0.49±3.34	1.04±2.27	1.797	0.006
RSH (mm)	-3.81±14.48	2.80±9.37	3.119	0.371
T1-Tilt	1.11±7.93	2.82±5.78	1.181	0.139
CAT (°)	4.11±3.52	3.56±2.31	0.990	0.327
CAT < 5°/CAT ≥ 5°	32/23	34/21	1.005	0.403
SRS-22	3.92±0.25	4.08±0.022	-5.600	< 0.001

Table 2. Comparing demographical data and radiographic parameters between preoperative

Variables	CAT < 5° (n = 32)	CAT ≥ 5° (n = 23)	T or chi square value	*P* Value
Age (year)	15.09±1.94	14.10±2.32	-1.432	0.158
Gender (Female/Male)	26/6	21/2	1.088	0.446
Follow-up (month)	26.38±4.14	26.32±3.24	-0.057	0.955
Risser	3.84±1.32	2.65±1.92	-2.569	0.014
LIV (T1/T2/T3/T4/T5/T6)	0/2/13/12/4/1	3/2/9/5/3/1	5.425	0.366
Lenke 1/2	25/7	16/7	0.517	0.341
PTC (°)	23.97±7.76	25.91±10.99	0.770	0.455
MTC (°)	45.09±6.03	45.22±9.54	0.059	0.953
TL/LC (°)	27.44±10.60	28.17±12.68	0.234	0.816
Coronal balance (mm)	13.50±9.31	11.70±8.72	-0.728	0.470
CA (°)	2.22±1.58	3.04±2.79	1.394	0.169
RSH (mm)	12.03±7.15	11.96±10.90	-0.31	0.976
T1-Tilt	4.63±3.68	7.87±6.51	2.350	0.023
CAT (°)	2.16±1.72	6.83±3.60	6.401	< 0.001
SRS-22	3.94±0.29	3.90±0.19	0.148	0.883

CAT < 5° group and CAT ≥ 5° group.

(h) Thoracolumbar/lumbar cobb angle (TL/LC), and (i) The saving segments from the upper instrumented vertebrae to T1 (UIV-T1).

Those parameters were assessed by two authors, independently. Any disagreement was removed through discussion. Scoliosis Research Society (SRS-22) questionnaire was employed to assess the clinical outcome of those individuals before surgery, and at follow-up.

Statistical analyses

Comparison analyses between preoperatively and at follow-up were conducted by paired t-tests. Comparison analyses between CAT ≥ 5° group and CAT < 5° group were conducted by independent samples t-tests. Categorical data were assessed by Chi-square test. Correlation analyses were performed by Pearson test. To investigate the risk factors of CAT ≥ 5° at follow-up, and binary logistic regression models (forward stepwise conditional) was were constructed by variables that were of significance in a comparison study. That a two-tailed P < 0.05 meant statistical significance. Statistical analyses were conducted by SPSS statistical software v. 18.0 (Chicago, IL, USA).

Result

Characteristics of patients

There were 55 AIS patients comprised of 47 female patients (85.45%) and 8 male patients (14.55%) in this study. The mean age, follow-up time, and Risser at the time of surgery was 14.77±2.04 years, 26.35±3.67 months, and 3.45±1.69, respectively. Preoperatively, 23 patients (41.80%) exhibited CAT ≥ 5° with an average CAT of 6.83±3.60, and 32 patients (58,18%) exhibited CAT < 5° with an average CAT of 2.16±1.72.

Effects of surgery

At follow-up, 21 patients (38.18%) exhibited CAT ≥ 5° with an average CAT of 5.86±1.20, and 34 patients (61.82%) exhibited CAT < 5° with an average CAT of 2.15±1.56. Furthermore, 14 patients with a preoperative CAT < 5° developed CAT ≥ 5° at follow-up, whereas 16

Table 3. Comparison analyses on parameters between CAT < 5° group and CAT ≥ 5° group at follow-up

