

## Economic burden of nonoperative treatment of adult spinal deformity

Peter G. Passias, MD,<sup>1</sup> Waleed Ahmad, MS,<sup>1</sup> Pooja Dave, BS,<sup>1</sup> Renaud Lafage, MS,<sup>2</sup> Virginie Lafage, PhD,<sup>2</sup> Jamshaid Mir, MD,<sup>1</sup> Eric O. Klineberg, MD,<sup>3</sup> Khaled M. Kabeish, MD,<sup>4</sup> Jeffrey L. Gum, MD,<sup>5</sup> Breton G. Line, BS,<sup>6</sup> Robert Hart, MD,<sup>7</sup> Douglas Burton, MD,<sup>8</sup> Justin S. Smith, MD, PhD,<sup>9</sup> Christopher P. Ames, MD,<sup>8</sup> Christopher I. Shaffrey, MD,<sup>10</sup> Frank Schwab, MD,<sup>2</sup> Richard Hostin, MD,<sup>11</sup> Thomas Buell, MD,<sup>12</sup> D. Kojo Hamilton, MD,<sup>12</sup> and Shay Bess, MD,<sup>6</sup> on behalf of International Spine Study Group

<sup>1</sup>Departments of Orthopaedic and Neurologic Surgery, Division of Spine, NYU Langone Medical Center; New York Spine Institute, New York, New York; <sup>2</sup>Department of Orthopedics, Hospital for Special Surgery, New York, New York; <sup>3</sup>Department of Orthopaedics, Lenox Hill Hospital, Northwell Health, New York, New York; <sup>4</sup>Department of Orthopaedic Surgery, Johns Hopkins Medical Center, Baltimore, Maryland; <sup>5</sup>Norton Leatherman Spine Center, Louisville, Kentucky; <sup>6</sup>Department of Spine Surgery, Denver International Spine Clinic, Presbyterian St. Luke's/Rocky Mountain Hospital for Children, Denver, Colorado; <sup>7</sup>Department of Orthopaedic Surgery, Swedish Neuroscience Institute, Seattle, Washington; <sup>8</sup>Department of Orthopaedic Surgery, University of Kansas Medical Center, Kansas City, Kansas; <sup>9</sup>Department of Neurosurgery, University of Virginia, Charlottesville, Virginia; <sup>10</sup>Department of Neurological Surgery, University of California, San Francisco, California; <sup>11</sup>Department of Orthopaedic Surgery, Southwest Scoliosis Center, Dallas, Texas; and <sup>12</sup>Department of Neurological Surgery, University of Pittsburgh School of Medicine, Pittsburgh, Pennsylvania

**OBJECTIVE** The purpose of this study was to investigate the cost utility of nonoperative treatment for adult spinal deformity (ASD).

**METHODS** Nonoperatively and operatively treated patients who met database criteria for ASD and in whom complete radiographic and health-related quality of life data at baseline and at 2 years were available were included. A cost analysis was completed on the PearlDiver database assessing the average cost of nonoperative treatment prior to surgical intervention based on previously published treatments (NSAIDs, narcotics, muscle relaxants, epidural steroid injections, physical therapy, and chiropractor). Utility data were calculated using the Oswestry Disability Index (ODI) converted to SF-6D with published conversion methods. Quality-adjusted life years (QALYs) used a 3% discount rate to account for residual decline in life expectancy (78.7 years). Minor and major comorbidities and complications were assessed according to the CMS.gov manual's definitions. Successful nonoperative treatment was defined as a gain in the minimum clinically importance difference (MCID) in both ODI and Scoliosis Research Society (SRS)–pain scores, and failure was defined as a loss in MCID or conversion to operative treatment. Patients with baseline ODI  $\leq$  20 and continued ODI of  $\leq$  20 at 2 years were considered nonoperative successful maintenance. The average utilization of nonoperative treatment and cost were applied to the ASD cohort.

