

The impact of the lower instrumented level on outcomes in cervical deformity surgery

ABSTRACT

Background: The lower instrumented vertebrae (LIVs) in cervical deformity (CD) constructs may have varying effects on patient outcomes that are still poorly understood.

Objective: The objective of the study is to compare outcomes in CD patients undergoing instrumented correction according to the relation of LIV with primary driver (PD).

Methods: Patients who met radiographic criteria for CD were included in the study. Patients were stratified by PD of deformity: cervical (C) through AMES classification (TS-CL >20 or cervical sagittal vertical axis >40) and thoracic (T) through hyper/hypokyphosis (TK) from T4-T12 (60 < TK < 40). Patients were further stratified by LIV in relation to curve apex (above/below). Univariate and multivariate analyses identified group differences in postoperative health-related quality-of-life and distal junctional kyphosis (DJK) (>10° LIV and LIV + 2) rate up to 1 year.

Results: Sixty-two patients were analyzed. Twenty-one patients had a C-PD and 41 had a T-PD by definition. 100% of C-PDs had LIVs below CL apex, while 9.2% of T-PDs had LIVs below (caudal) to TK apex and 90.8% had LIVs above TK apex. By 1 year, C patients trended lower Neck Disability Index (NDI) (21.9 vs. 29.0, $P = 0.245$), lower numeric rating scales neck pain (4.2 vs. 5.1, $P = 0.358$), and significantly higher EuroQol five-dimensional questionnaire Visual Analog Scale (69.2 vs. 52.4, $P = 0.040$). When T patients with LIVs below TK apex were excluded, remaining T patients with LIV above apex had significantly higher 1-year NDI than C patients (37.5 vs. 21.9, $P = .05$). T patients also trended higher rates of postoperative DJK than C (19.5% vs. 4.8%, $P = 0.119$).

Conclusions: Stopping before apex was more common in patients with a primary thoracic driver (T) and associated with deleterious effects. Primary cervical driver (C) tended to have LIVs inclusive of CL apex with lower rates of DJK.

Keywords: Cervical, deformity, outcomes

INTRODUCTION

The natural shift from a flexible lordotic cervical spine to a relatively fixed thoracic kyphotic spine gives rise to highly heterogenic presentation and manifestation of cervical deformity (CD).^[1,2] To improve specification of CD subtypes, the AMES-ISSG cervical spine deformity classification system was developed. Categorizing CD based on primary sagittal or coronal deformity apex, the classification system provides a basis for greater case-specific management and treatment.^[3,4] Passias *et al.* further delineated CD by primary driver (PD) regions of deformity and their influence on cervical and global postoperative alignment.^[2] The authors demonstrated that PDs originating in the thoracic versus the cervical region of

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the spine result in significant CD differences; particularly, thoracic PD patients were shown to have greater thoracic kyphosis (TK), lumbar lordosis, T1 slope, and CO-2 angle.^[2]

Despite greater appreciation for the complexity and varied presentation of CD, distal junctional kyphosis (DJK) following corrective fusion surgery remains a significant postoperative concern.^[5,6] High mechanical stress due to rigid instrumentation may subsequently alter the alignment of adjacent levels above or below the fusion.^[7] DJK occurs when adjacent levels below the instrumented vertebra slowly shift, possibly resulting in further malalignment, instrumentation failure, myelopathy, and radiculopathy.^[8] Determining the level where instrumentation ends can influence surgical outcomes, as correct placement of the lower instrumented vertebrae (LIVs) has been shown to reduce the risk of DJK in thoracic deformity surgery.^[9] Given the known biomechanical complexities of CD, selecting proper placement of the LIV may be multifactorial and requires further investigation.

It is currently unknown if certain factors, including PD type, should influence placement of the LIV below the apex of deformity during corrective CD surgery. Furthermore, the effects of LIV on health-related quality-of-life (HRQL) outcomes after CD surgery are still poorly understood. The objective of this study is to compare outcomes in CD patients undergoing instrumented correction according to the relation of LIV with consideration of cervical and thoracic PD of deformity.

