Does spinal fusion to T2, T3, or T4 affects sagittal alignment of the cervical spine in Lenke 1 AIS patients

A retrospective study

Jian Zhao, MDa, Ziqiang Chen, MDa, Mingyuan Yang, MDa, Gengwu Li, MDa,b, Yingchuan Zhao, MDa,* Meng Li, MDb,∗

Abstract

The aim of this study was to investigate whether spinal fusion to T2, T3, or T4 affects sagittal alignment of the cervical spine in Lenke 1 adolescent idiopathic scoliosis (AIS) patients.

A retrospective study comprised of 64 Lenke 1 AIS patients was performed to assess the radiographic and clinical outcome. According to the upper instrumented vertebrae (UIV) (T2, T3, or T4), the patients were divided into 3 groups. Comparison analyses were performed among these 3 groups of patients as between pre-op, immediate post-op, and final follow-up, as well as between these groups.

Between groups, comparison analyses did not detect a statistical difference in cervical lordosis (CL) preoperatively (P = .501), immediately after surgery (P = .799), and at follow-up (P = .510). Immediately after surgery, CL increased significantly in all groups (T2, P = .004, T3, P < .001 and T4, P = .002 respectively). Compared with immediate postoperatively, CL at final follow-up increased in T2 group (P = .037), and T4 group (P = .010). Furthermore, CL at follow-up was significantly correlated with the following parameters: preoperative (coronal plane balance [r = .349, P = .004], pelvic tilt [r = .347, P = .004], pelvic incidence [r = .261, P = .031], and CL [r = .471, P < .001]) immediately postoperative (CL [r = .946, P < .001], T1-slope [r = −0.646, P < .001], and thoracic kyphosis (TK) [r = −0.353, P = .003]), and at follow-up (TK [r = −0.342, P = .004], and T1-slope [r = −0.821, P < .001]). However, there was no significant correlation between a selection of UIV and CL at follow-up (r = .031, P = .802). Moreover, Scoliosis Research Society (SRS-22) scores between groups were similar preoperatively (P = .242), immediately after surgery (P = .828), and at follow-up (P = .219).

In Lenke 1 AIS patients, the selection of UIV mainly affects the coronal plane, especially shoulder balance. Fusion to T2, T3, or T4 did not affect the alignment of the cervical spine, and the SRS-22 score.

Level of evidence: Level IV.

Abbreviations: AIS = adolescent idiopathic scoliosis, CA = clavicle angle, CB = coronal plane balance, CL = cervical lordosis, CSA = cervical sagittal alignment, HRQOL = health-related quality of life, LIV = lower instrumented vertebrae, LL = lumbar lordosis, MTC = major thoracic curve, PI = pelvic incidence, PT = pelvic tilt, PTC = proximal thoracic curve, RSH = radiological shoulder height difference, SRS = Scoliosis Research Society, SS = sacral slope, SVA = sagittal vertical axis, TK = T5-T12 kyphosis, T/LLC = thoracolumbar/lumbar curve, TLK = thoracolumbar kyphosis, TPA = T1 pelvic angle, UV = upper instrumented vertebrae, UV-T1 = The saving segments from UV to T1.

Keywords: adolescent idiopathic scoliosis, cervical sagittal alignment, Lenke 1, posterior fusion, shoulder balance

1. Introduction

Adolescent idiopathic scoliosis (AIS) is a 3-dimensional deformity, which may contain coronal curves, sagittal alignment abnormalities, and axial rotation. Approximately 2~3% of young individuals meet the diagnostic criteria (Cobb >10° in the coronal plane).[1] For those suffering from severe spinal deformity, surgical correction may be recommended to restore spinal alignment.[2,3] As the pedicle screw constructs were employed to treat this deformity, excellent correction in the

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*JZ, ZC, and MY contributed equally to this work.

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Department of Orthopedics, Changhai Hospital, Second Military Medical University, Shanghai, 2Panzhihua Central Hospital, Panzhihua, Sichuan Province, China.

Correspondence: Ming Li, and Yingchuan Zhao, Department of Orthopedics, Changhai Hospital, Second Military Medical University, Shanghai 200438, People’s Republic of China (e-mails: limingsmmu@sina.cn, 125893198@qq.com).

