Spine

DIAGNOSTICS

The Importance of C2 Slope, a Singular Marker of Cervical Deformity, Correlates With Patient-reported Outcomes

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Study Design. Retrospective review of a prospectively collected database.

Objective. To define a simplified singular measure of cervical deformity (CD), C2 slope (C2S), which correlates with postoperative outcomes.

Summary of Background Data. Sagittal malalignment of the cervical spine, defined by the cervical sagittal vertical axis (cSVA) has been associated with poor outcomes following surgical correction of the deformity. There has been a proliferation of parameters to describe CD. This added complexity can lead to confusion in classifying, treating, and assessing outcomes of CD surgery.

Methods. A prospective database of CD patients was analyzed. Inclusion criteria were cervical kyphosis$>10°$, cervical scoliosis$>10°$, cSVA>4 cm, or chin-brow vertical angle $>25°$.

Patients were categorized into two groups and compared based on whether the apex of the deformity was in the cervical (C) or the cervicothoracic (CT) region. Radiographic parameters were correlated to C2S, T1 slope (T1S) and 1-year health-related quality-of-life outcomes as measured by the EuroQol 5 Dimension questionnaire (EQ5D), modified Japanese Orthopedic Association Scale, numeric rating scale for neck pain, and the Neck Disability Index (NDI).

Results. One hundred four CD patients (C$=74$, CT$=30$; mean age 61 yr, 56% women, 42% revisions) were included. CT patients had higher baseline cSVA and T1S ($P<0.05$). C2S correlated with T1 slope minus cervical lordosis (TS-CL) ($r=0.98$, $P<0.001$) and C0-C2 angle, cSVA, CL, T1S ($r=0.37$–0.65, $P<0.001$). Correlation of cSVA with C0-C2 was weaker ($r=0.48$, $P<0.001$). At 1-year postoperatively, higher C2S correlated with worse EQ-5D ($r=0.28$, $P=0.02$); in CT patients, higher C2S correlated with worse NDI, modified Japanese Orthopedic Association Scale, numeric rating scale for neck pain, and EQ5D (all $r>0.5$, $P\leq0.05$). Using linear regression, moderate disability by EQ5D corresponded to C2S of $20°$ ($r^2=0.08$). For CT patients, C2S$=17°$ corresponded to moderate disability by NDI ($r^2=0.4$), and C2S$=20°$ by EQ5D ($r^2=0.25$).

Conclusion. C2S correlated with upper-cervical and subaxial alignment. C2S correlated strongly with TS-CL (R$=0.98$, $P<0.001$) because C2S is a mathematical approximation of TS-CL. C2S is a useful marker of CD, linking the occipitocervical and cervico-thoracic spine. C2S defines the presence of a mismatch between cervical lordosis and thoracolumbar alignment. Worse 1-year postoperative C2 slope correlated with worse health outcomes.

Key words: C2 slope, cervical deformity, cervicothoracic deformity, deformity correction, health related outcome measures, sagittal alignment, T1 slope, T1 slope minus cervical lordosis.

Level of Evidence: 3

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S agittal spinal alignment has been recognized as an important factor contributing to disability in patients with adult spinal deformity.[1–3] More recently, studies have shown that cervical spinal deformity is associated with poor health[4,5] Initially studies reported the cervical sagittal vertical axis (cSVA) and C2-C7 kyphosis as primary parameters to describe cervical deformity (CD).[6,7] However, cervical kyphosis may not be the best descriptor of CD, as in many cases it is a physiologic response to normal thoracolumbar sagittal alignment. In fact, a third of asymptomatic adults have kyphotic cervical alignment.[8,9]

This has prompted the description of T1 slope minus cervical lordosis as a more applicable parameter akin to the use of pelvic incidence minus lumbar lordosis to describe lumbar flatback deformity.[10,11] The Ames-ISSG classification of CD is a comprehensive assessment that incorporates three separate radiographic parameters of cervical sagittal alignment.[12] Moreover, several other parameters of cervical alignment have been described providing different advantages in the description of CD.[13–15] Seemingly, as our understanding of CD expands and becomes more nuanced, there has been a proliferation of radiographic measurements that can distract from the fundamental need of these parameters which is to reliably describe cervical sagittal malalignment and its correlation with functional disability. However, a lack of definitive consensus regarding the utility of various alignment parameters has led to significant variability in diagnosis and surgical management of CD.[16]

The aim of this study was to attempt to simplify the measurement of CD by introducing a parameter that can consolidate the measurements of CD and better correlate with established health quality of life outcome measures.