METHODS

Study inclusion and exclusion criteria

This was a retrospective analysis of consecutively enrolled patients >18 years of age with primary cervical diagnoses undergoing cervical fusion by a single spine surgeon at an academic institution. Institutional review board approval was obtained, and before enrollment, informed consent was obtained. Criteria for database inclusion required a planned elective multilevel (at least 2 contiguous levels fused) posterior or anterior cervical fusion ending proximal to or distal to the cervicothoracic junction with mild to severe radiographic CD: cervical kyphosis >10°, scoliosis (coronal Cobb >10°), positive cervical sagittal imbalance (cervical sagittal vertical axis [cSVA] >4 cm or TS-CL >10°), or chin-to-brow vertical angle (CBVA) >25°. The database encompasses a range of diagnoses including cervical disc herniation, spinal stenosis, spondylolisthesis, degenerative scoliosis, and adjacent segment disease. Patients included had neurological involvement, either radiculopathy or myelopathy or both, in addition to mild CD. Study inclusion criteria

required full baseline and 1-year HRQL and radiographic data. Exclusion criteria comprised of a history of cervical fusion, diagnosis of trauma, ankylosing spondylitis, rheumatoid arthritis or chronic autoimmune conditions, neoplasm, systemic infection, or preoperative spinal infection.

Data collection, radiographic, and HRQL assessment

Patient demographic and clinical data assessed included patient age, gender, body mass index (BMI), and Charlson comorbidity index (CCI) burden. Operative data were collected and included total number of levels fused, surgical approach, decompression and osteotomy incidence, estimated blood loss, and total operative time.

To assess the regional and global radiographic parameters of the spine, preoperative and follow-up full-length free-standing lateral spine radiographs were measured with SpineView® (ENSAM, Laboratory of Biomechanics, Paris, France) software at a single academic center. Cervical radiographic parameters assessed included (cSVA: C2 plumbline offset from the posterosuperior corner of C7), T1 slope minus CL (TS-CL: mismatch between T1 slope and cervical curvature), CBVA. Global radiographic alignment parameters investigated included T4-T12 angle (TK).

Collection of HRQL data included the modified Japanese orthopedic association (mJOA) score, neck disability index (NDI), EuroQol five-dimensional questionnaire (EQ5D), and the numeric rating scales (NRS) for neck and back pain.

Cervical deformity drivers and patient grouping

Blinded preoperative patient radiographs (cervical, full-spine, and flexion-extension) were assessed to identify PDs of CD. Surgeon consensus and grouped all patients into deformity PD type according to the AMES-ACD classification system.^[2] The AMES-ACD classification system incorporates a sagittal deformity descriptor (C – cervical; CT – cervicothoracic; T – thoracic) if they demonstrated a TS-CL >20° or a cSVA >40 mm. In contrast, the T patients were identified through hyper/hypokyphosis (TK) at the T4-T12 angle with an angle >60° and <40°. These patients were then further grouped by their LIV in relation to the curve apex, either above or below.

Assessment of distal junction kyphosis

DJK was defined per physician note or radiographically as DJK angle <−10° (kyphosis between the superior endplate of the LIV and the inferior endplate of the second distal vertebra [LIV-2]) and a baseline to postoperative change in the DJK angle by <−10°.

Statistical analysis

Demographic, clinical, and surgical data were assessed with descriptive analyses. Chi-square and independent sample *t*-test analyses assessed the frequencies and means of patient characteristic between PD (C or T) of deformity and location of the LIV. One-way analysis of variance ascertained significant variation for continuous variables. Tests were two sided, and significance was set to a $P < 0.05$. All analyses were conducted with IBM Statistical Package SPSS software (version 23.0, Armonk, NY, USA).

