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The Relationship Between Improvements in Myelopathy and Sagittal Realignment in Cervical Deformity Surgery Outcomes

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Study Design. Retrospective review.

Objective. Determine whether alignment or myelopathy improvement drives patient outcomes after cervical deformity (CD) corrective surgery.

Summary of Background Data. CD correction involves radiographic malalignment correction and procedures to improve motor function and pain. It is unknown whether alignment or myelopathy improvement drives patient outcomes.

Methods. Inclusion: Patients with CD with baseline/1-year radiographic and outcome scores. Cervical alignment improvement was defined by improvement in Ames CD modifiers. modified Japanese Orthopaedic Association (mJOA) improvement was defined as mild [15–17], moderate [12–14], severe [<12]. Patient groups included those who only improved in alignment, those who only improved in mJOA, those who improved in both, and those who did not improve. Changes in quality-of-life scores (neck disability index [NDI], EuroQuol-5 dimensions [EQ-5D], mJOA) were evaluated between groups.

Results. A total of 70 patients (62 yr, 51% F) were included. Overall preoperative mJOA score was 13.04 ± 2.35. At baseline, 21 (30%) patients had mild myelopathy, 33 (47%) moderate, and 16 (23%) severe. Out of 70 patients 30 (44%) improved in mJOA and 13 (18.6%) met 1-year mJOA minimal clinically important difference. Distribution of improvement groups: 16/70 (23%) alignment-only improvement, 13 (19%) myelopathy-only improvement, 18 (26%) alignment and myelopathy improvement, and 23 (33%) no improvement. EQ-5D improved in 11 of 16 (69%) alignment-only patients, 11 of 18 (61%) myelopathy/alignment improvement, 13 of 13 (100%) myelopathy-only, and 10 of 23 (44%) no myelopathy/alignment improvement. There were no differences in decompression, baseline alignment, mJOA, EQ-5D, or NDI between groups. Patients who improved only in myelopathy showed significant differences in baseline-1Y EQ-5D (baseline: 0.74, 1 yr:0.83, $P < 0.001$). One-year C2-S1 sagittal vertical axis (SVA; mJOA $r = -0.424$, $P = 0.002$; EQ-5D $r = -0.261$, $P = 0.050$; NDI $r = 0.321$, $P = 0.015$) and C7-S1 SVA (mJOA $r = -0.494$, $P < 0.001$; EQ-5D $r = -0.284$, $P = 0.031$; NDI $r = 0.334$, $P = 0.010$) were correlated with improvement in health-related qualities of life.

Conclusion. After CD-corrective surgery, improvements in myelopathy symptoms and functional score were associated with superior 1-year patient-reported outcomes. Although there were no relationships between cervical-specific sagittal parameters and patient outcomes, global parameters of C2-S1 SVA and C7-S1 SVA showed significant correlations with overall 1-year mJOA, EQ-5D, and NDI. These results highlight myelopathy improvement as a key driver of patient-reported outcomes, and confirm the importance of sagittal alignment in patients with CD.

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Cervical deformity (CD) refers to a cluster of disorders affecting cervical spine alignment. The most prevalent form of CD is progressive cervical kyphosis, a condition commonly associated with increased anterior pressure and tension in the spinal cord and subsequent myelopathy.[1,2] Because of the wide range of etiologies that contribute to the development of CD, treatment is often dependent on presentation; however, for patients presenting with severe neurological deficit or functional impairment, surgical management is indicated.[3] Thus, in addition to correcting sagittal alignment, surgical management of CD aims to decompress neural elements and improve overall health-related quality of life (HRQL).

Metrics used in the literature to assess patient outcomes after CD-corrective surgery include radiographic measurements such as C2–7 lordosis and cervical global sagittal vertical axis (cSVA), HRQL assessments such as the neck disability index (NDI) and three-level EuroQuol-5 dimensions questionnaire (EQ-5D-3L), and functional assessments including the modified Japanese Orthopaedic Association (mJOA) questionnaire.[4–6] Although these HRQL assessments are validated for general spine pathology, they are not validated as CD-specific outcomes measurements. As such, it is important to evaluate the effectiveness of the EQ-5D, NDI, and mJOA assessments in an experimental framework specific to CD.