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coronal plane was achieved. However, recent reports have shown that AIS patients corrected by pedicle screws may subsequently develop hypokyphosis in the thoracic spine.\[^{4,5}\] So, much more attention has recently been given to the sagittal alignment for aforementioned reason.

The purpose of AIS surgery is to maintain balance, prohibit progress of the curve, correct the curve, and preserve the best possible motion segment.\[^{6-8}\] The selection of upper instrumented vertebrae (UIV) and lower instrumented vertebrae (LIV) is important.\[^{9,10}\] When it comes to selecting the UIV, the shoulder balance is always the principal factor in determining where to stop, thus (T2 for left shoulder elevation, T3 for level shoulders, and T4 for right shoulder elevation, respectively) should be selected.\[^{11,12}\]

Recently, several studies\[^{13-15}\] have focused on the change of the sagittal plane that occurs after corrective deformity surgery, especially on cervical sagittal alignment (CSA). Hiyama et al\[^{16}\] demonstrated that CSA was affected by the thoracic deformity. Similarly, Hwang et al\[^{17}\] proposed that there was a significant relation between thoracic kyphosis (TK) and CSA. Another study detected a positive correlation between CSA and T2 tilt in the sagittal plane.\[^{15}\]

However, it is always assumed that the CSA is significantly associated with health-related quality of life (HRQOL) in those individuals suffering from spinal deformity, especially in adult deformity patients.\[^{18-20}\] Some reports suggest that individuals with cervical lordosis (CL) of \(\leq 20\) degrees are more susceptible to cervicogenic disorders, especially those kyphotic patients with a Cl \(\leq 0\) degree.\[^{21}\] For the non-lordosis patients, it was inferred the significantly higher frequency of progression in terms of age-related cervical spine degeneration at the long-term follow-up.

Previously, Yanik et al\[^{22}\] investigated the relationship between UIV and CSA in Lenke 3C and 6C scoliosis, which was insignificant. This study suggested that fusion segments can be extended to appropriate upper levels for the purpose of achieving shoulder balance, without being concerned about a change in CSA. With respect to Lenke 1 AIS patients, no study has reported the effects of UIV on CSA after surgical correction. Therefore, we carried out this study in Lenke 1 AIS patients, to determine whether fusion to T2, T3, or T4 affects sagittal alignment of the cervical spine.

### 2. Materials & Methods

#### 2.1. Patient Population

The study was approved by the Ethics Institutional Review Board of Chang Hai Hospital. A retrospective study was conducted. A total of 64 Lenke 1 AIS patients were included in this study. All patients accepted posterior pedicle screw instrumentation and fusion, from January 2012 to January 2015, in Chang Hai Hospital by the same group of surgeons. Minimal follow-up was 20 months. Patients were divided into 3 groups according to UIV (T2, T3, and T4). The UIV was chosen based on the pre-op shoulder balance (T2 for higher left shoulder, T3 for even shoulder, and T4 for higher right shoulder).

#### 2.2. Radiographic and Clinical Assessment

Preoperatively, immediately after surgery, and final follow-up coronal and lateral x-ray films were reviewed (Fig. 1, Fig. 2 and Fig. 3). Patient-bending radiographs were employed to assess the curve flexibility. According to these imaging data, Lenke classifications were determined by the 2 authors separately, and any differences of opinion were resolved. Radiographic measurements were also performed independently by these 2 doctors. Finally, the average value was accepted for the statistical analysis. UIV-T1 meant the saving segments from UIV to T1. The coronal measurement included the proximal thoracic curve (PTC), major thoracic curve (MTC), thoracolumbar/lumbar curve (TL/LLC), and coronal plane balance (CB). The sagittal parameters included CL, T1-slope, T1 pelvic angle (TPA), T2-T5 kyphosis, T5-T12 kyphosis (TK), thoracolumbar kyphosis (TLK), lumbar lordosis (LL), and sagittal vertical axis (SVA). The CL refers to the angle between the inferior endplate of C2 and the inferior endplate of C7. T1-slope refers to the angle between the superior endplate of T1 and a horizontal line. TPA refers to the angle between the line from the center of the femoral head to the center of the T1 vertebra and the line from the center of the femoral head to the center of the S1 endplate.