RESULTS

Baseline demographics

Sixty-two patients who underwent elective cervical fusion surgeries by a single surgeon were included in this study. The average age was 54.9 years and 62.8% of patients were female. Mean BMI for the cohort was 29.6 kg/m² with a mean CCI of 0.65 ± 1.0. The most common comorbidities were diabetes (27.9%), vascular disease (19.1%), and pulmonary disease (7.5%). At baseline, the patients included had a mean NDI of 60.2, EQ5D Visual Analog Scale (VAS) of 61.1, mJOA 12.8, NRS Neck 8.0, NRS Back 6.5. 21 (33.9%) of the patients presented with cervical PDs (C-PD) and 41 (66.1%) had identified thoracic PDs (T-PD). Between the PD groups, age, gender, BMI, and CCI were not significant ($P > 0.050$). Baseline HRQLs were also not significantly different between the two driver groups, $P > 0.050$.

Radiographic parameters and lower instrumented vertebra location

For the cohort, the mean preoperative TS-CL was 28.1°, cSVA 26.9 mm, T4-T12 angle of 38.1°. 100% (21/21) of C-PD patients had LIVs below their CL apex, while 9.2% of T-PD patients had LIVs caudal to the TK apex. 90.8% of T-PD had their LIVs above the TK apex.

Patient-reported outcomes between primary driver groups

At baseline and 3 months postoperatively, there were no differences in HRQLs between C-PD and T-PD groups. By 1 year, C-PD patients trended toward lower NDI scores (C-PD: 21.9 vs. T-PD: 29.0, $P = 0.245$), lower NRS neck pain scores (C-PD: 4.2 vs. T-PD: 5.1, $P = 0.358$), and significantly higher EQ5D VAS (C-PD: 69.2 vs. T-PD: 52.4, $P = 0.040$) in comparison to the thoracic PD group. No significant differences in mJOA were found ($P > 0.05$).

Patient-reported outcomes based upon lower instrumented vertebra apex

When thoracic patients with LIVs below the thoracic apex (9.2%) were excluded from the analysis, remaining thoracic patients with LIV above apex had significantly

higher (worse) 1-year NDI than cervical patients (37.5 vs. 21.9, $P = 0.05$). Thoracic patients also trended higher rates of postoperative DJK than cervical patients (19.5% vs. 4.8%, $P = 0.119$).

DISCUSSION

The onset of proximal junctional kyphosis of the thoracolumbar spine due to improper instrumentation length and location is well established in literature.^[10-13] Although less commonly assessed, DJK can develop after corrective surgery for Scheuermann disease, adolescent idiopathic scoliosis (AIS), and CD.^[8,14,15] Reported DJK incidence for CD corrective surgery is approximately 23.8% at 2-year postoperative and can be a costly complication resulting in revision surgery.^[15,16] Until recently, corrective surgery for CD did not consider the interdependence of global sagittal alignment, such as cervicothoracic, thoracic, and lumbosacral PDs of CD, during long-term cervical realignment strategy.^[2,17] The influence of PD on appropriate LIV fixation for CD surgery is currently unknown. This study attempts to determine whether or not LIV below or above deformity apex based on PD affects postoperative HRQL and incidence of DJK.

In this study, 100% of CD patients with cervical PDs had LIV below the cervical lordosis apex, while only 9.2% of CD patients with thoracic PDs had LIV below the TK apex. At 1-year postoperative, cervical PD patients trended toward improved NDI and NRS neck pain scores with significantly higher EQ5D VAS scores. When thoracic PD patients with LIV below the TK apex were excluded, cervical PD patients had significantly higher 1-year NDI than the remaining thoracic PD patients. In addition to worse HRQL, thoracic PD patients trended toward higher rates of DJK at 1-year follow-up, suggesting that inclusion of apex beyond the CD may play a role in reduced DJK incidence. Interestingly, these findings are not consistent with a study evaluating DJK incidence and HRQL for CD corrective surgery. A recent retrospective review of 101 CD patients who underwent corrective deformity surgery did not find DJK to be correlated with HRQL outcomes.^[15]

