Original Article

Cervical deformity patients with baseline hyperlordosis or hyperkyphosis differ in surgical treatment and radiographic outcomes

ABSTRACT

Introduction: Patients with symptomatic cervical deformity (CD) requiring surgical correction often present with hyperkyphosis (HK), though patients with hyperlordotic curves may require surgery as well. Few studies have investigated differences in CD-corrective surgery with regards to HK and hyperlordosis (HL).

Materials and Methods: Operative CD patients (C2-C7 Cobb >10°, cervical lordosis [CL] >10°, cervical sagittal vertical axis [cSVA] >4 cm, chin-brow vertical angle >25°) with baseline (BL) and 1Y radiographic data. Patients were stratified based on BL C2-7 lordosis (CL) angle: those >1 standard deviation (SD) from the mean (−6.96° ±21.47°) were hyperlordotic (>14.51°) or hyperkyphotic (28.43°) depending on directionality. Patients within 1 SD were considered the control group.

Results: One hundred and two surgical CD pts (61 years, 65%F, 30 kg/m^2) with BL and 1Y radiographic data were included. Twenty pts met definitions for HK and 21 pts met definitions for HL. No differences in demographics or disability were noted. HK had higher estimated blood loss (EBL) with anterior approaches than HL but similar EBL with the posterior approach. Op-time did not differ between groups. Control, HL, and HK groups differed in BL TS-CL (36.6° vs. 22.5° vs. 60.7°, $P < 0.001$) and BL-sagittal vertical axis (SVA) (10.8 vs. 7.0 vs. −47.8 mm, $P = 0.001$). HL pts had less discectomies, less corpectomies, and similar osteotomy rates to HK. HL had 3 revisions of HK and controls (28.6 vs. 10.0 vs. 9.2%, respectively, $P = 0.046$). At 1Y, HL pts had higher cSVA, and trended higher SVA and SS than HK. In terms of BL-upper cervical alignment, HK pts had higher McGregor's-slope (16.1° vs. −3.3°, $P = 0.001$) and C0-C2 Cobb (43.3° vs. 26.9°, $P < 0.001$), however postoperative differences in McGregor's slope and C0-C2 were not significant. HK drivers of deformity were primarily C (90%), whereas HL had primary computed tomography (38.1%), upper thoracic (23.8%), and C (14.3%) drivers.

Conclusions: Hyperlodotic patients trended higher revision rates with greater radiographic malalignment at 1Y postoperative, perhaps due to undercorrection compared to kyphotic etiologies.

Keywords: Cervical deformity, cervical lordosis, hyperlordosis, spine surgery

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INTRODUCTION

Since our earliest understanding of the human spine, it has generally been accepted that the cervical, thoracic, and lumbar curvatures exist in reciprocal lordotic and kyphotic harmony. As that understanding evolves, it has become increasingly evident that a wide variation of spinal curvatures exists in a healthy population, particularly for the cervical spine.[1,2] The cervical spine is incredibly complex with intricacies allowing for sufficient support of the cranium and an impressively wide range of motion. Because of its high mobility, a broad range of normal cervical alignment has been described, ranging from 9° to 22.2° between C2 and C7 segments.[3] Indeed, recent evidence suggests the cervical spine need not necessarily be lordotic at all, with straight or kyphotic angulations existing as normal variants.[4]

The most common method to assess cervical lordosis (CL) is with the Cobb angle, typically measured from C2 to C7. This angle may underestimate true CL but it remains a clinical mainstay with high intra- and inter-rater reliability.[5] While the majority of CL originates in the upper cervical spine (atlanto-axial joint), the subaxial region lies adjacent to the cervicothoracic junction and is more susceptible to lordotic or kyphotic compensation from thoracic changes below.[2] The unique load distribution of the cervical spine onto one anterior column (36%) and two posterior columns (64%) also plays an important role in determining subaxial curvature, especially under mechanical stress.[6] Whether these compensatory changes manifest into a hyperlordotic or hyperkyphotic cervical spine depends upon the etiology causing the cervical deformity (CD).

