JNS SPINE

CLINICAL ARTICLE

J Neurosurg Spine 39:646–651, 2023

Should realignment goals vary based on patient frailty status in adult spinal deformity?

Presented at the 2023 AANS/CNS Joint Section on the Disorders of the Spine and Peripheral Nerves

Peter G. Passias, MD,[1] Jamshaid M. Mir, MD,[1] Tyler K. Williamson, DO,[1] Peter S. Tretiakov, BS,[1] Pooja Dave, BS,[1] Virginie Lafage, PhD,[2] Renaud Lafage, MS,[3] and Andrew J. Schoenfeld, MD, MSc[4]

[1]Departments of Orthopedic and Neurological Surgery, Division of Spine Surgery, NYU Langone Medical Center, New York Spine Institute, New York, New York; [2]Department of Orthopedics, Lenox Hill Hospital, Northwell Health, New York, New York; [3]Department of Orthopedics, Hospital for Special Surgery, New York, New York; and [4]Department of Orthopaedic Surgery, Brigham and Women's Hospital, Harvard Medical School, Boston, Massachusetts

OBJECTIVE The objective of this study was to adjust the sagittal age-adjusted score (SAAS) to accommodate frailty in alignment considerations and thereby increase the predictability of clinical outcomes and junctional failure.

METHODS Surgical adult spinal deformity (ASD) patients with 2-year data were included. Frailty was assessed with the continuous ASD modified frailty index (ASD-mFI). Two-year outcomes were proximal junctional kyphosis (PJK), proximal junctional failure (PJF), major mechanical complications, and best clinical outcome (BCO), defined as Oswestry Disability Index (ODI) score < 15 and Scoliosis Research Society outcomes questionnaire total score > 4.5 by 2 years. Linear regression analysis established a 6-week score based on the component scores of SAAS, frailty, and US normal values for ODI score. Logistic regression analysis followed by conditional inference tree run forest analysis generated categorical thresholds. Multivariate analysis, controlling for age, baseline deformity, and history of revision, was used to compare outcome rates, and logistic regression generated odds ratios for the continuous score. Thirty percent of the cohort was used as a random sample for internal validation.

RESULTS In total, 412 patients were included (mean ± SD age 60.1 ± 14.2 years, 80% female, BMI 26.9 ± 5.4 kg/m^2). Baseline frailty categories were as follows: 57% not frail, 30% frail, and 14% severely frail. Overall, by 2 years, 39% of patients had developed PJK, 8% PJF, and 21% mechanical complications; 22% had undergone a reoperation; and 15% met BCO. When the cohort as a whole was assessed, the 6-week SAAS had a correlation with the development of PJK and PJF, but not mechanical complications, reoperation, or BCO. Development of mechanical complications, PJF, reoperation, and BCO demonstrated correlations with ASD-mFI (all $p < 0.05$). Regression analysis modifying SAAS on the basis of ODI norms and frailty generated the following equation: frailty-adjusted SAAS (FAS) = 0.108 × T1 pelvic angle + 0.162 × pelvic tilt − 0.39 × pelvic incidence − lumbar lordosis − 0.03 × ASD-mFI − 1.6771. With conditional inference tree analysis, thresholds were derived for FAS: aligned < 1.7, offset 1.7–2.2, and severely offset > 2.2. Significance between FAS categories was found for PJK, PJF, mechanical complications, reoperation, and BCO by 2 years. Binary logistic regression, controlling for baseline deformity and revision status, demonstrated significance between FAS and all 5 outcome variables (all $p < 0.01$). Internal validation saw each outcome variable maintain significance between categories, with even greater odds for PJF (OR 13.4, 95% CI 4.7–38.3, $p < 0.001$).

CONCLUSIONS Consideration of physiological age, in addition to chronological age, may be beneficial in the management of operative goals to maximize clinical outcomes while minimizing junctional failure. This combination enables the spine surgeon to fortify a surgical plan for even the most challenging patients undergoing ASD corrective surgery.

https://thejns.org/doi/abs/10.3171/2023.5.SPINE23456

KEYWORDS adult spinal deformity; age-adjusted alignment; frailty

ABBREVIATIONS ASD = adult spinal deformity; ASD-mFI = ASD modified frailty index; BCO = best clinical outcome; CCI = Charlson Comorbidity Index; CIT = conditional inference tree; FAS = frailty-adjusted SAAS; HRQOL = health-related quality of life; LL = lumbar lordosis; ODI = Oswestry Disability Index; PI = pelvic incidence; PI-LL = mismatch between PI and LL; PJF = proximal junctional failure; PJK = proximal junctional kyphosis; PT = pelvic tilt; SAAS = sagittal age-adjusted score; SRS = Scoliosis Research Society; T1PA = T1 pelvic angle; UIV = upper instrumented vertebra.

