Original Study

Cervical sagittal alignment and the impact of posterior spinal instrumented fusion in patients with Lenke type 1 adolescent idiopathic scoliosis

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Background: Clinical decision making, preoperative planning, and surgical correction for adolescent idiopathic scoliosis (AIS) has traditionally focused on obtaining the maximum coronal plane correction to improve cosmesis and function. More recently, restoring sagittal alignment has also received increasing attention in AIS patients, correlating with positive health-related quality of life (HRQOL) outcomes in multiple studies. In this realm, cervical sagittal alignment (CSA) has also emerged as one of the variables that may correlate with clinical and functional outcomes in AIS patients undergoing surgical correction. Several studies have focused on studying the cervical sagittal plane parameters in patients with spinal deformity, while few have investigated the impact of surgical correction on CSA. In this study, we aimed to capture the baseline cervical sagittal characteristics and evaluate the changes in CSA in a cohort of AIS patients with Lenke type I curves following posterior spinal instrumented fusion (PSIF).

Methods: We evaluated our longitudinal database of patients who had surgical correction for AIS between January 1, 2015 and September 1, 2017. The initial search yielded 270 patients. Next, the following inclusion criteria were applied to identify the study cohort: (I) patients who had Lenke type 1 curves, (II) patients with adequate pre-operative and post-operative radiographs (posterior-anterior and lateral), (III) patients who had a minimum radiographic follow-up of 6 months, and (IV) patients who were treated with the same standard rod instrumentation system. In addition, the following exclusion criteria were applied: (I) patients with neuromuscular disorders, (II) patients with prior spine surgery, and (III) those who received greater than Schwab-2 osteotomies. A total of 30 patients were included in our final analysis. The C2–C7 angle, C0–C2 angle, C2–C7 sagittal vertical axis (SVA), McGregor slope (McGS), and the T1 slope angle were measured preoperatively and at 6 months. A kyphotic measurement was assigned a negative value while positive values were used to describe lordotic measurements. Descriptive statistics and paired sample *t*-test were used to compare pre-and post-operative data with a cutoff P value of 0.05 to determine statistical significance.

Results: Overall, CSA improved in most patients post-operatively, with 19/30 (63%) resulting in improved lordosis. Pre-operatively, mean C2–C7 cervical lordosis was −4.3°, which improved to −0.5° postoperatively (P=0.075), with a mean difference of 3.7°. Simultaneously, mean C0–C2, C2–C7 SVA, McGS, and T1 slope changed from 17° (range, −18° to 41°), 26.5 mm (range, 10 to 45 mm), 4° (range, −7.5° to 25°), and 17.4° (range, 1° to 42°) to 16° (range, 0° to 34.4°, mean difference =1.01°, and P=0.548), 28.2 mm (range, 9 to 57 mm, mean difference =2 mm, and P=0.244), 4.03°, (range, −7.8° to 25°, mean difference =0.16, and P=0.916), and 18° (range, 5.4° to 42°, mean difference =0.37, and P=0.761) (mean change of C2–C7 angle of 3.76°).

Conclusions: This study demonstrated baseline cervical kyphosis and a trend towards cervical lordosis restoration in patients with AIS and a Lenke type 1 curve who underwent PSIF. This study adds to emerging evidence and, together with further studies, will help estimate the impact of PSIF on the cervical sagittal profile, the effect of CSA on patient reported outcomes, and ways to address cervical sagittal malalignment when undertaking the surgical correction for specific curve types in AIS.

Keywords: Adolescent idiopathic scoliosis (AIS); cervical sagittal alignment (CSA); posterior spinal fusion

Submitted May 09, 2018. Accepted for publication May 25, 2018.
doi: 10.21037/jss.2018.05.17
View this article at: http://dx.doi.org/10.21037/jss.2018.05.17

Introduction

Clinical decision making, preoperative planning, and surgical correction for adolescent idiopathic scoliosis (AIS) has traditionally focused on obtaining the maximum coronal plane correction to improve cosmesis and function (1,2). More recently, restoring sagittal alignment has also received increasing attention in AIS patients, correlating with positive health-related quality of life (HRQOL) outcomes in multiple studies (3,4). Additionally, it has been suggested that a dynamic inter-play may exist between the degree of thoracic kyphosis and nearby cervical and lumbar curvatures (1,2,5-11). Multiple studies have emphasized the importance of restoring thoracic kyphosis in the hypo-kyphotic AIS patients to maintain a normal lumbar lordosis (3,12,13). In the long-term, iatrogenic loss of lumbar lordosis has been shown to correlate with marked morbidity and disability (14). Therefore, surgical correction techniques in AIS have gradually evolved to include restoration of the sagittal balance, and this became a primary focus for many surgeons.