MATERIALS AND METHODS

Study Design
Following Institutional Review Board approval, patients with adult CD were prospectively enrolled at 11 institutions throughout the United States that specialize in treating spinal deformity. Inclusion criteria for the prospective database were $\geq$ 18 years and the presence of CD. CD was defined radiographically as any one of: cervical kyphosis (CK, C2–7 sagittal Cobb angle >10°), cervical scoliosis (C2–7 coronal Cobb angle >10°), C2–7 sagittal vertical axis (cSVA) >4 cm or chin-brown vertical angle >25°. Patients with spinal neoplasm, spinal infection, or who were pregnant or planning on becoming pregnant were excluded from the study.

This prospective CD database was analyzed retrospectively and patients were categorized into two groups based on the location of the primary deformity along the cephalocaudal axis. The cervico-thoracic (CT) group had the apex of deformity located in the CT region while the cervical group had the apex of deformity located in the cervical (C) region.

Data Collection
Demographic information, radiologic measurements, and health-related quality of life (HRQL) measurements were collected for each patient. Demographic data included patient age, body mass index, and patient sex. HRQOL outcomes included several commonly used metrics to measure disability in spine surgery: the Neck Disability Index (NDI), the Euroqol 5 Dimension (EQ5D), the Modified Japanese Orthopaedic Association Scale (mJOA), and Numeric Rating Scale: Neck (NRS: Neck).[17]

Alignment parameters of the cervical spine were measured to describe the extent of CD at baseline as well as postoperatively. All subjects had at least two orthogonal radiographs of the cervical spine at baseline. C2 slope (C2S), C1 slope (C1S), C0-C2 Cobb angle (C0-C2), C2-C7 Cobb, cSVA), T1 slope minus cervical lordosis (TS-CL), T4-T12 Cobb angle (TK), T1 Slope (T1S), T1 pelvic angle (TPA), pelvic tilt (PT), pelvic incidence minus lumbar lordosis (PI-LL) were measured (Figure 1A–C). All radiographic measurements were performed at a single institution using dedicated, verified software, Surgimap (Version 2.2.7, Nemaris Inc, New York, NY).

C2 Slope
C2 Slope is a novel measurement proposed to describe CD. It can be described by the angle between the lower end plate of C2 and the horizontal plane. C2 slope is a mathematical approximation of TS-CL that is useful when T1 slope and C7 slope are approximately equal (Figure 2). It is hypothesized that C2 slope can accurately describe CD by acting as a link between the occipitocervical and cervico-thoracic spine.

Statistical Analysis
Demographics, radiologic measurements, and HRQL measurements were collected for each patient and expressed using means, standard deviations, and ranges. Correlations between established parameters of cervical alignment as well as HRQL scores and C2 slope were measured in an attempt to quantify the utility of C2 slope to describe CD. Pearson correlation and linear regression were used to analyze the relationship of C2S and established radiographic parameters and postoperative HRQL scores at 1-year follow-up. Linear regression was used to match a C2S angle with previously established measures of CD, including both alignment parameters and disability as measured by HRQL scores. All statistical analyses were performed using the Statistics Package for the Social Sciences (SPSS Version 23, IBM Corp, Armonk, NY). All results were considered significant if $P < 0.05$.

RESULTS

Demographic Information
One hundred four patients with CD met inclusion criteria for this study. The mean age of the cohort was 61 years. 56% of the cohort were women and 42% of the cohort were undergoing revision surgery (Table 1). In 74 patients, the apex of deformity occurred in the cervical region, while in 30 patients the apex of deformity occurred in the CT region.