ACCOMPANYING EDITORIAL See pp 643–645. DOI: 10.3171/2023.6.SPINE23571.
SUBMITTED May 2, 2023. **ACCEPTED** May 22, 2023.
INCLUDE WHEN CITING Published online August 11, 2023; DOI: 10.3171/2023.5.SPINE23456.

Rates of corrective surgery for adult spinal deformity (ASD) have been increasing given its significant impact on quality of life.[1–4] Understanding of the parameters associated with deformity has led to an increased understanding of realignment strategies and targets. With different classification systems such as the Global Alignment and Proportion score and Scoliosis Research Society (SRS)–Schwab classification for categorization of deformity in existence, the development of another categorization system was created in part due to patient ability to tolerate invasive surgery given their age and frailty.[3–7] Given that chronological age has been a common metric used to assess patient ability to withstand surgery, the sagittal age-adjusted score (SAAS) is a novel externally validated radiographic alignment metric that was created to take the patient's age into consideration for alignment targets.[8,9]

SAAS is calculated on the basis of the patient's age and assesses three different metrics. Alignment is based on the pelvic incidence (PI) to lumbar lordosis (LL) difference (i.e., PI-LL), pelvic tilt (PT), and T1 pelvic angle (T1PA). A score is calculated on the basis of how far the value is from the calculated value. Several studies have investigated the usefulness of SAAS and its correlation leading to favorable outcomes. One study found that SAAS was a better predictor of postoperative improvements in sagittal balance than traditional parameters. SAAS has also been shown to have a strong correlation with health-related quality-of-life (HRQOL) measures, indicating its usefulness in evaluating the impact of sagittal balance on patient outcomes.[10–12] Despite its potential usefulness, SAAS has some limitations. SAAS is a relatively new parameter, and its clinical relevance and usefulness require further investigation. Furthermore, although SAAS takes into account age, it does not account for physiological age or frailty.

HRQOL measures such as SRS-22 questionnaire and Oswestry Disability Index (ODI) scores have been used in ASD patients as metrics to assess the clinical impact of baseline disability and to track patient outcomes. They have also been classically used as surrogates for assessing frailty in these patients, especially before spine-specific frailty indices for ASD. Although the association between frailty and HRQOL varies among the literature, worsening frailty has been associated with decreased likelihood of achieving substantial clinical benefit and adverse outcomes.[7,13,14] Therefore, our study assessed outcomes based on HRQOL, as well as complications and reoperations, to encompass a greater overall picture of patient outcomes. The aim of our study was to assess whether a scoring parameter that takes into account frailty better tailors realignment goals. We hypothesized that SAAS accounting for frailty would perform better at potentiating clinical success while minimizing complications relative to radiographic criteria alone.

Methods

Study Design and Inclusion and Exclusion Criteria

This study was a retrospective analysis of a prospectively collected single-center ASD database. IRB approval was obtained prior to study initiation, and informed consent was given by each included patient prior to enrollment in the registry. The means through which the data were collected and the outcomes defined, along with the general inclusion criteria, have been extensively described in prior publications. We included operative ASD patients who had complete radiographic and HRQOL data at baseline and 2-year follow-up in the current investigation. Cases secondary to trauma, infection, and malignancy were excluded.

Data Collection and Radiographic Parameters

Demographic information included age, BMI, biological sex, and Charlson Comorbidity Index (CCI) score. Frailty was assessed with the externally validated continuous ASD modified frailty index (ASD-mFI).[15,16] Surgical parameters consisted of levels fused, operative time, length of stay, surgical approach, and use of decompressions and osteotomies. We recorded postoperative complications as documented in the data set and based on clinical follow-up. Prospectively collected patient-reported outcome measures were collected at baseline, as well as at follow-up intervals, and included the following: SRS-22 and ODI scores.

Free-standing full-length lateral spine radiographs (36-inch cassette) were taken and assessed at baseline and follow-up. SpineView software (ENSAM, Laboratory of Biomechanics) was used to analyze the radiographs according to standardized and validated techniques that have been previously published in the literature. The spinopelvic radiographic parameters measured were PT, PI, T1PA, LL (L1–S1), and PI-LL.