Variables	CAT < 5° (n = 34)	CAT ≥ 5° (n = 21)	T or chi-square value	*P* Value
Age (year)	14.74±1.78	14.81±2.44	0.130	0.897
Gender (Female/Male)	31/3	16/5	2.346	0.236
Follow-up (month)	26.63±3.55	25.96±3.65	-0.680	0.499
Risser	353±1.40	3.05±2.09	-1.027	0.309
LIV (T1/T2/T3/T4/T5/T6)	0/2/13/12/4/1	3/2/9/5/3/1	7.207	0.366
Lenke 1/2	28/6	13/8	2.861	0.086
Preoperative PTC (°)	22.44±9.19	28.57±8.07	2.516	0.015
Follow-up PTC (°)	13.88±7.16	20.48±7.38	3.281	0.002
Preoperative MTC (°)	45.26±7.54	44.95±7.92	-0.146	0.884
Follow-up MTC (°)	17.56±7.49	16.10±9.12	-0.648	0.520
Preoperative TL/LC (°)	29.94±11.59	24.19±10.40	-1.857	0.069
Follow-up TL/LC (°)	13.03±7.35	10.10±6.71	-1.485	0.144
Preoperative coronal balance (mm)	12.15±7.92	13.71±10.73	0.622	0.537
Follow-up coronal balance (mm)	9.88±6.38	6.24±6.29	-2.069	0.043
Preoperative CA (°)	3.03±7.35	1.81±1.25	-2.073	0.043
Follow-up CA (°)	2.15±1.50	1.81±1.36	-0.838	0.406
Preoperative RSH (mm)	13.68±9.50	9.29±6.99	-1.832	0.073
Follow-up RSH (mm)	8.50±5.97	6.90±5.17	-1.012	0.316
Preoperative T1-Tilt	6.09±5.23	5.31±5.35	-0.189	0.851
Follow-up T1-Tilt	4.18±3.49	7.00±3.32	2.972	0.004
Preoperative CAT (°)	4.15±3.96	4.05±2.74	-0.101	0.920
UIV-T1	2.65±1.01	2.24±1.22	-1.345	0.184
SRS-22	4.08±0.24	4.09±0.20	0.148	0.883

patients with a preoperative CAT ≥ 5° developed CAT < 5° at follow-up. Compared with pre-operation, those parameters at follow-up changed significantly, including PTC (P < 0.001), MTC (P < 0.001), TL/LC (P < 0.001), Coronal Balance (P = 0.002), CA (P = 0.006), and SRS-22 (P < 0.001). **Table 1** demonstrated the preoperative and postoperative values of the coronal radiographic parameters and SRS-22 scores in those AIS Patients. There was no difference in average age (P = 0.158), gender distribution (P = 0.446), follow-up time (P = 0.459), LIV (P = 0.366), SRS-22 (P = 0.638), and Lenke type curve distribution (P = 0.341) between groups. Besides, no significant difference was observed in PTC (P = 0.455), and MTC (P = 0.953), TL/LC (P = 0.816), CA (P = 0.169), RSH (P = 0.976), CB (P = 0.470) between groups. However, significant difference was observed in terms of Risser sign (P = 0.041) and T1-Tilt (P = 0.023) (**Table 2**).

Difference between CAT ≥ 5° group and CAT < 5° at follow up

At follow-up, we detected statistical difference in PTC (P = 0.002), CB (P = 0.043), and T1-Tilt (P = 0.004) between groups. However, no significant difference was observed in MTC (P = 0.520), TL/LC (P = 0.144), CA (P = 0.406), RSH (P = 0.316), UIV-T1 (P = 0.184), and SRS-22 (P = 0.883) between two groups (**Table 3**). Significant correlations were detected between postoperative CAT and postoperative PTC (r = 0.377, P = 0.012), postoperative CA (r = 0.421, P = 0.001), postoperative RSH (r = 0.483, P < 0.001), and postoperative T1-Tilt (r = 0.557, P < 0.001) (**Table 4**).

Multivariate analysis on risk factor of CAT ≥ 5° at follow up

Binary logistic regression analysis showed that postoperative PTs (P = 0.002) was the primary contributor in the equation (OR = 1.129, 95% CI = 1.038-1.228, P = .024), rather than preoperative PTC (P = 0.760), preoperative CA (P = 0.129) postoperative CB (P = 0.183), and Postoperative T1-tilt (P = 0.307) (**Table 5**).

Discussion

Recently, several studies have focused on the cervical sagittal alignment for the potential

Table 4. Correlations between postoperative CAT and preoperative and follow-up parameters

Variables	Pearson correlation coefficient (r)	*P* value
UIV-T1 (segments)	-0.129	0.346
Preoperative PTC (°)	0.120	0.381
Follow-up PTC (°)	0.377	0.012
Preoperative MTC (°)	-0.106	0.442
Follow-up MTC (°)	-0.061	0.657
Preoperative LC (°)	-0.192	0.161
Follow-up LC (°)	-0.160	0.244
Preoperative CB (mm)	0.122	0.377
Follow-up CB (mm)	0.172	0.209
Preoperative CA (°)	-0.008	0.952
Follow-up CA (°)	0.421	0.001
Preoperative RSH (mm)	-0.106	0.441
Follow-up RSH (mm)	0.483	< 0.001
Preoperative T1T (°)	-0.261	0.055
Follow-up T1T (°)	0.557	< 0.001
Preoperative CAT (°)	-0.129	0.346

