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Impact of Prior Cervical Fusion on Patients Undergoing Thoracolumbar Deformity Correction

Authors: Manjot Singh, BS;[1] Mariah Balmaceno-Criss, BS;[1] Mohammad Daher, BS;[1] Renaud Lafage, MS;[2] Robert K. Eastlack, MD;[3] Munish C. Gupta, MD;[4] Gregory M. Mundis, MD;[3] Jeffrey L. Gum, MD;[5] Kojo D. Hamilton, MD, FAANS;[6] Richard Hostin, MD;[7] Peter G. Passias, MD;[8] Themistocles S. Protopsaltis, MD;[8] Khaled M. Kebaish, MD;[9] Lawrence G. Lenke, MD;[10] Christopher P. Ames, MD;[11] Douglas C. Burton, MD;[12] Stephen M. Lewis, MD, FRCS;[13] Eric O. Klineberg, MD;[14] Han Jo Kim, MD;[15] Frank J. Schwab, MD;[2] Christopher I. Shaffrey, MD;[16] Justin S. Smith, MD, PhD;[17] Breton G. Line, BS;[18] Shay Bess, MD;[18] Virginie Lafage, PhD;[2] Bassel G. Diebo, MD;[1] Alan H Daniels, MD[1*]; on behalf of the ISSG

Affiliations:

[1] Department of Orthopedic Surgery, Warren Alpert Medical School of Brown University, Providence, Rhode Island, USA

[2] Department of Orthopedic Surgery, Lenox Hill Hospital, Northwell Health, New York, New York, USA

[3] Division of Orthopaedic Surgery, Scripps Clinic, La Jolla, California, USA

[4] Department of Orthopedic Surgery, Washington University, St. Louis, Missouri, USA

[5] Norton Leatherman Spine Center, Louisville, Kentucky, USA

[6] Department of Neurological Surgery, University of Pittsburgh, Pittsburgh, Pennsylvania, USA

[7] Southwest Scoliosis and Spine Institute, Plano, Texas, USA

[8] Department of Orthopedics, New York University Langone Orthopedic Hospital, New York, New York, USA

[9] Department of Orthopedic Surgery, Johns Hopkins University School of Medicine, Baltimore, Maryland, USA

[10] Department of Orthopedic Surgery, Columbia University Medical Center, New York, New York, USA

[11] Department of Neurological Surgery, University of California, San Francisco, California, USA

[12] Department of Orthopaedic Surgery, University of Kansas Medical Center, Kansas City, Kansas, USA

[13] Department of Orthopedics, University of Toronto, Toronto, Canada

[14] Department of Orthopedic Surgery, University of Texas McGovern Medical School, Houston, Texas, USA

[15] Department of Orthopedic Surgery, Hospital for Special Surgery, New York, New York, USA

[16] Department of Neurosurgery, Duke Spine Division, Durham, North Carolina, USA

[17] Department of Neurosurgery, University of Virginia Medical Center, Charlottesville, Virginia, USA

[18] Department of Spine Surgery, Denver International Spine Center, Denver, Colorado, USA

Corresponding Author:

Alan Daniels, MD

Department of Orthopedic Surgery

Warren Alpert Medical School of Brown University

1 Kettle Point Ave

East Providence, RI 02914

Phone: 401-330-1420

Email: alandanielsmd@gmail.com

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STRUCTURED ABSTRACT:

Study Design: Retrospective analysis of prospectively collected data.

Objective: Evaluate the impact of prior cervical constructs on upper instrumented vertebrae (UIV) selection and postoperative outcomes among patients undergoing thoracolumbar deformity correction.

Background: Surgical planning for adult spinal deformity (ASD) patients involves consideration of spinal alignment and existing fusion constructs.

Methods: ASD patients with (ANTERIOR or POSTERIOR) and without (NONE) prior cervical fusion who underwent thoracolumbar fusion were included. Demographics, radiographic alignment, patient-reported outcome measures (PROMs), and complications were compared. Univariate and multivariate analyses were performed on POSTERIOR patients to identify parameters predictive of UIV choice and to evaluate postoperative outcomes impacted by UIV selection.

Results: Among 542 patients, with 446 NONE, 72 ANTERIOR, and 24 POSTERIOR patients, mean age was 64.4 years and 432 (80%) were female. Cervical fusion patients had worse preoperative cervical and lumbosacral deformity, and PROMs ($p<0.05$). In the POSTERIOR cohort, preoperative LIV was frequently below the cervicothoracic junction (54%) and uncommonly (13%) connected to the thoracolumbar UIV. Multivariate analyses revealed that higher preoperative cervical SVA (coeff=-0.22, 95%CI=-0.43–-0.01, p=0.038) and C2SPi (coeff=-0.72, 95%CI=-1.36–-0.07, p=0.031), and lower preoperative thoracic kyphosis (coeff=0.14, 95%CI=0.01–0.28, p=0.040) and thoracolumbar lordosis (coeff=0.22, 95%CI=0.10–0.33, p=0.001) were predictive of cranial UIV. Two-year postoperatively, cervical patients continued to have worse cervical deformity and PROMs (p<0.05) but had comparable postoperative complications. Choice of thoracolumbar UIV below or above T6, as well as the number of unfused levels between constructs, did not affect patient outcomes.

