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

## A retrospective study

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**Abstract**

The aim of this stusy 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 ($P=.795$), 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 [$r=0.347$, $P=.004$), pelvic incidence [$r=0.261$, $P=.031$], and CL [$r=0.471$, $P<.001$]) immediately postoperative (CL [$r=0.946$, $P<.001$], 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 ($r=0.031$, $P=.802$). 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, TL/LLC = thoracolumbar/lumbar curve, TLK = thoracolumbar kyphosis, TPA = T1 pelvic angle, UIV = upper instrumented vertebrae, UIV-T1 = The saving segments from UIV 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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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 $\leq 20$ are more susceptible to cervicogenic disorders, especially those kyphotic patients with a CL $\leqq 0$ 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 detect 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 $\pm$ 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 $\pm$ 2.44 months, 24.35 $\pm$ 2.57 months, and 24.94 $\pm$ 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

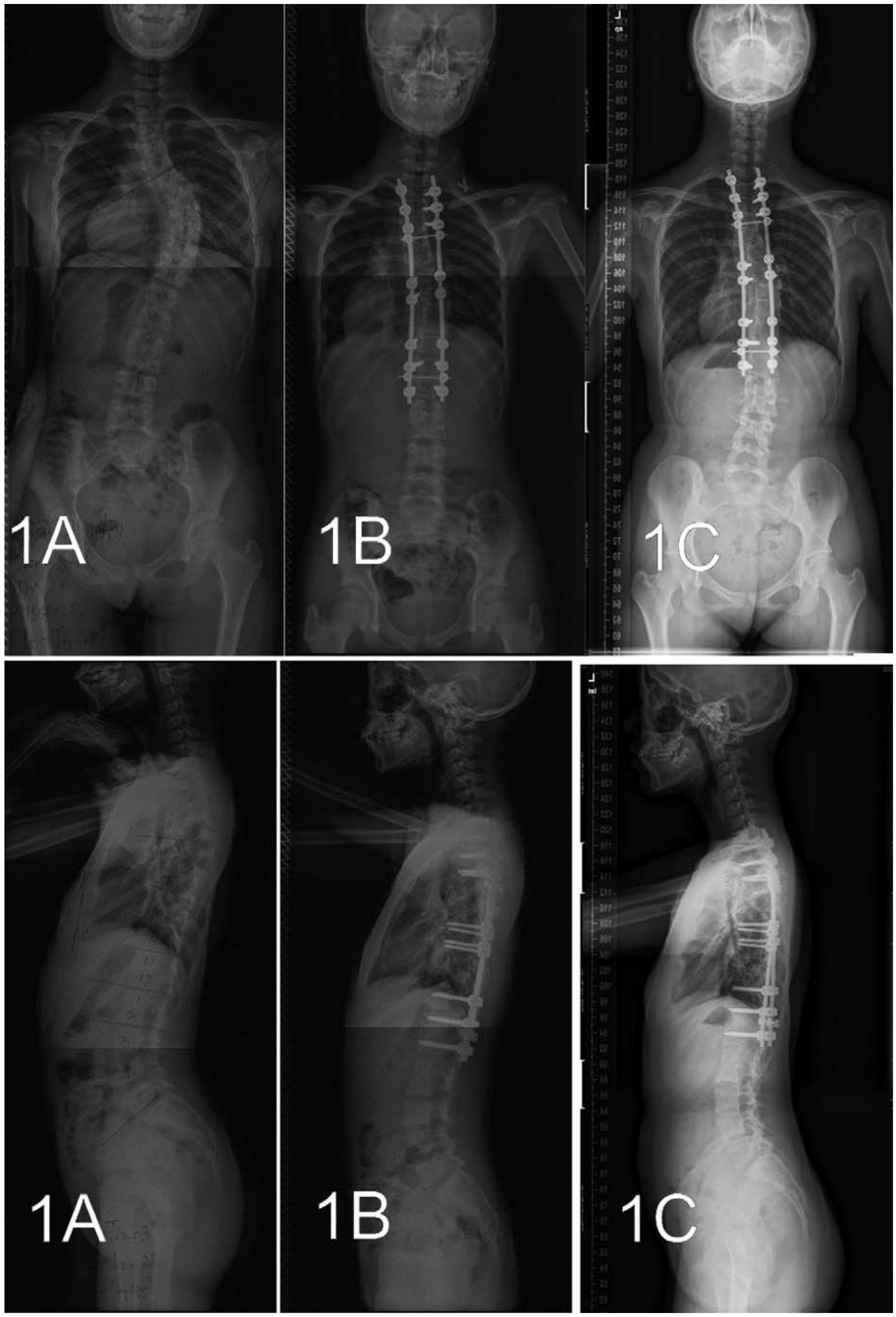


**Figure 1.** T2 was selected as the upper instrumented vertebrae, preoperative (A), immediately after surgery (B), and final follow-up (C) x-ray films.

(PTC, MTC, LC, CA, RSH, C L, 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, C L, 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

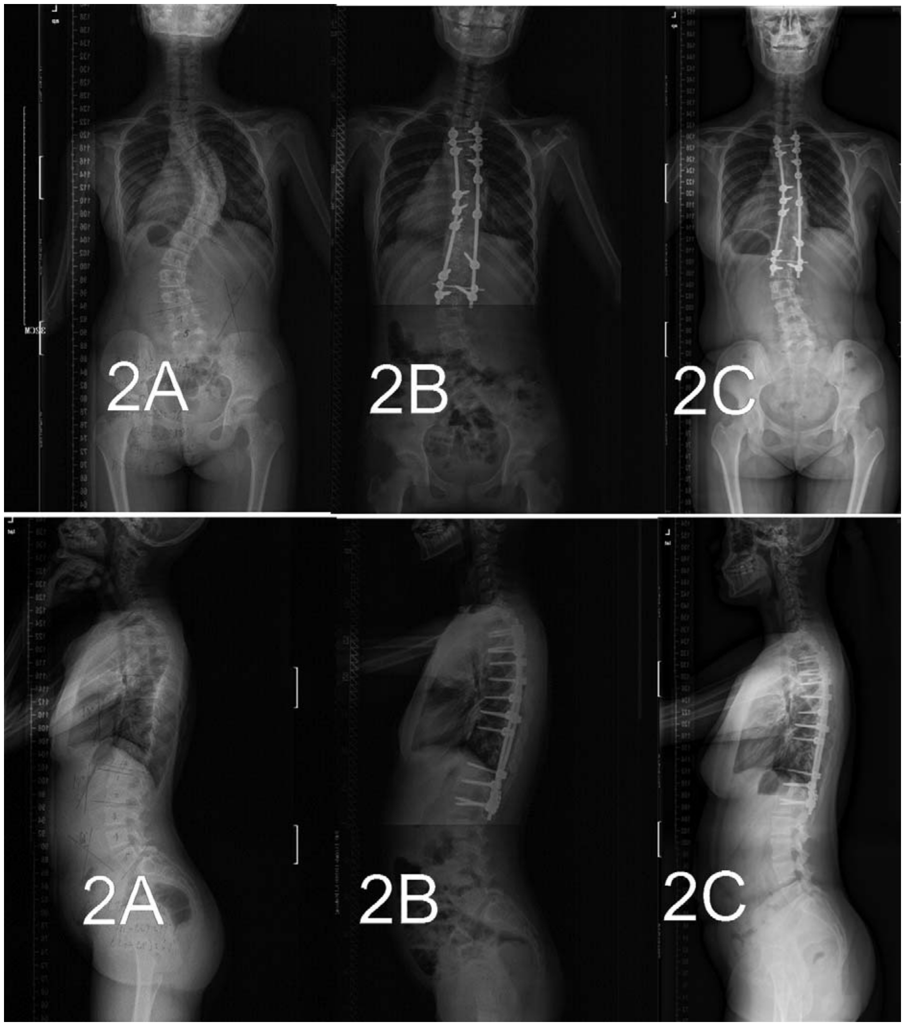


**Figure 2.** T3 was selected as the upper instrumented vertebrae, preoperative (A), immediately after surgery (B), and final follow-up (C) x-ray films.