Figure 1. Schematic representation of: (A) cervico-thoracic, (B) spino-pelvic, and (C) global radiographic measurements used in this study. PT indicates pelvic tilt; PI, pelvic incidence; SS, sacral slope; TPA, T1 pelvic angle; C2PT, C2 pelvic tilt.
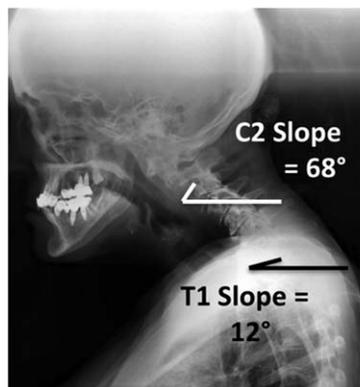
Baseline Alignment

Patients with the apex of deformity occurring in the CT region were found to have larger deformities at baseline, as measured by the cSVA (Table 2). As was expected, C2 slope was found to have the strongest correlation with TS-CL for all patients. In the CD group, C2 slope was found to be most strongly correlated with TS-CL (0.97, $P = 0.001$), C1 slope (0.65, $P = 0.001$), C0-C2 Cobb angle (0.61, $P = 0.001$), and cSVA (0.61, $P = 0.001$) (Table 3). In the CT group, C2 slope was found to be most strongly correlated with TS-CL (0.98, $P = 0.001$), C1 slope (0.91, $P < 0.001$), cSVA (0.82, $P = 0.001$), and C0-C2 Cobb angle (0.56, $P = 0.002$) (Table 3).

C2 Slope and Postoperative Outcomes

The correlation of C2 Slope and different health-related outcome measures was analyzed (Table 4). It was found

that, for all patients, C2S correlated with worse EQ5D scores at 1-year follow-up ($r = 0.28$, $P = 0.02$). For patients with the apex of deformity in the CT region, C2S was significantly correlated with worse HRQL scores at 1 year (NDI, mJOA, NRS Neck, EQ5D > 0.5, $P \leq 0.05$) (Table 4).

Using linear regression, C2S was matched to moderate disability, as determined by HRQL scores, and cervical malalignment, as determined by cSVA for the entire cohort of patients (Table 5). For all patients, a C2S of 36° was found to match a cSVA 4 cm ($r^2 = 0.43$) and a C2S of 20° was found to match "moderate disability" as measured by the EQ5D scale ($r^2 = 0.08$). For patients with the apex of deformity in the CT region, a C2S of 17° was found to match with moderate disability as determined by the NDI scale ($r^2 = 0.4$) and a C2S of 20° matched with moderate disability as determined by the EQ5D scale ($r^2 = 0.25$) (Table 5).

Figure 2. C2 slope in a patient with cervical deformity. Depiction of the C2 slope in a patient with cervical deformity. The high C2 slope and low T1 slope demonstrate that the deformity is entirely within the cervical region. C2 slope is a mathematical approximation of T1 slope minus cervical lordosis since T1 slope and C7 slope are approximately equal, as demonstrated.

TABLE 1. Demographic and Surgical Parameters in Patients With Cervical and Cervico-thoracic Deformities.[1]

	Cervical (N = 70)	Cervico-thoracic (N = 34)	P Value*
Demographic parameters			
Age (yr)	60 ± 11.3	63.1 ± 9.2	0.16
Females (%)	42 (56.8)	18 (62.1)	0.66
BMI	26.6 ± 10.9	28.1 ± 3.3	0.57
Previous fusion (%)	31 (41.9)	18 (62.1)	0.08
CCI	0.74 ± 1.08	0.69 ± 1.28	0.83
Smoker (%)	9 (12.5)	1 (3.4)	0.27
Surgical parameters			
No. of fusion levels			
Anterior	2 ± 1.8	1 ± 1.7	**0.01**
Posterior	6.2 ± 4.7	10.8 ± 4.7	**< 0.001**
EBL (mL)	730 ± 800	1287 ± 994	**0.003**
Operative time (min)	358 ± 142	386 ± 265	0.58
3-Column osteotomies[†] (%)	8 (11.1)	16 (48.5)	**< 0.001**
HRQOL parameters			
mJOA	13.4 ± 2.7	13.5 ± 2.2	0.84
NDI	48.3 ± 18.7	51 ± 18.1	0.48
EQ5D	9.9 ± 2.1	9.8 ± 1.8	0.85

*P values in bold indicate significant differences between cervical and cervico-thoracic deformity patients.
[†]Includes pedicle subtraction osteotomies, vertebral column resection, or open wedge osteotomies.
BMI indicates body mass index; CCI, Charlson Comorbidity Index; EBL, estimated blood loss; mJOA, modified Japanese Orthopedic Association score; NDI, neck disability index; EQ5D, EuroQol five dimensions questionnaire.