Conclusions: Among patients who underwent thoracolumbar deformity correction, prior cervical fusion was associated with more severe spinopelvic deformity and PROMs preoperatively. The choice of thoracolumbar UIV was strongly predicted by their baseline cervical and thoracolumbar alignment. Despite their poor preoperative condition, these patients still experienced significant improvements in their thoracolumbar alignment and PROMs after surgery, irrespective of UIV selection.

Level of Evidence: IV

Keywords: Adult Spinal Deformity, Cervical Fusion, Thoracolumbar Fusion, Uppermost Instrumented Vertebrae, Radiographic Outcomes, Complications

KEY POINTS

- In planning a spinal fusion, an assessment of previously fused and instrumented levels is imperative

- In the present study, prior cervical fusion who underwent thoracolumbar deformity correction had more severe spinopelvic deformity and patient-reported outcome measures (PROMs) preoperatively.
- The choice of thoracolumbar uppermost instrument vertebrae (UIV) was strongly predicted by baseline cervical and thoracolumbar alignment.
- Despite their poor preoperative condition, these patients still experienced significant improvements in their thoracolumbar alignment and PROMs after surgery, irrespective of UIV selection.

INTRODUCTION

Surgical planning in adult spinal deformity (ASD) surgery necessitates careful consideration of many patient-specific factors including patient medical history, frailty, bone health, preoperative spinopelvic alignment, functional measures, and patient goals. The precise determination of optimal construct length and number of segments fused or instrumented is especially important.[1] Failure to meticulously plan the cranial- and caudal-most points of a fusion can result in adverse events such as adjacent segment disease and proximal junctional kyphosis.[2] Such complications affect a substantial portion of patients undergoing thoracolumbar fusion, and are a major cause of revision surgery.[3,4]

In planning a spinal fusion, assessing previously fused and instrumented levels is imperative. Previous research underscores the importance of restricting fusion to segments that contribute to pain, deformity, or poor functional outcomes.[5] Additionally, studies emphasize the importance of achieving and maintaining anatomic spinal alignment through meticulous rod contouring and careful selection of upper (UIV) and lower (LIV) instrumented vertebrae to avoid further development of deformity and need for subsequent revisions.[6–8] Yet, none of these investigations explore the impact of prior constructs in the cervical spinal region on construct length and positioning of the UIV.

Prior spinal constructs can alter the overall biomechanical stress distribution in both the fused and the unfused spine, potentially influencing the approach to the thoracolumbar fusion to mitigate the risk of long-term surgical complications such as adjacent segment disease and junctional failure. Furthermore, inadequate correction during prior fusion may be a cause of continued pain and may alter patient expectations, as well as surgical decision-making, in selecting the appropriate length of the thoracolumbar construct. As such, the purpose of this study is to assess the role of prior cervical fusion on the choice of thoracolumbar UIV and, in turn, on postoperative outcomes in severe ASD patients undergoing correction of thoracolumbar deformity.

METHODS

Study Design:

This retrospective cohort study utilized prospectively collected data of ASD patients from thirteen different spinal deformity centers in the United States. Institutional review board approval was obtained from all centers before data collection and informed consent was obtained from each patient included in the study.

Patient Selection:

Adult patients aged 18 years or older were included in the database if they had (i) a diagnosis of adult degenerative or idiopathic scoliosis with a Cobb angle >20°, (ii) sagittal vertical axis (SVA) >5cm, (iii) pelvic tilt (PT) >25°, and (iv) thoracic kyphosis (TK) >60°. Patients with an alternative form of scoliosis (i.e., neuromuscular, congenital) were excluded. Patients without and with prior anterior or posterior cervical fusion were subsequently included in the current study if they underwent thoracolumbar fusion with an UIV at or above T12 and LIV at or below

S1, and had preoperative and two-year postoperative full-body radiographs and patient-reported outcome measures (PROMs) data available.