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 ($P<0.001$), 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 ($r=0.646$, $P<.001$), 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

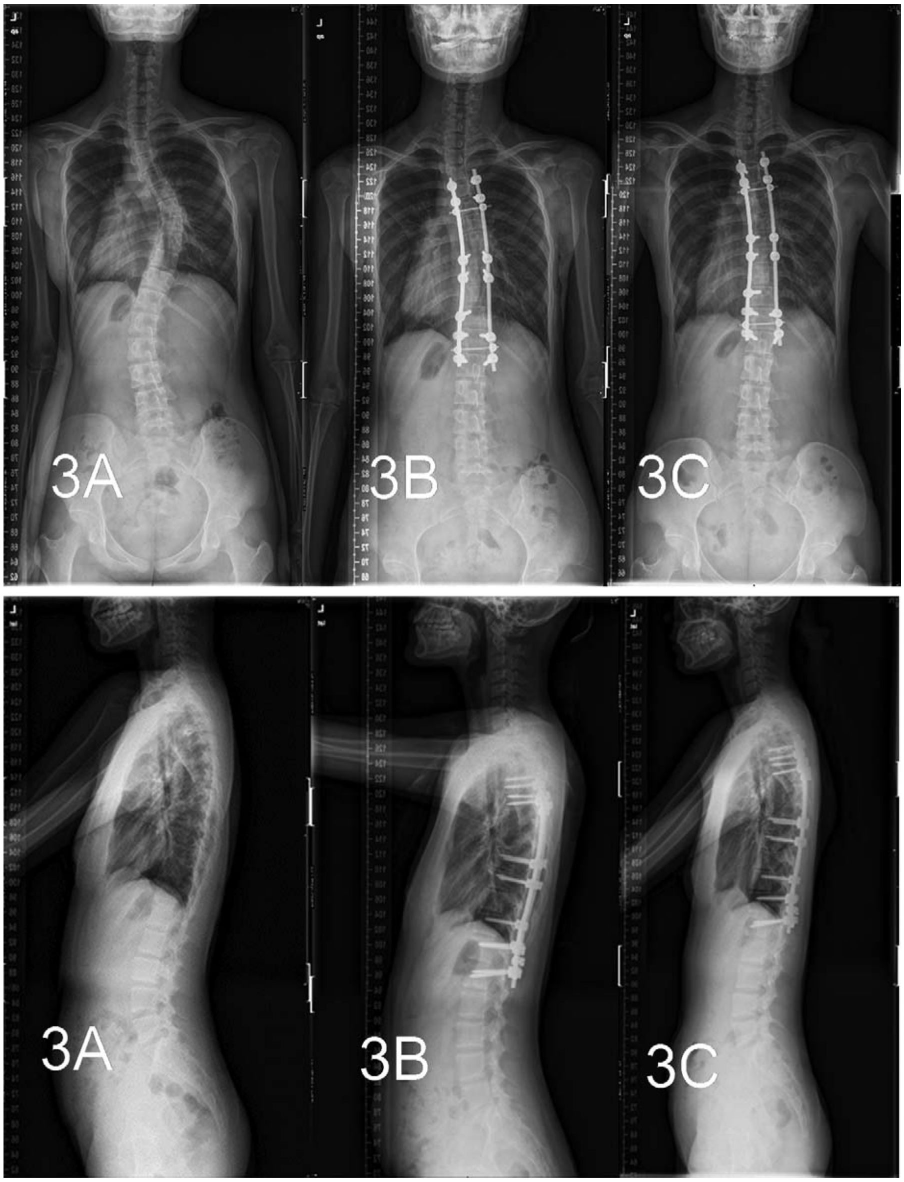


**Figure 3.** T4 was selected as the upper instrumented vertebrae, preoperative (A), immediately after surgery(B), and final follow-up (C) x-ray films.

**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 | 0 | 2 | 2 | |
| Lenke1A− | 0 | 4 | 0 | |
| Lenke1A+ | 6 | 20 | 8 | |
| Lenke1AN | 0 | 0 | 2 | .039 |
| Lenke1B− | 4 | 4 | 4 | |
| Lenke1BN | 2 | 0 | 0 | |
| Lenke1C− | 4 | 4 | 2 | |
| LenkeCN | | | | |

LIV=lower instrumented vertebrae.