Clinical Outcome Assessment

Best clinical outcome (BCO) was defined as having 2-year outcomes without proximal junctional kyphosis (PJK), proximal junctional failure (PJF), and major mechanical complications, along with the BCO as defined by Smith et al. as ODI score < 15 and SRS total score > 4.5.[17]

Complications Assessed

Radiographic criteria for PJK and PJF were used, with PJK defined as greater than 10° change from baseline in upper instrumented vertebra (UIV)+2 angulation and greater than 10° angulation. PJF values were based on the criteria reported by Lafage et al. of greater than 22° change from baseline in terms of UIV to UIV+2 angulation along with the angle being greater than 28°.[18]

Mechanical complications were defined as any complication pertaining to the implant, including implant malposition, prominence, failure, painful implant, interbody dislocation, screw nerve impingement, screw fracture, rod dislocation, and rod fracture. Major mechanical complications were those that required invasive intervention or caused prolonged or permanent morbidity or mortality.

Development of the Frailty-Adjusted Realignment Score

A 6-week score based on SAAS, frailty, and US normal values for ODI was established on the basis of the logistic regression analysis based on published work by Lafage

TABLE 1. Comorbidities of the included patients

Comorbidity	Value
Arthritis	39
Cancer	13
Depression	20
Diabetes	7
Heart disease	11
Hypertension	33
Kidney disease	3
Liver disease	2
Lung disease	5
Neurological	3
Osteoporosis	18
Peripheral vascular disease	2
Psychiatric	5
Total no.	1.9 ± 1.8

Values are shown as % or mean ± SD

et al.[19] The score was based on the correlations of these factors with achieving BCO and the development of mechanical complications or PJF. Generation of categorical thresholds was based on the rates of mechanical complications determined by using logistic regression followed by conditional inference tree (CIT) analysis.

Statistical Analysis

Linear regression analysis established a 6-week score based on the component scores of SAAS, frailty, and US normal values for ODI by using an equation previously published by Lafage et al.[8] Logistic regression analysis followed by CIT run forest analysis generated categorical thresholds. Multivariate analysis controlling for age, baseline deformity, and history of revision was used to compare the outcome rates, and logistic regression generated odds ratios for the continuous scores. A random sample of 30% of the cohort was used for internal validation. Statistical analysis was conducted using SPSS version 28.0.1 (IBM Corp.), with all p values less than 0.05 being considered significant.

Results

Cohort Overview

In total, 412 patients with 2-year data were included. The mean ± SD patient age was 60.1 ± 14.2 years, 80% of patients were female, and BMI was 26.9 ± 5.4 kg/m^2. Based on the Passias-modified ASD-mFI, the mean frailty score of the cohort was 6.5 ± 4.8. Baseline frailty categories were as follows: 57% of patients were not frail, 30% frail, and 14% severely frail. Osteoporosis was present in 18% of patients at baseline, with a mean CCI score of 1.7 ± 1.7. Comorbidity data are depicted in Table 1.

Radiographic Alignment

Baseline radiographic alignment was 23.8° ± 11.2° in PT, 54.4° ± 12.4° in PI, 38.6° ± 21.6° in LL (L1–S1), and 15.8° ± 21.3° in PI-LL mismatch. T1PA at baseline was 22.7°±13.4°, and SVA was 6.5 ± 7.1 cm.

The mean postoperative radiographic parameters were follows: PT of 19.0° ± 10.2°, PI-LL of 1.3° ± 13.9°, LL of 53.1° ± 14.1°, T1PA of 15.0° ± 9.6°, and SVA of 2.4 ± 4.4 cm. Radiographic characteristics at baseline, postoperation, 1 year, and 2 years are listed in Table 2.

Surgical Details

Patients had a mean number of fused levels of 13.2 ± 2.8, an estimated blood loss of 1680 ± 1273 ml, and operative time of 416 ± 176 minutes. The overall cohort had a mean UIV of T7–8, and 72% underwent osteotomies, 28% three-column osteotomies, 56% decompression, and 59% interbody fusion with the following approaches: 64% posterior and 35% anterior and posterior. In total, 79.4% were same day surgical procedures, whereas 20.6% were staged. All patients had a component of their surgery that was open, and 19.9% had a component of a minimally invasive surgical approach as well. Surgical characteristics are listed in Table 3.

