2019

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et al.

Original Article

AOSPINE

Global Spine Journal
2019, Vol. 9(1) 6-13
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DOI: 10.1177/2192568217705655
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Outcomes of Fusions From the Cervical Spine to the Pelvis

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Abstract

Study Design: Retrospective cohort study.

Objective: Determine the indications, complications, and clinical outcomes in patients requiring fusions from the cervical spine to the pelvis. Several investigators have examined fusions from the thoracic spine to the sacrum, but no similar study has been performed for cervical-to-pelvis fusions.

Methods: Patients from 2003 to 2014 with an upper instrumented vertebrae (UIV) in the cervical spine (any level) and a lower instrumented vertebrae (LIV) in the sacrum or pelvis were included in the study. Those with infectious or acute trauma-related deformities were excluded. Patient demographics, medical history, diagnosis, operative procedure, and health-related quality of life measures were analyzed. Student's *t* test, Kruskal-Wallis test, and χ^2 test were used as appropriate; significance was set at $P < .05$ for all tests.

Results: Fifty-five patients met inclusion criteria for the study. Average follow-up was 2.8 years. Proximal junctional kyphosis was the most common indication for cervical-to-pelvis fusions (36%). The most common UIV was C2 (29%) followed by C7 (24%). There was an average 31° correction in maximum kyphosis and a 3.3 cm improvement in sagittal vertical axis. In adults, the rate of complication was 71.4%, with a major complication rate of 39.3% and reoperation rate of 53.6%. There was significant improvement in the Scoliosis Research Society (SRS-22r) score (3.0 to 3.5; $P < .01$).

Conclusion: Proximal junctional kyphosis is the most common indication for patients requiring fusion to the cervical spine. Adult patients incur a significant risk of major complications and reoperations. However, significant improvement in SRS-22r outcomes are noted in these patients.

Keywords

cervical spine fusion, health-related quality of life, long fusion, adult deformity

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Introduction

Patients presenting with spinal deformities sometimes require operations with long fusion constructs extending from the cervical spine to the pelvis. Several investigators have examined outcomes and complications in long fusions extending from the sacrum to the thoracic spine, but no similar study has been performed in fusions from the sacrum to the cervical spine.[1-5] While an upper instrumented vertebrae (UIV) in the cervical spine is less common than an upper thoracic (UT) or lower thoracic (LT) spine, there are several scenarios where fusion to the cervical spine might be necessary. These scenarios may include index operations (eg, neuromuscular disorders resulting in a drop head or chin on chest deformity, myelopathy in the presence of scoliosis and kyphosis, or kyphoscoliosis that involves the cervical spine) or revision cases (eg, proximal junctional kyphosis [PJK], pseudarthrosis, progressive cervical deformity resulting in coronal or sagittal decompensation, or myelopathy in a patient that has previously been fused to the UT spine). In this subset of patients requiring fusion from the cervical spine to pelvis, the impact of surgery on radiographic parameters, health-related quality of life (HRQOL), and rates of complication are unknown.

We sought to address this deficiency by conducting a retrospective review of patients who had received a fusion from the cervical spine to pelvis. The specific aims of this project were to define the impact of cervical-pelvis fusion on radiographic outcomes and HRQOL.

Methods

Following institutional review board approval, a retrospective review was performed to identify patients that had undergone a fusion from the cervical spine to the pelvis. Patients from 4 institutions who had undergone surgery between June 2003 and August 2014 were included. All patients with a UIV from the occiput to C7 and a lower instrumented vertebrae in the sacrum or pelvis were included in this study.

General information (age, body mass index, follow-up time), medical history (prior surgical procedures, comorbidities, American Society of Anesthesiologists score, and smoking), operative details (indication, revision vs primary, estimated blood loss, procedure time, and osteotomies), radiographic measurements, postoperative complications (medical vs surgical and major vs minor), and preoperative and postoperative HRQOL data (Scoliosis Research Society-22R questionnaire [SRS-22r], neck disability index [NDI], and Oswestry Disability Index [ODI]) were collected. In patients who underwent reoperation procedures during the follow-up period, reason for reoperation was recorded. A major complication was defined as one requiring return to the operating room or one that significantly altered postoperative management (ie, myocardial infarction, bowel obstruction). A minor complication was defined as one that did not significantly alter hospital course (ie, superficial wound infection resolved with PO antibiotics, urinary tract infection, etc).[6]

In addition to the preoperative and postoperative HRQOL data, change in outcomes was calculated where applicable. Change in SRS-22r was calculated as the postoperative value minus the preoperative value. This was performed so a positive value for change in HRQOL outcomes represents an improvement in outcomes while a negative change represents a worse postoperative outcome.[7] Minimum clinically important difference (MCID) was calculated for the SRS-22r scores and was set at 0.4 for all domains; this corresponds to an improvement of one interval in 2 out of the 5 questions for each domain.[8]

Statistical Analysis

A paired Student's t test was used between pre- and postoperative HRQOL outcomes to determine if there had been a significant change. Similarly, a paired t test was used to determine if significant changes had occurred with respect to the radiographic parameters presented. The level of significance was set at $P < .05$ for all tests.

