Segmental analysis of radiological outcomes after one and two-level anterior cervical discectomy and fusion

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SIGNIFICANCE

This study provides insight into the impact of cervical lordosis on adjacent segmental alignment, and the segmental differences between cervical and thoracolumbar spine.

INTRODUCTION

- Development of cervical degenerative disease caused by factors such as aging can lead to the loss of cervical lordosis
- Anterior cervical discectomy and fusion (ACDF) is a common surgical procedure to treat cervical degenerative diseases
- Previous study in the thoracolumbar spine found that increased index lordosis (vertebral level at which implant was placed) did not impact global alignment, but adjacent segments experienced reciprocal kyphosis. There are no similar studies in the cervical region.
- This study aims to determine the impact of adding lordosis or kyphosis at the index level on adjacent segmental alignment of the cervical spine.

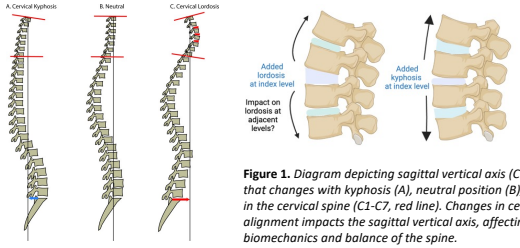

Figure 1. *Diagram depicting sagittal vertical axis (C1-S1, black line) that changes with kyphosis (A), neutral position (B), and lordosis (C) in the cervical spine (C1-C7, red line). Changes in cervical sagittal alignment impacts the sagittal vertical axis, affecting load biomechanics and balance of the spine.*

METHODS

625 patients underwent ACDF between 2019-2022

249 patients underwent *cervical ACDF

53 pts: 3 level cervical ACDF
24 pts: 4 level cervical ACDF
**if most levels fused = less opp for ASD to occur

170 patients underwent 1-2 level cervical ACDF
79 pts: 1 level
91 pts: 2 level

~exclusion criteria

64 patients included in study

	Increased lordosis	No change lordosis
Cage level (1 level)		
C2-C3	0	0
C3-C4	0	2
C4-C5	5	1
C5-C6	4	7
C6-C7	3	3
C7-T1	1	0
Cage level (2 level)		
C3-C5	2	1
C4-C6	5	3
C5-C7	14	12
C6-T1	1	0

Table . A total of 64 patients with 107 interbody levels (C5-C7 most common fused) were included after exclusion criteria. 249 patients underwent cervical ACDF, and with 53 and 24 patients excluded for 3-4 level ACDF. 170 patients underwent 1-2 level ACDF (79 patients: 1 level, 91 patients: 2 level).

METHODS (CONT).

1. Patient selection

Inclusion:
- **Pts > 18 years, 1-2 level cervical ACDF w/ conduit cages at OSUWMC between 2019-2022**

Exclusion:
- patients without a preoperative film
- last postoperative film < 6 month
- death before 1-year postoperative film
- patients receiving revision surgery
- 2 cage morph surgeries
- if images are external and cannot be measured with Nilread

2. Patient demographic data

- Age, sex, height, weight, BMI
- American Society of Anesthesiologist (ASA) classifications (1, 2, 3)
- smoking status
- drug use
- alcohol use
- diabetes mellitus
- osteopenia/osteoporosis

3. Radiographic data

- Upright, lateral x-ray
- **Radiographs measured using: preop, 6 week, last postop (≥ 6 months or 1 year)**

Collected Preop, 6 week, last postop, & delta measurements (2 reviewers)
- **Global cervical lordosis (C1-C7)**
- **Cervical lordosis (C2-C7)**
- **External auditory canal (EAC) to C7**
- **C2-C7 Sagittal vertical axis (SVA)**
- **Anterior and posterior interspace disc height**
  - C2-C3, C3-C4, C4-C5, C6-C7, C7-T1
- **Mean Index ADH**
- **Mean Index PDH**
- **Mean Index level segmental lordosis**
- **Mean Adjacent level lordosis**
- **Occipitocervical inclination (OCI)**
- **Occiput-C2 angle (OC2A)**
- **Occiput-C2 spinous process distance (OC2D)**
- **C7 slope**
- **T1 slope**

4. Analysis

2 cohorts
- increased lordosis vs. no increase/change lordosis
- Defined: if delta = + or – (delta is mean postop – mean preop index lordosis)

Stats:
- R programming (unpaired/paired t-tests, linear regression)