Recent studies demonstrate cervical radiographic parameters as significantly correlated with HRQL measures. One group investigated changes in health measures for 318 patients undergoing corrective surgery for thoracolumbar sagittal deformity, finding a significant correlation between baseline C2–7 SVA values of 5 cm or more and worse outcomes on multiple HRQL different assessments.[7] Another study focused on patients undergoing multilevel cervical fusion for sagittal malalignment, finding

Figure 1. Case example: preoperative (left) and postoperative (right) cervical lateral radiographs for (**A**) a patient who improved in modified Japanese Orthopaedic Association scale (mJOA) only and (**B**) a patient who improved in alignment only. For patient A, baseline and 1-year cervical sagittal vertical axis (cSVA) measurements were 50.68 and 46.50 mm, respectively, mJOA scores were 11 and 18, EQ-5D scores were 0.659 and 0.738, and neck disability index (NDI) scores were 54 and 10. For patient B, baseline and 1-year cSVA measurements were 64.44 and 49.79 mm, respectively, mJOA scores were 13 and 14, EQ-5D scores were 0.799 and 0.799, and NDI scores were 13 and 34.

postoperative positive sagittal balance to be significantly correlated with poor NDI scores.[6] It is important to note, however, that restoration of cervical alignment is not the only factor contributing to improved patient outcomes following CD-corrective surgery. Postoperative myelopathy improvement may also contribute to improved patient-reported outcomes measures, but the extent of this influence is ill characterized in the literature.[6,8]

Using physician reported mJOA scores as a measure of myelopathy improvement, the goal of the present study is to determine whether reaching cervical alignment goals or achieving clinically significant improvement in mJOA contributes more to overall improvement in postoperative status of patients undergoing CD-corrective surgery.

MATERIALS AND METHODS

Data Source

This study is a retrospective review of a prospective, multicenter database of patients with CD enrolled from 2013 to 2016 at 13 spine surgery centers across the United States. All participating research centers obtained institutional review board approval before study improvement. Inclusion criteria for the database were patients ages 18 years or older with radiographic evidence of CD, as defined by the presence of at least one of the following on baseline imaging: cervical kyphosis (C2–7 Cobb angle $>10°$), cervical scoliosis (C2–7 coronal Cobb angle $<10°$), C2–7 SVA (cSVA) of more than 40 mm or chin-brow vertical angle of $25°$ or more. Inclusion criteria for this study were baseline mJOA scores 17 or lesser, as well as complete radiographic and HRQL assessment information at baseline and 1-year postoperative visit.

Data Collection and Radiographic Assessment

Demographic and clinical data collected in the database included patient age, sex, body mass index, history of prior cervical surgery, and baseline mJOA score. Surgical data collected included operative time, estimated blood loss, surgical approach, osteotomy use and number of osteotomies, levels fused, and instrumentation used. Full-length free-standing lateral spine radiographs (36″ cassette) were used to assess patients at baseline and 1-year postoperative time points. Radiographs were analyzed using SpineView (ENSAM, Laboratory of Biomechanics, Paris, France) software according to validated and standardized techniques previously described in the literature.[9–11] Cervical radiographic parameters assessed were cervical lordosis (CL: angle between the lower endplates of C2 and C7), cSVA (C2 plumb line offset from the posterosuperior corner of C7), and T1 slope minus CL mismatch (TS-CL: mismatch between T1 slope and CL). Spinopelvic radiographic parameters assessed were SVA (C7-S1 SVA: C7 plumb line relative to the posteriosuperior corner of S1), C2-S1 SVA, pelvic incidence minus lumbar lordosis (PI-LL: mismatch between PI and LL), and pelvic tilt (PT: angle between the vertical and the line through the sacral midpoint to the center of the two femoral heads). The only cranial parameter assessed was McGregor line slope (angle between horizontal and line from posterior edge of hard palate to caudal point of occipital curve).

Patient Outcomes Assessment

The three-level EuroQuol-5 Dimensions questionnaire (EQ-5D-3L), NDI, and mJOA questionnaire were used to assess patient HRQL outcomes. The EQ-5D-3L measures patient health across five dimensions (mobility, self-care, usual activities, pain or discomfort, and anxiety or depression), with three levels for each dimension (no problem, some problems, severe problems).[12] The NDI measures neck disability across 10 dimensions (neck pain intensity, self-care, lifting, reading, headache, concentration, work, driving, sleeping, and recreation), with six severity levels for each dimension.[13] The mJOA has been widely used as an accurate assessment tool for measuring severity of neurological deficits in patients with myelopathy.[14] All HRQL scores were collected at baseline and 1 year postoperatively.