Results

Patient and Surgical Characteristics

A total of 55 patients were identified. The average age was 44.9 years (range 3.9 to 81.8) with the majority (n = 37, 67.3%) being adults. The average follow-up time was 2.8 years (range 2 months to 9.5 years). There were 36 female (65.5%) and 19 male (34.5%) patients (Table 1). The majority of cases (n = 34, 61.8%) were revision cases; data about index versus revision procedures was not available for 8 patients (Table 1). The most common indication for surgery was PJK (n = 20, 36.4%) followed by kyphosis (n = 10, 18.2%) and kyphoscoliosis (n = 5, 9.1%).

Fusions were performed most commonly to C2 (n = 16, 29.1%) or C7 (n = 13, 23.6%). There were 5 cases (9.1%) with fusion to the occiput (Table 2). A total of 20 patients (36.4%) underwent 21 vertebral column resections (VCRs). VCR was performed at levels ranging from T2 to T9, with resections in the UT spine (T2-T4) being most common (n = 13, 59.1% of all VCRs). There were 8 patients (14.5%) who underwent a pedicle subtraction osteotomy (PSO) and 6 patients (10.9%) who underwent Smith-Petersen osteotomy (SPO); these were typically performed in the lower cervical (C4-7) and UT (T1-4) spine.

Radiographic Outcomes

The preoperative cervicothoracic/UT Cobb angle averaged 32.7 ± 33.5°. Maximum kyphosis was 82.3 ± 39.8° (range 16° to 180°) and improved to 52.0 ± 21.4° (range 1° to 93°; $P = .001$; Table 3). Preoperative C7 sagittal vertical axis (C7 SVA) averaged 35.8 ± 74.9 mm, range (−80.9 mm to 256.0 mm) and improved to −2.5 ± 43.7 mm (range −101.8

Table 1. Demographic Data of Patients Who Underwent Fusion From the Cervical Spine to the Pelvis.

	Fusion From C-Spine to Pelvis (N = 55)
Age, mean ± SD (range)	44.9 ± 26.5 (3.9-81.8)
Gender, n (%)	
Female	36 (65.5%)
Male	19 (34.5%)
BMI, mean ± SD (range)	29.6 ± 6.2 (17.8-40.6)
Follow-up time (years), mean ± SD (range)	2.76 ± 2.1 (0.1-9.5)
Indication, n (%)	
PJK	20 (36.4%)
Kyphosis	10 (18.2%)
Kyphoscoliosis	5 (9.1%)
Myelopathy	4 (7.3%)
Other	16 (29.1%)
Revision, n (%)	
No	13 (23.6%)
Yes	34 (61.8%)
ASA score	
Grade II	7 (12.7%)
Grade III	20 (36.4%)
Smoker, n (%)	
No	24 (43.6%)
Yes	4 (7.3%)

Abbreviations: BMI, body mass index; PJK, proximal junctional kyphosis; ASA, American Society of Anesthesiologists.

to 80.0 mm; $P = .004$). Similarly, the C2 SVA ($P = .002$), T1 slope (TS; $P = .014$), and Basion-C7 (B-C7) SVA ($P = .005$) all improved significantly. There were no significant changes in thoracic kyphosis (TK), lumbar lordosis (LL), pelvic tilt (PT), sacral slope (SS), or T1-pelvis angle (T1PA).