In this realm, cervical sagittal alignment (CSA) has also emerged as one of the variables that may correlate with clinical and functional outcomes in AIS patients undergoing surgical correction (5,6,8,10,11). Previous studies have noted a prevalence of cervical kyphosis in the AIS population, and that thoracolumbar fusion results in alternations in cervical sagittal profile (15-17). However, it is unclear whether this kyphosis would change following surgical correction and how it may affect clinical and patient-reported outcomes. Several studies have focused on studying the cervical sagittal plane parameters in patients with deformity, while few have investigated the impact of surgical correction on CSA.

In this study, we aimed to capture the baseline cervical sagittal characteristics and evaluate the changes in CSA in a cohort of AIS patients with Lenke type I curves following posterior spinal instrumented fusion (PSIF).

Methods

Patient selection

Following institutional review board (IRB) approval, we evaluated the prospectively collected single-institute database of patients who had surgical correction for AIS between January 1, 2015 and September 1, 2017 aged between 10 to 25 years old. The initial search yielded 270 patients who were treated with PSIF for AIS. Among those patients, we applied the following inclusion criteria to identify the study cohort: (I) patients who had Lenke type 1 curves, (II) patients with adequate pre-operative and post-operative radiographs (posterior-anterior and lateral), (III) patients who had a minimum radiographic follow-up of 6 months, and (IV) patients who were treated with the same standard rod instrumentation system. In addition, the following exclusion criteria were applied: (I) patients with neuromuscular disorders, (II) patients with prior spine surgery, and (III) those who received greater than Schwab-2 osteotomies. Applying these criteria yielded a total of 30 patients that were included in our final analysis. These patients had a mean age of 15 years (range, 11 to 19 years). There were 25 girls and 5 boys. Mean body mass index (BMI) was 22.5 kg/m^2 (range, 15.7 to 36 kg/m^2). On average, 7 spinal segments were fused (range, 5 to 11 levels; *Table 1*). In all surgeries, a single, standard pedicle screw and rod system was utilized. Three board certified orthopaedic surgeons performed all surgeries at a major academic medical center. Immediate pre-operative radiographs and 6-month post-operative radiographs were measured.

Study endpoints

The C2 to C7 angle, C0 to C2 angle, C2 to C7 sagittal

Table 1 Patient demographics

Patient number	Gender	Race	Age at surgery	BMI (kg/m^2)	Type of curve (Lenke)	Fusion level	Number of levels fused
1	F	W	14	23.5	1	T7–L1	6
2	M	W	15	17.6	1	T7–L2	7
3	F	W	15	20.2	1	T4–L2	10
4	F	W	15	18.3	1	T5–T12	7
5	F	U	14	25.9	1	T5–T11	6
6	F	W	12	36	1	T5–T11	6
7	F	W	15	24.6	1	T4–T10	6
8	F	W	13	26.8	1	T5–T11	6
9	F	W	19	22.2	1	T4–T11	7
10	F	W	14	22.8	1	T5–T12	7
11	F	M	16	29.2	1	T5–T11	6
12	F	W	14	17.9	1	T4–L2	10
13	F	W	17	21.4	1	T5–T12	7
14	F	W	13	20.5	1	T3–T11	8
15	F	W	22	22.6	1	T4–L3	11
16	F	W	13	20.2	1	T5–L3	10
17	F	W	17	18.4	1	T7–L1	6
18	F	B	11	22.3	1	T5–T12	7
19	M	W	18	34.7	1	T5–T11	6
20	F	W	14	25.1	1	T6–T11	5
21	F	W	15	22.2	1	T5–T12	7
22	F	W	14	20.6	1	T5–T11	6
23	F	W	13	19.1	1	T5–T12	7
24	M	W	16	20.4	1	T5–L2	9
25	F	W	13	23	1	T5–T11	6
26	F	W	13	15.7	1	T4–T12	8
27	F	W	14	20	1	T5–T12	7
28	F	W	17	20.3	1	T6–T12	6
29	M	B	18	24.7	1	T3–T12	9
30	M	W	19	19.7	1	T4–L1	9