CD can occur in both the coronal and sagittal planes, though the latter is more frequent and associated with better clinical outcomes when surgically corrected.[7-9] Cervical kyphosis or hyperkyphosis (HK) is the most common presentation of sagittal CD and may arise secondary to degenerative causes, autoimmune phenomena, or previous spine surgery.[10,11] Hyperlordosis (HL), though rarer, can also manifest itself into a form of CD separate from its kyphotic counterpart. No consensus currently exists for optimal correction of CD, and there is a dearth of literature comparing hyperlordotic versus hyperkyphotic types with respect to postoperative alignment and outcomes.

Our objective, through a retrospective analysis of a cohort of operative CD patients, was to identify differences in surgical treatment, radiographic alignment, and clinical outcomes between two extremes of cervical spinal curvature–HL and HK–measured via the Cobb method. Overall, we aimed to shed light on a relatively rare and understudied patient population within CD in hopes of optimizing surgical strategy and perioperative planning.

MATERIALS AND METHODS

Data source

This study is a retrospective review of a prospective, multicenter CD database. Consenting patients were consecutively enrolled at 13 surgical centers across the United States from 2013 to 2017. All participating centers obtained Institutional Review Board approval before patient enrollment. Inclusion criteria for the database were age >18 years and radiographic evidence of CD, as defined by the presence of at least one of the following on baseline (BL) imaging: cervical kyphosis (C2-7 Cobb angle >10°), cervical scoliosis (C2-7 coronal Cobb angle <10°), C2-7 cervical sagittal vertical axis (cSVA) >40 mm or chin-brow vertical angle >25°. Additional inclusion criteria for the present analysis included available BL and 1-year postoperative (1Y) sagittal radiographic imaging.

Data collection and radiographic assessment

Patient demographics, comorbidities, self-reported disability index, and radiographic data were obtained with standardized patient questionnaires at the preoperative interval. Procedural, peri-operative, and postoperative radiographic data were collected following surgery at 1-year follow-up. Standardized health-related quality of life (HRQL) measures were administered at BL and 1Y study intervals and included the neck disability index (NDI), numeric rating scale (NRS) for both neck and back pain, the modified Japanese Orthopedics Association (mJOA) outcomes questionnaire, and the EuroQol 5-dimensions 3-severity-level (EQ-5D) questionnaire.

Preoperative standing lateral radiographs were collected at BL and 1Y intervals, and analyzed with SpineView® (ENSAM, Laboratory of Biomechanics, Paris, France) software as previously published.[12-14] Cervical alignment was assessed based on the following sagittal parameters: C2–C7 angle measured via the Cobb method, C2–C7 sagittal vertical axis (SVA), mismatch between T1 slope and (TS-CL), T1 slope, C0–C2 lordosis, and McGregor's slope (MGS) as previously described.[15] Global sagittal alignment was assessed based on the (SVA, C7 plumbline relative to the posterosuperior corner of S1, pelvic tilt (PT), and mismatch between plasticity index and liquid limit (PI-LL) as previously described.[15-17] Postoperative distal junctional kyphosis (DJK) was also assessed through the Cobb angle method between the superior endplate of the lowest instrumented vertebra (LIV) and the inferior endplate of the vertebra two levels superior to the LIV (LIV + 2). An angle >10° with a progression of at least 10° from BL was considered DJK.

Statistical analysis

Patients were grouped by respective CL C2–C7 angle relative to the mean CL angle of the cohort. A C2–C7 angle greater than or less than one standard deviation (SD) of the mean was considered HK or HL depending on respective directionality. C2–C7 angles within 1 SD of the mean were considered controls. Demographic, radiographic, and clinical, and surgical variables were summarized using means and SDs for continuous variables, and frequencies and percentages for categorical variables. Differences in BL demographics, surgical factors, radiographic alignment, and clinical outcomes between HK, HL, and control groups were assessed using analysis of variance sampling for normally distributed continuous variables, Mann–Whitney U tests for nonnormally distributed continuous variables and Chi-squared tests for categorical variables. Radiographic alignment at 1-year postoperative was compared across groups as described above, with a statistical cut-off of $P < 0.05$ indicating statistical significance. All statistical analyses were performed using SPSS software (v23.0, IBM, Armonk, NY, USA).

