

Do the newly proposed realignment targets bridge the gap between radiographic and clinical success in adult cervical deformity corrective surgery

ABSTRACT

Hypothesis: The myelopathy-based cervical deformity (CD) thresholds will associate with patient-reported outcomes and complications.

Materials and Methods: This study include CD patients (C2-C7 Cobb > 10°, CL > 10°, cervical sagittal vertical axis > 4 cm, or CBVA > 25°) with BL and 1-year (1Y) data. Modifiers assessed low (L), moderate (M), and severe (S) deformity: CL (L: >3°; M:-21° to 3°; S: <-21°), TS-CL (L: <26°; M: 26° to 45°; S: >45°), C2-T3 angle (L: >-25°; M:-35° to -25°; S: <-35°), C2 slope (L: <33°; M: 33° to 49°; S: >49°), MGS (L: >-9° and <0°; M: -12° to -9° or 0° to 19°; S: < -12° or > 19°), and frailty (L: <0.18; M: 0.18–0.27, S: >0.27). Means comparison and ANOVA assessed outcomes in the severity groups at BL at 1Y. Correlations found between modifiers assessed the internal relationship.

Results: One hundred and four patients were included in the study (57.1 years, 50%, 29.3 kg/m²). Baseline S TS-CL, C2-T3, and C2S modifiers were associated with increased reoperations ($P < 0.01$), while S MGS, CL, and C2-T3 had increased estimated blood lost (>1000ccs, $P < 0.001$). S MGS and C2-T3 had more postop DJK (60%, $P = 0.018$). Improvement in TS-CL, C2S, C2-T3, and CL patients had better numeric rating scale (NRS) back (<5) and EuroQOL 5-Dimension questionnaire (EQ5D) at 1 year ($P < 0.05$). Improving the modifiers correlated strongly with each other (0.213–0.785, $P < 0.001$). Worsened TS-CL had increased NRS back scores at 1 year (9, $P = 0.042$). Worsened CL had increased 1-year modified Japanese Orthopedic Association (mJOA) (7, $P = 0.001$). Worsened C2-T3 had worse NRS neck scores at 1 year ($P = 0.048$). Improvement in all six modifiers (8.7%) had significantly better health-related quality of life (HRQL) scores at follow-up (EQ5D, NRS, and Neck Disability Index).

Conclusions: Newly proposed CD modifiers based on mJOA were closely associated with outcomes. Improvement and deterioration in the modifiers significantly impacted the HRQL.

Keywords: Alignment, cervical deformity, outcomes

INTRODUCTION

Cervical deformity (CD) has various etiologies including, degenerative and inflammatory as well as traumatic, and has the potential to produce major disability, pain, and neurological manifestations.^[1,2] CD has the potential to cause stenosis, compression of the spinal cord, or tensioning of the spinal cord across a malaligned cervical spine which can lead to myelopathy and spinal cord dysfunction.^[3-5] Current CD classification systems to aid in surgical optimization are correlated poorly with patient outcomes. Considering these symptoms of severe CD, a proper scoring tool for CD should include neurological symptoms in the assessment. These thresholds can help guide


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surgical intervention to restore alignment and decompress neural elements to improve quality of life.^[2,6]

The Scoliosis Research Society (SRS)-Schwab criteria and age-adjusted Schwab criteria developed for adult spinal deformity (ASD) have been statistically linked to improved health-related quality of life (HRQL) scores and decreased complications. This thoracolumbar ASD protocol has become an essential component of corrective treatment planning to guide target alignment goals.^[7-11] While no uniformly accepted classification exists for cervical-specific deformities, Ames *et al.* recently comprised one of the first comprehensive classification systems for CD, which includes both clinical and radiographic factors. Specifically, it focuses on five modifiers: TS-CL (reflecting mismatch of T1 slope and cervical lordosis), C2-C7 sagittal vertical axis (SVA), McGregor's slope for horizontal gaze (chin-brow vertical angle [CBVA]), myelopathy severity (established by the modified Japanese Orthopaedic Association [mJOA]) as well as elements of the SRS-Schwab Classification for ASD.^[12,13] This classification system has yet to be clinically validated. Progression of CD and cervical myelopathy may eventually lead to compression of the spinal cord, producing characteristic symptoms of a disrupted horizontal gaze, dysphagia, incontinence, and radiculopathy. Currently, myelopathy remains an understudied factor when considering patient outcomes from corrective CD surgery. Preliminary evidence by Passias *et al.* found that myelopathy played a critical role in patient-reported outcomes as measured by HRQLs, which correlated with an improved mJOA score. The goal of this study is to determine whether new alignment criteria taken based on cervical myelopathy severity into consideration, stratified through mJOA scores, can help optimize target thresholds to improve patient-reported outcomes.