TABLE 2. Comparison of Baseline Radiographic Sagittal Alignment Parameters Between Patients With Cervical and Cervico-thoracic Deformities.[1]

Radiographic Parameters	Cervical (N = 70)	Cervico-thoracic (N = 34)	P Value*
Cervico-thoracic			
McGregor slope	2.7 ± 15	6.9 ± 14.5	0.24
C0–C2 cobb	39.2 ± 11.7	42.7 ± 11.4	0.18
C2 slope	36.5 ± 19.2	44.2 ± 20.7	0.07
C1 slope	5 ± 16.9	8.8 ± 19.6	0.34
C2–C7 cobb	8.4 ± 23.1	2.2 ± 17.6	0.20
cSVA	37.9 ± 21.1	52.7 ± 13.8	**0.001**
T1Slope	28.7 ± 17.6	42.1 ± 15.9	**0.001**
TS-CL	27 ± 14.1	29.4 ± 11	0.44
T4-T12 cobb	39.5 ± 16.4	38.6 ± 15.8	0.79
Spino-pelvic			
Lumbar lordosis	50.1 ± 7.7	56.2 ± 15.2	0.09
Pelvic incidence	54.3 ± 12.2	57.1 ± 12.1	0.29
Pelvic tilt	19.6 ± 11.9	20.7 ± 11.7	0.66
PI-LL	2.5 ± 19.7	2.9 ± 16.5	0.91
Global			
SVA	10.9 ± 72.6	12.8 ± 75.8	0.9
TPA	14.8 ± 13.3	14.7 ± 12.7	0.97
CPT	41.8 ± 23.4	58.2 ± 24.2	**0.002**

*P values in bold indicate significant differences between cervical and cervico-thoracic deformity patients.
cSVA indicates C2–C7 sagittal vertical axis; TS-CL, T1 slope minus cervical lordosis; PI-LL, pelvic incidence minus lumbar lordosis; TPA, T1 pelvic angle; CPT, C2 pelvic tilt.

TABLE 3. Correlation of C2 Slope and T1 Slope With Parameters of Cervical Deformity at Baseline.

Primary Cervical Deformity

		C2 Slope	C1 Slope	MGS	C0-C2 Angle	C2-C7 Angle	cSVA	TS-CL	T1 Slope	TK	TPA	PT	PI-LL	
C2 slope	R	1.0	0.65	0.18	0.61	−0.61	0.61	0.97	0.28	0.38	−1.0	0.08	−0.20	
	P value*	n/a	**0.001**	0.14	**0.001**	**0.001**	**0.001**	**0.001**	**0.01**	**0.01**	0.39	0.94	0.08	
T1 slope	R	0.28	0.27	−0.03	0.19	0.52	0.62	0.72	1.0	0.55	0.18	0.16	**0.04**	
	P value	**0.01**	**0.02**	0.98	0.10	**0.002**	**0.001**	**0.001**	n/a	**0.001**	0.12	0.17	0.73	

Primary Cervico-thoracic Deformity

		C2 Slope	C1 Slope	MGS	C0-C2 Angle	C2-C7 Angle	cSVA	TS-CL	T1 Slope	T4-T12 Cobb	TPA	PT	PI-LL
C2 slope	R	1.0	0.91	−0.51	0.56	−0.62	0.82	0.98	0.38	0.33	0.29	0.21	0.16
	P value	**0.00**	**0.001**	**0.02**	**0.002**	**0.001**	**0.001**	**0.001**	**0.03**	0.07	0.12	0.26	0.39
T1 slope	R	0.38	0.29	−0.20	0.37	0.40	0.52	0.42	1.0	0.47	0.50	0.32	0.28
	P value	**0.03**	0.13	0.38	0.06	**0.03**	**0.005**	**0.02**	n/a	**0.002**	**0.005**	0.09	0.21

*P values in bold indicate statistically significant correlations.

C2S indicates C2 slope; C1S, C slope; MGS, McGregor slope; cSVA, (C2−C7), sagittal vertical axis; (TS-CL), T1 slope minus cervical lordosis; TPA, T1 pelvic angle; PT, pelvic tilt; PI-LL, pelvic incidence minus lumbar lordosis.

TABLE 4. Correlation of C2 Slope and HRQL in CT Patients With 1-year follow-up.