Outcomes Analysis

Patient mJOA scores were classified as mild (15–17), moderate (12–14), and severe (0–11).[14] Minimal clinically important difference (MCID) improvements in mJOA and EQ-5D scores were set at 2 and 0.1, respectively, based on previously published MCID values.[15–17] Improvements in cervical alignment were determined using the Ames classification for CD, and defined as improvement in at least one Ames modifier grade from baseline to 1-year. Patients were divided into four improvement groups for analysis: those who only improved in mJOA, those who only improved in cervical alignment, those who improved in both, and those who did not improve in either category.

Statistical Analysis

All statistical analyses were performed using SPSS software (version 23.0, Armonk, NY). Baseline patient demographics, procedural information, and outcome scores were tabulated and frequencies determined. Paired Student *t* tests were used to compare baseline/1-year radiographic parameters, baseline/1-year EQ-5D, NDI, and mJOA scores, and baseline/1-year changes in neurologic impairment. Analysis of variance with Tukey *post-hoc* analysis was used to compare baseline to 1-year changes in EQ-5D, NDI, mJOA, and radiographic cervical alignment between each of the four patient improvement groups. Relative interactions between preoperative myelopathy severity and deformity were assessed using nonparametric Mann-Whitney *U* tests. Pearson bivariate correlation coefficients and nonparametric Spearman rho correlations were used, as appropriate depending on variance, to assess relationships between radiographic parameters, mJOA, EQ-5D, and NDI scores at baseline and 1 year time points. Similarly, Pearson correlation coefficients were also used to quantify associations between baseline 1-year changes in mJOA, EQ-5D, and NDI. Analyses were two tailed and $P < 0.05$ was considered statistically significant.

TABLE 1. Baseline Demographic, Comorbidity, Procedural, Clinical, and Radiographic Characteristics of Entire Patient Cohort

Parameters	Patients With Cervical Deformity
Age (yr)	62.8 ± 10.8
% Female	60.0%
Body mass index (BMI)	28.9 ± 7.8
Previous cervical surgery	27 (39.7%)
History of smoking	23 (34.3%)
Diabetes mellitus	5 (7.1%)
Osteoporosis	9 (12.9%)
Depression	20 (28.6%)
Approach	
Anterior	11 (15.7%)
Posterior	32 (45.7%)
Combined	27 (38.6%)

RESULTS

Study Cohort Overview

Seventy patients met inclusion criteria (mean age: 62.7 ± 10.0 yr, mean body mass index: 28.9 ± 7.8 kg/m^2, 60% female). There were 27 (39.7%) patients with a prior history of cervical surgery, 23 (34.3%) with a prior history of smoking, 20 (28.6%) with depression, 5 (7.1%) with diabetes, and 9 (12.9%) with osteoporosis. By approach, 32 (45.7%) of procedures were posterior only, 11 (15.7%) were anterior only, and 27 (38.6%) were combined (Table 1). Nineteen (27.1%) patients underwent Smith-Petersen osteotomy, 10 (14.3%) underwent closing wedge osteotomy, and 14 (20.0%) underwent corpectomy. There were no significant differences in baseline mJOA, NDI, or EQ-5D between the four patient improvement groups. Patients with more severe preoperative myelopathy, as indicated by mJOA scores of less than 15, had more severe cervical and cervicothoracic sagittal malalignment than patients with mild or no preoperative myelopathy: cSVA (85.7 ± 4.1 *vs.* 44.9 ± 24.2 mm, $P < 0.001$) and C2-T3 lordosis (44° ± 19° *vs.* 14° ± 20° $P = 0.002$).

Improvement in Radiographic Parameters

Mean overall baseline alignment values are detailed in Table 2. At 1 year postoperatively, patients showed significant improvement in C2-C7 lordosis ($P < 0.001$), McGregor slope, ($P < 0.001$), TS-CL ($P < 0.001$), C7-S1 SVA ($P = 0.002$), and C2-S1 SVA ($P = 0.029$). There were no significant changes between overall baseline and 1-year cSVA, PT, PI-LL, and C2-T3 SVA (all $P > 0.050$).