MATERIALS AND METHODS

Data overview

Patients with a clinical diagnosis of cervical spine deformity, greater or equal to 18 years of age, and undergoing cervical fusion procedures by a single spine surgeon were included in the dataset. The database required radiographic evidence of CD, defined as cervical kyphosis (C2-7 sagittal Cobb angle > 10), cervical scoliosis (C2-C7 coronal Cobb angle > 10), C2-C7 SVA (C2-C7 SVA) > 4 cm, or chin-brow vertical angle (CBVA) > 25, measured with preoperative radiographs. Institutional Review Board approval was obtained before enrollment, and every patient gave consent before data collection.

Study inclusion criteria

Patients included had full baseline and 1-year radiographic and health-related quality of life (HRQL) data.

Data collection

Basic baseline data were collected before operative intervention, including age, gender, body mass index (BMI), and comorbidity burden, otherwise described as the Charlson Comorbidity Index (CCI).

Surgical data were also collected for analysis, such as total number of levels fused, surgical approach, decompression type, and osteotomy type: three-column osteotomy, Ponte osteotomy, and facet osteotomy. Patient-reported outcomes were collected and recorded in the dataset, including the Neck Disability Index (NDI), modified Japanese Orthopaedic Association scale (mJOA), and EuroQOL 5-Dimension questionnaire (EQ5D), but these HRQL questionnaires (HRQLs) were not utilized in the present study.

Baseline up to 1-year postoperative radiographs were measured using validated software programming (SpineView; ENSAM Laboratory of Biomechanics, Paris, France) at a single academic center. Cervical sagittal alignment and balance were evaluated using C2-7 Cobb angle for cervical lordosis (CL: angle between the lower endplates of C2 and C7), cervical SVA (cSVA: C2 plumb line offset from the posterosuperior corner of C7), and the mismatch between T1 slope and CL (TS-CL). Global sagittal alignment measures assessed included thoracic kyphosis (TK: angle between the lower endplates of T4 and T12), lumbar lordosis (LL: angle between the lower endplates of L1 and S1).

Newly proposed cutoffs

Passias and colleagues created radiographic and clinical modifiers of deformity based on myelopathy severity for low (L), moderate (M), and severe (S) deformity through novel thresholds. These include baseline CL, TS-CL, C2-T3 angle, C2 slope, McGregor's slope, and frailty status defined by the modified CD frailty index. A CL > 3° is noted as L, M is 21° to 3°; while S is < -21°. The TS-CL modifier has an L of < 26°, M of 26° to 45°, and S is > 45°. The remainder of modifiers was as follows: C2-T3 angle (L: > -25°; M: -35° to -25°; and S: < -35°), C2 slope (L: < 33°; M: 33° to 49°; and S: > 49°), MGS (L: > -9° and < 0°; M: -12° to -9° or 0° to 19°; and S: < -12° or > 19°), and frailty status (L: < 0.18; M: 0.18-0.27; and S: > 0.27).

Statistical analysis

Basic baseline demographic, clinical, and radiographic factors were compared between the osteotomy groups through means comparison, ANOVA Chi-squared tests, and Student's *t*-tests, as appropriate. Means comparison and ANOVA assessed outcomes (reoperation, complications, DJK, meeting minimal clinically important difference [MCID] for HRQLs) in each of the severity groups at baseline, and those

that improved, remained the same, or worsened in patients with follow-up at 1 year. Correlations were found between the modifiers to determine internal relationship. P lower than 0.05 would be recognized as reaching significance. All analyses were performed using the Statistical analysis was performed using SPSS software (version 21.0, IBM, Armonk, New York).