Previous research indicates that placement of the LIV beyond the apex of deformity is successful in minimizing DJK in cervical and thoracic deformity surgery.^[9,18-20] An aforementioned study by Yang *et al.* assessed DJK incidence in thoracic AIS based on inclusion of the stable sagittal vertebra (SSV) defined as the most proximal lumbar vertebra crossing the vertical line from the posterior-superior corner of the sacrum.^[9,21] The authors noted LIV below the SSV

demonstrated lower rates of DJK incidence in comparison to cases in which the LIV was superior to the SSV.^[9] Passias *et al.* found that inclusion of driver apex for CD corrective surgery in cases of cervical and thoracic PDs is especially important for reducing postoperative deformity.^[18] A retrospective analysis of 98 CD patients by Osterhoff paper *et al.* assessed surgical outcomes. Inclusion of the cervicothoracic junction in the LIV leads to lower rates of symptomatic pathologies below fixation.^[19]

This analysis demonstrates that inclusion of the apex of deformity was more commonly performed in CD patients with cervical PDs compared to thoracic PDs. When the LIV was above the apex of deformity, thoracic PD patients showed significantly worse postoperative HRQL compared to cervical PD patients. Furthermore, thoracic PDs patients trended toward greater DJK incidence at 1-year follow-up.

Limitations

The retrospective nature of the cohort can inherently lead to potential reporting or observer bias. Using data collected from one surgeon operating in an academic setting may not be representative of the average physician and average hospital, a primary cervical diagnoses patient receives treatment at in the United States. Furthermore, a study of this nature cannot examine causality and 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. This study is also limited by a limited patient sample size, especially for the cervical PD group. At 1-year postoperative, this study may be hindered by a relatively short follow-up time for DJK incidence.

CONCLUSIONS

Stopping before apex in patients with a primary thoracic driver and associated with deleterious effects. Those with a primary cervical driver tended to have LIVs inclusive of CL apex with lower rates of postoperative DJK. In addition, thoracic PD patients with LIVs above TK apex had significantly higher NDI and lower EQ5D VAS scores by 1 year.

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Conflicts of interest

Peter G Passias MD – Reports personal consulting fees for Spinewave, Zimmer Biomet, DePuy Synthes, and Medicea outside the submitted work.