	NDI	mJOA	NRS Neck	EQ5D	EQ5D VAS	SWAL Burden
Baseline						
R	-0.05		0.13	−0.32	−0.34	−0.48
P value	0.98		0.62	0.22	0.22	0.05
1 year						
R	0.63	−0.65	0.49	−0.50	−0.28	−0.02
P value	0.01	0.02	0.05	0.05	0.3	0.93

NDI indicates neck disability index; HRQL, health-related quality-of-life; NRS, numeric rating scale.

DISCUSSION

Cervical alignment is an important determinant of disability and health status.[4,6,18] As a population, CD patients have been shown to be comparable to individuals with severe visual impairment, emphysema, and renal failure in terms of general health status.[4,5,19] The cervical sagittal vertical axis or cSVA is the classic descriptor of cervical alignment and remains an important parameter to consider in patients with CD. In a population of patients who underwent posterior cervical fusions, Tang *et al*[4] demonstrated that cSVA greater than 4 cm is associated with worse disability by NDI and the 36-Item Short Form Survey. Several other subsequent studies have reported cSVA in describing outcomes of CD corrections.[20]

Importance of T1 Slope Minus Cervical Lordosis

T1 slope minus cervical lordosis (TS-CL) was introduced as a superior alternative to cervical kyphosis to better define cervical angular alignment.[21] Cervical kyphosis can be a normal physiologic standing alignment, particularly in younger people who stand with a negative SVA.[8,9] In a study on 106 subjects without neck pain, 34% had cervical kyphosis.[20] Rather than evaluating whether a patient has kyphosis or not, TS-CL describes the harmony between cervical alignment and thoracolumbar alignment, or more specifically upper thoracic alignment. If the two components of TS-CL are considered separately, the T1 slope is a reflection of underlying thoracolumbar alignment. Knott *et al*[22] demonstrated that among spine patients, if the T1

TABLE 5. C2 Slope Matched With Established Alignment Parameters and HRQL Scores

Cervical and Cervico-thoracic Deformity

	C2S	r²
cSVA: 4 cm	36°	0.43
EQ5D: moderate disability	20°	0.08

Cervico-thoracic deformity

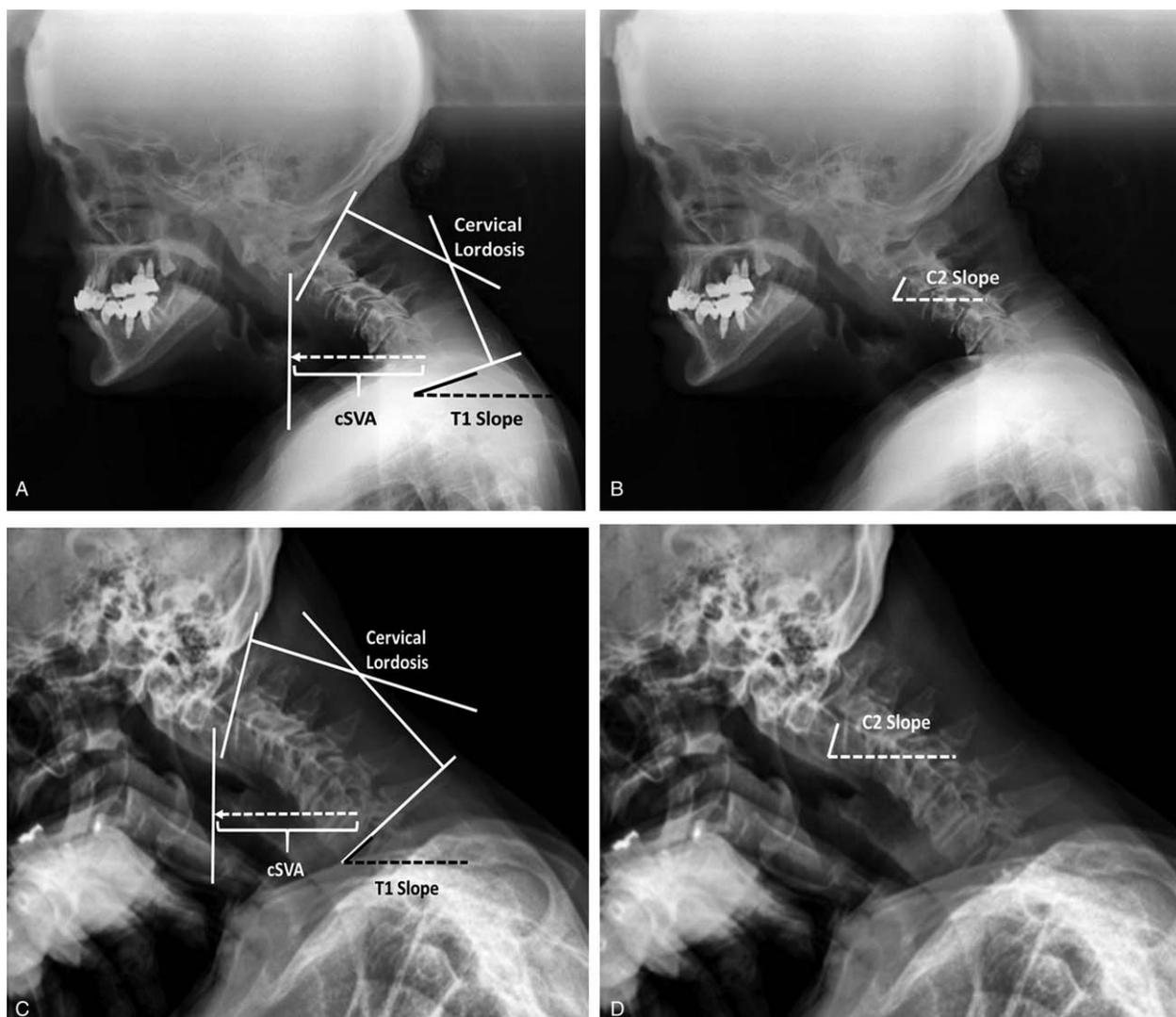|	C2S	r²
NDI: moderate disability	17°	0.4
EQ5D: moderate disability	20°	0.25