Health-Related Quality of Life

Of the 55 patients included in the study, 9 (16.3%) did not have any HRQOL data recorded and were excluded from this analysis; the remaining 46 patients (83.6%) were included for HRQOL analysis. The preoperative SRS-22r total score was 3.0 ± 0.7, and the most recent SRS-22r score was 3.5 ± 0.9 (Table 4). Because this was a retrospective review of patient charts, we were limited by the consistency of data collection. Pre- and postoperative HRQOL scores were not available for all patients, and the number of patients in whom each score was available is noted in the tables. Preoperative SRS scores were available in 32 (69.7%) of the patients and postoperative scores in 42 (91.3%) of the patients. The change in score was only calculated if pre- and postoperative scores were available. Complete data on the SRS-22r score was available for 28 patients (60.9%), ODI score was available in 19 patients (41.3%), and NDI score was available in 13 patients (28.2%). Given the small number of patients with ODI and NDI data, we report only the results of our SRS scores. The average change in SRS Total score was 0.4 ($P = .001$; Table 5). The greatest change occurred in the Mental Health (0.94, $P = .001$) and Pain (0.64, $P = .001$) domains. There was a significant improvement in all domains of the SRS-22r except Self Image ($P = .080$) and Satisfaction ($P = .094$). The MCID was achieved in all domains except Self Image ($P = .080$) and Satisfaction ($P = .094$). MCID was achieved in more than 50% of patients for all domains except Self Image and Satisfaction.

Table 2. Surgical Details Regarding Patients Undergoing Fusion From the Cervical Spine to the Pelvis.

	Fusion From C-Spine to Pelvis (N = 55)
OR time (minutes), mean ± SD (range)	328 ± 118 (164-477)
EBL (mL), mean ± SD (range)	2138 ± 2240 (50-9100)
Any osteotomy	
No	17 (30.9%)
Yes	31 (56.4%)
Number of VCR	
None	10 (18.2%)
1.0	19 (34.5%)
2.0	1 (1.8%)
Number of PSO	
None	12 (21.8%)
1	8 (14.5%)
Number of SPO	
None	14 (25.5%)
1.0	2 (3.6%)
2.0	1 (1.8%)
3.0	1 (1.8%)
5.0	1 (1.8%)
9.0	1 (1.8%)
UIV	
O	5 (9.1%)
C1	1 (1.8%)
C2	16 (29.1%)
C3	5 (9.1%)
C4	5 (9.1%)
C5	5 (9.1%)
C6	6 (10.9%)
C7	13 (23.6%)
BMP	
No	5 (9.1%)
Yes	25 (45.5%)

Abbreviations: OR, operating room; EBL, estimated blood loss; VCR, vertebral column resection; PSO, pedicle subtraction osteotomy; SPO, Smith-Petersen (chevron type) osteotomy; UIV, upper instrumented vertebrae; BMP, Bone Morphogenetic Protein.

Impact of UIV on HRQOL

For the subset of 28 patients with complete HRQOL follow-up, we wished to examine the impact of cervical UIV on HRQOL scores. Patients were divided into groups by UIV: (1) upper cervical (C1-C2), (2) mid cervical (C3-5), and (3) lower cervical (C6-7). Fusions to the occiput were excluded

Table 3. Preoperative and Most Recent Radiographic Data (More Negative Values Correspond to Increasing Lordosis).

	Baseline, Mean ± Standard Deviation (Range)	Most Recent Follow-up, Mean ± Standard Deviation (Range)	*P* Value
Cervicothoracic Cobb	26 ± 33 (0, 138)	12 ± 17 (0, 80)	.017
CSVL	20 ± 40 (−80, 104)	8 ± 24 (−45, 60)	.083
Maximum kyphosis	69 ± 45 (−3, 180)	42 ± 28 (−27, 93)	0
Cervical lordosis	−25 ± 33 (−65, 50)	−27 ± 20 (−60, 44)	.813
Occiput—C2	−44 ± 18 (−76, −23)	−35 ± 17 (−69, −6)	.001
C2 SVA	54 ± 46 (−62, 124)	50 ± 32 (0, 147.2)	.723
C7 SVA	41 ± 72 (−81, 256)	7 ± 47 (−101.8, 80)	.003
Basion—C7 SVA	76 ± 48 (7, 196)	62 ± 57 (−27.6, 193.7)	.15
Basion—S1 SVA	65 ± 61 (−51, 199)	32 ± 49 (−80.6, 127.1)	.002
T1 slope	43 ± 23 (9, 88)	36 ± 15 (9, 73)	.148
TS minus CL	66 ± 36 (−15, 127)	61 ± 34 (−33, 108)	.208
T2 slope	40 ± 25 (1, 91)	26 ± 17 (−6, 73)	.009
T1PA	27 ± 15 (4, 71)	32 ± 24 (0, 90)	.791
Thoracic kyphosis	57 ± 41 (−10, 152)	35 ± 33 (−25, 103)	.022
T10-L2	26 ± 26 (−1, 82)	27 ± 27 (−1, 89)	.867
Lumbar lordosis	−62 ± 20 (−120, −20)	−58 ± 14 (−102, −35)	.949
Pelvic incidence	50 ± 22 (9, 89)	49 ± 23 (4, 85)	.912
PI minus LL	−11 ± 26 (−51, 35)	−15 ± 27 (−65, 24)	.391
Pelvic tilt	32 ± 11 (7, 51)	31 ± 15 (6, 65)	.71
Sacral slope	27 ± 16 (0, 54)	40 ± 12 (22, 63)	.056

Abbreviations: CSVL, central sacral vertical line; SVA, sagittal vertical axis; CL, cervical lordosis; LL, lumbar lordosis.