RESULTS

Overall cohort realignment

One hundred and two CD patients meeting inclusion criteria underwent corrective surgery. At 1-year, patients showed significant improvement in both regional and global alignment compared to BL: mean C2-7 Cobb angle increased ($P < 0.001$), TS-CL decreased ($P = 0.002$), C2-7 SVA decreased ($P < 0.001$), and C7-S1 SVA decreased as well ($P < 0.001$). Table 1 illustrates the overall cohort realignment.

Baseline demographics and radiographic details

One hundred and two surgical CD patients (61.4 ± 10.2 years, 29.0 ± 7.94 kg/m^2, Charlson comorbidity index [CCI]: 0.89 ± 1.19) had complete radiographic and clinical data at BL. Mean CL C2–C7 angle was −6.96° with an SD of 21.47° for the entire cohort. Twenty-one patients met definitions for HL, with a C2–C7 Cobb angle ≥ +14.51° (>1SD) at BL and a mean angle of 25.8°. Twenty patients met definitions for HK, with a C2-C7 Cobb angle ≤ −28.43° at BL and a mean angle of −41.7°. The remaining patients were within one SD of the mean C2–C7 angle and considered controls.

No differences in age ($P = 0.611$), body mass index ($P = 0.297$), and CCI ($P = 0.356$) were noted between HL, HK, and controls at BL [Table 2]. Radiographic differences existed at BL, with HK patients presenting significantly more malaligned in terms of TS-CL ($P < 0.001$), C7-S1 SVA ($P = 0.001$), MGS ($P = 0.002$) and C0–C2 upper CL ($P < 0.001$) compared to HL and controls. No significant differences in C2–C7 plumbline (cSVA), PT, sacral slope, and PI-LL were noted at BL (all $P > 0.05$).

In terms of BL HRQL metrics, no differences were found at BL between groups. HK, HL, and controls scored similarly in BL neck disability ($P = 0.922$), myelopathy symptoms ($P = 0.060$), EQ5D ($P = 0.106$), and NRS for neck pain ($P = 0.952$) [Table 3].

Procedural and perioperative details

The surgical approach differed according to BL HL or HK presentation. HL patients trended higher rates of posterior only approaches (73.7%) than HK (31.6%) or controls (46.5%) ($P = 0.028$), while HK patients trended higher rates of combined (anterior then posterior) approaches than HL patients (47.4% vs. 10.5%, $P = 0.046$). No differences in rates of anterior-only approaches were noted between groups ($P = 0.435$). HL patients trended significantly less index discectomies than HK or controls ($P = 0.023$). HL patients also trended less corpectomies than HK or controls ($P = 0.071$) but had similar rates of laminectomies and osteotomies ($P > 0.05$) [Table 2].

Perioperative outcomes including estimated blood loss (EBL), operative time (optime), length of stay (LOS) did not differ significantly between groups. For anterior approaches, HL patients trended less EBL than HK patients ($P = 0.286$) but similar to controls ($P = 0.841$). For posterior approaches, no differences in EBL were noted across groups ($P = 0.861$). HL patients trended lower optimes than HK for anterior approaches ($P = 0.136$) but similar optimes for posterior approaches ($P = 0.861$), though neither reached statistical significance. LOS did not differ significantly between groups as well ($P = 0.765$) [Table 2].

Postoperative radiographic outcomes at 3-months and 1-year

One-hundred and two surgical CD patients with complete postoperative radiographic data to a minimum follow-up of 1-year were analyzed. At 3 months postoperative, HL patients trended towards greater global malalignment: HL patients had greater PT on average than HK and control patients (27.6 vs. 22.9 vs. 20.3, $P = 0.059$), in addition to trending higher PI-LL mismatch (11.3 vs. 5.3 vs. 3.3, $P = 0.292$). No trends in cervical regional alignment parameters including TS-CL ($P = 0.392$) or cSVA ($P = 0.717$) were noted between HL and HK groups at 3-months.