Clavicle angle (CA) coupled with radiological shoulder height difference (RSH) was employed to assess the shoulder balance.\[^{23}\] The pelvic sagittal radiographic parameters, comprised of pelvic incidence (PI), sacral slope (SS), and pelvic tilt (PT), were measured. The Scoliosis Research Society (SRS)-22 questionnaire was used to assess the clinical outcome of those individuals. The Questionnaire survey was performed before the surgery, immediately after surgery, and at follow-up.

#### 2.3. Statistical analysis

Descriptive statistics were demonstrated by means ± standard deviation (SD). Comparisons between 3 groups (T2, T3, and T4 groups) at 3 different time points (pre-op, immediate post-op, and final follow-up) were performed using 1-way analysis of variance. The Pearson method was employed to analyze the correlation between in final follow-up CL and other parameters. All statistical analyses were conducted utilizing SPSS statistical software v. 18.0 (SPSS Inc, Chicago, IL). \(P\) value \(<.05\) was set as statistical significance.

### 3. Results

Totally, 64 patients were included in this study. No statistical differences were detected among the 3 groups in terms of age (\(P = .688\)), sex distribution (\(P = .759\)), and Risser sign (\(P = .244\)). The average follow-up time was similar (23.75 ± 2.44 months, 24.35 ± 2.57 months, and 24.96 ± 2.44 months, \(P = .387\)). However, significant statistical differences were observed in terms of the lumbar instrumented vertebrae (LIV) (\(P = .027\)) and Lenke1 subtypes (\(P = .039\)). Table 1 demonstrated the demographic characteristics.

#### 3.1. Comparison analysis between groups (T2, T3, and T4)

Preoperatively, significant differences were revealed in terms of TL/LLC (\(P = .002\)), CA (\(P < .001\)), RSH (\(P < .001\)), LL (\(P = .001\)), SS (\(P = .012\)), whereas there were no differences in PTC (\(P = .087\)), MTC (\(P = .075\)), CB (\(P = .074\)), CL (\(P = .501\)), T1-slope (\(P = .259\)), TPA (0.323), T2-T5 (\(P = .880\)), TK (\(P = .493\)), TLK (\(P = .178\)), PT (\(P = .527\)), PI (0.115), SVA (0.122), and SRS-22 (\(P = .242\)) (Table 2).

Immediately after surgery, there were significant differences in CB (\(P = .033\)), LL (\(P = .005\)), and SS (\(P = .025\)), whereas no statistical significance was detected in the following parameters
(PTC, MTC, LC, CA, RSH, CL, T1-slope, TPA, T2-T5, TK, TLK, PT, PI, SVA, and SRS-22) (Table 3).

At follow-up, there were significant differences in CB ($P = .033$), LL ($P = .011$), and SS ($P = .026$). No significant differences were detected in PTC, MTC, LC, CA, RSH, CL, T1-slope, TPA, T2-T5, TK, TLK, PT, PI, SVA, and SRS-22 (Table 4).

3.2. Comparison analyses in post-op vs. pre-op and follow-up vs. post-op

In T2 group, the following parameters improved immediately after surgery with significant decrease: PTC ($P < .001$), MTC ($P < .001$), TL/LLC ($P < .001$), CA ($P = .021$), and RSH ($P = .001$). Furthermore, CL also improved ($P = .004$). No differences were observed in the following parameters: CB, T1-slope, TPA, T2-T5, TK, TLK, LL, SS, PT, PI, and SVA (Table 5). When compared with immediate postoperation, the following parameters increased significantly: MTC ($P < .001$), CL ($P = .037$), T1-slope ($P = .008$), TLK ($P = .039$), LL ($P = .029$), and PT (Table 5).

In T3 group, the following parameters improved immediately after surgery: PTC ($P < .001$), MTC ($P < .001$), TL/LLC ($P < .001$), RSH ($P = .035$), CL ($P < .001$), T2-T5 ($P = .015$), TLK ($P = .017$), LL ($P < .001$), SS ($P < .001$), PI ($P = .041$), and SVA ($P = .008$), whereas no significance was revealed in other

Figure 1. T2 was selected as the upper instrumented vertebrae, preoperative (A), immediately after surgery (B), and final follow-up (C) x-ray films.
parameters (Table 6). When compared with immediate post-operation, the following parameters changed significantly and improved immediately after surgery with significant decrease: PTC ($P < .001$), LL ($P = .017$), and SVA (0.007) (Table 6).