Improvement in Myelopathy and Patient-Reported Outcomes

Overall preoperative EQ-5D score was 0.73 ± 0.06, NDI score was 48.28 ± 18.17, and mJOA score was 13.04 ± 2.35 (Table 3). Before surgery, 21 patients (30.0%) were classified as reporting "mild" myelopathy, 33 (47.1%) had "moderate" myelopathy, and 16 (22.9%) had "severe". At 1 year postoperatively, 13 (18.6%) patients reached MCID for EQ-5D (seven from the "mild" myelopathy category, two from "moderate," and four from "severe"). Similarly, at 1 year, 13 (18.6%) patients reached MCID for mJOA score (four from the "mild" myelopathy category, five from "moderate," and four from "severe"). Overall 1-year patient improvement in clinical myelopathy symptoms is detailed in Table 4. Patients reaching 1-year MCID for

TABLE 2. Comparison of Mean Preoperative and 1-Year Radiographic Parameters for All Patients

Radiographic Parameter	Baseline	1 Year	Difference	*P*
PT (°)	19.99 ± 11.62	19.09 ± 11.70	−1.16 ± 6.35	0.162
PI-LL (°)	2.03 ± 17.44	3.86 ± 17.15	1.06 ± 11.41	0.475
C2-S1 SVA (mm)	55.69 ± 81.26	75.95 ± 74.63	21.86 ± 69.21	0.029*
C7-S1 SVA (mm)	11.68 ± 74.56	36.93 ± 66.81	26.41 ± 61.07	0.002*
T4-T12 TK (°)	−40.21 ± 14.42	−43.60 ± 14.76	−3.52 ± 10.02	0.008*
T1 slope (°)	31.83 ± 17.48	36.04 ± 14.10	5.54 ± 10.31	<0.001*
TS-CL (°)	38.92 ± 19.89	26.75 ± 12.80	−11.57 ± 19.04	<0.001*
C2-C7 CL (°)	−6.59 ± 19.33	9.38 ± 14.93	16.63 ± 19.28	<0.001*
C2-C7 SVA (mm)	48.93 ± 26.07	42.32 ± 16.85	−5.07 ± 19.53	0.070
C2-T3 (°)	−17.10 ± 21.33	2.00 ± 15.39	17.89 ± 23.28	<0.001*
C2-T3 SVA (mm)	82.81 ± 42.32	79.06 ± 27.57	−1.08 ± 29.69	0.797
C2 slope (°)	39.62 ± 21.37	25.84 ± 13.46	−13.03 ± 19.93	<0.001*
C1 slope (°)	3.29 ± 18.77	−7.93 ± 12.77	−10.75 ± 17.72	<0.001*
C0 slope (°)	0.21 ± 14.79	−8.25 ± 10.07	−7.59 ± 15.24	<0.001*
C0-C2 angle (°)	33.63 ± 12.94	29.00 ± 9.88	−5.16 ± 11.17	0.003*
McGS (°)	6.77 ± 13.57	−1.16 ± 9.44	−7.27 ± 13.06	<0.001*

CL indicates cervical lordosis; LL, lumbar lordosis; McGS, McGregor line slope; PI, pelvic incidence; PT, pelvic tilt; SVA, sagittal vertical axis; TK, thoracic kyphosis; TS, T1 slope.

Asterisked values denote statistical significance of $P < 0.050$.

TABLE 3. Comparison of Mean Preoperative and 1-Year Cervical Sagittal Vertical Axis, EuroQuol-5 Dimensions, Neck Disability Index, and Modified Japanese Orthopaedic Association scale Scores for All Patients and by Alignment/Modified Japanese Orthopaedic Association scale Patient Improvement Group