**RESULTS** A total of 824 patients were included (mean age 58.24 years, 81% female, mean body mass index 27.2 kg/m<sup>2</sup>). Overall, 75.5% of patients were in the operative and 24.5% were in the nonoperative cohort. At baseline patients in the operative cohort were significantly older, had a greater body mass index, increased pelvic tilt, and increased pelvic incidence–lumbar lordosis mismatch (all  $p < 0.05$ ). With respect to deformity, patients in the operative group had higher rates of severe (i.e., ++) sagittal deformity according to SRS–Schwab modifiers for pelvic tilt, sagittal vertical axis, and pelvic incidence–lumbar lordosis mismatch ( $p < 0.05$ ). At 2 years, patients in the operative cohort showed significantly increased rates of a gain in MCID for physical component summary of SF-36, ODI, and SRS-activity, SRS-pain, SRS-appearance, and SRS-mental scores. Cost analysis showed the average cost of nonoperative treatment 2 years prior

**ABBREVIATIONS** ASD = adult spinal deformity; BMI = body mass index; HRQOL = health-related quality of life; LOS = length of stay; MCID = minimum clinically importance difference; ODI = Oswestry Disability Index; PI-LL = pelvic incidence–lumbar lordosis mismatch; PT = pelvic tilt; QALY = quality-adjusted life year; SRS = Scoliosis Research Society; SVA = sagittal vertical axis.

**SUBMITTED** March 30, 2023. **ACCEPTED** July 24, 2023.

**INCLUDE WHEN CITING** Published online September 15, 2023; DOI: 10.3171/2023.7.SPINE23195.

to surgical intervention to be \$2041. Overall, at 2 years patients in the nonoperative cohort had again in ODI of 0.36, did not show a gain in QALYs, and nonoperative treatment was determined to be cost-ineffective. However, a subset of patients in this cohort underwent successful maintenance treatment and had a decrease in ODI of 1.1 and a gain in utility of 0.006 at 2 years. If utility gained for this cohort was sustained to full life expectancy, patients' cost per QALY was \$18,934 compared to a cost per QALY gained of \$70,690.79 for posterior-only and \$48,273.49 for combined approach in patients in the operative cohort.

**CONCLUSIONS** Patients with ASD undergoing operative treatment at baseline had greater sagittal deformity and greater improvement in health-related quality of life postoperatively compared to patients treated nonoperatively. Additionally, patients in the nonoperative cohort overall had an increase in ODI and did not show improvement in utility gained. Patients in the nonoperative cohort who had low disability and sagittal deformity underwent successful maintenance and cost-effective treatment.

<https://thejns.org/doi/abs/10.3171/2023.7.SPINE23195>

**KEYWORDS** cost; adult spinal deformity; nonoperative; management; pain

**A**DULT spinal deformity (ASD) is a complex malalignment that often requires surgical intervention to relieve patients of severe pain and disability. As attention on cost-effectiveness and healthcare spending has heightened, recent literature suggests that the cost of corrective ASD surgery can be upwards of \$100,000.<sup>1-3</sup> With the prevalence of ASD ranging from 32% to 68%, there is increased focus on the optimal treatment modality for these patients.

The initial course of treatment for patients with ASD is often nonoperative, consisting of physical therapy, medication, steroid injections, bracing, and chiropractor visits.<sup>4</sup> Depending on the initial level of deformity, disability, and pain, patients will often cross over to operative management to limit disease progression and improve quality of life. Prior to this crossover, however, the amount of resource utilization in conservative treatment varies and the additional economic burden of prolonged nonoperative treatment has been understudied in the literature.

The aim of our study was to analyze the resource utilization and cost of nonoperative treatment for patients with ASD. Additionally, we determined to which cohort an extensive nonoperative course of treatment would be beneficial, and in which it would be most cost-effective.

## Methods

### Study Design, Inclusion, and Exclusion Criteria

A retrospective cohort review of a prospective multicenter ASD database was conducted. Institutional review board approval and informed consent was obtained from 13 centers across the US prior to patient enrollment. Inclusion criteria encompassed patients  $\geq 18$  years and a minimum of one of the following radiographic measures: pelvic tilt (PT)  $\geq 25^\circ$ , Cobb angle  $\geq 20^\circ$ , sagittal vertical axis (SVA)  $\geq 5$  cm, and/or thoracic kyphosis  $> 60^\circ$ . Operatively and nonoperatively treated patients who met database criteria for ASD with complete radiographic and health-related quality of life (HRQOL) data at baseline and at 2 years postsurgery were included for analysis. Patients included in the nonoperative cohort were identified as those who had only undergone nonoperative treatment at the time of analysis, including physical/occupational therapy, pain management, chiropractor visits, and steroid injections.