In T4 group, the following parameters improved immediately after surgery: PTC ($P < .001$), MTC ($P < .001$), TL/LLC ($P < .001$), CA ($P < .001$), RSH ($P < .001$), CL ($P = .002$), TLK ($P < .001$), LL ($P = .023$), and PI ($P = .018$), whereas no significance was revealed in other parameters (Table 7). When compared with immediate postoperation, the following parameters changed significantly: MTC ($P = .013$), TL/LC ($P = .043$), and CL ($P = .010$) (Table 7).

### 3.3. Correlations between CL at follow-up and preoperative, postoperative and follow-up parameters

Correspondingly, correlation analysis detected that CL at follow-up was correlated with preoperative CL ($r = 0.471$, $P < .001$), CL immediately after surgery ($r = 0.946$, $P < .001$), T1-slope immediately after surgery ($r = 0.846$, $P < .001$), T1-slope at follow-up ($r = 0.821$, $P < .001$), TK immediately after the surgery ($r = -0.353$, $P < .003$), TK at follow-up ($r = -0.342$, $P < .004$), preoperative PT ($r = -0.347$, $P < .004$), and preoperative PI ($r = 0.261$, $P < .031$) (Table 4). However, we did not find any significant correlation between the selection of UIV and CL at follow-up ($r = 0.031$, $P = .802$, respectively) (Table 8).

### 3.4. HRQOL assessment

Immediately after the surgery, SRS-22 scores did not change significantly in all the groups, which is T2 ($P = .353$), T3 ($P = .611$), and T4 ($P = .486$) groups (Table 2). At the final follow-up, SRS-22 scores improved significantly in T2 ($P = .008$), T3 ($P < .001$), and T4 ($P = .004$) groups (Tables 5, 6 and 7), whereas comparison analysis between groups did not reveal any difference preoperatively ($P = .242$), immediately after the surgery ($P = .828$) and at the final follow-up ($P = .219$) (Tables 2–4).

### 4. Discussion

Several studies have focused on thoracic hypokyphosis in patients treated by posterior pedicle screw instrumentation.[24] Correspondingly, it was reported that the decrease of TK after surgery may result in kyphotic changes in CSA.[4,5] As the TK decreased, the kyphotic effect on CSA increased.[9,17] Recently, Wang et al.[25] reported that CL was strongly correlated with the T1-slope. Based on 30 Lenke 5C AIS patients, Wang et al.[25] proposed that CL was related to the global thoracic sagittal

![Figure 2. T3 was selected as the upper instrumented vertebrae, preoperative (A), immediately after surgery (B), and final follow-up (C) x-ray films.](image-url)
Table 1
Patient demographics in this study.

| Variables          | T2 group (N = 16) | T3 group (N = 34) | T4 group (N = 18) | P  |
|--------------------|-------------------|-------------------|-------------------|----|
| Age, y             | 14.50 ± 2.50      | 14.47 ± 2.4       | 14.00 ± 1.37      | .688|
| Sex (female/male)  | 14/2              | 28/6              | 14/4              | .759|
| Follow-up, mo      | 23.75 ± 2.44      | 24.35 ± 2.57      | 24.94 ± 2.44      | .387|
| Risser             | 3.50 ± 1.71       | 2.94 ± 1.92       | 3.66 ± 0.84       | .244|
| LIV (T12/L1/L2/L3) | 2/2/6/6           | 8/18/4/4          | 4/6/2/6           | .027|
| Lenke curve type   |                   |                   |                   |    |
| Lenke1A+           | 0                 | 4                 | 0                 |    |
| Lenke1AN           | 6                 | 20                | 8                 |    |
| Lenke1B+           | 0                 | 0                 | 2                 | .039|
| Lenke1BN           | 4                 | 4                 | 4                 |    |
| Lenke1C+           | 2                 | 0                 | 0                 |    |
| LenkeCN            | 4                 | 4                 | 2                 |    |