Improvement Group	Baseline	1 yr	*P*	% Improved	% MCID
All patients (N = 70)					
EQ-5D	0.73 ± 0.06	0.78 ± 0.08	<0.001*	44 (62.9%)	13 (18.6%)
NDI	48.29 ± 18.17	35.99 ± 20.60	<0.001*	50 (71.4%)	
mJOA	13.04 ± 2.35	13.73 ± 2.86	0.082	31 (44.3%)	13 (18.6%)
cSVA	48.93 ± 26.07	42.32 ± 16.85	0.070	21 (30.0%)	
mJOA improvement only (N = 13)					
EQ-5D	0.74 ± 0.05	0.83 ± 0.06	0.001*	13 (100%)	5 (38.5%)
NDI	45.55 ± 17.99	23.69 ± 19.83	<0.001*	12 (92.3%)	
mJOA	12.76 ± 3.03	16.23 ± 2.24	<0.001*	13 (100%)	7 (53.8)%
cSVA	57.18 ± 16.32	54.38 ± 14.29	0.113	0 (0.00%)	
Alignment improvement only (N = 16)					
EQ-5D	0.73 ± 0.06	0.77 ± 0.06	0.032*	11 (68.8%)	2 (12.5%)
NDI	50.65 ± 17.80	42.58 ± 21.48	0.113	11 (68.8%)	
mJOA	13.38 ± 2.55	12.61 ± 2.18	0.006*	0 (0.00%)	0 (0.00%)
cSVA	54.88 ± 19.31	40.38 ± 12.72	0.003*	11 (68.8%)	
mJOA and alignment improvement (N = 18)					
EQ-5D	0.73 ± 0.06	0.78 ± 0.08	0.016*	11 (61.1%)	6 (33.3%)
NDI	50.97 ± 16.21	32.63 ± 18.00	0.001*	15 (83.3%)	
mJOA	12.89 ± 1.94	14.94 ± 2.41	<0.001*	18 (100%)	10 (55.6%)
cSVA	42.30 ± 32.90		37.16 ± 17.37	0.844	10 (55.6%)
No improvement (N = 23)					
EQ-5D	0.74 ± 0.07	0.74 ± 0.07	0.764	10 (43.5%)	2 (8.7%)
NDI	46.09 ± 20.51	40.99 ± 19.87	0.029*	11 (47.8%)	
mJOA	13.09 ± 2.19	11.75 ± 2.27	<0.001*	0 (0.00%)	0 (0.00%)
cSVA	45.65 ± 27.89	43.70 ± 19.16	0.712	0 (0.00%)	

cSVA indicates cervical sagittal vertical axis; EQ-5D, EuroQuol-5 dimensions questionnaire; MCID, minimal clinically important difference; mJOA, modified Japanese Orthopaedic Association scale; NDI, Neck Disability Index.

Asterisked values denote statistical significance of $P < 0.050$.

mJOA showed significant improvement in hand numbness ($P = 0.019$) and hyperreflexia ($P = 0.037$), but not in hand clumsiness, gait stability, or lower-extremity spasticity (all $P > 0.050$).

Assessed by patient improvement groups, 13 (18.6%) patients improved in mJOA score only, 16 (22.9%) improved in alignment only, 18 (25.7%) patients improved in both alignment and mJOA score, and 23 (32.9%) patients did not improve in either alignment or mJOA score from baseline to 1 year postoperative (Table 3). Patients who improved in mJOA only ($P = 0.010$) and patients who improved in both mJOA and alignment ($P = 0.032$) had significantly larger baseline/1-year changes in NDI score than patients who did not improve in wither mJOA or alignment (Figure 1). Although patients who improved in alignment only showed no significant 1-year improvements in hand clumsiness, hand numbness, gait instability, hyperreflexia, and lower limb spasticity (all $P > 0.050$), patients who improved in both alignment and mJOA showed significant 1-year improvements in both hand clumsiness ($P = 0.004$) and hand numbness ($P = 0.001$). Patients who improved in mJOA only also showed significant 1-year improvement in hyperreflexia ($P = 0.017$) and tended to improve in hand numbness ($P = 0.054$, Table 4).