Data Extraction:

Patient demographics included age, sex, body mass index (BMI), race, Edmonton Frailty Score (EFS), and preoperative UIV and LIV. Radiographic measurements based on coronal and sagittal full-length standing films included sacral slope (SS), PT, pelvic incidence (PI), C2 pelvic angle (C2PA), C2-C7 cervical lordosis (CL), T1 slope minus CL (TS-CL), T4-T12 TK, T10-L2 thoracolumbar lordosis (TL), L1-S1 lumbar lordosis (LL), PI-LL, cervical SVA (cSVA), SVA, C2 spinopelvic inclination (C2SPi), T1 spinopelvic inclination (T1SPi), C2-C7 cervical apex, T4-T12 thoracic apex, and L1-S1 lordotic apex. PROMs included Oswestry Disability Index (ODI), Neck Disability Index (NDI), Scoliosis Research Society 22-item (SRS-22) for activity, pain, and total, and Short Form 36-item (SF-36) for Physical (PCS) and Mental (MCS) Component Scores. Finally, postoperative complications included junctional, implant-related, neurologic, and radiographic complications and revisions.

Statistical Analyses:

Eligible patients were stratified according to their history of prior cervical fusion: NONE (no prior fusion), ANTERIOR (prior anterior cervical fusion), and POSTERIOR (prior posterior cervical fusion). Patient demographics, radiographic spinopelvic alignment, PROMs, and complications were compared at preoperative and/or two-year postoperative visits using $\chi 2$ tests and student's t-tests for categorical and quantitative variables, respectively. Common practices in the selection of thoracolumbar UIV, including the location of postoperative UIV (i.e., cervical, upper thoracic, and lower thoracic) and the number of unfused levels between the constructs, were similarly compared as well. Multivariate regression analyses, accounting for age, sex, and frailty, were performed to identify preoperative determinants of the choice of thoracolumbar UIV, as well as to evaluate two-year postoperative outcomes, among the POSTERIOR cohort. All statistical analyses were conducted using SPSS Statistics for Windows, Version 29.0 (Armonk, NY: IBM Corp), with statistical significance defined as $p < 0.05$.

RESULTS

Patient Demographics:

Among the 542 patients included in this study, consisting of 446 NONE, 72 ANTERIOR, and 24 POSTERIOR patients, the mean age was 64.37 years and 432 (79.7%) were female. Prior cervical fusion patients had higher BMI (NONE = 27.66 kg/m^2, ANTERIOR = 29.42 kg/m^2, POSTERIOR = 29.44 kg/m^2; p=0.015) and were frailer (3.35, 4.16, 4.29; p<0.001) but the mean age, sex, and race were otherwise comparable across groups (p>0.05) (**Table 1, Figure 1**).

Radiographic Spinopelvic Alignment:

Preoperatively, prior cervical fusion patients, specifically ANTERIOR patients, had worse C2PA (25.93°, 31.25°, 27.31°; p=0.002), TS-CL (18.60°, 20.21°, 25.40°; p=0.025), cSVA (27.19mm, 35.68mm, 40.71mm; p<0.001), C2SPi (0.94°, 3.30°, 3.32°; p=0.001), PT (24.96°, 28.32°, 23.98°; p=0.018), PI-LL (17.82°, 24.35°, 18.21°; p=0.024), SVA (63.24mm, 91.74mm, 77.83mm; p=0.002), and T1SPi (-1.63°, 0.56°, -0.43°; p=0.010) (**Table 2A**). Two-year postoperatively, prior cervical fusion patients continued to have worse TS-CL (21.70°, 26.17°, 27.70°; p=0.001) and cSVA (31.59mm, 41.20mm, 39.30mm; p<0.001) (**Table 2B**).

Patient-Reported Outcome Measures:

Preoperatively, prior cervical fusion patients had worse ODI (44.26, 52.42, 57.21; p<0.001), NDI (24.15, 33.66, 40.41; p<0.001), SRS-22 activity (2.85, 2.53, 2.39; p=0.001), pain (2.39, 2.00, 1.93; p<0.001), and total (2.78, 2.57, 2.41; p<0.001), and SF-36 PCS (30.45, 26.60, 28.56; p=0.002) and MCS (46.67, 45.23, 39.38; p=0.036) (**Table 2A**). Two-year postoperatively, prior cervical fusion patients continued to have worse ODI (25.24, 37.50, 43.29; p<0.001), NDI (21.07, 32.45, 38.74; p<0.001), SRS-22 activity (3.58, 3.12, 2.91; p<0.001), pain (3.57, 3.06, 2.71; p<0.001), total (3.73, 3.33, 3.27; p<0.001), and SF-36 PCS (40.37, 24.86, 29.11; p<0.001) and MCS (52.24, 48.36, 51.82; p=0.042) (**Table 2B**).