REFERENCES

1. Liebsch C, Graf N, Appelt K, Wilke HJ. The rib cage stabilizes the human thoracic spine: An *in vitro* study using stepwise reduction of rib cage structures. *PLoS One* 2017;12:e0178733.
2. Passias PG, Jalai CM, Lafage V, Lafage R, Protosaltis T, Ramchandran S, *et al.* Primary drivers of adult cervical deformity: prevalence, variations in presentation, and effect of surgical treatment strategies on early postoperative alignment. *Neurosurgery* 2018;83:651-9.
3. Ames CP, Smith JS, Eastlack R, Blaskiewicz DJ, Shaffrey CI, Schwab F, *et al.* Reliability assessment of a novel cervical spine deformity classification system. *J Neurosurg Spine* 2015;23:673-83.
4. Ames CP, Smith JS, Scheer JK, Shaffrey CI, Lafage V, Deviren V, *et al.* A standardized nomenclature for cervical spine soft-tissue release and osteotomy for deformity correction: Clinical article. *J Neurosurg Spine* 2013;19:269-78.
5. Protosaltis T, Bronsard N, Soroceanu A, Henry JK, Lafage R, Smith J, *et al.* Cervical sagittal deformity develops after PJK in adult thoracolumbar deformity correction: Radiographic analysis utilizing a novel global sagittal angular parameter, the CTPA. *Eur Spine J* 2017;26:1111-20.
6. Glassman SD, Coseo MP, Carreon LY. Sagittal balance is more than just alignment: Why PJK remains an unresolved problem. *Scoliosis Spinal Disord* 2016;11:1.
7. Hart RA, McCarthy I, Ames CP, Shaffrey CI, Hamilton DK, Hostin R. Proximal junctional kyphosis and proximal junctional failure. *Neurosurg Clin N Am* 2013;24:213-8.
8. Lowe TG, Lenke L, Betz R, Newton P, Clements D, Haher T, *et al.* Distal junctional kyphosis of adolescent idiopathic thoracic curves following anterior or posterior instrumented fusion: Incidence, risk factors, and prevention. *Spine (Phila Pa 1976)* 2006;31:299-302.
9. Yang J, Andras LM, Broom AM, Gonsalves NR, Barrett KK, Georgiadis AG, *et al.* Preventing distal junctional kyphosis by applying the stable sagittal vertebra concept to selective thoracic fusion in adolescent idiopathic scoliosis. *Spine Deform* 2018;6:38-42.
10. Lee GA, Betz RR, Clements DH 3rd, Huss GK. Proximal kyphosis after posterior spinal fusion in patients with idiopathic scoliosis. *Spine (Phila Pa 1976)* 1999;24:795-9.
11. McClendon J Jr, Smith TR, Sugrue PA, Thompson SE, O'Shaughnessy BA, Koski TR. Spinal implant density and postoperative lumbar lordosis as predictors for the development of proximal junctional kyphosis in adult spinal deformity. *World Neurosurg* 2016;95:419-24.
12. Park WM, Choi DK, Kim K, Kim YJ, Kim YH. Biomechanical effects of fusion levels on the risk of proximal junctional failure and kyphosis in lumbar spinal fusion surgery. *Clin Biomech (Bristol, Avon)* 2015;30:1162-9.
13. Arlet V, Aebi M. Junctional spinal disorders in operated adult spinal deformities: Present understanding and future perspectives. *Eur Spine J* 2013;22 Suppl 2:S276-95.
14. Ghasemi A, Stubig T, A Nasto L, Ahmed M, Mehdian H. Distal junctional kyphosis in patients with Scheuermann's disease: A retrospective radiographic analysis. *Eur Spine J* 2017;26:913-20.
15. Passias PG, Vasquez-Montes D, Poorman GW, Protosaltis T, Horn SR, Bortz CA, *et al.* Predictive model for distal junctional kyphosis after cervical deformity surgery. *Spine J* 2018;18:2187-94.
16. Poorman GW, Passias PG, Qureshi R, Hassanzadeh H, Horn S, Bortz C, *et al.* Cost-utility analysis of cervical deformity surgeries using 1-year outcome. *Spine J* 2018;18:1552-7.
17. Steinmetz MP, Stewart TJ, Kager CD, Benzell EC, Vaccaro AR. Cervical deformity correction. *Neurosurgery* 2007;60:S90-7.
18. Passias PG, Bortz C, Horn S, Segreto F, Poorman G, Jalai C, *et al.* Drivers of cervical deformity have a strong influence on achieving optimal radiographic and clinical outcomes at 1 year after cervical deformity

- surgery. *World Neurosurg* 2018;112:e61-8.
19. Osterhoff G, Ryang YM, von Oelhafen J, Meyer B, Ringel F. Posterior multilevel instrumentation of the lower cervical spine: Is bridging the cervicothoracic junction necessary? *World Neurosurg* 2017;103:419-23.
 20. Protopsaltis TS, Ramchandran S, Hamilton DK, Sciubba D, Passias PG, Lafage V, *et al.* Analysis of successful versus failed radiographic outcomes after cervical deformity surgery. *Spine (Phila Pa 1976)* 2018;43:E773-81.
 21. Cho KJ, Lenke LG, Bridwell KH, Kamiya M, Sides B. Selection of the optimal distal fusion level in posterior instrumentation and fusion for thoracic hyperkyphosis: The sagittal stable vertebra concept. *Spine (Phila Pa 1976)* 2009;34:765-70.