By 1-year, HL patients had greater cervical and global malalignment, as illustrated by a significantly higher average cSVA ($P = 0.041$) and global SVA ($P = 0.092$). HL patients also trended higher mean sacral slope ($P = 0.091$), but similar TS-CL mismatch ($P = 0.234$), PT ($P = 0.375$) and PI-LL mismatch ($P = 0.736$). No differences in upper cervical parameters for MGS and C0–C2 angle were found at 3-months or 1-year (all $P > 0.05$). No differences in DJK

Table 1: Demographic, procedural, and radiographic differences (baseline and 1-year postoperatively) between patients with baseline hyperkyphosis, hyperlordosis, or neither (control)

	Control	HL	HK	*P*
Demographics				
Age (years)	60.3	59.1	61.8	0.709
Gender (female %)	63	68.4	72.2	0.710
BMI (kg/m^2)	30.1	27.4	27.3	0.222
CCI	1.00	0.74	0.63	0.495
Procedural factors				
Posterior only approach (%)	46.5	73.7	31.6	0.028*
Anterior only approach (%)	19.8	10.5	10.5	0.435
Combined approach (%)	33.7	10.5	47.4	0.046*
EBL, anterior approach (cc)	170.7	160.0	335.0	0.229
EBL, posterior approach (cc)	812.4	882.4	925.9	0.879
Operative time, anterior approach (min)	228.2	155.0	296.8	0.110
Operative time, posterior approach (min)	339.5	315.1	378.9	0.573
Length of stay (days)	7.71	8.31	6.00	0.765
Corpectomy	0.45	0.00	0.74	0.071
Discectomy	1.80	1.00	2.85	0.023*
Osteotomy	2.23	2.00	2.42	0.875
Smith-peterson osteotomy	0.85	1.38	0.80	0.577
Revision (%)	9.2	28.6	10.0	0.046*
Baseline radiographics				
C2-C7 Cobb	−6.89	25.8	−41.7	<0.001*
C2-C7 SVA (mm)	43.7	50.5	53.4	0.443
TS-CL (°)	36.6	22.5	60.7	<0.001*
T1 slope	29.7	48.3	19.0	<0.001*
C7-S1 SVA (mm)	10.8	7.01	−47.8	0.001*
PT (°)	20.4	18.1	17.9	0.799
PI-LL (°)	3.06	−1.91	−6.24	0.110
Sacral slope (°)	34.2	37.1	32.8	0.483
McGregor's slope (°)	3.28	−3.26	16.1	0.002*
C0-C2 angle (°)	32.8	26.9	43.3	<0.001*
PJK (%)	25.6	46.2	16.7	0.280
Radiographic parameters at 1Y				
C2-C7 Cobb	4.80	20.2	−0.60	<0.001*
C2-C7 SVA (mm)	39.5	49.8	33.8	0.041*
TS-CL (°)	30.1	24.2	26.7	0.234
T1 slope	34.9	44.3	26.1	0.003*
C7-S1 SVA (mm)	31.3	15.7	−13.3	0.092
PT (°)	19.6	17.5	23.0	0.375
PI-LL (°)	2.57	−0.84	−0.03	0.736
Sacral slope (°)	34.4	37.5	29.1	0.091
McGregor's slope (°)	−1.45	−3.79	−0.92	0.650
C0-C2 angle (°)	29.6	27.1	29.1	0.765
DJK rate (%)	26.7	15.8	26.3	0.597

Italicized values approached statistical significance, *Statistical significance to P<0.05. BMI – Body mass index, CCI – Charlson comorbidity index, EBL – Estimated blood loss, SVA – Sagittal vertical axis, TS – T1 slope, CL – Cervical lordosis, DJK – Distal junctional kyphosis, PI – Pelvic incidence, LL – Lumbar lordosis, HL – Hyperlordosis, HK – Hyperkyphosis, PT – Pelvic tilt, PJK – Proximal junctional kyphosis

magnitude (HL: 12.74°, HK: 15.51°, control: 12.66°, $P = 0.795$) or DJK rate (HL: 15.8%, HK: 26.3%, control: 26.7%, $P = 0.597$) were found between groups [Table 2].