Surgical Complications:

Two-year postoperatively, POSTERIOR patients had a similar complication profile and rates of surgical fusion (61.5%, 55.6%, 54.2%; p=0.518) as NONE and ANTERIOR patients (**Table 3**). Revision rates (31.8%, 30.6%, 33.3%; p=0.962) were also comparable across groups.

Common Practices in UIV and LIV Selection:

Prior to their thoracolumbar fusion, POSTERIOR patients had longer cervical constructs, with a higher UIV (mid cervical: N/A, 56.9%, 95.8%; p<0.001) and a lower LIV (below cervicothoracic junction: N/A, 11.1%, 54.2%; p<0.001) (**Table 4**). After undergoing thoracolumbar fusion, POSTERIOR patients had larger thoracolumbar constructs, with a higher UIV (cervical: 0.2%, 1.4%, 12.5%; p<0.001) and a similar LIV (ilium: 96.6%, 98.6%, 100.0%; p=0.448).

Thoracolumbar UIV among POSTERIOR patients sometimes connected to their prior cervical construct or was fused into the construct levels (0 levels: N/A, 1.4%, 12.5%; p=0.010).

Preoperative Determinants of UIV:

Multivariate linear regression analyses accounting for age, sex, and frailty revealed that higher preoperative cSVA (coeff=-0.22, 95%CI=-0.43–-0.01, p=0.038) and C2SPi (coeff=-0.72, 95%CI=-1.36–-0.07, p=0.031), and lower preoperative TK (coeff=0.14, 95%CI=0.01–0.28, p=0.040) and TL (coeff=0.22, 95%CI=0.10–0.33, p=0.001) were predictive of a more cranial UIV. Furthermore, more caudal preoperative cervical LIV (coeff=-1.20, 95%CI=-2.36–-0.03, p=0.045) and lower TL (coeff=0.13, 95%CI=0.04–0.22, p=0.006) were predictive of fewer levels unfused in-between the two constructs (Supplemental Table 1, Supplemental Digital Content 1, http://links.lww.com/BRS/C500).

Choice of UIV and Two-Year Postoperative Outcomes:

Multivariate linear regression analyses accounting for age, sex, and frailty revealed that a more cranial selection of UIV was only associated with higher TS-CL (coeff=-0.27, 95%CI=-0.50–-0.04, p=0.023) but not any of the other two-year postoperative spinopelvic outcomes or PROMs. Furthermore, fewer levels unfused in-between were associated with higher two-year postoperative TS-CL (coeff=-0.18, 95%CI=-0.33–-0.04, p=0.017) and better two-year postoperative SRS-22 activity (coeff=-3.15, 95%CI=-5.92–-0.38, p=0.029), pain (coeff=-2.33, 95%CI=-4.26–-0.40, p=0.021) and total (coeff=-4.19, 95%CI=-7.50–-0.89, p=0.016) scores (Supplemental Table 2, Supplemental Digital Content 2, http://links.lww.com/BRS/C501). Multivariate logistic regression analyses accounting for age, sex, and frailty revealed that choice of UIV below or above T6 and levels unfused in-between below or above 5 levels were not associated with two-year postoperative complications or reoperation (Supplemental Table 3, Supplemental Digital Content 3, http://links.lww.com/BRS/C502).

DISCUSSION

In this large multicenter thoracolumbar adult spinal deformity patient cohort, prior cervical fusion patients had worse spinal alignment and PROMs preoperatively. This cohort significantly improved after thoracolumbar fusion surgery, although they continued to have worse cervical deformity and PROMs two-year postoperatively. Posterior cervical fusion patients frequently had a preoperative cervical construct that extended caudal to the cervicothoracic junction, though only 12.5% underwent fusion connecting the cervical to the thoracolumbar construct. The choice of thoracolumbar UIV and number of unfused levels in-between constructs were predicted by preoperative cervical (cSVA, C2SPi) and thoracic alignment (TK, TL). However, such surgical considerations had minimal impact on two-year postoperative outcomes, with only some improvement in SRS-22 scores in those with fewer unfused levels in-between constructs. These findings suggest that while prior cervical constructs should still be incorporated into preoperative surgical planning, they do not provide a clear prescriptive UIV in most cases.

Prior spine surgery often predisposes patients to poor outcomes both preoperatively and postoperatively. In the present study, for instance, prior cervical fusion patients had worse baseline cervical deformity (C2PA, TS-CL, cSVA, C2SPi), thoracolumbar deformity (PT, PI-LL, SVA, T1SPi), and PROMs (ODI, NDI, SRS-22, SF-36). Previous studies have highlighted the importance of achieving and maintaining optimal spinopelvic alignment during index operation on postoperative outcomes. Failure to meet alignment targets has been shown to result in loss of three-dimensional spinal alignment secondary to adjacent region compensation and junctional failure.[9,10] Prior cervical fusion patients in this study may have had inadequate correction during the primary surgery and subsequent loss of alignment, which may explain their severe cervical deformity. Although it is unclear whether this played a role in the development of their current thoracolumbar pathology, lack of cervical motion following prior fusion may have prevented compensatory changes in cervical lordosis to combat sagittal malalignment in the lower spine, thus resulting in higher thoracolumbar deformity.[11] Many studies have previously shown an association between prior spine surgery and worse general health status.[12] Such global malalignment likely contributes to the worse functional outcomes observed in this patient population.