NDI indicates neck disability index; HRQL, health-related quality-of-life; NRS, numeric rating scale.

slope was greater than 25°, then the significant thoracolumbar deformity was present, as all these patients had a C7 SVA greater than 8 cm.
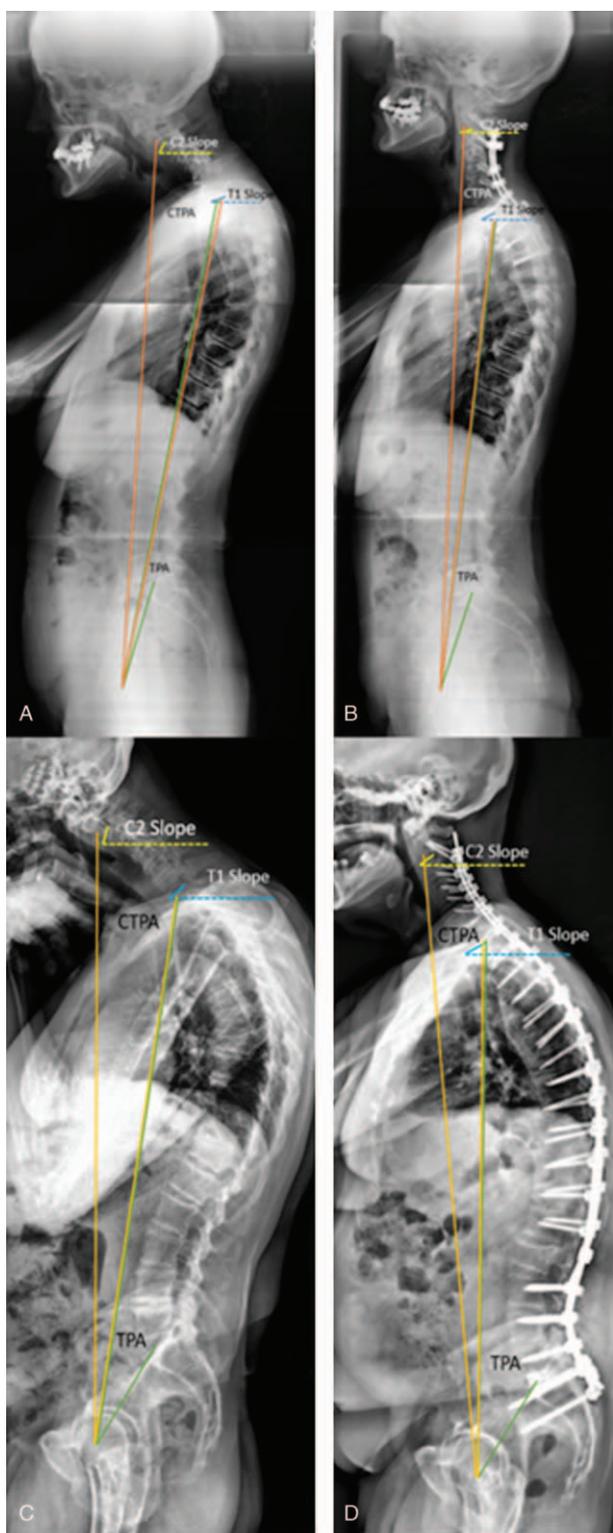
Klineberg et al[23] showed that when the T1 slope exceeds 32°, underlying thoracolumbar deformity is likely to be present with a sensitivity of 69% and a specificity of 69%. When combined with cervical lordosis in the TS-CL parameter, the balance between cervical alignment and thoracolumbar alignment is described. Protopsaltis et al[21] showed that even in the presence of underlying thoracolumbar deformity, if the mismatch between TS-CL exceeded 17°, then CD is present. Ames et al demonstrated that among patients who had undergone cervical fusions, a mismatch exceeding 20° corresponded to a cSVA of more than 4 cm, the published threshold for CD and moderate disability.[21]