### Data Collection and Radiographic Parameters

Using standardized data collection forms, patient demographic, clinical, and operative data were recorded. The demographic data compiled consisted of a patient's age, sex, body mass index (BMI), and Charlson Comorbidity Index. Levels fused, length of stay (LOS), operative time, performance of decompression, surgical approach, and osteotomies encompassed the surgical parameters. To certify data accuracy, study coordinators at each center assisted with data collection, allowing for routine auditing. Patient-reported outcome measures collected prospectively at baseline and at follow-up visits were as follows: Oswestry Disability Index (ODI), SF-36 questionnaire, and Scoliosis Research Society Outcomes Questionnaire (SRS-22). Improvements in outcomes were evaluated using minimum clinically importance difference (MCID) thresholds; these were used based on published values in the literature for ODI (12.8), SF-36 (4.9), SRS-pain (0.587), SRS-mental (0.42), SRS-activity (0.375), and SRS-appearance (0.8).

At baseline and follow-up intervals, full-length free-standing lateral spine radiographs (36-inch cassette) were collected. Using SpineView (ENSAM; Laboratory of Biomechanics) software, radiographic images were analyzed according to previously published validated and standardized techniques.<sup>5-7</sup> Spinopelvic radiographic parameters measured included pelvic incidence, PT, thoracic kyphosis (T4–12), SVA, pelvic incidence–lumbar lordosis mismatch (PI-LL), and LL (T12–S1).

### Cost Calculation

The PearlDiver database was used to calculate costs by using job order cost accounting (charge analysis). Reflecting both Medicare reimbursement and private insurance, the PearlDiver data are some of the most comprehensive data sets with access to Medicare reimbursement charges, outcome data, and trends. Using mean costs associated with procedures based on 2018 ASD diagnosis-related groups, the database allows for increased generalizability.<sup>8-12</sup> Major and minor complications, major and minor comorbidities, and revisions were assessed and accounted for according to CMS.gov manual definitions.<sup>13</sup> Two-year reimbursement consisted of a standardized estimate in which regression analysis of Medicare pay scales was used for all services rendered within a 30-day window,

including estimates regarding costs of postoperative complications, outpatient healthcare encounters, revisions, and medical-related readmissions. After accounting for major and minor complications, major and minor comorbidities, LOS, revisions, and death, the cost per quality-adjusted life year (QALY) at 2-year follow-up as well as life expectancy were calculated. For nonoperative patients, national averages of nonoperative treatment received prior to surgical intervention were derived from the PearlDiver database based on the most common treatment modalities. Narcotics, muscle relaxants, epidural steroid injections, physical therapy/occupational therapy, chiropractor, and NSAIDs were determined to be the most common nonoperative treatment based on previously published literature. Based on usage of nonoperative treatment, a cost analysis was conducted to determine the overall cost of this treatment.

### Utility Calculation

Utility data were calculated by converting ODI to SF-6D based on a conversion methodology published in the literature.<sup>9,14,15</sup> QALYs were used as an assessment of outcome, with QALYs gained calculated via the following equation:<sup>16</sup>  $QALYs\ gained = (Q^i - Q)(1 - e^{-rL}/r)$ .

As a measure of HRQOL, QALYs allow for a calculation of quality of life (Q) while accounting for life expectancy (L), Napier's mathematical constant (*e*), and the discount rate (*r*). QALYs used a 3% discount rate as recommended by the WHO to account for residual decline in life expectancy.<sup>8,17,18</sup> The total utility gained was determined from the improvement in Q ( $Q^i - Q$ ) and was multiplied by the life expectancy to determine total QALYs gained. The US national averages for males (76.9 years) and females (81.6 years) were manually selected for life expectancy.