accelerated cervical degeneration with aging [15, 16]. Conversely, there were few reports focused on cervical coronal alignment. It was proposed that neck tilt was distinct from shoulder imbalance, and that clinical neck tilt grading was strongly correlated with CAT [13]. This study also quantitatively assessed the cervical axis angle ranging from 2.11°±1.2° to 7.17°±2.2° in different neck tilt groups [13]. In our study, 23 patients (41.82%) exhibited CAT ≥ 5° preoperatively, and 21 patients (38.18%) exhibited CAT ≥ 5° at the final follow-up. Therefore, CAT phenomenon was common in AIS patients before and after surgery. There was no difference in occurrences of CAT ≥ 5° between pre-operation and post-operation (P = 0.236). In CAT ≥ 5° group, T1-Tilt was higher than the control group preoperatively and at follow-up. At follow-up, significant correlations were detected between postoperative CAT and postoperative PTC (r = 0.377, P = 0.012), postoperative CA (r = 0.421, P = 0.001), postoperative RSH (r = 0.483, P < 0.001), and postoperative T1-Tilt (r = 0.557, P < 0.001). The previous report supported that clinical neck tilt grading was correlated with CAT and T1-Tilt [13]. Correspondingly, we observed that T1-Tilt was most correlated with CAT than RSH and CA. Therefore, our findings echoed the conclusion that clinical neck tilt was strongly correlated with T1-Tilt [13].

In contrast to few reports on cervical axis tilt, there are a series of studies on shoulder imbalance and its relevant risk factors. Shoulder imbalance can be influenced by RSH [17], CHD [10], and CA [18]. In this study, we also detected significant correlation between CAT and RSH, CA as wells T1-Tilt, postoperatively. It was reported that T1-Tilt did not correlate with shoulder balance [19]. Additionally, another two studies proposed that T1-Tilt was poorly correlated with clinical shoulder appearance [10, 18]. On the contrary, this study detected that postoperative T1-Tilt was highly correlated with postoperative CAT (r = 0.557, P < 0.001), which conformed that neck tilt or CAT was distinct from shoulder imbalance.

Furthermore, this was the first study focused on the risk factors of CAT at follow-up. Regression analysis revealed that follow-up PTC was the primary contributors to follow-up CAT. Other institutions have focused on PT curve and its influence in shoulder balance. Compared with the MT curve, PT curve is of higher rigidity, and it is difficult to determine whether to fuse the PT or not [19]. Therefore, the PT curve might fail to compensate for overcorrection of the MT curve, which led to shoulder imbalance [8]. In addition, it was commonly accepted that postoperative shoulder balance was highly associated with postoperative PT [19] and the UIV [11, 12] in Lenke 1 and 2 AIS patients. However, this study did not detect the difference in selecting UIV between CAT ≥ 5° group and CAT < 5° group. To guarantee horizontal sight, the flexible cervical spine could easily compensate for overcorrection of MTC and fusion of PTC. Therefore, the surgeons can select the UIV based on the shoulder balance without caring postoperative CAT.

Although CAT can be observed before and after surgery, this phenomenon did not influence in SRS-22 score. It was reported that Health-related quality of life (HRQoL) was significantly correlated with severity of cobb angle in AIS patients [20]. On the contrary, another study reported that there was no difference in HRQoL by curve severity [19]. Generally, there were several factors other than CAT associated with HRQoL such as SRS-22 score.

In this study, we identified the primary coronal factors of CAT in Lenke 1 and 2 AIS patients,

Table 5. Binary logistic regression analysis by forward stepwise (Conditional) for risk factors of CAT ≥ 5°. Follow-up CAT was the dependent variable. CAT ≥ 5° group was designate as 1, CAT < 5° is as 0, in order to interpret the findings. The independent variables were follow-up parameters (PTC, CB, CA and T1-Tilt) and preoperative PT

Variable	B	Standard error	Wald	Df	*P* value	OR	95% CI
Constant	-2.547	0.807	9.967	1	0.005		
Follow-up PTC (°)	0.121	0.043	7.991	1	0.002	1.129	1.038-1.228

Variables were not in the regression model: follow-up parameters [CB (P = 0.183), CA (P = 0.749) and T1-Tilt (P = 0.307)]. and preoperative PT (P = 0.760).

and further confirmed that CAT was different from shoulder imbalance.

Several limitations should be assessed in this paper. Firstly, this retrospective study included only 55 patients. Secondly, the follow-up time were relatively short. Therefore, studies with larger sample size and longer follow-up time are needed to explore this issue.

Conclusion

CAT was different from shoulder imbalance. There was significant correlation between postoperative CAT and postoperative PTC and postoperative T1-Tilt. The primary contributors to postoperative CAT was postoperative PTC rather than postoperative T-tilt and UIV.

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Disclosure of conflict of interest

None.

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