Table 4. Baseline and Most Recent Follow-up HRQOL Scores in Patients Undergoing Fusion From the Cervical Spine to the Pelvis.

	Baseline HRQOL					Most Recent Follow-up				
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max
SRS Activity	32	2.8	1.0	1.0	5.0	42	3.4	1.2	1.4	5.0
SRS Pain	32	2.6	0.8	1.3	4.0	42	3.2	1.0	1.4	4.7
SRS Self Image	32	2.9	1.0	1.3	4.6	42	3.3	1.0	1.6	5.0
SRS Mental Health	32	2.9	1.1	0.0	5.0	42	3.9	1.0	1.6	5.0
SRS Satisfaction	32	3.6	0.9	1.0	5.0	40	3.9	0.7	2.4	5.0
SRS Total	32	3.0	0.7	1.9	4.4	42	3.5	0.9	1.9	4.7

Abbreviations: HRQOL, health-related quality of life; SRS, Scoliosis Research Society.

because of a lack of preoperative HRQOL data for analysis and comparison.

For fusions in the upper cervical spine, the preoperative SRS scores were significantly lower in the SRS Activity (P = .025), Pain (P = .050) and Self Image (P = .026) domains although there was no difference in the total SRS score (P = .155; Appendix Table A1). This difference between SRS scores persisted postoperatively (Appendix Table A2). Patients fused to the upper cervical spine had lower SRS Activity (P = .003), Pain (0.004), Self Image (P = .025), Satisfaction (P = .008), and Total (P = .004) scores at final follow-up. The change in SRS scores (Most Recent SRS score − Preoperative SRS score) was similar between the 2 groups (P > .05) for all domains except Mental Health; patients fused to the upper cervical spine had a lower increase in Mental Health scores (P = .013).

Complications

Complications data was available for 28 patients (60.9%). The average age of this subset was 66.9 ± 8.1 years (age 46.9-81.8) with 25 females (89.3%; Table 6). Average follow-up was 1.4 years (range 6 weeks to 6.8 years). These patients were most commonly fused to C2 (n = 15, 53.6%; Appendix Table B). The rate of complications in this patient population was 71.4% with a major complication rate of 39.3%. There were 17 patients (60.7%) with medical complications and 12 patients (42.9%) with surgical complications (Table 7). The rate of major surgical complications was 28.6%. A total of 15 patients (53.6%) required 24 reoperations in the follow-up period. There were 7 patients (25%) diagnosed with pseudarthrosis requiring reoperation, 3 patients with neurologic deficits, and 3 patients with wound problems. Of the 24 reoperations, 10 (41.7%) were for pseudarthrosis. There were 4 reoperations (16.7%) for wound problems/infection and 3 reoperations (12.5%) for neurologic deficits.

Discussion

While cervical to pelvis fusions are uncommon procedures, their prevalence may increase in the coming years due to the increasing prevalence of adjacent segment degeneration in the adult population.[9] Unfortunately, because these procedures are not frequently performed, they have not been well characterized in the literature. In this series, we show that cervical to pelvis fusions are most commonly performed due to PJK and that they are associated with significant risk; they have a 39.3% rate of major complications and a 53.6% rate of reoperation. However, despite this high rate of complications, we show that

Table 5. Change in HRQOL Scores in Patients for Whom Both Pre- and Postoperative HRQOL Scores Were Available[a].

	Change From Preoperative						MCID					
	N	Mean	SD	Min	Max	*P* Value	% Exceed MCID	Mean Number MCID	SD	Min	Max	*P* Value
SRS Activity	28	0.4	0.8	−1.0	3.3	.005	50.0%	1.2	2.06	−2.5	8.3	.005
SRS Pain	28	0.6	.9	−1.7	2.2	.001	64.3%	2.0	2.0	−4.0	6.0	.001
SRS Self Image	28	0.3	1.0	−2.1	2.6	.080	39.3%	1.0	2.0	−5.0	7.0	.080
SRS Mental Health	28	0.9	1.3	−1.2	5.0	.001	53.6%	2.0	3.0	−3.0	13.0	.001
SRS Satisfaction	26	0.4	1.1	−1.3	3.0	.094	38.5%	0.9	2.7	−3.3	7.5	.094
SRS Total	28	0.4	.6	−0.9	2.2	.001	53.6%	1.0	1.5	−2.3	5.5	.001

Abbreviations: HRQOL, health-related quality of life; SRS, Scoliosis Research Society; MCID, minimum clinically important difference.
[a]For HRQOL, $P < .05$ indicates that the change in HRQOL scores was significant, while for MCID, $P < .05$ denotes that change in MCID was significantly greater than 0.