F, female sex; M, male sex; W, white race; B, black race; U, unknown; M, multiracial; BMI, body mass index.

vertical axis (SVA), McGregor slope (McGS), and the T1 slope angle were measured preoperatively and at final follow-up on lateral cervical standing radiographs. C2–C7 lordosis was defined as the Cobb angle between the lower endplates of C2 and C7. C0–C2 lordosis was measured as the angle between the line from the anterosuperior border of the atlas to the inferior end of the occiput and lower endplates of C2. C2–C7 SVA was measured as the distance from the posterosuperior corner of C7 and the vertical line from the center of the C2 body. The McGS and T1 slope (18) were defined as the angle of the McGregor line and T1 superior end plate against a horizontal line, respectively. Kyphotic measurements were assigned negative values, while positive values were used to describe lordotic measurements. For every patient, two senior authors performed the measurements twice independently. For every patient, two senior authors performed the measurements twice independently. Basic descriptive statistical analysis was used.

Data analysis

Statistical analysis was mainly descriptive. Patient data was entered into an Excel spreadsheet (Excel, Microsoft Corporation, Redmond, Washington, USA) after removing patient identifiers. Pre-operative and post-operative measurements in each category were compared using the paired sample *t*-test. All statistical analysis was performed using SPSS version 24 (IBM Corporation, Armonk, New York, USA). A cutoff P value of 0.05 was set to determine statistical significance.

Results

Overall, CSA improved in all patients post-operatively, with 19/30 (63%) resulting in improved lordosis. Pre-operatively, mean C2–C7 cervical lordosis was −4.3°, which improved to −0.5° postoperatively (P=0.075), with a mean difference of 3.7°. Simultaneously, mean C0–C2, C2–C7 SVA, McGS, and T1 slope changed from 17° (range, −18° to 41°), 26.5 mm (range, 10 to 45 mm), 4° (range, −7.5° to 25°), and 17.4° (range, 1° to 42°) to 16° (range, 0° to 34.4°, mean difference =1.01°, and P=0.548), 28.2 mm (range, 9 to 57 mm, mean difference =2 mm, and P=0.244), 4.03°, (range, −7.8° to 25°, mean difference =0.16, and P=0.916), and 18° (range, 5.4° to 42°, mean difference =0.37, and P=0.761) (mean change of C2–C7 angle of 3.76°). These results are illustrated in *Tables 2,3*.

Discussion

Despite the increasing appreciation in sagittal plane alignment with surgical correction for AIS, our current knowledge on CSA changes in these patients, particularly those with a major thoracic or proximal curve, is lacking. In this study, we aimed to evaluate changes in CSA and the effect of PSIF on cervical alignment in a cohort of AIS patients with Lenke type 1 curves. Our results demonstrated that CSA trended towards improved lordosis, primarily with an improvement in sub-axial cervical lordosis and slight improvement in McGregor and T1 slopes. AIS patients with Lenke type 1 curves are frequently hypo-kyphotic, which has been shown to correlate with compensatory cervical kyphosis. Cervical kyphosis has been associated with chronic neck pain, disability, and worse HRQOL (19).

There are several limitations to this study. The main limitation is the small sample size, which may have precluded our analysis from reaching a point of statistical significance in the pre- to post-test cohort analysis. However, the consistent findings in our results may point to a degree of internal validity. Additionally, the relatively short follow-up may not reflect the true long-term results. However, we mainly aimed to evaluate patients at 6 months to capture immediate post-surgical changes in sagittal alignment while allowing for settling and resolution of pain and muscle spasm in the early post-operative period. Furthermore, other thoracic sagittal plane parameters were not measured, including the degree of thoracic kyphosis. Nevertheless, all patients had the same curve type and we mainly aimed to study changes in the cervical region, which have not been well-studied in previous published reports.