**Table 2**

**Comparisons analyses in preoperative radiological parameters between groups.**

| Variables | T2 group | T3 group | T4 group | *P* (ANOVA) |
|---|---|---|---|---|
| PTC, ° | 23.38±2.96 | 25.32±7.18 | 21.25±5.60 | .087 |
| MTC, ° | 45.69±2.44 | 44.35±6.25 | 45.33±6.82 | .705 |
| TL/LC, ° | 36.08±5.90 | 25.47±9.60 | 29.00±11.72 | .002 |
| CB, mm | −10.25±18.90 | −0.41±14.16 | 0.00±12.60 | .074 |
| CA, ° | 2.60±1.69 | 0.00±2.24 | −5.22±2.65 | <.001 |
| RSH, mm | 13.61±7.67 | −3.29±11.82 | −12.67±11.69 | <.001 |
| CL, ° | −2.64±9.11 | 1.24±14.89 | 2.70±14.43 | .501 |
| T1-slope, ° | 9.87±3.54 | 12.16±5.56 | 12.19±4.36 | .259 |
| TPA | 21.25±3.40 | 19.51±3.64 | 19.93±4.29 | .323 |
| T2-T5, ° | 10.81±4.76 | 11.12±6.59 | 11.94±9.03 | .880 |
| TK, ° | 18.94±10.29 | 20.89±11.42 | 17.34±8.24 | .493 |
| TLK, ° | 5.69±3.82 | 2.53±7.21 | 3.99±2.46 | .178 |
| LL, ° | −48.69±6.91 | −48.05±8.27 | −39.41±8.90 | .001 |
| SS, ° | 45.95±9.73 | 41.91±5.82 | 37.96±8.26 | .012 |
| PT, ° | 10.45±6.04 | 12.65±7.18 | 12.14±5.04 | .527 |
| PI (°) | 56.25±11.30 | 54.18±8.71 | 49.78±8.36 | .115 |
| SVA, mm | 9.51±19.13 | −8.07±33.16 | −2.40±22.27 | .122 |
| SRS-22 | 3.84±0.29 | 3.96±0.24 | 3.97±0.20 | .242 |

ANOVA=analysis of variance, 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/LLC=thoracolumbar/lumbar curve, TLK=thoracolumbar kyphosis, TPA=T1 pelvic angle.

alignment rather than regional T2-T5 kyphosis. Similarly, Yagi et al[15] also proposed that the CSA in AIS patients was closely related to the global sagittal spine 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 Lenke1 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 the surgery ($r$=−0.353, $P$<.003), and TK at follow-up ($r$=−0.342, $P$<.004) (Table 8). Therefore, our findings supported that 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.[25]

**Table 3**

**Comparisons analyses in postoperative radiological parameters between groups.**

| Variables | T2 group | T3 group | T4 group | *P* (ANOVA) |
|---|---|---|---|---|
| PTC, ° | 10.88±2.47 | 11.76±4.08 | 8.61±6.20 | .060 |
| MTC, ° | 12.19±3.25 | 13.97±6.30 | 15.89±5.23 | .149 |
| TL/LC, ° | 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, ° | 1.36±0.75 | 0.62±1.54 | 1.06±1.66 | .210 |
| RSH, mm | 5.44±5.76 | 3.03±8.36 | 8.06±6.20 | .065 |
| CL, ° | −9.81±12.74 | −8.18±10.14 | −9.72±3.82 | .795 |
| T1-slope, ° | 14.36±7.94 | 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, ° | 8.06±4.14 | 8.35±5.18 | 7.50±4.54 | .830 |
| TK, ° | 24.31±10.91 | 21.03±7.63 | 20.78±7.38 | .381 |
| TLK, ° | 4.75±3.26 | 6.15±3.13 | 6.94±2.48 | .108 |
| LL, ° | −48.38±13.70 | −39.56±8.15 | −45.56±5.54 | .005 |
| SS, ° | 44.75±14.16 | 36.35±8.12 | 37.83±9.00 | .025 |
| PT, ° | 12.25±4.12 | 14.12±5.35 | 14.22±5.06 | .418 |
| PI, ° | 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, 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/LLC=thoracolumbar/lumbar curve, TLK=thoracolumbar kyphosis, TPA=T1 pelvic angle.