Two years postoperatively, prior cervical fusion patients had similar thoracolumbar deformity but continued to have worse cervical deformity (TS-CL, cSVA) and PROMs (ODI, NDI, SRS-22, SF-36). Surgical management of ASD has previously been shown to offer good improvement in long-term radiographic and clinical outcomes.[13,14] However, the current thoracolumbar procedure did not address the cervical deformity or deformity-related functional changes that may have persisted after their prior surgery or developed thereafter. Indeed, while some studies point to the contrary, literature generally agrees that preoperative cervical deformity and associated prior spine surgery has a worsening effect on functional outcomes following subsequent deformity corrections.[15–17] This may be due to a failure to undergo compensatory changes in the upper spine, such as extension of the neck, to accommodate for the loss of lumbar lordosis. Posterior cervical instrumentation covered more levels and frequently went below the cervicothoracic junction, which may have provided some stabilizing force to the thoracic and thoracolumbar spine. This, however, did not translate to better preoperative PROMs for these patients. Other studies have similarly shown that anterior and posterior approaches offer similar long-term functional outcomes, although they further add that anterior instrumentation is associated with lower rates of pseudoarthrosis and need for subsequent revision which was not observed in this study.[18–20] These findings suggest that achieving and maintaining adequate cervical correction during initial surgery may allow for better upper spine compensation for any subsequent lower spine pathology, thus resulting in better preoperative and long-term postoperative outcomes.

Prior constructs or, more specifically, uncorrected deformity from prior constructs may play a role in surgeon decision-making on the selection of the thoracolumbar UIV and on the number of levels left unfused in-between. In the present study, prior posterior cervical constructs frequently extended beyond the cervicothoracic junction.[21,22] The new thoracolumbar UIV sometimes connected to their prior instrumentation, but more frequently ended in the lower thoracic region, with cervical (cSVA, C2SPi) and thoracic (TK, TL) alignment being the primary determinants of UIV. Indeed, previous literature agrees that T10 in the lower thoracic region is the most common UIV followed by T3 in the upper thoracic region since this avoids the cervicothoracic and thoracolumbar junctions which can be more prone to junctional failure.[23] The choice of UIV across these two regions is then dependent on the presence of coronal deformity (e.g., upper thoracic UIV if coronal curve is greater than 20°) and thoracic kyphosis (e.g., upper thoracic UIV if thoracic kyphosis is greater than 55°).[23] The adolescent idiopathic scoliosis classification, which considers preservation of motion segments, prevention of proximal or distal junctional kyphosis, shoulder imbalance, and neck pain, has also been established to assist surgeons in determining appropriate levels for instrumentation among adolescent idiopathic scoliosis patients.[24–26] Although no similar consensus guidelines have been established among adults, the three-dimensional TK is generally considered the most important determinant of UIV and, thus, the number of levels left unfused in-between.[27,28] Increased kyphosis in the thoracic spine likely necessitates cranial extension of the thoracolumbar UIV to achieve and maintain proper sagittal alignment. Increased cervical malalignment, as shown in this study, likely alters UIV selection through a similar change in the global sagittal profile.

The present study has several potential limitations. First, the sample size, especially of the prior posterior cervical fusion cohort, may be underpowered to detect significant differences. Second, decision-making regarding the choice of UIV from the surgeon perspective was not assessed and could provide valuable insights into the role of prior cervical fusion on UIV selection. Third, the current study did not explore the association between the timing of prior cervical fusion and current thoracolumbar deformity correction, which may impact the findings as well. Finally, only two-year postoperative radiographic and clinical outcomes were available for analyses; longer follow-up period may provide deeper insights into the durability of both constructs and their outcomes, especially in comparison to a single construct.

CONCLUSIONS

Prior cervical fusion patients have more severe preoperative cervical and thoracolumbar deformity and worse PROMs than isolated thoracolumbar deformity patients. While this does not preclude them from having good radiographical and surgical outcomes in the thoracolumbar spine, they often continue to exhibit worse postoperative cervical deformity and functional outcomes following thoracolumbar fusion. Choice of thoracolumbar UIV was most strongly predicted by preoperative cervical and thoracic alignment rather than the presence or absence of previous cervical fusion.