Clinical Outcomes

At baseline, the ODI score was 42.5 ± 18.5, with a mean 2-year ODI score of 26.0 ± 20.0. The SRS-22r score was 2.8 ± 0.7 at baseline and 3.7 ± 0.8 at 2 years. The minimal clinically important difference in ODI was reached by 57% of patients at 1 year and 54% at 2 years. BCO was achieved in 15% of the cohort.

TABLE 2. Radiographic measurements

Measurement	Baseline	Postop	1 yr	2 yrs
C7–plumb line, mm*	36.4 ± 34.5	26.7 ± 21.1	27.5 ± 22.0	26.8 ± 22.5
PT, °	23.8 ± 11.2	19.0 ± 10.2	20.5 ± 10.1	20.9 ± 10.1
PI, °	54.4 ± 12.4	54.4 ± 12.3	54.7 ± 12.5	54.6 ± 12.4
LL, °	38.6 ± 21.6	53.1 ± 14.1	52.8 ± 14.4	52.1 ± 14.2
PI-LL, °	15.8 ± 21.3	1.3 ± 13.9	1.9 ± 14.4	2.5 ± 14.2
T1PA, °	22.7 ± 13.4	15.1 ± 9.6	16.0 ± 10.3	16.5 ± 10.4
Sagittal vertical axis, mm	65.2 ± 71.1	24.5 ± 44.2	21.6 ± 49.5	24.7 ± 50.0

All values are shown as mean ± SD.
* Absolute values are shown.

TABLE 3. Surgical characteristics

Characteristic	Value
Levels fused, no.	13.2 ± 2.8
UIV	T7–8
Osteotomy	72
3-column osteotomy	28
Decompression	56
Interbody fusion	59
Approach	
Posterior only	64
Anterior & posterior	35
Op time, mins	416 ± 176
Estimated blood loss, ml	1680 ± 1273

Values are shown as % or mean ± SD.

Complications, Clinical Outcomes, and Frailty-Adjusted Score Development

Overall, by 2 years, 39% of patients developed PJK, 8% PJF, and 21% mechanical complications; 22% underwent reoperation; and 15% met BCO. When the cohort as a whole was assessed, the 6-week SAAS was correlated with development of PJK and PJF but not mechanical complications, reoperation, or BCO. Development of mechanical complications, PJF, reoperation, and BCO demonstrated correlations with ASD-mFI score (all $p < 0.05$).

Regression analysis, which modified SAAS on the basis of the normal ODI values and frailty, generated the following equation: frailty-adjusted SAAS (FAS) = $0.108 \times \text{T1PA} + 0.162 \times \text{PT} - 0.39 \times \text{PI} - \text{LL} - 0.03 \times \text{ASD-mFI} - 1.6771$.

Derivation of Categorical Thresholds and Comparison of Outcomes Between SAAS and FAS

With CIT analysis, thresholds were derived for the FAS score: aligned < 1.7, offset 1.7–2.2, and severely offset > 2.2. Significance between FAS categories was found for PJK, PJF, mechanical complications, reoperation, and BCO by 2 years.

Binary logistic regression, controlling for baseline deformity and revision status, demonstrated significance between FAS and all 5 outcome variables (all $p < 0.01$) (Table 4). Internal validation saw each outcome variable maintain significance between categories, with even greater odds for PJF (OR 13.4, 95% CI 4.7–38.3, $p < 0.001$) (Table 5).

Discussion

General acceptance of the use of surgical planning with target realignment goals has led to improved clinical success and mitigation of complications in the ASD population. Although SAAS was developed with this purpose, validation studies have demonstrated that performance can be improved. We anticipate that some of these issues may be derived from the inability of SAAS to account for patient frailty, which is a vital driver of adverse events after surgical correction. In the current work, we modified SAAS realignment targets to account for frailty and to better tailor correction with physiological tolerance for surgical invasiveness. A simplified FAS was developed to balance achieving good clinical outcome against the chances of developing mechanical or radiographic complications.

In our analysis, patients proportioned in FAS sustained significantly lower rates of PJF and reoperations, even when accounting for baseline deformity and invasiveness of the procedure. The importance of BMI and regional osteopenia in contributing to adverse events after ASD has been well established. We believe that FAS is advantageous over solitary parameters given that BMI and low bone mineral density are components of ASD-mFI. As a composite measure incorporating these risk factors, FAS presents a more holistic assessment of patient risk while minimizing data inputs and utilization of multiple scoring metrics.