RESULTS

	Increased lordosis (n = 35)	No change/increase lordosis (n = 29)	P-value
Global cervical lordosis (C1-C7)			
Preop	35.83 +/- 13.16	45.71 +/- 14.34	**0.0056**
Postop	40.66 +/- 14.11	44.98 +/- 12.33	0.3616
Change	4.83 +/-13.04	-0.27 +/- 10.11	**0.04439**
P-value	**0.0354**	0.4539	
Cervical lordosis (C2-C7)			
Preop	5.79 +/- 10.35	11.62 +/- 13.31	0.053
Postop	9.11 +/- 12.76	12.14 +/- 12.21	0.3066
Change	3.14 +/- 9.68	0.64 +/- 8.86	0.252
P-value	**0.04099**	0.661	
EAC-C7			
Preop	33.51 +/- 14.34	30.75 +/- 21.43	0.5796
Postop	32.99 +/- 19.23	29.53 +/- 19	0.3133
Change	-0.356 +/- 13.73	-1.37 +/- 13.65	0.5239
P-value	0.8791	0.3529	
C2-C7 SVA			
Preop	32.51 +/- 11.69	31.46 +/- 14.86	0.7534
Postop	32.63 +/- 15.66	30.92 +/- 15.51	0.5464
Change	**0.123 +/- 9.88**	**-0.186 +/- 8.59**	0.5924
P-value	0.9418	0.5202	

	Increased lordosis (n = 35)	No change/increase lordosis (n = 29)	P-value
OCI			
Preop	104.57 +/- 9.63	102 +/- 9.47	0.2881
Postop	104.79 +/- 10.01	101.62 +/- 10.77	0.2285
Change	0.21 +/- 5.92	-0.82 +/- 10.12	0.9354
P-value	0.8318	0.8343	
OC2A			
Preop	20.76 +/- 8.49	21.36 +/- 9.24	0.786
Postop	20.59 +/- 8.06	20.41 +/- 8.21	0.9332
Change	-0.171 +/- 6.99	-1.125 +/- 5.91	0.9033
P-value	0.8856	0.3929	
OC2D			
Preop	24.78 +/- 6.49	26.41 +/- 6.75	0.4301
Postop	24.63 +/- 4.84	26.53 +/- 5.8	0.2326
Change	-0.32 +/- 5.16	0.059 +/- 4.48	0.3806
P-value	0.8612	0.8871	
C7 slope to floor			
Preop	24.23 +/- 8.59	28.79 +/- 10.11	0.05541
Postop	24.51 +/- 9.46	27.24 +/- 10.28	0.2741
Change	0.29 +/-9.34	-1.64 +/- 6.27	0.3504
P-value	0.8575	0.187	
T1 slope to floor			
Preop	26.44 +/- 8.79	31.91 +/- 8.93	0.1155
Postop	30.36 +/- 9.26	33.94 +/- 10.61	0.6745
Change	3.85 +/- 7.48	2.13 +/- 6.61	0.3194
P-value	**0.005814**	0.1159	

Table 2. *Increased lordosis → Increased global alignment.
- Significant difference in preop GCL between 2 groups
- Significant Change in GCL (C1-C7) from preop to postop when add lordosis
- Significant Change in CL (C2-C7) from preop to postop when add lordosis
- *C2-C7 SVA decreased when you add kyphosis (not a significant change)
- *Increased lordosis → Increased T1 slope

	Increased lordosis (n = 35)	No change/increase lordosis (n = 29)	P-value
Index segmental lordosis			
Preop	1.54 +/- 2.85	4.62 +/- 2.43	**2.122e-05**
Postop	5.12 +/- 2.59	2.09 +/- 2.17	**4.707e-06**
Change	3.75 +/- 3.26	-2.55 +/- 2.11	**3.46e-11**
P-value	**4.85e-07**	**3.594e-07**	
Index Anterior disc space height (mm)			
Preop	3.47 +/- 0.78	4.17 +/- 1.21	**0.008026**
Postop	5.92 +/- 1.69	5.36 +/- 1.29	0.1439
Change	2.45 +/- 1.74	1.19 +/- 1.5	**0.002788**
P-value	**9.398e-10**	**0.0001391**	
Index Posterior disc space height (mm)			
Preop	3.28 +/- 0.95	3.03 +/- 1.13	0.3375
Postop	4.69 +/- 1.35	4.69 +/- 1.15	0.9986
Change	1.42 +/- 1.56	1.72 +/- 1.36	0.5025
P-value	**5.233e-06**	**4.68e-07**	
Adjacent segmental lordosis			
Preop	1.7 +/- 4.79	3.39 +/- 4.27	**0.01207**
Postop	2.16 +/- 5.29	3.43 +/- 3.81	0.07721
Change	0.33 +/- 3.95	0.125 +/- 3.33	0.813
P-value	0.6724	0.9729	