RESULTS

Cohort overview

One hundred and four patients were included in the present study. The mean age was 57.1 years, with 50% of the cohort as female. The mean BMI was 29.3 kg/m² and a CCI of 0.59. The baseline myelopathy severity as determined by mJOA scores was 13.1.

Rates of severe myelopathy modifiers

At baseline, the rate of S myelopathy modifiers is as follows: 9.2% TS-CL, 14.7% MGS, 8.7% C2-C7, 7.9% C2-T3, 10.5% C2 slope, and 49.5% frailty. Rates of L and M modifiers are shown in Table 1.

Baseline myelopathy modifiers and outcomes

Baseline S TS-CL, C2-T3, and C2S modifiers were significantly associated with increased reoperations ($P < 0.01$), while S MGS, CL, and C2-T3 had increased EBL ($> 1000\text{ccs}$, $P < 0.001$). S MGS and C2-T3 had more postoperative DJK (60%, $P = 0.018$).

Postoperative changes in myelopathy modifiers and outcomes

At 1 year, 22.1% of patients improved or remained low in TS-CL modifier, 8.7% in MGS, 24% in CL, 56.7% in C2-T3 modifier, 11.5% C2S, and 28.8% in frailty status. Improvement in TS-CL, C2S, C2-T3, and CL patients had superior NRS Back scores (< 5) and EQ5D scores at 1 year ($P < 0.05$). Patients who improved in frailty status modifier at 1 year met MCID for NDI (50%) and EQ5D at a greater rate (30%), $P < 0.001$. Those who remained severe or became more severe in the change from baseline to 1 year ranged from 3.8% to 10.6%. This was primarily seen in the frailty status modifier. Improvement in TSCL, CL, C2-T3, C2S, and frailty modifiers correlated strongly with each other (0.213–0.785, $P < 0.001$). Patients

who worsened in their TS-CL had increased NRS back scores at 1 year (9, $P = 0.042$). Worsened CL modifier patients had increased 1-year mJOA scores (7, $P = 0.001$). Worsened C2-T3 modifier patients had significantly worse NRS neck scores at 1 year ($P = 0.048$). Improvement in all six modifiers (8.7%) had significantly better HRQL scores at follow-up (EQ5D, NRS, and NDI).

DISCUSSION

The cervical spine has an essential role in facilitating the movement of the head and neck, maintaining horizontal gaze, and protecting neurovascular components.^[14] Nontraumatic degeneration of the cervical spine is the most common cause of CD in the elderly population and when progressive may lead to a decline in quality of life and functional independence.^[5,15] CD has the potential to cause stenosis, compression of the spinal cord, or tensioning of the spinal cord across a malaligned cervical spine which can lead to myelopathy and spinal cord dysfunction.^[3-5] Current CD classification systems to aid in surgical optimization are correlated poorly with patient outcomes. Considering these symptoms of severe CD, a proper scoring tool for CD should include neurological symptoms in the assessment. In symptomatic patients, surgery is often required, and corrective procedures are associated with a significant improvement in HQRLs.^[5,14,16] Despite this, there are no comprehensive guidelines for target alignment available for use in surgical planning.^[12] This study demonstrated that the thresholds established based on myelopathy severity, using mJOA as a proxy, were significantly associated with improved patient outcomes demonstrated by HQRLs. The modifiers used were stratified individually into three categories: low (L), moderate (M), and severe (S).