Table 6. Description of Cohort for Whom Complication Data Was Available.

	Complications in Fusion From C-Spine to Pelvis (N = 28)
Age, mean ± SD (range)	66.9 ± 8.1 (46.9-81.8)
Gender, n (%)	
Female	25 (89.3%)
Male	3 (10.7%)
BMI, mean ± SD (range)	29.6 ± 6.2 (17.8-40.6)
Follow-up time (months), mean ± SD (range)	17.6 ± 20.3 (0.3-81.9)
Indication, (%)	
PJK	16 (57.1%)
Kyphosis	3 (10.7%)
Kyphoscoliosis	2 (7.1%)
Myelopathy	3 (10.7%)
Other	5 (17.9%)
Revision, n (%)	
No	5 (17.9%)
Yes	21 (75%)
ASA score, n (%)	
Grade II	7 (25%)
Grade III	20 (71.4%)
Smoker, n (%)	
No	24 (85.7%)
Yes	4 (14.3%)

Abbreviations: BMI, body mass index; ASA, American Society of Anesthesiologists.

Table 7. Characteristics and Complication Rates of Adult Patients Undergoing Cervical-Pelvis Fusions.

Number of Patients With Complications (N = 28)	
	n (%)
Any complication	20 (71.4%)
Major complications	11 (39.3%)
Minor complications	15 (53.6%)
Any surgical complications	12 (42.9%)
Major	8 (28.6%)
Minor	6 (21.4%)
Any medical complications	17 (60.7%)
Major	6 (21.4%)
Minor	14 (50.0%)
Reoperation required	15 (53.6%)
Pseudarthrosis	7 (25.0%)

this operation results in a clinically significant improvement in SRS scores.

Previous investigations of long fusion constructs have focused on the choice of UIV in the thoracic spine.[1,2,4,5] In a series of 198 patients, Kim et al reported a major complication rate of 57% with UT fusions and 39% with LT fusions. Their rate of reoperation after the index procedure was 15% in UT fusions and 22% in UT fusions with a total of 3 reoperations for pseudarthrosis.[2] Fujimori and colleagues also reported that their rate of major complications was 32% for the UT group and 51% for the LT group, with a 16% to 18% rate of pseudarthrosis.[1]

Our rate of major complications is similar to that reported by Kim et al[2] and Fujimori et al.[1] Our cohort did have a relatively high rate of reoperations (53.1%) compared to the cohort of Kim et al[2] and O'Shaughnessy et al.[4] Our rate of reoperation was similar to that of Fujimori et al.[1] The largest driver of reoperation in our cohort was pseudarthrosis; it was both the most common indication for revision and some patients required multiple visits to the operating room to solve this problem. This relatively high incidence of pseudarthrosis is unsurprising in an older (the average age of this subset was 66.9) adult population that requires a fusion that must cross the cervicothoracic junction. A high rate of cervicothoracic non-union is in keeping with prior studies of long fusions showing a high incidence of pseudarthrosis at the thoracolumbar and lumbosacral junction as the spine transitions from a mobile to a relatively less mobile motion segment.

The high degree of risk associated with these procedures makes it vitally important to consider their etiology. In this subset of adult patients, the majority of patients (57.1%) were indicated due to PJK. PJK is a common cause of revision for all long fusion constructs and is multifactorial in origin.[10-12] To our knowledge, this is the first case series to illustrate the risk incurred by PJK patients requiring an extension of their fusion to the cervical spine.