Although avoidance of complications is a major focus in preoperative planning, the ultimate goal of surgical correction is to relieve the majority of the dysfunction and disability that affects quality of life in patients with spinal deformity; thus, realignment goals targeting clinical success are paramount. FAS demonstrated superior clinical utility compared with SAAS. Furthermore, patients

TABLE 4. Comparison of complication rates by original SAAS and FAS

Values	No. of Patients	Range of Frailty Score	PJK*	p Value	PJF*	p Value	Mechanical Complication*	p Value	Any Reop*	p Value
FAS										
Aligned	67	1.9	34.3	0.127	5.5	0.029	16.4	0.376	13.4	0.007
Offset	220	5.3	36.4		7.5		20.5		19.6	
Severely offset	125	11.1	46.4		13.6		24.8		31.2	
Original SAAS										
Over	199	6.3	43.7	0.164	10.6	0.094	18.6	0.088	22.1	0.229
Match	117	6.6	35.9		8.6		18.8		26.5	
Under	96	6.5	33.3		3.1		29.2		16.7	

* Percent of patients is shown.

TABLE 5. Comparison of BCO based on original SAAS and FAS

Values	No. of Patients	Range of Frailty Score	BCO*	p Value
FAS				
Aligned	67	1.9	24.2	<0.001
Offset	220	5.3	19.0	
Severely offset	125	11.1	3.3	
Original SAAS				
Over	199	6.3	14.9	0.867
Match	117	6.6	14.3	
Under	96	6.5	16.8	

* Percent of patients is shown. Based on the definition of Smith et al.[17]

optimized on the basis of FAS were 13 times less likely to develop PJF and were significantly more likely to meet good clinical outcomes.

The modification of SAAS has shown clinical utility in these patients. It is important to note that this exploratory approach to examine the effects of patient-specific factors on complications and their incorporation into alignment targets is limited. The retrospective nature of the current study comes with its inherent bias, and selection and expertise bias were potentially present. Of course, we encourage surgeons to utilize their clinical decision-making when necessary and our adjusted score as a reference tool that provides a simplified model of a relatively complex patient population. Further studies assessing external validation of our study are warranted.

Conclusions

Consideration of physiological age, in addition to chronological age, may be beneficial in the management of operative goals to maximize clinical outcomes while minimizing junctional failure. This combination enables the spine surgeon to fortify a surgical plan for even the most challenging patients undergoing ASD corrective surgery.

References

1. Safaee MM, Ames CP, Smith JS. Epidemiology and socioeconomic trends in adult spinal deformity care. *Neurosurgery*. 2020;87(1):25-32.
2. Zygourakis CC, Liu CY, Keefe M, et al. Analysis of national rates, cost, and sources of cost variation in adult spinal deformity. *Neurosurgery*. 2018;82(3):378-387.
3. Naresh-Babu J, Kwan KYH, Wu Y, et al. AO Spine adult spinal deformity patient profile: a paradigm shift in comprehensive patient evaluation in order to optimize treatment and improve patient care. *Global Spine J*. Published online August 17, 2021. doi:10.1177/21925682211037935
4. Passias PG, Poorman GW, Jalai CM, et al. Morbidity of adult spinal deformity surgery in elderly has declined over time. *Spine (Phila Pa 1976)*. 2017;42(16):E978-E982.
5. Simcox T, Antoku D, Jain N, Acosta F, Hah R. Frailty syndrome and the use of frailty indices as a preoperative risk stratification tool in spine surgery: a review. *Asian Spine J*. 2019;13(5):861-873.
6. Sciubba D, Jain A, Kebaish KM, et al. Development of a preoperative adult spinal deformity comorbidity score that correlates with common quality and value metrics: length of stay, major complications, and patient-reported outcomes. *Global Spine J*. 2021;11(2):146-153.
7. Reid DBC, Daniels AH, Ailon T, et al. Frailty and health-related quality of life improvement following adult spinal deformity surgery. *World Neurosurg*. 2018;112:e548-e554.
8. Lafage R, Smith JS, Elysee J, et al. Sagittal age-adjusted score (SAAS) for adult spinal deformity (ASD) more effectively predicts surgical outcomes and proximal junctional kyphosis than previous classifications. *Spine Deform*. 2022; 10(1):121-131.
9. Park SJ, Lee CS, Kang BJ, et al. Validation of age-adjusted ideal sagittal alignment in terms of proximal junctional failure and clinical outcomes in adult spinal deformity. *Spine (Phila Pa 1976)*. 2022;47(24):1737-1745.
10. Passias PG, Segreto FA, Imbo B, et al. Defining age-adjusted spinopelvic alignment thresholds: should we integrate BMI? *Spine Deform*. 2022;10(5):1077-1084.
11. Lafage R, Smith JS, Soroceanu A, et al. Predicting mechanical failure following cervical deformity surgery: a composite score integrating age-adjusted cervical alignment targets. *Global Spine J*. Published online March 29, 2022. doi: 10.1177/21925682221086535
12. Byun CW, Cho JH, Lee CS, Lee DH, Hwang CJ. Effect of overcorrection on proximal junctional kyphosis in adult spinal deformity: analysis by age-adjusted ideal sagittal alignment. *Spine J*. 2022;22(4):635-645.
13. Laverdière C, Georgiopoulos M, Ames CP, et al. Adult spinal deformity surgery and frailty: a systematic review. *Global Spine J*. 2022;12(4):689-699.
14. Beauchamp-Chalifour P, Flexman AM, Street JT, et al. The impact of frailty on patient-reported outcomes after elective thoracolumbar degenerative spine surgery. *J Neurosurg Spine*. 2021;35(5):607-615.
15. Passias PG, Moattari K, Pierce KE, et al. Performance of the modified adult spinal deformity frailty index in preoperative risk assessment. *Spine (Phila Pa 1976)*. 2022;47(20):1463-1469.
16. Akbik OS, Al-Adli N, Pernik MN, et al. A comparative analysis of frailty, disability, and sarcopenia with patient characteristics and outcomes in adult spinal deformity surgery. *Global Spine J*. Published online April 6, 2022. doi: 10.1177/21925682221082053
17. Smith JS, Shaffrey CI, Lafage V, et al. Comparison of best versus worst clinical outcomes for adult spinal deformity surgery: a retrospective review of a prospectively collected, multicenter database with 2-year follow-up. *J Neurosurg Spine*. 2015;23(3):349-359.
18. Lafage R, Schwab F, Glassman S, et al. Age-adjusted alignment goals have the potential to reduce PJK. *Spine (Phila Pa 1976)*. 2017;42(17):1275-1282.
19. Lafage R, Schwab F, Challier V, et al. Defining spino-pelvic alignment thresholds: should operative goals in adult spinal deformity surgery account for age? *Spine (Phila Pa 1976)*. 2016;41(1):62-68.