Correlations between Radiographic Parameters and Patient-Reported EuroQuol-5 Dimensions/Neck Disability Index Outcomes

C2-S1 SVA ($r = -0.261$, $P = 0.050$) and C7-S1 SVA ($r = -0.284$, $P = 0.031$) were the only radiographic parameters significantly correlated to EQ-5D score at 1 year. No significant relationships were observed between 1-year radiographic parameters and reaching 1-year MCID for EQ-5D. At baseline, no radiographic parameters were correlated to NDI score. At 1 year postoperatively, PT ($r = -0.309$, $P = 0.016$), C2-S1 SVA ($r = 0.321$, $P = 0.015$), C7-S1 SVA ($r = 0.334$, $P = 0.010$), C1 slope ($r = 0.354$, $P = 0.004$), C0 slope ($r = 0.301$, $P = 0.017$), and McGregor slope ($r = 0.350$, $P = 0.008$) were all significantly correlated to NDI score (Table 5). To assess the effect

TABLE 4. 1-Year Changes in Myelopathy Clinical Symptoms By Patient Alignment/Modified Japanese Orthopaedic Association Improvement Group

Improvement Group	Hand Clumsiness	Hand Numbness	Abnormal Gait	Hyperreflexia	Lower Limb Spasticity
All patients (N = 70)					
Baseline (%)	27 (39.13%)	38 (55.07%)	20 (28.99%)	16 (23.19%)	5 (7.25%)
1 yr (%)	14 (20.29%)	17 (24.64%)	7 (10.14%)	2 (2.90%)	2 (2.90%)
P	0.004*	<0.001*	0.001*	0.001*	0.182
mJOA improvement only (N = 13)					
Baseline (%)	5 (38.46%)	8 (61.54%)	3 (23.08%)	5 (38.46%)	0 (0.00%)
1 yr (%)	2 (15.38%)	3 (23.08%)	0 (0.00%)	0 (0.00%)	0 (0.00%)
P	0.191	0.054	0.082	0.017*	
Alignment improvement only (N = 16)					
Baseline (%)	7 (43.75%)	8 (50.00%)	3 (18.75%)	3 (18.75%)	0 (0.00%)
1 yr (%)	4 (25.00%)	6 (37.50%)	2 (12.50%)	1 (6.25%)	0 (0.00%)
P	0.188	0.333	0.580	0.333	
mJOA and alignment improvement (N = 18)					
Baseline (%)	10 (55.56%)	13 (72.22%)	4 (22.22%)	5 (27.78%)	3 (16.67%)
1 yr (%)	3 (16.67%)	3 (16.67%)	2 (11.11%)	1 (5.56%)	2 (11.11%)
P	0.004*	<0.001*	0.331	0.104	0.579
No improvement (N = 23)					
Baseline (%)	5 (21.70%)	9 (39.10%)	10 (43.50%)	3 (13.00%)	2 (8.70%)
1 yr (%)	5 (21.70%)	5 (21.70%)	3 (13.60%)	0 (0.00%)	0 (0.00%)
P	1.000	0.186	0.005*	0.083	0.162

mJOA indicates modified Japanese Orthopaedic Association scale.
Asterisked values denote statistical significance of $P < 0.050$.

of sagittal realignment on HRQL outcomes independent of spinal cord decompression, a subanalysis was conducted on the eight patients undergoing CD-corrective surgeries involving only fusion, without decompressive components. In these fusion only-patients, there was a significant relationship between BL-1Y changes in C0-C2 angle and EQ-5D ($P = 0.037$, $r = -0.900$), as well as BL-1Y changes in SVA and mJOA ($P = 0.008$, $r = 0.926$).

TABLE 5. Correlations Between 1-Year Radiographic Parameters and 1-Year Patient Outcome Measures

1-Year radiographic parameter	1 Year mJOA *R*	1 Year mJOA *P*	1 Year EQ-5D *R*	1 Year EQ-5D *P*	1 Year NDI *R*	1 Year NDI *P*
PT (°)	0.173	0.202	0.139	0.289	−0.309	0.016*
PI-LL (°)	−0.084	0.537	0.040	0.764	−0.184	0.160
C2-S1 SVA (mm)	−0.424	0.002*	−0.261	0.050*	0.321	0.015*
C7-S1 SVA (mm)	−0.494	<0.001*	−0.284	0.031*	0.334	0.010*
T4-T12 TK (°)	0.061	0.656	0.064	0.626	−0.071	0.591
T1 Slope (°)	−0.105	0.449	−0.081	0.547	0.110	0.411
TS-CL (°)	−0.143	0.307	−0.218	0.103	0.233	0.081
C2-C7 CL (°)	0.012	0.930	0.095	0.484	−0.078	0.566
C2-C7 SVA (mm)	0.117	0.404	0.113	0.404	−0.062	0.645
C2-T3 (°)	−0.146	0.295	0.026	0.847	−0.038	0.780
C2-T3 SVA (mm)	0.048	0.733	0.076	0.575	−0.016	0.904
C2 slope (°)	−0.095	0.497	−0.201	0.133	0.228	0.087
C1 slope (°)	−0.197	0.132	−0.236	0.060	0.354	0.004*
C0 slope (°)	−0.202	0.124	−0.243	0.055	0.301	0.017*
C0-C2 angle (°)	0.049	0.726	−0.063	0.646	0.026	0.849
McGS (°)	−0.169	0.225	−0.231	0.086	0.350	0.008*