LV = lower instrumented vertebrae.
alignment rather than regional T2-T5 kyphosis. Similarly, Yagi et al.[13] also proposed that the CSA in AIS patients was closely related to the sagittal spinal balance rather than regional TK. By contrast, Yanik et al.[22] determined that the TK and T1-slope decrease is responsible for the decline of CL in Lenke 3C and 6C AIS patients. In our study, only Lenke 1 patients were included. Our study also showed that CL at follow-up was correlated with preoperative CL ($r = 0.471, P < .001$), CL immediately after surgery ($r = 0.946, P < .001$), T1-slope immediately after surgery ($r = -0.646, P < .001$), T1-slope at follow-up ($r = -0.821, P < .001$), TK immediately after surgery ($r = -0.353, P < .003$), and TK at follow-up ($r = -0.342, P < .004$) (Table 8). Therefore, our findings supported the cervical sagittal alignment was associated with global thoracic sagittal alignment. In addition, other parameters such as CB and PT also demonstrated a significant correlation with CL. Thus, cervical sagittal alignment may also be affected by a cluster of factors such as surgical technique, and different implants.[23]

Previous studies had reported decreased CSA after corrective surgery,[11,24] whereas because there were no significant hypokyphotic changes in TK post-op, our study found a significant increase of CL in each group immediately after surgery. Moreover, CL at follow-up was increased in T2 ($P = .037$) and T4 ($P = .010$) groups compared with immediate postoperative results. We inferred that the cervical sagittal alignment can adjust to increase CL to guarantee a horizontal vision.

Initially, Legarreta et al.[26] demonstrated that UV at T4 or lower levels had a lordotic effect on CL postoperatively, wh kyphotic effect was observed with UV at T3 or above, especially for those treated by pedicle screws. However, Yanik et al.[22] did not find any significant association of UV levels with CSA in Lenke 3C and 6C AIS patients. Additionally, several other reports did not indicate the correlation between CSA and UV level.[17,27] In this study, we investigated the correlation between CL and the number of saving segments from UV to T1. The corresponding findings demonstrated that CL at follow-up was not correlated with UV levels. Therefore, we thought that the CL was not associated with UV.

We selected the level of UV according to preoperative shoulder balance, and used RSH and CA to quantitatively assess it.[9] Those individuals in the T3 group were level-shouldered preoperatively. T2 group included patients with a pre-op higher

| Table 3 | Comparisons analyses in postoperative radiological parameters between groups. |
|---------|---------------------------------|
| Variables | T2 group | T3 group | T4 group | $P$ (ANOVA) |
| PTC, o  | 10.88 ± 2.47 | 11.76 ± 4.08 | 8.61 ± 6.20 | .090 |
| MTC, o  | 12.19 ± 3.25 | 13.97 ± 6.30 | 15.89 ± 5.23 | .149 |
| TLARC, o | 14.44 ± 5.55 | 10.35 ± 6.65 | 10.39 ± 5.75 | .078 |
| CB, mm  | −2.31 ± 5.63 | −5.00 ± 8.03 | 1.50 ± 10.63 | .033 |
| CA, o   | 1.38 ± 0.75 | 0.62 ± 1.54 | 1.06 ± 4.66 | .210 |
| RSH, mm | 5.44 ± 5.76 | 3.03 ± 8.36 | 0.00 ± 5.80 | .065 |
| CL, o   | −9.81 ± 12.74 | −8.15 ± 10.14 | −9.72 ± 5.82 | .705 |
| T1-slope, o | 14.36 ± 7.90 | 12.09 ± 5.74 | 11.83 ± 5.33 | .411 |
| TPA     | 19.94 ± 3.82 | 19.09 ± 3.32 | 18.39 ± 3.52 | .440 |
| T2-T5, o | 8.06 ± 4.14 | 8.35 ± 5.18 | 7.50 ± 4.54 | .630 |
| TK, o   | 24.31 ± 10.91 | 21.03 ± 7.63 | 20.78 ± 7.38 | .381 |
| TLK, o  | 4.76 ± 2.52 | 6.15 ± 3.13 | 6.94 ± 2.48 | .108 |
| LL, o   | −48.38 ± 13.70 | −39.56 ± 8.15 | −45.56 ± 5.94 | .005 |
| SS, o   | 44.75 ± 14.16 | 36.35 ± 8.12 | 37.83 ± 9.00 | .025 |
| PT, o   | 12.25 ± 4.12 | 14.12 ± 5.35 | 14.22 ± 5.06 | .418 |
| PL, o   | 57.00 ± 15.09 | 50.47 ± 9.33 | 52.06 ± 9.77 | .155 |
| SVA, mm | 13.06 ± 13.52 | 6.53 ± 18.56 | 2.06 ± 18.93 | .197 |
| SRS-22  | 3.89 ± 0.23 | 3.93 ± 0.27 | 3.92 ± 0.17 | .828 |