Disclosures

Dr. Passias reported personal consulting fees from Medtronic and Globus outside the submitted work. Dr. V. Lafage reported personal consulting fees from Alphatec and Globus Medical; personal royalty fees from NuVasive; personal fees for lectures from Johnson & Johnson and Stryker; executive committee member of ISSG; and committee member of the Scoliosis Research Society outside the submitted work. Mr. R. Lafage reported personal fees from Carlsmed outside the submitted work. Dr. Schoenfeld reported grants paid to an institution from DOD and NIH-

NIAMS; personal fees from Wolters Kluwer and Springer outside the submitted work; editorial board member of *Journal of Bone and Joint Surgery*; editor-in-chief of *Spine*; and board of directors member of NASS.

Author Contributions

Conception and design: Passias, Williamson. Acquisition of data: Passias, Mir, Williamson, Dave, R Lafage, V Lafage. Analysis and interpretation of data: Passias, Mir, Williamson, Tretiakov, V Lafage, Schoenfeld. Drafting the article: Passias, Mir, Williamson, Schoenfeld. Critically revising the article: Passias, Mir, Williamson, Tretiakov, Dave, V Lafage, Schoenfeld. Reviewed submitted version of manuscript: Passias, Mir, Williamson, Schoenfeld. Approved the final version of the manuscript on behalf of all authors: Passias. Statistical analysis: Passias, Mir, Williamson, Dave, Schoenfeld. Administrative/technical/material support: Passias, Mir, R Lafage. Study supervision: Passias.

Supplemental Information

Previous Presentations

This work was presented as a poster at the North American Spine Association (NASS) Annual Meeting, Chicago, IL, October 12–15, 2022; as a poster at the American Association of Neurological Surgeons (AANS) Annual Scientific Meeting, Philadelphia, PA, April 29–May 2, 2022; as a podium presentation at the International Meeting on Advanced Spine Techniques (IMAST), Miami, FL, April 6–9, 2022; and as a podium presentation at the Spine Summit Annual Meeting, Miami Beach, FL, March 16–19, 2023.

Correspondence

Peter G. Passias: New York Spine Institute, NYU Langone Medical Center, Orthopedic Hospital—NYU School of Medicine, New York, NY. peter.passias@nyumc.org.