While these procedures are certainly risky, our data suggests that most patients do find some improvement in HRQOL scores following this procedure. When we queried patients who had pre- and postoperative SRS data available, we found a significant improvement in all domains except Satisfaction and Self Image. In the Activity, Pain, and Mental Health subdomains, these improvements averaged at least 1 MCID. In a series of 198 patients, Kim et al showed that fusion to the UT and LT spine both resulted in a significant improvement in HRQOL scores (SRS and ODI).[2] They demonstrated a mean change in SRS score that exceeded the MCID in all domains except Mental Health at 2 years with a Total SRS score of 3.68 at 2-year follow-up. This is comparable to our total SRS score of 3.5. Fujimori and colleagues also reported similar results, with a final SRS score of 3.4 in UT fusions and 3.5 in LT fusions with an improvement of 2.1 and 1.1 in the UT and LT groups, respectively.[1] Prior studies have shown that UT and LT UIV have no impact on patient outcomes in adult scoliosis.[2] We show that patients undergoing upper cervical to pelvis fusions tend to have lower baseline SRS scores and have lower SRS scores at follow-up. These findings are not surprising: one would expect patients requiring fusion to C2 (vs C7) to have more severe deformity and/or require additional procedures such as cervical laminectomies. Postoperatively, again, the more severe pathology and the loss of subaxial spine motion would be expected to lower functional outcomes. Importantly, however, all patients experienced similar improvements in SRS scores regardless of the choice of cervical UIV.

These conclusions must be tempered by the limitations of this study; chiefly, the retrospective and heterogeneous nature of this study cohort. This study cohort consists of patients treated over an 11-year period, making standardization of data collection, particularly complications and clinical outcomes, extremely difficult. This is evidenced in the fact that only 28 patients had complications data and the same number had pre- and postoperative SRS scores. These limitations increase the possibility of biased reporting of outcomes and underreporting of complications. While mitigating these risks is impossible in a retrospective study, we have attempted to provide the reader with as much data on these cohorts as possible to allow for more nuanced interpretation. Despite these limitations, we believe this study provides valuable data for the field. Fusions from the cervical spine to the pelvis represent uncommon operations that are difficult to study prospectively. For these types of uncommon conditions, in particular, level IV evidence can offer important guidance to physicians.[13]

In this series, we show that PJK is the most common indication for patients requiring fusion to the cervical spine. We show that adult patients undergoing this procedure incur a significant risk of major complications and reoperations. However, despite this risk, patients undergoing fusion from the cervical spine to the pelvis have clinically significant improvement in HRQOL scores.

Appendix A

Table A1. Functional Outcomes Based on Level of UIV in the Cervical Spine.

	C1-C2					C3-C5					C6-C7					
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	*P* Value
Preoperative																
SRS Activity	11	2.3	0.7	1.8	4.2	7	2.6	1.2	1.0	4.5	13	3.4	1.0	1.8	5.0	.025
SRS Pain	11	2.3	0.8	1.5	3.8	7	2.6	1.0	1.3	4.0	13	2.9	0.7	2.0	4.0	.050
SRS Self Image	11	2.4	0.9	1.3	4.2	7	2.8	0.9	1.6	3.8	13	3.5	0.9	1.3	4.6	.026
SRS Mental Health	11	3.3	0.9	2.0	5.0	7	3.1	0.7	2.0	4.0	13	2.4	1.3	0.0	4.5	.259
SRS Satisfaction	11	3.5	1.0	1.5	5.0	7	3.7	0.8	2.4	4.8	13	3.6	0.9	1.0	4.5	.468
SRS Total	11	2.7	0.6	2.0	3.7	7	2.9	0.9	1.9	4.1	13	3.3	0.7	1.9	4.4	.155
Most recent follow-up																
SRS Activity	13	2.6	.9	1.7	4.8	7	3.4	1.4	1.4	5.0	18	3.7	1.2	1.6	5.0	.003
SRS Pain	13	2.5	.9	1.4	4.6	7	3.5	.7	2.4	4.3	18	3.5	.9	1.6	4.7	.004
SRS Self Image	13	2.6	1.0	1.6	5.0	7	3.5	.9	2.0	4.4	18	3.6	.9	2.2	4.8	.025
SRS Mental Health	13	3.4	1.0	1.6	5.0	7	3.9	1.1	2.0	5.0	18	4.1	.9	2.0	5.0	.168
SRS Satisfaction	11	3.4	.6	2.4	4.5	7	4.7	.3	4.0	5.0	18	3.9	.6	2.8	5.0	.008
SRS Total	13	2.8	.7	1.9	4.6	7	3.7	.6	2.9	4.5	18	3.7	.8	2.3	4.7	.004

Abbreviations: UIV, upper instrumented vertebrae; SRS, Scoliosis Research Society.

Table A2. Change in Functional Outcomes by Cervical UIV.