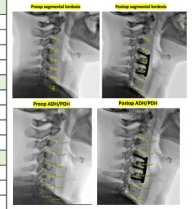

Table 3. *Increased lordosis → Increased index ADH & PDH
- Significant difference in preop index ADH between 2 groups
- *Significant Change in index lordosis from preop to postop when you add lordosis / when add kyphosis
- Significant change in index ADH and PDH preop and postop for 2 groups)

	Increased lordosis (n = 35)	No change/increase lordosis (n = 29)	P-value
Above index level segmental lordosis (just 1 level above index)			
Preop	1.7 +/- 4.79	3.39 +/- 4.27	0.1435
Postop	2.16 +/- 5.29	3.43 +/- 3.81	0.2942
Change	0.33 +/- 3.95	0.125 +/- 3.33	0.6212
P-value	0.4638	0.9552	
Below index level segmental lordosis (just 1 level below index)			
Preop	3.37 +- 2.89	4.39 +/- 2.98	0.1869
Postop	4.24 +/- 3.24	4.82 +/- 3.4	0.4994
Change	0.61 +/- 2.33	0.43 +/- 3.36	0.4306
P-value	0.1534	0.4973	
Adjacent ADH (above + below)			
Preop	4.38 +/- 0.65	4.67 +/- 0.86	0.1406
Postop	4.47 +/- 0.97	4.67 +/- 0.71	0.1326
Change	0.082 +/- 0.74	0.034 +/- 0.69	0.6479
P-value	0.5194	0.9973	
Adjacent PDH (above + below)			
Preop	3.8 +/- 0.71	3.73 +/- 0.73	0.6991
Postop	3.73 +/- 0.62	3.82 +/- 0.68	0.5087
Change	-0.077 +/- 0.61	0.06 +/- 0.65	0.2941
P-value	0.461	0.4615	

RESULTS (CONT)

	Index lordosis (p-value)
Index ADH	**4.234e-06**
Index PDH	**0.09511**
Adjacent lordosis	0.3754
Adjacent ADH	0.6304
Adjacent PDH	0.2672
Global cervical lordosis (c1-c7)	0.06699
C2-C7 lordosis	0.7495
EAC-C7	0.9346
C2-C7 SVA	0.9458
OCI	0.7179
OC2A	0.608
OC2D	0.7445
C7 slope	0.09712
T1 slope	0.3445
Adjacent ADH	0.33
Adjacent PDH	0.5319

	Estimate	P-value
Above index level segmental lordosis (just 1 level above index)	-0.022634	0.91090
Below index level segmental lordosis (just 1 level below index)	0.134032	0.49161
Global cervical lordosis (C1-C7)	0.090306	0.15431
Cervical lordosis (C2-C7)	-0.040405	0.61194
EAC-C7	-0.037545	0.61767
C2-C7 SVA	0.004225	0.97172
Adjacent segmental lordosis	-0.044028	0.91413
Index Anterior disc space height	**1.590275**	**0.00047 *** **
Index Posterior disc space height	**-1.323907**	**0.00660 ** **
Adjacent ADH	0.569006	0.55142
Adjacent PDH	-0.996767	0.36958
OCI	-0.077657	0.27930
OC2A	-0.007497	0.93476
OC2D	-0.153930	0.21619
C7 slope	0.061143	0.45473
T1 slope	-0.159413	0.11537

Table 4. Both bivariate and multivariate linear regression showed that Index lordosis is significantly correlated with index ADH, PDH

CONCLUSION

- Increasing lordosis at the index level leads to an increased global alignment (global cervical lordosis C1-C7 and C2-C7), with exception of C2-C7 sagittal vertical axis, which decreased when kyphosis was added though the change was not significant.
- Increased index lordosis also led to increased index ADH, and T1 slope, indicating that more lordosis was needed to keep the neck vertical
- However, increased index lordosis had no significant change on adjacent segmental lordosis, adjacent ADH, and adjacent PDH
- This study provides insight into the impact of cervical lordosis on adjacent segmental alignment, and the segmental differences between cervical and thoracolumbar spine.

FUTURE STEPS

- In future work, we will expand the patient database to include more patients with 1-2 level cervical ACDF

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