CL indicates cervical lordosis; cSVA, cervical sagittal vertical axis; EQ-5D, EuroQuol-5 dimensions questionnaire; LL, lumbar lordosis; McGS, McGregor line slope; mJOA, modified Japanese Orthopaedic Association scale; NDI, Neck Disability Index; PI, pelvic incidence; PT, pelvic tilt; SVA, sagittal vertical axis; TK, thoracic kyphosis; TS, T1 slope.
Asterisked values denote statistical significance of $P < 0.050$.

Correlations Between Radiographic Parameters and Myelopathy Outcomes

C2-S1 SVA ($r=-0.424$, $P=0.002$) and C7-S1 SVA ($r=-0.434$, $P<0.001$) at 1 year were the only radiographic parameters significantly correlated to 1-year mJOA score (Table 5). No significant relationships were observed between radiographic parameters and reaching 1-year MCID for mJOA. Radiographic parameters also showed no significant relationship to categorical improvement in myelopathy, both for patients who went from "severe" myelopathy to "moderate" or "mild," and for patients who went from "moderate" myelopathy to "mild" at 1 year (all $P>0.050$).

Correlations between Myelopathy Improvement and Patient-Reported EuroQuol-5 Dimensions/Neck Disability Index Outcomes

At the 1-year interval, mJOA score was significantly correlated with to both EQ-5D ($r=0.349$, $P<0.001$) and NDI ($r=-0.342$, $P<0.001$) scores. Both 1-year mJOA score ($r=0.349$, $P=0.005$) and reaching 1-year MCID for mJOA were significantly correlated with reaching 1-year MCID for EQ-5D ($r=0.244$, $P=0.042$).

DISCUSSION

As compared to improvement in radiographic alignment, improvement in myelopathy is underinvestigated as an important factor contributing to improved patient outcomes following CD-corrective surgery. Given the current lack of CD-specific patient outcomes measurements, it is necessary to investigate the relationship between radiographic alignment improvement, myelopathy improvement, and improved postoperative clinical outcomes using existing patient-reported outcome measurements. This study found significant correlations between 1-year C2-S1 SVA, C7-S1 SVA, mJOA, and 1-year EQ-5D scores; however, only 1-year mJOA score showed a significant relationship with reaching 1-year MCID for EQ-5D. These results suggest that improvements in myelopathy symptoms and functional score play a critical role in driving patient-reported outcomes following CD-corrective surgery.

Although the literature is sparse in investigating the relationship between myelopathy, sagittal alignment, and HRQL outcomes after CD-corrective surgery, an important study published by Tang *et al*[6] showed a significant connection between cSVA of more than 40 mm and worse outcomes on NDI and SF-36 HRQL outcomes measures. This study was limited, however, in its inability to assess patient differences between pre and postoperative myelopathy. In contrast to the Tang *et al* study, our results showed no correlation between baseline or 1-year cSVA alignment and improvements in NDI, EQ-5D, or mJOA. In addition, our results showed a strong correlation between reaching MCID for mJOA and reaching MCID for EQ-5D, suggesting that improvement in myelopathy plays an important role in improved overall patient outcomes following CD-corrective surgery.

Every patient group in the present study showed baseline to 1-year improvement in HRQL outcomes. That said, patients who improved only in alignment showed poorer overall outcomes than patients who improved only in mJOA and patients who improved in both alignment and mJOA. This was evidenced by the inferior mean 1-year EQ-5D/NDI scores of patients who improved in alignment only, and the lower rates of reaching 1-year EQ-5D MCID. Furthermore, although 1-year NDI score was significantly correlated with C1 slope and C0 slope, there were no cervical radiographic parameters correlated with either 1-year EQ-5D score or 1-year EQ-5D MCID. These results support the hypothesis that improvement in myelopathy is more important to overall patient outcomes following CD-corrective surgery than improvement in cervical alignment alone.