In the present study, there were significant correlations between C2 slope and several radiographic parameters (Table 3). C2S was found to correlate most strongly with TS-CL for both patients with primary deformity located in the cervical region (r = 0.97, P < 0.001) and the CT region (r = 0.98, P < 0.001). This is because C2 slope functions as a mathematical approximation of TS-CL. Cervical lordosis is the slope of C7 minus the slope of C2. Since the slope of T1 is similar to the slope of C7 in most patients, the T1 slope minus cervical lordosis formula can be solved and simplified as C2 slope (Figure 2).

The TS-CL parameter quantifies whether a patient's cervical alignment is in harmony with the upper thoracic alignment which is described by T1 slope. If a patient has insufficient cervical lordosis to match a given T1 slope, then

Figure 3. C2 slope as a simplified measure of cervical deformity. Commonly used parameters to describe cervical deformity include cervical lordosis, cervical sagittal vertical axis (cSVA), and T1 slope minus cervical lordosis (TS-CL). C2 slope offers a simplified, comprehensive alignment parameter to provide valuable information regarding sagittal malalignment localized to the cervical spine. Panels (A) and (C) show how currently accepted parameters used to describe cervical deformity may be overly complex and complicate surgical planning. Panels (B) and (D) show the same radiographs with a comprehensive alignment parameter. C2 slope is useful to capture cervical deformity in two separate cases of cervical deformity (A and B as well as C and D).

Figure 4. C2 slope and T1 slope are useful in localizing malalignment. The relationship between C2 slope and T1 slope can help differentiate cervical malalignment resulting from appropriate compensation of thoraco-lumbar deformity and primary cervical deformity. When C2 slope is high and T1 slope is low, primary cervical deformity is likely. However, a high C2 slope and a high T1 slope imply deformity in both the cervical and thoraco-lumbar spine. A and B, Preop and postop radiographs of a patient with high C2 slope and low T1 slope, implying primary cervical deformity. In this case,

full body imaging may not be necessary. C and D, Preop and postop radiographs of a patient with high C2 slope and high T1 slope imply deformity is in both the cervical and thoracolumbar spine without cervical compensation. Full length spine films are necessary to evaluate thoracolumbar deformity. Interestingly, these two cases are the same radiographs from Figure 3, which illustrates how the relationship of C2 slope and T1 slope can be useful in localizing deformity and elucidating the need for full spine radiographs. TPA indicates T1 pelvic angle; CTPA, cervical-thoracic pelvic angle.

C2 will tilt forward and the C2 slope will be increased (Figure 2). Iyer *et al*[24] reported mean and ranges of various cervical alignment parameters among a cohort of 120 asymptomatic adults; the mean T1 slope was $26.1° \pm 9$ and the mean cervical lordosis was $-12.2° \pm 13.6$; therefore, the mean TS-CL was 13.9°. While the authors did not report normative values for C2 slope, the understanding that C2 slope is a simplified approximation of TS-CL allows for the assumption that normative values of C2 slope are similar to TS-CL (13.9°).