ANOVA = analysis of variance, CA = clavicle angle, CB = coronal plane balance, CL = cervical lordosis, LL = lumbar lordosis, MTC = major thoracic curve, P = pelvic incidence, PT = pelvic tilt, PTC = proximal thoracic curve, RSH = radiological shoulder height difference, SRS = Sacroiliac Joint, SS = sagittal slope, T1-slope = thoracolumbar kyphosis, TPA = T1 pelvic angle.
left shoulder, and the T4 group included patients with a higher right shoulder. RSH and CA were similar among these groups immediately after surgery. However, there was no significant association between HRQOL and CSA in these young individuals.[22] In this study, the SRS-22 score did not change significantly for each group immediately after surgery. However, SRS scores improved at final follow-up in T2 ($P < .001$) and T3 ($P < .001$) groups, when compared with their preoperative status. Moreover, there was no statistical difference among T2, T3, and T4 groups at different time points (preoperatively, immediately postoperatively, and at final follow-up). Previously, Scheer et al.[29] also reported that the primary spinal deformities had a far more significant influence in HRQOL when compared with compensatory alignment changes. Thus, we thought that the HRQOL depends mainly on the main deformity rather than on the UIV level.

This is the first study to focus on the post-op CSA in Lenke 1 AIS according to UIV level. However, there were some limits in this study. Only 64 individuals were included in this retrospective study. In addition, the follow-up time may be too short for cervical degenerative changes to occur. Therefore, studies with larger sample size and longer follow-up time are needed to explore this issue.

| Variables | Post-op vs. pre-op | $P$ | Follow-up vs. post-op | $P$ |
|-----------|-------------------|-----|-----------------------|-----|
| PTC, °   | 11.76 ± 4.08 vs. 25.32 ± 7.18 | <.001 | 13.03 ± 4.87 vs. 11.76 ± 4.08 | <.001 |
| MTC, °   | 13.97 ± 6.30 vs. 44.35 ± 6.25 | <.001 | 13.94 ± 7.23 vs. 13.97 ± 6.30 | .906 |
| TL/LC, ° | 10.35 ± 6.65 vs. 25.47 ± 9.60 | <.001 | 10.41 ± 7.08 vs. 10.35 ± 6.65 | .842 |
| CB, mm   | -5.00 ± 8.03 vs. -0.41 ± 14.16 | .057 | -5.35 ± 8.21 vs. -5.00 ± 8.03 | .272 |
| CA, °    | 0.62 ± 5.14 vs. 0.00 ± 2.10 | .942 | 0.94 ± 8.18 vs. 0.62 ± 5.14 | .303 |
| RSH, mm  | 3.03 ± 8.36 vs. -3.29 ± 11.82 | .035 | 3.24 ± 8.57 vs. 3.03 ± 3.86 | .577 |
| LL, °    | -8.18 ± 10.14 vs. 1.24 ± 14.89 | <.001 | -8.79 ± 12.35 vs. -8.18 ± 10.14 | .419 |
| T1-slope, ° | 12.09 ± 5.74 vs. 12.16 ± 5.56 | .950 | 12.85 ± 9.76 vs. 12.09 ± 5.74 | .508 |
| TPA      | 19.09 ± 3.32 vs. 19.51 ± 3.64 | .328 | 18.92 ± 3.70 vs. 19.09 ± 3.32 | .323 |
| T2-T5, ° | 8.35 ± 5.18 vs. 11.12 ± 6.59 | .015 | 7.26 ± 5.56 vs. 8.35 ± 5.18 | .129 |
| TK, °    | 21.03 ± 7.63 vs. 20.89 ± 11.42 | .941 | 21.38 ± 7.73 vs. 21.03 ± 7.63 | .310 |
| TLK, °   | 6.15 ± 3.13 vs. 2.53 ± 7.21 | .017 | 6.42 ± 4.05 vs. 6.15 ± 3.13 | .469 |
| LL, °    | -39.56 ± 8.15 vs. -48.05 ± 8.27 | <.001 | -40.82 ± 9.45 vs. -39.56 ± 8.15 | .017 |
| SS, °    | 36.35 ± 8.12 vs. 41.91 ± 6.62 | <.001 | 36.22 ± 8.75 vs. 36.35 ± 8.12 | .540 |
| PT, °    | 14.12 ± 5.35 vs. 12.65 ± 7.18 | .395 | 14.15 ± 5.77 vs. 14.12 ± 5.35 | .909 |
| PI, °    | 50.47 ± 9.33 vs. 54.18 ± 6.71 | .041 | 50.00 ± 9.11 vs. 50.47 ± 9.33 | .216 |
| SVA, mm  | 6.53 ± 18.56 vs. -8.67 ± 33.16 | .008 | 7.20 ± 18.98 vs. 6.53 ± 18.56 | .007 |
| SRS-22   | 3.93 ± 0.27 vs. 3.96 ± 0.24 | .611 | 4.11 ± 0.21 vs. 3.93 ± 0.27 | <.001 |