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Figure 1. Preoperative to two-year postoperative radiographs demonstrating thoracolumbar fusion in patients without (NONE) and with prior anterior (ANTERIOR) or posterior (POSTERIOR) cervical fusion.

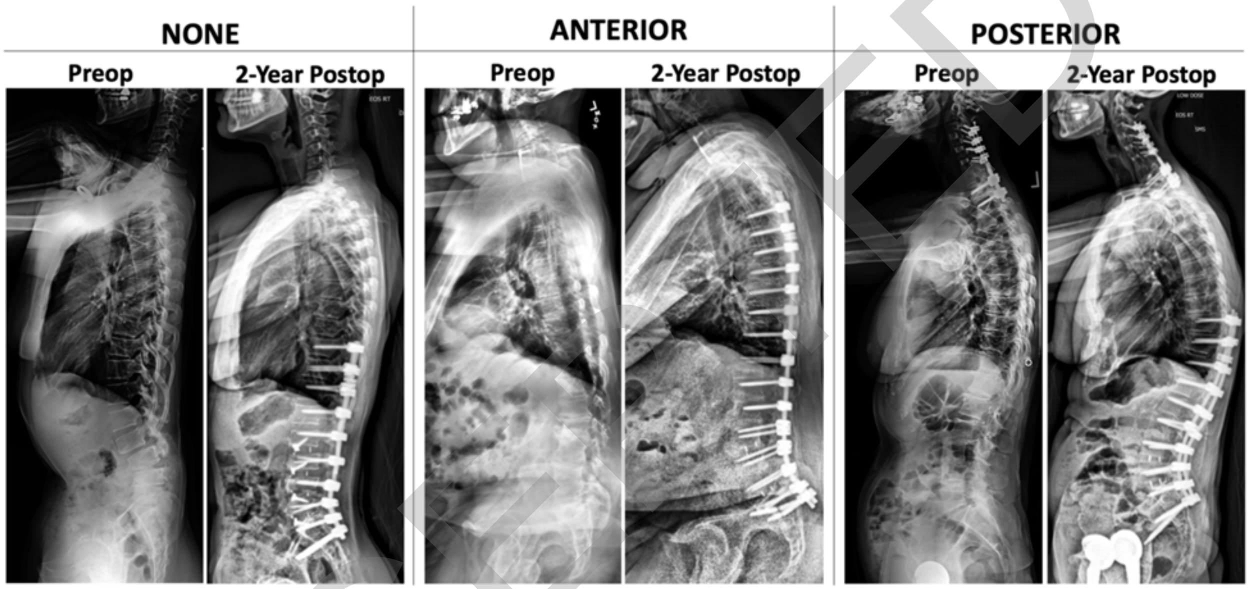

Table 1. Baseline Patient Characteristics

	NONE (N = 446)	ANTERIOR (N = 72)	POSTERIOR (N = 24)	P-value
Age (years)	64.24 (9.18)	64.99 (8.15)	64.93 (6.66)	0.764
Female Sex	335 (79.6)	55 (77.5)	22 (91.7)	0.309
BMI (kg/m^2)	27.66 (5.18)	29.42 (5.85)	29.44 (7.16)	**0.015**
Race				0.336
Asian	6 (1.4)	0 (0.0)	0 (0.0)	
Black/African	12 (2.8)	6 (8.6)	1 (4.3)	
Hispanic	6 (1.4)	2 (2.9)	0 (0.0)	
White/Caucasian	406 (93.8)	61 (87.1)	22 (95.7)	
Other	3 (0.7)	1 (1.4)	0 (0.0)	
Edmonton Frailty Score	3.35 (1.46)	4.16 (1.21)	4.29 (1.33)	**<0.001**

Categorical variables are presented as count (frequency) and continuous variables are presented as mean (standard deviation). Abbreviations: BMI = Body Mass Index.