There are other advantages of utilizing C2 slope to estimate the harmony between cervical lordosis and upper thoracic alignment. First, as C2 slope is a measurement of one angle and TS-CL is a measurement of three angular slopes, there will be less interobserver error in the C2 slope measurement. Iyer *et al*[15] reported the interobserver errors for common cervical radiographic parameters and showed that TS-CL, had a lower interclass correlation than cervical lordosis, which has one less angular measurement. Moreover, the endplate of C2 is generally much more visible on plain radiographs than either the endplates of C7 or of T1 which would further enhance its reliability.[25] Second, by distilling the concept of cervical and upper thoracic harmony into one slope measurement, communication for the purposes of clinical discussion and research analysis becomes more simplified (Figure 3A–D). The clinician can discern if a patient has a cervico-thoracic junctional malalignment with one parameter, the T1 slope and can quickly see how well the patient is compensating through cervical lordosis for that junctional alignment with one other parameter, the C2 slope (Figure 4A–D).

In patients with cervico-thoracic deformity, C2 slope was also found to correlate strongly with postoperative health-related outcome measures at 1-year postoperative follow-up. Higher C2S was found to be highly correlated with NDI (r = 0.63, P = 0.01) and mJOA (r = −0.65, P = 0.02) and moderately correlated to NRS Neck (r = 0.49, P = 0.05), and EQ5D (r = −0.50, P = 0.05) at 1-year postoperative follow-up. C2S showed moderate to high correlation with all health-related outcome metrics investigated including the NDI, mJOA, VAS, and EQ5D (all r > 0.5). Given the strong correlations of C2S with various validated outcome metrics, it is suggested that C2S can reliably predict outcome measures at 1 year postoperative follow-up.

Linear regression analysis was used in an attempt to define a "cut-off" value for significant disability for C2 slope. For the entire patient cohort of 104 patients with adult CD, a C2S of 36° was found to match with a cSVA of 4 cm ($r^2 = 0.43$) and a C2S of 20° was found to match "moderate disability" as measured by EQ5D scale ($r^2 = 0.08$). For patients with cervico-thoracic deformity, moderate disability as measured by the NDI and EQ5D metrics was found to match with a C2S of 17° ($r^2 = 0.4$) and 20° ($r^2 = 0.25$), respectively. Interestingly, in patients with cervico-thoracic deformity, moderate disability was found to match to C2S angles with low variability (17° to 20°), suggesting that a small range of C2S angles can reliably be utilized to define a cutoff value for CD.

Strengths of this study include prospective, multicenter data collection with a heterogeneous patient population. Potential limitations to the design of the study include lack of standardization for operative treatment of CD. Current literature has demonstrated that operative management for CD is significantly variable. Given this fact, the possibility of selection bias exists as operating surgeons decided surgical approach and technique based on clinical judgement rather than standardized criteria. Moving on from this study, it will be important to investigate the utility of C2S with a larger statistical power and validate the correlation of C2S with health-related outcome measures.

CONCLUSIONS

While measures of global and regional alignment have been well established to describe disability and outcomes in thoraco-lumbar deformity, current literature has been less convincing for deformity of the cervical spine. While a few parameters of CD, including cSVA and TS-CL, have shown some utility in predicting surgical outcomes and describing disability, literature to date is not conclusive. Here we propose a novel measurement, C2 slope, which is a mathematical approximation of TS-CL. C2 slope was found to correlate strongly with previously described measures of CD, including cSVA and TS-CL, for both cervical and cervico-thoracic deformity. C2S was also found to correlate moderately with health-related outcome measures at 1 year postoperative follow-up. Based on the results of this study, C2 slope can provide a simple and effective tool for surgeons to describe overall CD and aid in operative planning.

➤ Key Points

- ❏ A recent proliferation of parameters to describe CD has led to confusion in classifying, treating, and assessing outcomes of CD surgery.
- ❏ C2 slope is a novel alignment parameter that is a mathematical approximation of TS-CL.
- ❏ C2 slope is a useful marker of overall CD and correlates with health-related outcome measures.

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