### Statistical Analysis

Patients with ASD in the operative (identified by approach: posterior vs combined) and nonoperative cohorts in whom complete baseline and 2-year radiographic studies as well as HRQOL data were available were isolated. A cost analysis was conducted on the PearlDiver database assessing the average cost of nonoperative treatment prior to surgical intervention based on previously published treatments including the following: 1) NSAIDs; 2) narcotics; 3) muscle relaxants; 4) epidural steroid injection; 5) physical therapy; and 6) chiropractor. Utility data were calculated using ODI converted to SF-6D at 2 years with published conversion methods. Chi-square and independent sample t-tests assessed differences in baseline demographics, clinical data, and surgical characteristics. All statistical analyses were conducted using SPSS version 25 (IBM Corp.).

## Results

### Patient Demographics

A total of 824 patients with ASD met inclusion criteria. The mean patient age was  $58.2 \pm 14.8$  years, BMI was  $27.2 \pm 5.9$  kg/m<sup>2</sup>, Charlson Comorbidity Index was  $1.6 \pm 1.6$ , ASD-frailty index was  $2.9 \pm 1.7$ , and 81% of patients were female. Overall, 75.5% of patients were classified as op-

**TABLE 1. Comparison of cohort demographics in patients with ASD treated operatively or nonoperatively**

	Nonop	Op	p Value
Age (yrs)	59.9	52.1	<0.001
BMI (kg/m <sup>2</sup> )	27.7	25.4	<0.001
PT (°)	24.4	19.6	<0.001
PI-LL (°)	16.2	4.4	<0.001
SVA (cm)	51.1	62.3	0.032

erative and 24.5% were nonoperative. At baseline, patients in the operative cohort were significantly older (59.9 years vs 52.1 years,  $p < 0.001$ ); had a greater BMI (27.7 kg/m<sup>2</sup> vs 25.4 kg/m<sup>2</sup>,  $p < 0.001$ ); increased PT (24.4° vs 19.6°,  $p < 0.001$ ); and increased PI-LL (16.2° vs 4.4°,  $p < 0.001$ ). With respect to deformity, patients in the operative cohort had significantly higher rates of severe (i.e., ++ ) sagittal deformity according to SRS-Schwab modifiers for PT (29.3% vs 16.8%,  $p < 0.001$ ), SVA (29.6% vs 6.5%,  $p < 0.001$ ), and PI-LL (39.5% vs 19.3%,  $p < 0.001$ ) (Table 1).

### Surgical Details for Operative Cohort

Patients had a mean of  $11.1 \pm 4.2$  levels fused, an estimated blood loss of  $1574 \pm 1464$  mL, and operative time of  $377 \pm 134$  minutes. Overall, 69.7% of patients had a posterior-only approach, 29.6% had a combined approach, 0.7% had an anterior-only approach, 70% underwent an osteotomy, and 54% had a decompression performed. The average LOS for the cohort was  $7.7 \pm 4.3$  days.

### HRQOL Scores

Nonoperatively treated patients presented at the 2-year time point with significantly higher SRS-pain (3.3 vs 2.4,  $p < 0.001$ ); SRS-activity (3.9 vs 2.9,  $p < 0.001$ ); SRS-appearance (3.3 vs 2.4,  $p < 0.001$ ); SRS-mental (3.8 vs 3.4,  $p < 0.001$ ); SRS-satisfaction (3.4 vs 2.8,  $p < 0.001$ ); and SRS-total (3.5 vs 2.8,  $p < 0.001$ ) scores; and with lower ODI (23.1 vs 43.9,  $p < 0.001$ ) scores compared with the surgically treated cohort (Table 2).