Clinical outcomes at 3-months and 1-year

Differences in patient-reported HRQLs were analyzed across HL, HK, and control groups, both at 3-months and 1-year postoperative. Neither significant differences nor trends in NDI, mJOA, EQ5D, and NRS Neck pain scores were noted between groups at 3 months and 1 year (all $P > 0.05$). Rates of revision surgery were documented for patients as well. Of note, patients with BL HL had nearly three times the revision rate of HK and control patients, respectively (28.6% vs. 10% vs. 9.2%, $P = 0.046$) [Table 3].

Ames deformity classification

We correlated HL and HK groups with established Ames CD classifications. A significant majority (90%) of HK patients had their driver of deformity primarily in the cervical (C) region, whereas HL patients had primary cervicothoracic (CT, 38.1%), upper thoracic (UT, 23.8%), and cervical (14.3%) drivers.

Case examples

Figure 1 depicts pre- (left) and post- (right) operative full-length standing and cervical lateral radiographs of a 57-year-old female with BL HL (C2–C7 Cobb angle = 39.0°). By 1Y, cervical malalignment was still present, with cSVA = 86.8 mm and offset of T1 slope minus CL = 56.6°.

Figure 2 depicts neutral standing radiographs, preoperative (left) to 1Y postoperative (right) changes in a 58-year-old female with BL HK (BL: C2–C7 Cobb angle = −34.4°). CL was significantly restored at 1Y (C2–C7 Cobb = 4.3°) and cSVA significantly reduced (39.24-25.37 mm) without need for revision.

DISCUSSION

CD takes numerous forms and has etiologies ranging from iatrogenic causes to age-related degenerative changes.[8-11] Our study analyzed a cohort of CD patients with two extremes of cervical spinal curvature, both of whom benefited from corrective surgery as shown by improvement in radiographic alignment and modest myelopathy relief. Differences between HL and HK groups were found with respect to surgical treatment, sagittal realignment, and revision rates–though no differences in patient HRQLs were found. HL groups had persistent cervical sagittal malalignment (indicated by a higher cSVA) and global malalignment (indicated by a higher SVA and sacral slope) at 1-year follow-up compared to more conventional kyphotic CD patients. Importantly, HL patients also had a 31% revision rate in this period, which was three times higher than HK or controls. These patients had a higher rate of preoperative proximal junctional kyphosis (PJK), collectively leading us to believe that some patients with previous thoracolumbar correction and subsequent reciprocal changes in cervicothoracic alignment are being undertreated, or that such patients may not be as responsive to surgical correction due to the unique nature of their deformity.

To our knowledge, no previous database studies have investigated differences in management and outcomes with regards to this relatively rare CD sub-population. HL of the cervical spine has been well-documented in the literature with a wide range of symptomatology; however, no consensus for its range currently exists.[1,4,18-21] Blondel *et al*. reported a mean C2–C7 lordosis angle in asymptomatic individuals to range from 6.6° to 22.2° depending on age, with lordosis increasing with age and positive sagittal imbalance.[3] Using these normative ranges, our patients may have been expected to present with a more hyperlordotic subaxial curvature on average; however, Blondel *et al*. did not take into account the type or severity of CD. Our CD cohort had a mean C2-7 Cobb angle of −6.96° overall, indicating a much more severe kyphotic deformity at BL. Thus, given the number of chin-on-chest deformities and overall severity of CD in our patient population, we found it appropriate to define HL as a C2–C7 angle beyond one SD of the cohort average. We measured this using the same software as previously published by Blondel *et al*. to minimize any measurement inconsistency.

After surgical correction, patients who had HL of their cervical spine at BL showed more persistent cervical and global malalignment at 1-year compared to hyperkyphotic patients

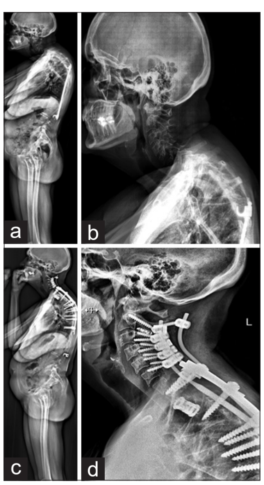

Figure 1: Pre- (a and b) and post-operative (c and d) full-length standing and cervical lateral radiographs of a patient with baseline hyperlordosis (C2-C7 Cobb angle = 39.0°). By 1Y, cervical malalignment was still present, with cervical sagittal vertical axis = 86.8 mm and offset of T1 slope minus cervical lordosis = 56.6°