**Table 4**

**Comparisons analyses in radiological parameters at follow-up between groups.**

| Variables | T2 group | T3 group | T4 group | *P* (ANOVA) |
|---|---|---|---|---|
| PTC, ° | 10.56±3.78 | 13.03±4.87 | 10.39±6.62 | .133 |
| MTC, ° | 13.63±3.63 | 13.94±7.23 | 16.78±6.03 | .237 |
| TL/LC, ° | 15.10±6.97 | 10.41±7.08 | 11.33±6.10 | .080 |
| CB, mm | −3.04±5.37 | −5.35±8.21 | 1.33±11.15 | .033 |
| CA, ° | 1.55±0.96 | 0.94±1.81 | 1.22±1.48 | .434 |
| RSH, mm | 5.88±6.52 | 3.24±8.57 | 7.00±6.10 | .198 |
| CL, ° | −12.74±15.95 | −8.79±12.35 | −11.50±5.64 | .510 |
| T1-slope, ° | 17.86±10.73 | 12.85±9.76 | 12.50±5.64 | .150 |
| TPA | 19.69±2.67 | 18.92±3.70 | 18.01±3.71 | .379 |
| T2-T5, ° | 8.31±5.29 | 7.26±5.36 | 6.33±5.40 | .564 |
| TK, ° | 25.16±12.21 | 21.38±7.73 | 20.47±7.55 | .266 |
| TLK, ° | 6.56±5.38 | 6.42±4.05 | 4.53±7.64 | .444 |
| LL, ° | −50.00±15.58 | −40.82±9.45 | −47.03±5.81 | .011 |
| SS, ° | 44.53±14.23 | 36.22±7.85 | 37.72±9.04 | .026 |
| PT, ° | 13.28±4.89 | 14.15±5.77 | 14.60±5.76 | .782 |
| PI, ° | 57.63±15.41 | 50.00±9.11 | 52.00±11.19 | .094 |
| SVA, mm | 13.86±14.86 | 7.20±18.98 | −0.71±28.40 | .138 |
| SRS-22 | 4.01±0.26 | 4.11±0.21 | 4.03±0.18 | .219 |

ANOVA=analysis of variance, 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/LLC=thoracolumbar/lumbar curve, TLK=thoracolumbar kyphosis, TPA=T1 pelvic angle.

Previous studies had reported decreased CSA after corrective surgery,[13,26] 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 UIV at T4 or lower levels had a lordotic effect on CL postoperatively, wh a kyphotic effect was observed with UIV at T3 or above, especially for those treated by pedicle screws. However, Yanik et al[22] did not find any significant association of UIV levels with CSA in Lenke 3C and 6C AIS patients. Additionally, several other reports did not indicate the correlation between CSA and UIV level.[17,27] In this study, we investigated the correlation between CL and the number of saving segments from UIV to T1. The corresponding findings demonstrated that CL at follow-up was not correlated with UIV levels. Therefore, we thought that the CL was not associated with UIV.

We selected the level of UIV 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 5**

**Comparisons of the preoperative and postoperative radiological parameters, and the radiological parameters at follow-up in T2 group.**