Patients with posterior-only and combined approach (operative cohort) did not significantly differ in baseline ODI (44.3 vs 41.5,  $p = 0.263$ ). At 2 years, there were no significant differences between the cohorts on meeting MCID for ODI, physical component summary, SRS-activity, SRS-pain, SRS-appearance, or SRS-mental scores (all  $p > 0.05$ ). At 2 years, patients in the operative cohort achieved MCID at higher rates for SRS-activity (66.4% vs 24.3%,  $p < 0.001$ ); SRS-pain (68.4% vs 28.2%,  $p < 0.001$ ); SRS-appearance (71% vs 8.9%,  $p < 0.001$ ); SRS-mental (43% vs 19.4%,  $p < 0.001$ ); and ODI (51.8% vs 6.0%,  $p < 0.001$ ) scores.

### Cost Analysis

Cost analysis showed the average cost of nonoperative treatment 2 years prior to surgical intervention to be \$2041. Overall, at 2 years patients in the nonoperative cohort had again in ODI of 0.36, did not show a gain in QALYs, and nonoperative treatment was found to be cost-ineffective.

**TABLE 2. Comparison of cohort-reported metrics at 2 years postoperatively**

Outcome Score	Nonop	Op	p Value
SRS-pain	3.3	2.4	<0.001
SRS-activity	3.9	2.9	<0.001
SRS-appearance	3.3	2.4	<0.001
SRS-mental	3.8	3.4	<0.001
SRS-satisfaction	3.4	2.8	<0.001
SRS-total	3.5	2.8	<0.001
ODI	23.1	43.9	<0.001

### Cost of Nonoperative Maintenance

A subset of patients in the nonoperative cohort underwent successful maintenance treatment and had a decrease in ODI of 1.1 and a gain in utility of 0.006 at 2 years. If utility gained for this cohort was sustained to full life expectancy, these patients' cost per QALY was \$18,934, compared to a cost per QALY gained of \$70,690.79 for a posterior-only and \$48,273.49 for a combined approach in patients who underwent operation. Post hoc testing for patients with a posterior-only versus a combined approach showed significantly greater reoperation rates (8.3% vs 18%) and higher frailty scores at baseline (all  $p < 0.05$ ). The mean 2-year cost for operative treatment was calculated to be \$66,860.19. Patients in the operative cohort had a decrease in ODI of 16.82 and a gain in utility of 0.087 at 2 years.

### Discussion

ASD is a significant physiological and economic burden for patients that can require extensive nonoperative management followed by an invasive surgical intervention.<sup>19</sup> With the increase in literature on the benefits of surgical treatment and the significant improvement that patients experience postoperatively, there remains a paucity of data on the benefits of a conservative approach.<sup>4</sup> With no established consensus on clinical decision-making and definitive indications for corrective surgery, our study aimed to determine the efficacy of nonoperative and operative treatment in terms of QALYs and cost-effectiveness.

Literature from Passias et al. found that in patients treated nonoperatively who had an ODI  $\geq 40$ , abnormal spinopelvic mismatch, and coronal scoliosis were significantly associated with conversion to operative treatment.<sup>20</sup> This study provided insight beyond pure radiographic parameters and suggested the incorporation of significant clinical disability as an indication for surgical treatment. Additional studies comparing patients with ASD electing operative or nonoperative care previously substantiated this evidence of diminished patient-reported outcome measures for patients who eventually undergo operative treatment.<sup>21,22</sup> These studies have been important to understanding the role of disability in disease burden and in paving the way for more definitive treatment recommendations in an increasingly value-based care system.

A recent meta-analysis comparing 2-year outcomes

of operative and nonoperative treatment of ASD further determined that SRS-22 questionnaire and ODI scores improved significantly postoperatively in patients who underwent surgery, despite a worse baseline health status.<sup>4</sup> While attributing this diminished health status to possibly increased comorbidities and a progressive spinal deformity, the authors demonstrated that HRQOL was significantly improved in surgically treated patients. However, their study still did not address the extent of initial nonoperative treatment or the cost-effectiveness of either approach.<sup>4</sup>

When analyzing cost-effectiveness of nonoperative treatment, our study similarly found that patients with ASD who underwent surgery had greater sagittal deformity at baseline and increased improvement in HRQOLs postoperatively. Additionally, we were able to isolate a cohort of patients with low disability and sagittal deformity who experienced successful maintenance of pain and disability while undergoing cost-effective nonoperative treatment. Although nonoperative treatment in the cohort with low disability was found to be cost-effective, an overall comparison of patient-reported outcomes found that this cohort had on average lower rates of reaching MCID than were found in the surgically treated cohort. Therefore, careful consideration of patient preoperative presentation, as well as their desire for undergoing surgery, is necessary for guiding operative versus nonoperative management. Further studies are required to determine the cost-effectiveness of operative treatment compared to maintenance or the disadvantages of nonoperative treatment.