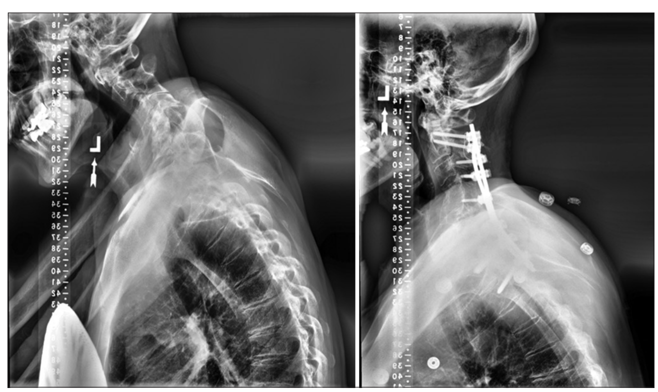

Figure 2: Neutral standing radiographs, preoperative (left) to 1Y postoperative (right) changes in a patient with baseline hyperkyphosis (baseline: C2–C7 Cobb angle = −34.4°). Cervical lordosis was significantly restored at 1Y (C2–C7 Cobb = 4.3°) and cervical sagittal vertical axis significantly reduced (39.24 to 25.37 mm) without need for revision

Table 2: Pre-to post-operative changes in sagittal alignment for our entire cohort of cervical deformity patients

Sagittal alignment parameters	Overall CD cohort correction		
	Preoperative	Postoperative	*P*
C2-C7 Cobb angle (°)	−7.13	6.84	<0.001*
C2-C7 SVA (mm)	46.7	40.5	0.002*
TS-CL (°)	37.5	28.5	<0.001*
C7-S1 SVA (mm)	−0.96	23.0	<0.001*
PT (°)	19.6	19.7	0.910
PI-LL (°)	0.77	2.31	0.167
Sacral slope (°)	34.2	34.0	0.872

*Statistical significance to $P<0.05$. CD – Cervical deformity, SVA – Sagittal vertical axis, TS – T1 slope, CL – Cervical lordosis, PI – Pelvic incidence, LL – Lumbar lordosis, PT – Pelvic tilt

Table 3: Differences in patient-reported outcome measures between control, hyperlordosis, and hyperkyphosis cohorts at baseline and 1-year follow-up

	PROMs			
	Control	HL	HK	*P*
Baseline				
mJOA	13.48	14.78*	12.56*	0.048*
NDI	49.78	46.15	50.86	0.666
EQ5D	0.726*	0.766*	0.731	0.037*
NRS neck pain	6.88	6.67	6.79	0.938
1-year postoperative				
mJOA	14.10	15.24	14.14	0.371
NDI	37.50	34.68	37.84	0.877
EQ5D	0.774	0.818	0.790	0.139
NRS neck pain	4.10	4.29	4.79	0.740

*Statistical significance to $P<0.05$. PROMs – Patient-reported outcome measures, HL – Hyperlordosis, HK – Hyperkyphosis, mJOA – Modified Japanese orthopedics association, NDI – Neck disability index, NRS – Numeric Rating Scale

or controls (within 1 SD), with a higher cSVA (49.7 mm), SVA (15.7 mm), and sacral slope (37.5). Previous studies have investigated etiologies of pathological changes in the cervical spine such as HL, particularly with respect to previous thoracolumbar fixation.[22-27] Smith *et al*. demonstrated that in a cohort of patients with adult spinal deformity (ASD), positive sagittal malalignment correlated with abnormally increased CL in an effort to maintain horizontal gaze.[26] Some of these patients were shown to undergo spontaneous correction of their cervical HL following correction of their primary sagittal malalignment with pedicle subtraction osteotomy, with a significant reduction in mean C2-7 Cobb angle from 30.8° to 21.6° (P < 0.001). Similarly, Jang *et al*. found that in a cohort of 53 patients treated for lumbar degenerative kyphosis, thoracic kyphosis (TK) was significantly restored from 1.1° to 17.6° following correction of sagittal malalignment.[28] Despite these important findings, the nature of reciprocal changes in adjacent segments, especially cervical, remains complex.