Table 2A. Preoperative Spinopelvic and Patient-Reported Outcomes

	NONE (N = 446)	ANTERIOR (N = 72)	POSTERIOR (N = 24)	P-value
Cervical Parameters				
C2PA (°)	25.93 (10.98)	31.25 (13.61)	27.31 (9.38)	**0.002**
CL (°)	9.57 (15.22)	12.29 (14.67)	7.68 (12.22)	0.312
TS-CL (°)	18.60 (11.16)	20.21 (13.70)	25.40 (13.97)	**0.025**
cSVA (mm)	27.19 (13.78)	35.68 (15.44)	40.71 (13.24)	**<0.001**
C2SPi (°)	0.94 (5.21)	3.30 (5.78)	3.32 (4.97)	**0.001**
Thoracolumbar Parameters				
SS (°)	30.24 (10.90)	28.30 (12.19)	28.18 (9.66)	0.284
PT (°)	24.96 (9.28)	28.32 (11.73)	23.98 (9.18)	**0.018**
PI (°)	55.20 (11.99)	56.62 (14.24)	52.16 (13.51)	0.305
TK (°)	-31.96 (17.61)	-32.40 (20.60)	-34.64 (17.95)	0.771
TL (°)	-15.60 (19.16)	-14.07 (19.45)	-13.00 (16.90)	0.684
LL (°)	37.37 (19.87)	32.27 (20.31)	33.95 (16.02)	0.103
PI-LL (°)	17.82 (18.46)	24.35 (21.52)	18.21 (14.78)	**0.024**
SVA (mm)	63.24 (63.87)	91.74 (72.21)	77.83 (54.27)	**0.002**
T1SPi (°)	-1.63 (5.74)	0.56 (6.44)	-0.43 (4.93)	**0.010**
Patient-Reported Outcome Measures				
ODI	44.26 (15.54)	52.42 (14.70)	57.21 (14.76)	**<0.001**
NDI	24.15 (17.65)	33.66 (19.12)	40.41 (14.20)	**<0.001**

SRS-22				
Activity	2.85 (0.82)	2.53 (0.79)	2.39 (0.51)	**0.001**
Pain	2.39 (0.79)	2.00 (0.72)	1.93 (0.69)	**<0.001**
Total	2.78 (0.60)	2.57 (0.58)	2.41 (0.54)	**<0.001**
SF-36				
PCS	30.45 (8.73)	26.60 (7.82)	28.56 (6.48)	**0.002**
MCS	46.67 (13.08)	45.23 (15.68)	39.38 (15.26)	**0.036**

Variables are presented as mean (standard deviation). Abbreviations: C2PA = C2 Pelvic Angle, CL = Cervical Lordosis, TS-CL = T1 Slope Minus Cervical Lordosis, cSVA = Cervical Sagittal Vertical Axis, C2SPi = C2 SpinoPelvic Inclination, SS = Sacral Slope, PT = Pelvic Tilt, PI = Pelvic Incidence, TK = Thoracic Kyphosis, TL = Thoracolumbar Lordosis, LL = Lumbar Lordosis, PI-LL = Pelvic Incidence minus Lumbar Lordosis, SVA = Sagittal Vertical Axis, T1SPi = T1 SpinoPelvic Inclination, ODI = Oswestry Disability Index, NDI = Neck Disability Index, SRS-22 = Scoliosis Research Society 22-item (SRS-22), SF-36 = Short Form 36-item, PCS = Physical Component Score, MCS = Mental Component Score.

Table 2B. Two-Year Postoperative Spinopelvic and Patient-Reported Outcomes

	NONE (N = 446)	ANTERIOR (N = 72)	POSTERIOR (N = 24)	P-value
Cervical Parameters				
C2PA (°)	21.85 (10.18)	24.62 (10.26)	23.79 (8.92)	0.083
CL (°)	12.29 (15.77)	12.14 (16.43)	7.15 (10.94)	0.343
TS-CL (°)	21.70 (11.10)	26.17 (13.47)	27.70 (11.51)	**0.001**
cSVA (mm)	31.59 (14.38)	41.20 (14.76)	39.30 (15.35)	**<0.001**
C2SPi (°)	-0.65 (4.71)	0.21 (4.82)	1.20 (5.72)	0.101
Thoracolumbar Parameters				
SS (°)	32.93 (9.52)	32.02 (10.65)	29.68 (9.42)	0.242
PT (°)	22.42 (9.33)	24.33 (10.49)	21.91 (8.74)	0.267
PI (°)	55.36 (11.99)	56.35 (13.82)	51.60 (13.53)	0.272
TK (°)	-46.92 (15.43)	-49.44 (18.57)	-43.75 (12.75)	0.263
TL (°)	-9.50 (12.15)	-11.05 (13.84)	-6.97 (11.22)	0.356
LL (°)	52.47 (13.12)	52.52 (12.35)	46.19 (10.05)	0.074
PI-LL (°)	2.88 (14.09)	3.83 (13.91)	5.41 (9.52)	0.626
SVA (mm)	29.94 (55.47)	32.06 (47.91)	42.41 (49.58)	0.549
T1SPi (°)	-4.22 (5.16)	-4.60 (4.68)	-3.21 (5.50)	0.523
Patient-Reported Outcome Measures				
ODI	25.24 (19.53)	37.50 (19.15)	43.29 (18.05)	**<0.001**
NDI	21.07 (16.35)	32.45 (18.07)	38.74 (15.56)	**<0.001**