### Limitations

The present study had several limitations that we acknowledge. The cost data used for operative and nonoperative treatment were attained from the PearlDiver database, which provides average Medicare reimbursements. This methodology may affect the generalizability of our results and underestimate cost efficiency relative to private insurers due to lower reimbursement from Medicare.<sup>23</sup> Additionally, because the Medicare population is older there may be increased costs associated with a higher incidence of complications and difficulty in management. Furthermore, selection of patients for surgical intervention or nonoperative treatment lacked homogeneity and uniform censuses due to the multicenter and multisurgeon nature of the database. Selection for nonoperative management was due to several factors, including but not limited to the following: patient desire, surgical risk, and surgeon discretion. Moreover, the retrospective review of a multicenter database, although enhancing the clinical applicability of our findings, may introduce bias and result in errors during data processing.

### Conclusions

Patients with ASD undergoing operative treatment at baseline had greater sagittal deformity and greater improvement in HRQOL postoperatively compared to patients who did not undergo surgery. Additionally, patients in the nonoperative cohort overall had an increase in ODI and did not show improvement in utility gained. Patients with low disability and sagittal deformity treated nonop-

eratively underwent successful maintenance and cost-effective treatment.

## Acknowledgments

The International Spine Study Group (ISSG) is funded through research grants from DePuy Synthes and individual donations.