| Variables | Post-op vs. pre-op | P | Follow-up vs. post-op | P |
|---|---|---|---|---|
| PTC, ° | 10.88±2.47 vs. 23.38±2.96 | <.001 | 10.56±3.78 vs. 10.88±2.47 | .631 |
| MTC, ° | 12.19±3.25 vs. 45.69±2.44 | <.001 | 13.63±3.63 vs. 12.19±3.25 | <.001 |
| TL/LC, ° | 14.44±5.55 vs. 36.08±5.90 | <.001 | 15.10±6.97 vs. 14.44±5.55 | .158 |
| CB, mm | −2.31±5.63 vs. −10.25±18.90 | .077 | −3.04±5.37 vs. −2.31±5.63 | .254 |
| CA, ° | 1.36±0.75 vs. 2.60±1.69 | .021 | 1.55±0.96 vs. 1.36±0.75 | .471 |
| RSH, mm | 5.44±5.76 vs. 13.61±7.67 | .001 | 5.88±6.52 vs. 5.44±5.76 | .203 |
| CL, ° | −9.81±12.74 vs. −2.64±9.11 | .004 | −12.74±15.95 vs. −9.81±12.74 | .037 |
| T1-slope, ° | 14.36±7.94 vs. 9.87±3.54 | .053 | 17.86±10.73vs.14.36±7.94 | .008 |
| TPA | 19.94±3.82 vs. 21.25±3.40 | .250 | 19.69±2.67vs.19.94±3.82 | .069 |
| T2-T5, ° | 8.06±4.14 vs. 10.81±4.76 | .118 | 8.31±5.29 vs. 8.06±4.14 | .665 |
| TK, ° | 24.31±10.91 vs. 18.94±10.29 | .111 | 25.16±12.21 vs. 24.31±10.91 | .158 |
| TLK, ° | 4.75±3.26 vs. 5.69±3.82 | .469 | 6.56±5.38 vs. 4.75±3.26 | .039 |
| LL, ° | −48.38±13.70 vs. −48.69±6.91 | .936 | −50.00±15.58 vs. −48.38±13.70 | .029 |
| SS, ° | 44.75±14.16 vs. 45.95±9.73 | .743 | 44.53±14.23 vs. 44.75±14.16 | .541 |
| PT, ° | 12.25±4.12 vs. 10.45±6.04 | .083 | 13.28±4.89 vs. 12.25±4.12 | .006 |
| PI, ° | 57.00±15.09 vs. 56.25±11.30 | .838 | 57.63±15.41 vs. 57.00±15.09 | .136 |
| SVA, mm | 13.06±13.52 vs. 9.51±19.13 | .524 | 13.86±14.86 vs. 13.06±13.52 | .202 |
| SRS-22 | 3.89±0.23 vs. 3.84±0.29 | .353 | 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/LLC=thoracolumbar/lumbar curve, TLK=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, and at follow-up.

HRQOL in AIS patients is associated with coronal and sagittal alignment after surgery.[28] 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[19] 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.

**Table 6**

**Comparisons of the preoperative and postoperative radiological parameters, and the radiological parameters at follow-up in T3 group.**

| 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±1.54 vs. 0.00±2.10 | .942 | 0.94±1.81 vs. 0.62±1.54 | .303 |
| RSH, mm | 3.03±8.36 vs. −3.29±11.82 | .035 | 3.24±8.57 vs. 3.03±8.36 | .577 |
| CL, ° | −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±5.36 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±5.82 | <.001 | 36.22±7.85 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±8.71 | .041 | 50.00±9.11 vs. 50.47±9.33 | .216 |
| SVA, mm | 6.53±18.56 vs. −8.07±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/LLC=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, ° | 8.61±6.20 vs.20.22±6.05 | <.001 | 10.39±6.62 vs. 8.61±6.20 | .099 |
| MTC, ° | 15.89±5.23 vs. 45.33±6.82 | <.001 | 16.78±6.03 vs. 15.89±5.23 | .013 |
| TL/LC, ° | 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, ° | 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, ° | −9.72±3.82 vs. 2.70±14.43 | .002 | −11.50±5.64 vs. −9.72±3.82 | .010 |
| T1-slope, ° | 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±3.71vs.18.39±3.52 | .269 |
| T2-T5, ° | 7.50±4.54 vs. 11.94±9.03 | .058 | 6.33±5.40 vs. 7.50±4.54 | .251 |
| TK, ° | 20.78±7.38 vs. 17.34±8.24 | .178 | 20.47±7.55 vs. 20.78±7.38 | .616 |
| TLK, ° | 6.94±2.48 vs. 3.99±2.46 | <.001 | 4.53±7.64 vs. 6.94±2.48 | .192 |
| LL, ° | −45.56±5.54 vs. −39.41±8.90 | .023 | −47.03±5.81 vs. −45.56±5.54 | .073 |
| SS, ° | 37.83±9.00 vs. 37.96±8.26 | .946 | 37.72±9.04 vs. 37.83±9.00 | .613 |
| PT, ° | 14.22±5.06 vs. 12.14±5.04 | .121 | 14.60±5.76 vs. 14.22±5.06 | .492 |
| PI, ° | 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/LLC=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.**