SRS-22				
Activity	3.58 (0.91)	3.12 (0.87)	2.91 (0.75)	**<0.001**
Pain	3.57 (1.06)	3.06 (1.10)	2.71 (0.95)	**<0.001**
Total	3.73 (0.75)	3.33 (0.77)	3.27 (0.59)	**<0.001**
SF-36				
PCS	40.37 (11.14)	34.86 (10.81)	29.11 (8.77)	**<0.001**
MCS	52.24 (10.95)	48.36 (14.27)	51.82 (11.58)	**0.042**

Variables are presented as mean (standard deviation). Abbreviations: C2PA = C2 Pelvic Angle, CL = Cervical Lordosis, TS-CL = T1 Slope Minus Cervical Lordosis, cSVA = Cervical Sagittal Vertical Axis, C2SPi = C2 SpinoPelvic Inclination, SS = Sacral Slope, PT = Pelvic Tilt, PI = Pelvic Incidence, TK = Thoracic Kyphosis, TL = Thoracolumbar Lordosis, LL = Lumbar Lordosis, PI-LL = Pelvic Incidence minus Lumbar Lordosis, SVA = Sagittal Vertical Axis, T1SPi = T1 SpinoPelvic Inclination, ODI = Oswestry Disability Index, NDI = Neck Disability Index, SRS-22 = Scoliosis Research Society 22-item (SRS-22), SF-36 = Short Form 36-item, PCS = Physical Component Score, MCS = Mental Component Score.

Table 3. Two-Year Postoperative Complications

	NONE (N = 446)	ANTERIOR (N = 72)	POSTERIOR (N = 24)	P-value
Junctional				
Adjacent Segment Disease	11 (2.5)	0 (0.0)	1 (4.2)	0.336
Proximal Junctional Kyphosis	77 (17.3)	18 (25.0)	6 (25.0)	0.210
Implant				
Implant Malposition	17 (3.8)	3 (4.2)	0 (0.0)	0.611
Implant Failure	102 (22.9)	16 (22.2)	2 (8.3)	0.248
Neurologic				
Motor Deficits	5 (1.1)	0 (0.0)	0 (0.0)	0.581
Sensory Deficits	0 (0.0)	0 (0.0)	0 (0.0)	–
Radiculopathy	3 (0.7)	0 (0.0)	0 (0.0)	0.723
Myelopathy	4 (0.9)	1 (1.4)	0 (0.0)	0.820
Radiographic				
Coronal Imbalance	8 (1.8)	0 (0.0)	0 (0.0)	0.417
Sagittal Imbalance	10 (2.2)	1 (1.4)	1 (4.2)	0.722
Fusion Rate	273 (61.5)	40 (55.6)	13 (54.2)	0.518
Revision	142 (31.8)	22 (30.6)	8 (33.3)	0.962

Variables are presented as count (frequency).

Table 4. Common Practices for Choice of UIV and LIV

	NONE (N = 446)	**ANTERIOR (N = 72)**	**POSTERIOR (N = 24)**	**P-value**
Preop Cervical UIV (average)	-	C4-C5	C3	**<0.001**
Mid Cervical (C2-C4)	-	41 (56.9)	23 (95.8)	**<0.001**
Lower Cervical (C5-C7)	-	31 (43.1)	1 (4.2)	
Preop Cervical LIV (average)	-	C6-C7	T1	**<0.001**
Above CTJ (C2-C7)	-	64 (88.9)	11 (45.8)	**<0.001**
Below CTJ (T1-T4)	-	8 (11.1)	13 (54.2)	
Postoperative UIV (average)	T7-T8	T7-T8	T7	0.742
Cervical (C1-C7)	1 (0.2)	1 (1.4)	3 (12.5)	**<0.001**
Upper Thoracic (T1-T6)	175 (39.2)	28 (38.9)	5 (20.8)	
Lower Thoracic (T7-T12)	270 (60.5)	43 (59.7)	16 (66.7)	
Postoperative LIV (average)	Ilium	Ilium	Ilium	0.449
Sacrum	15 (3.4)	1 (1.4)	0 (0.0)	0.448
Ilium	431 (96.6)	71 (98.6)	24 (100.0)	
Levels In-Between	-	8.08 (3.52)	6.88 (3.54)	0.149
0 Levels	-	1 (1.4)	3 (12.5)	**0.010**
1-5 Levels	-	24 (33.3)	5 (20.8)	
5-10 Levels	-	23 (31.9)	13 (54.2)	
10-15 Levels	-	24 (33.3)	3 (12.5)	

Categorical variables are presented as count (frequency) and continuous variables are presented as mean (standard deviation). Abbreviations: UIV = Uppermost Instrumented Vertebrae, LIV = Lowermost Instrumented Vertebrae, CTJ = Cervicothoracic Junction.