CA = clavicle angle, CB = coronal plane balance, CL = cervical lordosis, LL = lumbar lordosis, MTC = major thoracic curve, PI = pelvic incidence, PT = pelvic tilt, PTC = proximal thoracic curve, RSH = radiological shoulder height difference, SRS = Scoliosis Research Society, SS = sacral slope, SVA = sagittal vertical axis, TK = T5-T12 kyphosis, TL/LC = thoracolumbar/lumbar curve, TLK = thoracolumbar kyphosis, TPA = T1 pelvic angle.
Table 7
Comparisons of the preoperative and postoperative radiological parameters, and the radiological parameters at follow-up in T4 group.

| Variables | Post-op vs. pre-op | P     | Follow-up vs. post-op | P     |
|-----------|-------------------|-------|-----------------------|-------|
| PTC, o    | 8.61 ± 6.20 vs. 20.22 ± 6.05 | <.001 | 10.39 ± 6.62 vs. 8.61 ± 6.20 | .099  |
| MTC, o    | 15.89 ± 5.23 vs. 45.33 ± 8.62 | <.001 | 16.78 ± 6.03 vs. 15.89 ± 5.23 | .013  |
| TL/LC, o  | 10.39 ± 5.75 vs. 29.00 ± 11.72 | <.001 | 11.33 ± 6.10 vs. 10.39 ± 5.75 | .043  |
| CB, mm    | 1.50 ± 10.63 vs. 0.00 ± 12.60 | .676   | 1.33 ± 11.15 vs. 1.50 ± 10.63 | .579  |
| CA, o     | 1.06 ± 1.66 vs. −5.22 ± 2.65 | <.001 | 1.22 ± 1.48 vs. 1.06 ± 1.66 | .507  |
| RSH, mm   | 8.06 ± 6.20 vs. −12.67 ± 11.69 | <.001 | 7.00 ± 6.10 vs. 8.06 ± 6.20 | .231  |
| CL, o     | −9.72 ± 3.82 vs. 2.70 ± 14.43 | .002   | −11.50 ± 5.64 vs. −9.72 ± 3.82 | .010  |
| T1-slope, o | 11.83 ± 5.33 vs. 12.19 ± 4.36 | .813   | 12.50 ± 5.64 vs. 11.83 ± 5.33 | .173  |
| TPA       | 18.39 ± 3.52 vs. 19.93 ± 4.29 | .380   | 18.01 ± 3.71 vs. 18.39 ± 3.52 | .269  |
| T2-T5, o  | 7.50 ± 4.54 vs. 11.94 ± 9.03 | .058   | 6.33 ± 5.40 vs. 7.50 ± 4.54 | .251  |
| TK, o     | 20.78 ± 7.38 vs. 17.34 ± 8.24 | .178   | 20.47 ± 7.55 vs. 20.78 ± 7.38 | .616  |
| TLK, o    | 6.94 ± 2.48 vs. 3.99 ± 2.46 | <.001 | 4.53 ± 7.64 vs. 6.94 ± 2.48 | .192  |
| LL, o     | −45.56 ± 5.54 vs. −39.41 ± 8.30 | .023   | −47.03 ± 5.81 vs. −45.56 ± 5.54 | .073  |
| SS, o     | 37.83 ± 9.00 vs. 37.96 ± 9.26 | .946   | 37.75 ± 8.40 vs. 37.83 ± 9.00 | .613  |
| PT, o     | 14.22 ± 5.06 vs. 12.14 ± 5.04 | .121   | 14.60 ± 5.76 vs. 14.22 ± 5.06 | .492  |
| Pl, o     | 52.06 ± 9.77 vs. 49.78 ± 8.36 | .018   | 52.00 ± 11.19 vs. 52.06 ± 9.77 | .923  |
| SVA, mm   | 2.06 ± 18.93 vs. −2.40 ± 22.27 | .324   | −0.71 ± 28.40 vs. 2.06 ± 18.93 | .292  |
| SRS-22    | 3.92 ± 0.17 vs. 3.97 ± 0.20 | .486   | 4.03 ± 0.18 vs. 3.92 ± 0.17 | .004  |