Indeed, our study is not the first to find a weak connection between cervical radiographic parameters and HRQL outcomes.[18,19] In a patient population diagnosed with adult idiopathic scoliosis, Aykac *et al*[20] found no correlation between patient-reported HRQL outcomes and the cervical-specific radiographic parameters of C0-C2 and C2-C7 lordosis. Guerin *et al*[21] also found no relationship between patient-reported HRQL outcomes and C2-C7 alignment; however, improvements in mean functional spinal unit angle were significantly correlated to favorable outcomes on the SF-36 survey, a patient-reported clinical outcomes instrument. That said, although our study found no correlations between cervical-specific sagittal parameters and patient-reported clinical outcomes, none of the HRQL assessment tools used in our analysis were specific to CD. To better assess the relationship between cervical malalignment and patient-reported outcomes in CD patients, a CD-specific HRQL instrument is necessary; however, such a tool has yet to be validated in the literature. Limitations with current patient-reported outcome measures are perhaps one of the largest areas of concern in the study of CD surgery, and should be the focus of intense future research.

In contrast to cervical-specific radiographic parameters, global SVA alignment showed a significant correlation with both 1-year EQ-5D and NDI scores. Relationships between C7-S1 SVA and patient-reported HRQL outcomes are not isolated to this study; Mac-Thiong *et al*[22] established correlations between positive C7-S1 SVA and worse Oswestry Disability Index scores in a population of patients diagnosed with adult scoliosis. Radovanovic *et al*[23] also found significant correlations between 1-year postoperative C7-S1 SVA and HRQL outcomes of patients undergoing surgery for lumbar degenerative spondylolisthesis. Of note, our study also found improved C2-S1 SVA—a global parameter that includes the cervical spine—to be significantly correlated with improved 1-year EQ-5D and NDI scores. This result suggests that the relationship between cervical alignment and patient-reported outcomes should not be overlooked. Indeed, our subanalysis of patients undergoing fusion-only, nondecompressive CD-corrective surgery showed a significant correlation between BL-1Y changes in C0-C2 angle and EQ-5D. Thus, although our results show that improvements in myelopathy symptoms and functional score play an important role in improved patient outcomes following CD-corrective surgery, realignment of the cervical curve does appear to influence patient-reported outcome measures. The respective roles of both cervical realignment and direct decompression on patient-outcomes in CD-corrective surgery remain ill-characterized in the literature.

This study appreciates a number of limitations. As the database used in this study is surgeon maintained, it lacks external validity and runs the risk of risk of surgeon-specific bias in patient selection. In addition, because surgeons at multiple different sites contribute to the database, there exists the risk of site-specific discrepancies in CD diagnosis. The small sample size of this study may also result in lack of statistical power. Still, the multicenter study design allows for increased generalizability of the results and the use of MCID as a metric for patient improvement lends increased clinical relevancy to the results.

CONCLUSION

After CD-corrective surgery, improvements in myelopathy symptoms and functional score were significantly associated with superior 1-year patient-reported outcomes. Although overall there were no relationships between cervical-specific sagittal parameters and patient outcomes, the global sagittal alignment parameters of C2-S1 SVA and C7-S1 SVA showed significant correlations with overall 1-year mJOA, EQ-5D, and NDI scores. Taken as a whole, these results indicate a connection between CD correction and improved patient-reported quality of life, and highlight myelopathy improvement as a key driver of patient-reported outcomes following CD-corrective surgery.

Key Points

- At 1-year postoperatively, 44% of patients improved in EQ-5D, 71.4% in NDI, and 44.3% in mJOA.
- Overall, improvements in 1-year postoperative mJOA, C2-S1 SVA, and C7-S1 SVA were correlated with improvements in 1-year EQ-5D and NDI scores.
- At 1-year postoperatively, 18.6% of patients met MCID for EQ-5D and mJOA, individually.
- Approximately 12.5% of patients who improved in cervical alignment only met 1-year MCID for mJOA, as compared to 33.3% of patients who improved in both cervical alignment and mJOA, and 38.5% of patients who improved in mJOA only.

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