| | Preoperative | | Postperative | | Follow-up | |
|---|---|---|---|---|---|---|
| Variables | *R* | *P* | *r* | *P* | *r* | *P* |
| UIV-T1 | 0.031 | .802 | | | | |
| PTC, ° | −0.048 | .704 | 0.005 | .970 | 0.00 | .999 |
| MTC, ° | 0.196 | .109 | 0.129 | .295 | 0.132 | .282 |
| TL/LC | −0.083 | .501 | 0.086 | .485 | 0.073 | .553 |
| CB | 0.349 | .004 | 0.106 | .391 | −0.068 | .581 |
| CA, ° | 0.058 | .640 | 0.212 | .083 | 0.077 | .533 |
| RSH, mm | 0.150 | .222 | 0.068 | .580 | 0.083 | .503 |
| CL, ° | 0.471 | <.001 | 0.946 | <.001 | 1 | <.001 |
| T1-slope, ° | −0.116 | .347 | −0.646 | <.001 | −0.821 | <.001 |
| TPA, ° | −0.123 | .316 | 0.190 | .122 | −0.060 | .625 |
| T2-T5, ° | −0.224 | .066 | <0.001 | .999 | −0.002 | .989 |
| TK, ° | −0.194 | .112 | −0.353 | .003 | −0.342 | .004 |
| TLK, ° | −0.093 | .451 | −0.108 | .379 | −0.019 | .878 |
| LL, ° | 0.034 | .785 | 0.070 | .572 | 0.084 | .498 |
| SS, | 0.034 | .782 | 0.010 | .935 | −0.009 | .941 |
| PT, ° | 0.347 | .004 | 0.105 | .394 | 0.054 | .661 |
| PI, ° | 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/LLC=thoracolumbar/lumbar curve, TLK=thoracolumbar kyphosis, TPA=T1 pelvic angle, UIV-T1=the saving segments from UIV to T1.

## 5. Conclusion

In Lenke 1 AIS patients, determination of UIV 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 UIV. Overall, the use of different UIV did not affect the postop CSA.

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## References

[1] Weinstein SL, Dolan LA, Cheng JC, et al. Adolescent idiopathic scoliosis. Lancet (London, England) 2008;371:1527–37.
[2] Li C, Xie Y, Li Z, et al. Intraoperative blood loss in female patients with adolescent idiopathic scoliosis during different phases of the menstrual cycle. PLoS One 2014;9:e112499.
[3] Ohashi N, Ohashi M, Endo N, et al. Administration of tranexamic acid to patients undergoing surgery for adolescent idiopathic scoliosis evokes pain and increases the infusion rate of remifentanil during the surgery. PLoS One 2017;12:e0173622.
[4] Ilharreborde B, Vidal C, Skalli W, et al. Sagittal alignment of the cervical spine in adolescent idiopathic scoliosis treated by posteromedial translation. Eur Spine J 2013;22:330–7.