The thresholds developed for this study were based on the mJOA, the most commonly used tool for characterizing the degree of myelopathy.^[17] Asher *et al.* found that improvement in mJOA was strongly correlated with patient-reported postoperative satisfaction, regardless of the patient's baseline myelopathy severity (30475334). The efficacy of mJOA in assessing CD surgery outcomes was the foundation for decision-making in developing alignment goals. Regression analysis utilizing radiographic parameters for McGregor's

Table 1: Baseline modified cervical severity criteria and change to 1 year postoperatively

	TS-CL.(%)	McGregor's slope (%)	C2-C7 angle (%)	C2-T3 angle (%)	C2 slope (%)	Frailty.(%)
Low	60.2	38.2	41.3	88.9	77.2	54.1
Moderate	30.6	47.1	50.0	3.2	12.3	37.7
Severe	9.2	14.7	8.7	7.9	10.5	8.2
Δ Baseline to 1 year						
Improved or remained low	41.4	42.9	43.8	20.0	26.7	13.1
Worsened or remained severe	13.8	28.6	15.6	6.7	6.7	18.0

CL: Cervical lordosis, TS: T1 slope

slope, CL, TS-CL, C2-T3 angle, and C2 slope combined with the mJOA score created alignment goals that differed from those previously proposed by Ames *et al.*

A patient's ability to look straight ahead or lie down flat is largely dependent on horizontal gaze, a key function in activities of daily living, such as driving.^[18] Measurement of the chin–brow angle is directly correlated with horizontal gaze and therefore has become one of the key parameters measured in CD corrective surgery.^[18] However, in a study it was found that only 52% had usable landmarks.^[19] McGregor's slope is measured with a line between the posterior portion of the hard palate to the opisthion in relation to the horizontal plane. This angle is found to be measurable in more patients than in the CBVA. Studies show that McGregor's slope is significantly correlated with the CBVA and therefore can be used as a surrogate.^[13,20] The values for MSG cutoffs can be considered stricter than those proposed by Ames *et al.* The same degree of malalignment that would be considered 0 (on a scale of 0, +, and ++) would qualify as severe in these new parameters. Ames *et al.* proposed 10° as an optimal surgical goal. More aggressive correction of a patient stratified as severe in these new thresholds may be responsible for the significant improvement in HQRLs found in this study compared to previous literature.^[12,21]

The TS-CL mismatch can be used in an analogous fashion to the utility of PI-LL used for ASD as part of the SRS-Schwab classification system, which has been clinically validated as significantly correlating with patient-reported HQRLs and disease state.^[22-25] Compared with the Ames *et al.* classification system, the thresholds for TS-CL used are less strict, with the value of L set as <26° in this study and a low deformity in the AMES criteria being <15°. The other two parameters used, C2-T3 and C2 slope, were not included in the AMES classification system.^[12]

Among the six parameters, the greatest degree of improvement, or maintenance in the L category, was found in the TS-CL, CL, and C2-T3 modifiers. Patients who improved in these three radiographic modifiers were also found to have better NSR back pain scores and EQ5D at 1 year postoperatively. Those patients who worsened in CL were found to have increased 1-year mJOA scores. Radiographic alignment and improvement in HQRL have been shown to have a significant correlation; however, Passias *et al.* found that improvement in cervical myelopathy (using mJOA as a proxy) was the most prominent variable in reaching a MCID in EQ5D.^[2,26] Cervical myelopathy can progress with debilitating effects on numerous facets of a patient's activities of daily living. Therefore, improvements in alignment without relief of neurological symptoms may do little provide the relief that

patient's desire, offering the basis for the strong correlation between mJOA and HQRL scores. By utilizing mJOA for the development of these thresholds, the system takes this relationship into consideration to provide corrective parameters that prioritize restoration of function and quality of life rather than solely achieving radiographically appropriate alignment.

The retrospective nature of the cohort can inherently lead to potential reporting or observer bias. Data collected from a surgeon operating in a single setting may not be representative of the average treatment a patient with CD receives. Furthermore, a study of this nature cannot examine causality as both sagittal spinal alignment parameters and HRQL may be influenced by another confounding factor such as the underlying spinal diagnoses for which the patient was receiving spinal fusion surgery. In addition, at 1-year postoperative, this study may be hindered by a relatively short follow-up time.

CONCLUSIONS

For surgical CD patients, the use of newly proposed CD modifiers based on the mJOA scores was more closely associated with outcomes. Improvement and deterioration in these modifiers significantly impacted HRQL outcomes. Reorientation of realignment guidelines to myelopathy-based targets appears to have clinical benefits. Further long-term study is warranted.

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Conflicts of interest

There are no conflicts of interest.

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