	C1-C2					C3-C5					C6-C7					
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	*P* Value
Change in SRS scores																
SRS Activity	10	0.5	0.6	−0.4	1.2	5	0.9	1.4	0.1	3.3	11	.1	0.6	−1.0	1.0	.529
SRS Pain	10	0.2	0.9	−1.7	1.3	5	1.1	0.9	0.4	2.2	11	0.7	0.8	−0.5	1.7	.708
SRS Self Image	10	0.3	0.7	−0.6	2.1	6	0.7	1.4	−1.2	2.6	12	0.1	0.9	−2.1	1.3	.297
SRS Mental Health	10	0.2	0.8	−0.8	2.0	5	1.0	0.3	0.6	1.5	11	1.4	1.8	−1.2	5.0	.013
SRS Satisfaction	8	0.1	1.2	−1.3	1.5	5	1.1	1.0	0.0	2.4	11	0.2	1.0	−0.6	3.0	.140
SRS Total	10	0.2	0.5	−0.4	1.3	6	0.9	0.7	0.4	2.2	12	0.3	0.6	−0.9	1.1	.152
MCID																
SRS Function	10	1.2	1.6	−1.1	3.2	5	2.3	3.6	.2	8.8	11	0.4	1.7	−2.7	2.7	.196
SRS Pain	10	0.4	1.6	−2.8	2.2	6	1.6	1.5	0.0	3.7	11	1.3	1.3	−0.9	2.9	.797
SRS Self Image	10	0.4	0.9	−0.8	2.6	6	0.9	1.8	−1.5	3.3	12	0.2	1.1	−2.6	1.6	.458
SRS Mental Health	10	0.6	1.9	−1.9	4.8	5	2.4	0.8	1.4	3.6	11	3.3	4.4	−2.9	11.9	.013

Abbreviations: UIV, upper instrumented vertebrae; SRS, Scoliosis Research Society; MCID, minimum clinically important difference.

Appendix B

Table B. Operative Details for the Cohort in Whom Complication Data Was Available.

	Complications in Fusion From C-Spine to Pelvis (N = 28)
OR time (minutes), mean ± SD (range)	327.7 ± 117.6 (164-477)
EBL (mL), mean ± SD (range)	2137.5 ± 2240.3 (50-9100)
Any osteotomy, n (%)	
No	5 (17.9%)
Yes	23 (82.1%)
Number of VCR, n (%)	
None	17 (60.7%)
1	10 (35.7%)
2	1 (3.6%)
Number of PSO, n (%)	
None	20 (71.4%)
1	8 (28.6%)
Number of SPO, n (%)	
None	20 (71.4%)
1	2 (7.1%)
2	1 (3.6%)
3	1 (3.6%)
5	1 (3.6%)
9	1 (3.6%)
UIV, n (%)	
O	1 (3.6%)
C1	1 (3.6%)
C2	15 (53.6%)
C3	2 (7.1%)
C4	1 (3.6%)
C5	4 (14.3%)
C6	0 (0%)
C7	4 (14.3%)
BMP, n (%)	
No	1 (3.6%)
Yes	5 (17.9%)

Abbreviations: OR, operating room; EBL, estimated blood loss; VCR, vertebral column resection; PSO, pedicle subtraction osteotomy; SPO, Smith-Petersen (chevron type) osteotomy; UIV, upper instrumented vertebrae; BMP, Bone Morphogenetic Protein.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Dr Iyer has received grants from the CSRS outside the submitted work. Dr Kim reports personal fees from Medtronic, personal fees from Biomet, personal fees from K2M, personal fees from Stryker, personal fees from DePuy, grants from CSRS, outside the submitted work. Dr Theologis has nothing to disclose. Dr Nemani has nothing to disclose. Dr Albert reports personal fees and other fees from DePuy, personal fees and other fees from Biomet, other fees from Vertech, other fees from In Vivo Therapeutics, other fees from Paradigm Spine, other fees from Biomerix, other fees from Breakaway Imaging, other fees from Crosstree, other fees from Invuity, other fees from Pioneer, other fees from Gentis, other fees from ASIP, other fees from PMIG, personal fees from Facetlink, other fees from United Healthcare, other fees from CSRS, other fees from SRS, other fees from IMAST, other fees from AOA, outside the submitted work. Dr Lenke reports the following conflicts outside the submitted work: Quality Medical Publishing—Royalties; Setting Scoliosis Straight Foundation—Grant support; AO Spine—Grant support; SRS BOD; OREF BOD; Fox Family Foundation—Grant support; EOS Technology—Grant support; Broadwater—Honorarium; K2M Spine—consultant; Depuy-Synthes Spine—consultant; Medtronic—Royalties and consulting payments. Dr Burch reports personal fees from Medtronic, grants from Lilly Inc, grants from Integra Lifescience Corp, outside the submitted work. Dr Deviren reports grants and personal fees from NuVasive, grants from AOSpine, grants from Globus, outside the submitted work. Dr Protopsaltis reports personal fees from Medicrea, personal fees from Globus, personal fees from Innovasis, grants from Zimmer Spine, outside the submitted work. Dr Smith reports personal fees from Zimmer Biomet, personal fees from Nuvasive, personal fees from K2M, personal fees from Cerapedics, grants from DePuy Synthes, grants from AOSpine, grants from NREF, outside the submitted work. Mr Scheer has nothing to disclose. Dr Mizutani has nothing to disclose. Dr Klineberg reports personal fees from Depuy-Synthes, personal fees from Stryker, personal fees from K2M, grants and personal fees from AOSpine, outside the submitted work. Dr Ames reports personal fees from DePuy, personal fees from Medtronic, personal fees from Stryker, personal fees from Biomet Spine, personal fees from Stryker, outside the submitted work. In addition, Dr Ames has a patent, Fish & Richardson, P.C. issued.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