[5] Hilibrand AS, Tannenbaum DA, Graziano GP, et al. The sagittal alignment of the cervical spine in adolescent idiopathic scoliosis. J Pediatr Orthop 1995;15:627–32.
[6] Kuhns CA, Bridwell KH, Lenke LG, et al. Thoracolumbar deformity arthrodesis stopping at L5—fate of the L5-S1 disc, minimum 5-year follow-up. Spine (Phila Pa 1976) 2007;32:2771–6.
[7] Danielsson AJ, Nachemson AL. Back pain and function 23 years after fusion for adolescent idiopathic scoliosis: a case-control study-part II. Spine (Phila Pa 1976) 2003;28:E373–83.
[8] Lenke LG, Edwards CC2nd, Bridwell KH. The Lenke classification of adolescent idiopathic scoliosis: how it organizes curve patterns as a template to perform selective fusions of the spine. Spine (Phila Pa 1976) 2003;28:S199–207.
[9] Trobisch PD, Ducoffe AR, Lonner BS, et al. Choosing fusion levels in adolescent idiopathic scoliosis. J Am Acad Orthopaedic Surg 2013;21: 519–28.
[10] Harfouch BF, Weinstein SL. Intraoperative push-prone test a useful technique to determine the lowest instrumented vertebra in adolescent idiopathic scoliosis. J Spinal Disord Tech 2014;27:237–9.
[11] Roussouly P, Labelle H, Rouissi J, et al. Pre- and post-operative sagittal balance in idiopathic scoliosis: a comparison over the ages of two cohorts of 132 adolescents and 52 adults. Eur Spine J 2013;22(suppl 2):S203–15.
[12] Suk SI, Lee SM, Chung ER, et al. Selective thoracic fusion with segmental pedicle screw fixation in the treatment of thoracic idiopathic scoliosis: more than 5-year follow-up. Spine (Phila Pa 1976) 2005;30:1602–9.
[13] Wang L, Liu X. Cervical sagittal alignment in adolescent idiopathic scoliosis patients (Lenke type 1-6). J Orthopaedic Sci 2017;22:254–9.
[14] Youn MS, Shin JK, Goh TS, et al. Relationship between cervical sagittal alignment and health-related quality of life in adolescent idiopathic scoliosis. Eur Spine J 2016;25:3114–9.
[15] Yagi M, Iizuka S, Hasegawa A, et al. Sagittal Cervical Alignment in Adolescent Idiopathic Scoliosis. Spine Deform 2014;2:122–30.
[16] Hiyama A, Sakai D, Watanabe M, et al. Sagittal alignment of the cervical spine in adolescent idiopathic scoliosis: a comparative study of 42 adolescents with idiopathic scoliosis and 24 normal adolescents. Eur Spine J 2016;25:3226–33.
[17] Hwang SW, Samdani AF, Tantorski M, et al. Cervical sagittal plane decompensation after surgery for adolescent idiopathic scoliosis: an effect imparted by postoperative thoracic hypokyphosis. J Neurosurg Spine 2011;15:491–6.
[18] Protopsaltis TS, Scheer JK, Terran JS, et al. How the neck affects the back: changes in regional cervical sagittal alignment correlate to HRQOL improvement in adult thoracolumbar deformity patients at 2-year follow-up. J Neurosurg Spine 2015;23:153–8.
[19] Scheer JK, Passias PG, Sorocean AM, et al. Association between preoperative cervical sagittal deformity and inferior outcomes at 2-year follow-up in patients with adult thoracolumbar deformity: analysis of 182 patients. J Neurosurg Spine 2016;24:108–15.
[20] Iyer S, Nemani VM, Joseph N, et al. Impact of cervical sagittal alignment parameters on neck disability. Spine (Phila Pa 1976) 2016;41:371–7.
[21] McAviney J, Schulz D, Bock R, et al. Determining the relationship between cervical lordosis and neck complaints. J Manipulative Physiol Ther 2005;28:187–93.
[22] Yanik HS, Ketenci IE, Erdem S. Cervical sagittal alignment in extensive fusions for Lenke 3C and 6C scoliosis: the effect of upper instrumented vertebra. Spine (Phila Pa 1976) 2017;42:E355–e362.
[23] Qiu X-s, Ma W-w, Li W-g, et al. Discrepancy between radiographic shoulder balance and cosmetic shoulder balance in adolescent idiopathic scoliosis patients with double thoracic curve. Eur Spine J 2009;18:45–51.
[24] Lonner BS, Lazar-Antman MA, Sponseller PD, et al. Multivariate analysis of factors associated with kyphosis maintenance in adolescent idiopathic scoliosis. Spine (Phila Pa 1976) 2012;37:1297–302.
[25] Wang F, Zhou XY, Xu XM, et al. Cervical sagittal alignment limited adjustment after selective posterior thoracolumbar/lumbar curve correction in patients with Lenke type 5C adolescent idiopathic scoliosis. Spine (Phila Pa 1976) 2017;42:E539–46.
[26] Legarreta CA, Barrios C, Rositto GE, et al. Cervical and thoracic sagittal misalignment after surgery for adolescent idiopathic scoliosis: a comparative study of all pedicle screws versus hybrid instrumentation. Spine (Phila Pa 1976) 2014;39:1330–7.
[27] Canavese F, Turcot K, De Rosa V, et al. Cervical spine sagittal alignment variations following posterior spinal fusion and instrumentation for adolescent idiopathic scoliosis. Eur Spine J 2011;20:1141–8.
[28] Benli IT, Ates B, Akalin S, et al. Minimum 10 years follow-up surgical results of adolescent idiopathic scoliosis patients treated with TSRH instrumentation. Eur Spine J 2007;16:381–91.