## References

- Scheer JK, Hostin R, Robinson C, et al. Operative management of adult spinal deformity results in significant increases in QALYs gained compared to nonoperative management: analysis of 479 patients with minimum 2-year follow-up. *Spine (Phila Pa 1976)*. 2018;43(5):339-347.
- Carter OD, Haynes SG. Prevalence rates for scoliosis in US adults: results from the first National Health and Nutrition Examination Survey. *Int J Epidemiol*. 1987;16(4):537-544.
- Francis RS. Scoliosis screening of 3,000 college-aged women. The Utah Study—phase 2. *Phys Ther*. 1988;68(10):1513-1516.
- Choi SH, Son SM, Goh TS, Park W, Lee JS. Outcomes of operative and nonoperative treatment in patients with adult spinal deformity with a minimum 2-year follow-up: a meta-analysis. *World Neurosurg*. 2018;120:e870-e876.
- Champain S, Benchikh K, Nogier A, Mazel C, Guise JD, Skalli W. Validation of new clinical quantitative analysis software applicable in spine orthopaedic studies. *Eur Spine J*. 2006;15(6):982-991.
- O'Brien MF, Kuklo TR, Blanke KM, Lenke LG, eds. *Spinal Deformity Study Group Radiographic Measurement Manual*. Medtronic Sofamor Danek; 2005.
- Rillardon L, Levassor N, Guigui P, et al. Validation of a tool to measure pelvic and spinal parameters of sagittal balance. Article in French. *Rev Chir Orthop Reparat Mot*. 2003;89(3):218-227.
- Brown AE, Alas H, Pierce KE, et al. Obesity negatively affects cost efficiency and outcomes following adult spinal deformity surgery. *Spine J*. 2020;20(4):512-518.
- Poorman GW, Passias PG, Qureshi R, et al. Cost-utility analysis of cervical deformity surgeries using 1-year outcome. *Spine J*. 2018;18(9):1552-1557.
- Horn SR, Passias PG, Hockley A, et al. Cost-utility of revisions for cervical deformity correction warrants minimization of reoperations. *J Spine Surg*. 2018;4(4):702-711.
- Passias PG, Poorman GW, Bortz CA, et al. Predictors of adverse discharge disposition in adult spinal deformity and associated costs. *Spine J*. 2018;18(10):1845-1852.
- Qureshi R, Puvanesarajah V, Jain A, Shimer AL, Shen FH, Hassanzadeh H. A comparison of anterior and posterior lumbar interbody fusions: complications, readmissions, discharge dispositions, and costs. *Spine (Phila Pa 1976)*. 2017;42(24):1865-1870.
- Version 28.0 ICD-10 MS-DRGs Update. CMS.gov. Accessed July 31, 2023. <https://www.cms.gov/Medicare/Coding/ICD10/downloads/v28msdrgupdate.pdf>
- Carreon LY, Glassman SD, McDonough CM, Rampersaud R, Berven S, Shainline M. Predicting SF-6D utility scores from the Oswestry disability index and numeric rating scales for back and leg pain. *Spine (Phila Pa 1976)*. 2009;34(19):2085-2089.
- Carreon LY, Bratcher KR, Das N, Nienhuis JB, Glassman SD. Estimating EQ-5D values from the Oswestry Disability Index and numeric rating scales for back and leg pain. *Spine (Phila Pa 1976)*. 2014;39(8):678-682.
- Sassi F. Calculating QALYs, comparing QALY and DALY calculations. *Health Policy Plan*. 2006;21(5):402-408.
- Murray CJ. Quantifying the burden of disease: the technical basis for disability-adjusted life years. *Bull World Health Organ*. 1994;72(3):429-445.
- Tan-Torres T, Baltussen R, Adam T, et al, eds. *Making Choices in Health: WHO Guide to Cost-Effectiveness Analysis*. World Health Organization; 2003:71.
- Smith JS, Shaffrey CI, Ames CP, Lenke LG. Treatment of adult thoracolumbar spinal deformity: past, present, and future. *J Neurosurg Spine*. 2019;30(5):551-567.
- Passias PG, Jalai CM, Line BG, et al. Patient profiling can identify patients with adult spinal deformity (ASD) at risk for conversion from nonoperative to surgical treatment: initial steps to reduce ineffective ASD management. *Spine J*. 2018;18(2):234-244.
- Fu KM, Smith JS, Sansur CA, Shaffrey CI. Standardized measures of health status and disability and the decision to pursue operative treatment in elderly patients with degenerative scoliosis. *Neurosurgery*. 2010;66(1):42-47.
- Bess S, Line B, Fu KM, et al. The health impact of symptomatic adult spinal deformity: comparison of deformity types to United States population norms and chronic diseases. *Spine (Phila Pa 1976)*. 2016;41(3):224-233.
- Gum JL, Hostin R, Robinson C, et al. Impact of cost valuation on cost-effectiveness in adult spine deformity surgery. *Spine J*. 2017;17(1):96-101.

## Disclosures

Dr. Passias reported other financial or material support from Cerapedics and from Spinevision; paid presenter or speaker from Globus Medical; paid consultant from Medtronic, Royal Biologics, SpineWave, and Terumo; editorial or governing board at *Spine*; and research support from Cervical Scoliosis Research Society outside the submitted work. Mr. R. Lafage reported personal fees from Carlsmed outside the submitted work. Dr. V. Lafage reported consulting fees from Alphatec and from Globus Medical; royalties from NuVasive; personal fees from Johnson and Johnson and from Stryker for lectures; nonfinancial support from ISSG as an editorial committee member; and nonfinancial support from SRS as a committee member outside the submitted work. Dr. Klineberg reported consulting fees from DePuy Synthes Spine, Stryker, Medtronic, SI Bone, and Agnovos; stock ownership from MMI and Relatable; fellowship grant, chair elect, and fellowship chair from AO Spine; and chair elect from IMAST outside the submitted work. Dr. Kebaish reported royalties from DePuy Synthes, Stryker, Orthofix, and SpineCraft outside the submitted work. Dr. Gum reported personal fees from Acuity, DePuy, Medtronic, NuVasive, Stryker, FYR Medical, Expanding Innovations, Norton Healthcare, Inc., National Spine Health Foundation, Kyana, Pacira Pharmaceuticals, Baxter, Broadwater, North American Spine Society, and MiMedx; nonfinancial support from Fischer Owen travel fund; stock ownership in Cingulate Therapeutics and FYR Medical; grants for research funding from Alan L. & Jacqueline B. Stuart Spine Center, Biom'Up, Cerapedics, Inc., Empirical Spine, Inc., Medtronic, National Spine Health Foundation, Pfizer, SRS, Stryker, and Texas Scottish Rites Hospital; and journal reviews for *The Spine Journal*, *Spine Deformity*, and *Global Spine Journal* outside the submitted work. In addition, Dr. Gum had a patent issued for a device with Medtronic. Dr. Line reported personal fees from ISSG outside the submitted work. Dr. Hart reported personal fees from Globus and from SeaSpine; and stock ownership from Mirus and Amplify outside the submitted work. Dr. Burton reported personal fees from Globus, DePuy Spine, and Blue Ocean Spine; stock options from Progenerative Medical; and nonfinancial support from the ISSG and SRS boards of directors outside the submitted work. Dr. Smith reported grants from DePuy Synthes/ISSG Foundation (ISSGF) during the conduct of the study; personal fees from Cerapedics, Carlsmed, and NuVasive; grants from NuVasive; personal fees from ZimVie and