Previous studies mainly investigated the effect of AIS deformity on CSA. Lee *et al.* (15) performed an analysis of 181 asymptomatic children to determine normal sagittal spine parameters. They found significant variability in their study. Cervical kyphosis was found in 40% of their study patients. Mean cervical lordosis was −4.8±12.0 degrees. Similarly, Yu *et al.* (16) analyzed the CSA in 120 AIS patients. They categorized patients into four categories: cervical non-kyphosis, cervical kyphosis, cervical-middle-thoracic kyphosis, and cervical-lower-thoracic kyphosis. They found that 40% of their study patients exhibited cervical kyphosis and that the cervical angles and cervicothoracic angles were highly correlated. Despite this deformity in cervical alignment, global sagittal balance was still well maintained in this population.

Only few studies have attempted to quantify the effect of AIS surgical correction on CSA. Roussouly *et al.* (17) evaluated pre- and post-operative radiographic parameters in 132 AIS and adult scoliosis patients to evaluate various changes in global sagittal alignment including cervical lordosis by corrective surgery. They found that cervical hypolordosis and thoracic hypokyphosis were prevalent

Table 2 Preoperative and postoperative measurements

Patient number	Pre C2–C7 angle	Post C2–C7 SVA (mm)	Pre C0–C2 angle	Post C0–C2 angle	Pre C2–C7 SVA (mm)	Post C2–C7 angle	Pre McGS	Post McGS	Pre T1 slope	Post T1 slope
1	2.6	35	23.1	34.4	35	0	9.9	1	26	27
2	–7.2	24	25.3	24.5	15	2.5	–7.5	–7.8	12.2	15.5
3	7.9	42	14	22.1	42	12.5	25	7	42	36
4	–2.8	29	14.6	21.8	20	6.5	6.8	1	20	26.3
5	7.6	30	12.5	9.5	28	8.5	4.3	2.2	22	18
6	5.5	17	7	3.2	12	2.4	4.5	10	15.4	12.3
7	–14.4	35	26.7	19.5	34	–5.7	9.1	7.6	18.4	24.5
8	–8.3	38	27.8	25	40	–3.9	0	3.4	18	21.7
9	–13.8	29	22.1	21.3	27	–10.7	0	3.1	17	20.1
10	13	26	14.9	12.3	17	4.2	–1.3	7.6	26.3	23.3
11	–12.2	33	31.8	21.5	25	–13.7	–4.5	–0.5	17	14.9
12	–7	10	18	23.9	11	3.4	–2	–7	26.4	15.3
13	–37.7	28	41	33.4	16	–17.7	–3.1	2.1	1	13.6
14	1.2	26	30.7	16.4	33	–11	–3.7	6.6	14.2	13
15	–7.1	19	15.4	9.4	26	5.4	5.3	2.6	14.9	20.7
16	8.9	26	9.7	5.4	12.8	–5.3	0	6.8	16.5	5.6
17	–10.7	38	13.3	6.7	30	–3.2	10.5	16.7	9.9	14.9
18	5.2	18	22.2	1.7	32	17.3	0	11	27.4	27
19	5	40	6.9	12	42	11.1	3.3	–2	22.8	17.5
20	7	33	–18.6	11	22	5.4	–6	4	26.7	26
21	11.1	32	14.4	13.6	23	15.4	–4.5	2.6	32.8	42
22	–12.4	19	11.4	0	17	–7.3	6.3	–1.3	4.5	7.4
23	3.4	9	5.2	1.5	23	9.2	9.5	7.6	17.3	5.4
24	–12.7	20	12.3	20.7	20	–6.7	3	–6.8	9.7	6.3
25	7.7	33	10.4	18.7	33	–15.2	3.8	–3.9	13.7	7.2
26	10.3	28	24.1	21.3	34	–11.1	–6.3	3	12.7	7.6
27	–38.4	32	13.8	12.2	31	–24.7	24.2	25	5.1	9
28	–34.4	31	27	27.2	45	–13.7	20	3.2	6.5	18
29	4.2	57	20	19.5	36	22.4	2.5	18	19.9	20
30	–10.6	9	10.2	7	10	7.5	6.8	–2	5	16.3
Mean	–4.3	–0.54	16.9	15.9	26.4	28.2	3.9	4.03	17.4	17.7
P	0.075		0.548		0.244		0.916		0.761	

Pre, pre-operative; post, post-operative; SVA, sagittal vertical axis; McGS, McGregor slope.