CA = clavicle angle, CB = coronal plane balance, CL = cervical lordosis, LL = lumbar lordosis, MTC = major thoracic curve, PI = pelvic incidence, PT = pelvic tilt, PTC = proximal thoracic curve, RSH = radiological shoulder height difference, SRS = Scoliosis Research Society, SS = sacral slope, SVA = sagittal vertical axis, TK = T5-T12 kyphosis, TL/LC = thoracolumbar/lumbar curve, TLK = thoracolumbar kyphosis, TPA = T1 pelvic angle.

Table 8
Correlations between CL at follow-up and preoperative, postoperative and follow-up parameters.

| Variables | Preoperative | Postoperative | Follow-up |
|-----------|--------------|---------------|-----------|
| R | P | R | P | R | P |
| UV-T1 | 0.031 | .802 | 0.005 | .970 | 0.00 | .999 |
| PTC, o | −0.048 | .704 | 0.129 | .295 | 0.132 | .282 |
| MTC, o | 0.190 | .109 | 0.086 | .465 | 0.075 | .553 |
| TL/LC | −0.083 | .501 | 0.106 | .391 | 0.068 | .581 |
| CB | 0.949 | .004 | 0.212 | .083 | 0.077 | .533 |
| CA, o | 0.058 | .640 | 0.068 | .580 | 0.083 | .503 |
| RSH, mm | 0.150 | .222 | 0.046 | .946 | <.001 | 1 |
| CL, o | 0.471 | .<.001 | 0.946 | <.001 | 1 | <.001 |
| T1-slope, o | −0.116 | .347 | −0.646 | <.001 | −0.821 | <.001 |
| TPA, o | −0.123 | .316 | 0.190 | .122 | −0.060 | .625 |
| T2-T5, o | −0.224 | .066 | <.001 | .999 | −0.002 | .989 |
| TK, o | −0.134 | .112 | −0.353 | .003 | −0.342 | .004 |
| TLK, o | −0.093 | .451 | −0.108 | .379 | −0.019 | .878 |
| LL, o | 0.034 | .785 | 0.070 | .572 | 0.084 | .498 |
| SS, o | 0.034 | .782 | 0.010 | .935 | −0.009 | .941 |
| PT, o | 0.347 | .004 | 0.105 | .394 | 0.054 | .661 |
| Pl, o | 0.261 | .031 | 0.056 | .648 | 0.016 | .896 |
| SVA, mm | 0.151 | .218 | −0.172 | .161 | −0.163 | .183 |

CA = clavicle angle, CB = coronal plane balance, CL = cervical lordosis, LL = lumbar lordosis, MTC = major thoracic curve, PI = pelvic incidence, PT = pelvic tilt, PTC = proximal thoracic curve, RSH = radiological shoulder height difference, SRS = Scoliosis Research Society, SS = sacral slope, SVA = sagittal vertical axis, TK = T5-T12 kyphosis, TL/LC = thoracolumbar/lumbar curve, TLK = thoracolumbar kyphosis, TPA = T1 pelvic angle, UV-T1 = the saving segments from UV to T1.

5. Conclusion
In Lenke 1 AIS patients, determination of UV mainly depends on coronal parameters, especially with respect to shoulder balance. Post-op CL in Lenke 1 AIS is related to T1-slope and TK. There is no association between the SRS score and UV. Overall, the use of different UV did not affect the postop CSA.

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