DePuy Synthes; grants from DePuy Synthes/ISSGF and AOSpine; and personal fees from Thieme and SeaSpine outside the submitted work. Dr. Ames reported royalties from Stryker, Biomet Zimmer Spine, DePuy Synthes, NuVasive, Next Orthosurgical, K2M, and Medtronic; consulting fees from DePuy Synthes, Medtronic, Medtronic, K2M, Agada Medical, and Carlsmed; personal fees for research from Titan Spine, DePuy Synthes, and ISSG; nonfinancial support from *Operative Neurosurgery*; membership on the *Neurospine* editorial board; grants from SRS; nonfinancial support from ISSG as an executive committee member; nonfinancial support from Global Spinal Analytics as a director; and nonfinancial support from SRS as chair of the Safety and Value Committee outside the submitted work. Dr. Shaffrey reported grants from ISSGF to Duke University during the conduct of the study; and personal fees from NuVasive, Medtronic, SI Bone, and Proprio outside the submitted work. Dr. Schwab reported consulting fees and royalties from Zimmer Biomet and MSD; consulting fees from Mainstay Medical; personal fees from ISSG as an executive committee member; and shareholder status in VFT Solutions and SeaSpine outside the submitted work. Dr. Bess reported grants from DePuy Synthes, NuVasive, K2M, and ISSGF during the conduct of the study; and grants from DePuy Synthes, Medtronic, Globus, Stryker, SeaSpine, Carlsmed, and ISSGF outside the submitted work.

### Author Contributions

Conception and design: Passias, Ahmad, Dave, Kebaish, Gum, Line, Burton, Smith, Shaffrey, Hostin, Hamilton, Bess. Acquisition of data: Passias, Ahmad, Dave, R Lafage, V Lafage, Mir, Kebaish, Line, Hart, Burton, Smith, Hamilton, Bess. Analysis and interpretation of data: Passias, Ahmad, Dave, Mir,

Klineberg, Kebaish, Hostin. Drafting the article: Passias, Ahmad, Dave, Gum, Hostin, Hamilton, Bess. Critically revising the article: Passias, Ahmad, Dave, V Lafage, Kebaish, Gum, Hart, Burton, Smith, Shaffrey, Schwab, Hostin, Buell, Hamilton. Reviewed submitted version of manuscript: Ahmad, Dave, V Lafage, Kebaish, Gum, Line, Hart, Smith, Ames, Shaffrey, Schwab, Hostin, Buell, Hamilton, Bess. Approved the final version of the manuscript on behalf of all authors: Passias. Statistical analysis: Ahmad, Dave, Mir, Ames. Administrative/technical/material support: Ahmad, R Lafage, V Lafage, Mir, Kebaish, Line, Hostin. Study supervision: Kebaish, Line, Ames, Shaffrey.

### Supplemental Information

#### Previous Presentations

Podium presentation (virtual) at the North American Spine Society 2020 meeting, October 6–9, 2020.

### 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.