References

1. Fujimori T, Inoue S, Le H, et al. Long fusion from sacrum to thoracic spine for adult spinal deformity with sagittal imbalance: upper versus lower thoracic spine as site of upper instrumented vertebra. *Neurosurg Focus*. 2014;36:E9.
2. Kim HJ, Boachie-Adjei O, Shaffrey CI, et al. Upper thoracic versus lower thoracic upper instrumented vertebrae endpoints have similar outcomes and complications in adult scoliosis. *Spine (Phila Pa 1976)*. 2014;39:795-799.
3. Kim YJ, Bridwell KH, Lenke LG, Rhim S, Cheh G. An analysis of sagittal spinal alignment following long adult lumbar instrumentation and fusion to L5 or S1: can we predict ideal lumbar lordosis? *Spine (Phila Pa 1976)*. 2006;31:2343-2352.
4. O'Shaughnessy BA, Bridwell KH, Lenke LG, et al. Does a long-fusion "T3-sacrum" portend a worse outcome than a short-fusion "T10-sacrum" in primary surgery for adult scoliosis? *Spine (Phila Pa 1976)*. 2012;37:884-890.
5. Ha Y, Maruo K, Racine L, et al. Proximal junctional kyphosis and clinical outcomes in adult spinal deformity surgery with fusion from the thoracic spine to the sacrum: a comparison of proximal and distal upper instrumented vertebrae. *J Neurosurg Spine*. 2013;19:360-369.
6. Auerbach JD, Lenke LG, Bridwell KH, et al. Major complications and comparison between 3-column osteotomy techniques in 105 consecutive spinal deformity procedures. *Spine (Phila Pa 1976)*. 2012;37:1198-1210.
7. Scheer JK, Lafage V, Smith JS, et al. Impact of age on the likelihood of reaching a minimum clinically important difference in 374 three-column spinal osteotomies: clinical article. *J Neurosurg Spine*. 2014;20:306-312.
8. Crawford CH 3rd, Glassman SD, Bridwell KH, Berven SH, Carreon LY. The minimum clinically important difference in SRS-22 R total score, appearance, activity and pain domains after surgical treatment of adult spinal deformity. *Spine (Phila Pa 1976)*. 2015; 40:377-381.
9. Schwab F, Patel A, Ungar B, Farcy JP, Lafage V. Adult spinal deformity-postoperative standing imbalance: how much can you tolerate? An overview of key parameters in assessing alignment and planning corrective surgery. *Spine (Phila Pa 1976)*. 2010;35: 2224-2231.
10. Kim HJ, Bridwell KH, Lenke LG, et al. Patients with proximal junctional kyphosis requiring revision surgery have higher postoperative lumbar lordosis and larger sagittal balance corrections. *Spine (Phila Pa 1976)*. 2014;39:576-580.
11. Yagi M, Rahm M, Gaines R, et al. Characterization and surgical outcomes of proximal junctional failure in surgically treated patients with adult spinal deformity. *Spine (Phila Pa 1976)*. 2014;39:607-614.
12. Hart R, McCarthy I, O'Brien M, et al. Identification of decision criteria for revision surgery among patients with proximal junctional failure after surgical treatment of spinal deformity. *Spine (Phila Pa 1976)*. 2013;38:1223-1227.
13. Sangeorzan BJ, Swiontkowski M. Level-III and IV evidence: Still essential for the field of musculoskeletal medicine and surgery. *J Bone Joint Surg Am*. 2016;98:1151-1152.