Table 3 Comparison of pre- and post-operative changes in cervical sagittal alignment

Metrics	C2–C7 angle (deg)	C0–C2 angle (deg)	C2–C7 SVA (mm)	McGS (deg)	T1 slope (deg)
Mean	3.76	–1.02*	1.81	0.16	0.37
SD	11.15	9.16	8.32	8.39	6.60
Median	5.45	–2.70	1.00	0.25	–0.15
IQR	–1.575 to 10.225	–5.575 to 3.875	–1.75 to 8.75	–5.675 to 6.65	–3.85 to 4.725

*, negative value denotes kyphosis. IQR, interquartile range; SD, standard deviation; deg, degrees; SVA, sagittal vertical axis; McGS, McGregor slope.

in the AIS population they studied. They also noted that thoracolumbar fusion significantly changed global sagittal alignment. Specifically, improvements in cervical lordosis and thoracic kyphosis were associated with pre-operative thoracic kyphosis. Patients with pre-operative thoracic hypokyphosis had improved cervical lordosis and thoracic kyphosis post-operatively, whereas the inverse appeared to be true in patients with normal pre-operative thoracic kyphosis. In a recent study by Cho *et al.* (11), the authors investigated CSA changes in 318 patients who underwent surgical correction for AIS and compared the pre- and post-operative parameters according to the curve type (double major, single thoracic, and double thoracic curves) in two cohorts with either pre-operative cervical kyphosis or lordosis. Regardless of the curve type, they reported an increase in C2–C7 lordosis (range, –5.8° to –1.1°; $P<0.001$) and a decrease in C2–C7 SVA (range, 24.2 to 20.0 mm; $P<0.001$) postoperatively.

Additionally, Youn *et al.* (20) studied the relationship between CSA and HRQOL in AIS. They measured pre- and post-operative CSA and administered the Korean version of the Scoliosis Research Society Outcomes Questionnaire (SRS-22) and the Short Form Health Survey (SF-36) at last follow-up visits in 67 patients. They reported significant changes in cervical sagittal parameters in their study population and found that T1 slope and C2–C7 SVA were significant predictors of HRQOL. Similarly, Bao *et al.* evaluated the neck—disability index in asymptomatic and symptomatic adult patients and found that the C2–C7 SVA, McGS, and the slope of line of sight differed the most between these groups; C2–C7 angle did not show a statistical difference (21).

Conclusions

In conclusion, this study highlighted the changes in CSA in AIS patients and demonstrated a trend toward cervical lordosis restoration in these patients, reinforcing previous studies. Despite the limitations, we believe it will expand our current knowledge and provide an impetus for future studies. Larger, prospective, multi-center studies will help us further appreciate the impact of PSIF in AIS patients on the cervical sagittal profile, the effect of cervical sagittal profile on patient reported outcomes, and, potentially, ways to address cervical sagittal malalignment when undertaking the surgical correction for specific curve types in AIS.

Acknowledgements

None.

Footnote

Conflicts of Interest: TE Mroz: Cervical Spine Research Society: Board or committee member; North American Spine Society: Board or committee member; Pearl Diver, Inc.: Stock or stock Options; SpineLine, Editor. Global Spine Journal, Deputy Editor: Editorial or governing board; Stryker: IP royalties; Paid consultant. MP Steinmetz: AANS/CNS Section on Disorders of the Spine and Peripheral Nerves: Board or committee member; Biomet: IP royalties; Council of State Neurosurgical Societies: Board or committee member; Elsevier: Publishing royalties, financial or material support; Globus Medical: Paid consultant; Paid presenter or speaker; Intellirod: Paid presenter or speaker; Stryker: Paid presenter or speaker; World Neurosurgery and Operative Neurosurgery: Editorial or governing board. RC Goodwin. K2M: Paid consultant; Orthpediatrics: Paid consultant; Stryker: Paid consultant. The other authors have no conflicts of interest to declare.

Ethical Statement: The study was approved by the Institutional Review Board of the Cleveland Clinic Foundation (# 17-1135) and informed consent was waived.

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Cite this article as: Berger RJ, Sultan AA, Tanenbaum JE, Cantrell WA, Gurd DP, Kuivila TE, Mroz TE, Steinmetz MP, Goodwin RC. Cervical sagittal alignment and the impact of posterior spinal instrumented fusion in patients with Lenke type 1 adolescent idiopathic scoliosis. J Spine Surg 2018;4(2):342-348. doi: 10.21037/jss.2018.05.17