Other studies have suggested that despite adequate restoration of global sagittal balance, cervical HL may remain resistant to correction.[29] Oh *et al*. conducted a multicenter analysis of 57 ASD patients undergoing correction of their thoracic deformity and found that patients with concomitant cervical HL did not see significant improvement in their cervical malalignment. In fact, the authors were surprised to find that cSVA actually increased from 41.7 to 47.0 at 2-year follow-up. The authors suggested this may have been due to undercorrection of the entire deformity, particularly in the UT region from T1-4.[29] Our HL patients trended higher rates of concurrent PJK at BL, which typically occurs in the UT and cervicothoracic junction. Logically, we can posit that their cervical malalignment will thus remain resistant to correction if adjacent thoracic segments causing hyperlordotic reciprocal changes are not also adequately realigned.

HL patients trended higher positive sagittal malalignment with greater SVA and sacral slopes on average than hyperkyphotics. Though these relationships did not reach statistical significance (likely due to the low power of our sample size), they remain important in the context of whole-body alignment and chain of correlation–from the pelvis to lumbar, lumbar to thoracic, and thoracic to cervical. Numerous studies have shown pelvic incidence to accurately predict lumbar lordosis.[7,30,31] Likewise, CL has been correlated to changes in T1 slope, with Protopsaltis *et al*. reporting a T1 slope minus CL >17° indicative of CD.[32] Staub *et al*. also utilized normal gaze and mobile cervical spines to generate a normative TS-CL cut-off value of 16.5°.[33] The degree of change in T1 slope was found to directly correlate to a change in C2-7 Cobb angle, with an increase in one leading to an increase in another. Importantly, T1 slope is known to be the only cervical parameter that also correlates with other spinopelvic parameters.[34-38] Not surprisingly, we found that in patients with cervical HK whose C2-7 lordosis increased significantly (−40.0° to −0.59°, P < 0.001), T1 slope also increased significantly (13.8–26.1, P = 0.002) with significant improvement in T2-12 TK (P = 0.011). On the other hand, hyperlordotic patients whose C2-7 lordosis did not decrease significantly (24.8-20.2, P = 0.232) did not experience a significant improvement in T1 slope (45.0-44.3, P = 0.765) nor T2-12 TK (P = 0.327). Even when controlling for those patients who were previously fused, HL patients did not show significant decrease in C2-7 CL (29.3-19.3, P = 0.067) or improvement in T1 slope (43.2–44.3, P = 0.661) at 1-year.

Aside from the number of discectomies performed, we did not find significant differences between HL and HK patients with regards to surgical treatment. This lack of a difference may be problematic in light of recent findings of the literature, which have shown that UT osteotomies during correction of marked CD can indirectly decrease CL via a reduction in T1 slope.[33] While HL patients did show slightly higher rates of Smith-Peterson osteotomy than others, this trend was not close to reaching significance. These results, coupled with the persistence of cervical and global malalignment in HL patients as previously illustrated, may suggest a need for more aggressive surgical treatment.

Limitations of our study include the retrospective nature of our analysis, which may inherently restrict the granularity of our analyses. The strength of our multicenter-based study could also be considered a limitation, introducing potential variability in surgical technique, clinician preference, and procedural bias. Future studies should focus on prospective data collection and larger sample size, especially in the relatively rare sub-populations at hand. Though the present study found no differences between HL and HK patients with regards to clinical outcomes, future studies should correlate patient HRQL metrics with varying extremes of cervical curvature, as this could prove to be an important issue.

CONCLUSIONS

Cervical HL and HK exist within a spectrum of CD that remain underexplored. This multicenter analysis of consecutively enrolled CD patients undergoing surgical correction revealed that patients with a BL hyperlordotic deformity may be undertreated and inadequately realigned in the context of their unique presentation. Whereas hyperkyphotic CD patients had lower cSVA and SVA at 1-year, hyperlordotic cervical deformities proved more resistant to proper sagittal realignment. As a result, special consideration in this patient population should be encouraged, and clinicians should be aware of a potentially increased risk for persistent cervical malalignment following surgical correction.

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Conflicts of interest
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