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DEFORMITY

Patients With Adult Spinal Deformity Treated Operatively Report Greater Baseline Pain and Disability Than Patients Treated Nonoperatively; However, Deformities Differ Between Age Groups

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Study Design. Multicenter, prospective analysis of consecutive patients with adult spinal deformity (ASD).

Objective. Identify age-related radiographical parameters associated with poor health-related quality of life (HRQOL) and treatment preferences for ASD.

Summary of Background Data. Patients with ASD report discrepant severities of disability. Understanding age-associated differences for reported disability and treatment preferences may improve ASD evaluation and treatment.

Methods. Baseline demographic, radiographical, and HRQOL values were evaluated in a multicenter, prospective cohort of consecutive patients with ASD. Inclusion criteria: ASD, age more than 18 years, and no prior spine surgery. Patients were grouped into those treated operatively (OP) or nonoperatively (NON) and stratified into 3 age groups: G1, 50 years or less; G2, 50 to 65 years; G3, 65 years or more. HRQOL measures included Scoliosis Research Society-22r questionnaire, Oswestry Disability Index, and Short Form-36 Health Survey.

Results. Four hundred ninety-seven patients (OP = 156, NON = 341) with a mean age of 50.4 years met inclusion criteria. The OP group was older (53.3 *vs.* 49.0 yr), had larger scoliosis (49.3° *vs.* 43.3°), larger sagittal vertical axis (SVA, 33.2 *vs.* 13.7 mm), greater pelvic incidence-lumbar lordosis mismatch (6.6° *vs.* 3.1°), and worse HRQOL scores than the NON group, respectively ($P < 0.05$). Age stratification demonstrated worsening of SVA, spinopelvic alignment (SPA), and HRQOL scores with increasing age ($P < 0.05$). Age/treatment stratification demonstrated that younger OP had greater scoliosis than NON (G1OP = 49.9° *vs.* G1NON = 42.2°; G2OP = 56° *vs.* G2NON = 47.2°; $P < 0.05$) but similar SPA as NON. Older OP had similar scoliosis, but larger SVA than NON (G3OP = 100.6 *vs.* G3NON = 66.4 mm; $P < 0.05$). OP in all age groups reported worse HRQOL than NON ($P < 0.05$).

Conclusion. Poor HRQOL uniformly determined operative treatment for ASD. Spinal deformities differed between age groups. Younger OP had larger scoliosis but similar SPA and SVA than NON. Older OP had similar scoliosis but worse SVA than NON. Age-associated differences for poor HRQOL must be considered when evaluating patients with ASD.

Key words: adult spinal deformity, disability, surgery, nonoperative treatment.

Level of Evidence: 2

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Patients with adult spinal deformity (ASD) report greater functional limitations, greater daily analgesic use, and worse health-related quality of life (HRQOL) compared with population norms.[1–3] Despite the associations between ASD and disability, there is a prevalent misconception among

the medical community and third party payers that ASD is not associated with greater disability than the general population.[4–6] This misconception likely stems from the heterogeneity of the ASD disease state. Patients with ASD present with varying types and magnitudes of spinal deformity, and, therefore, report varying amounts of disability. Although there is an increasing awareness in the spine community of the types of ASD deformities that are most associated with pain and disability, the greater medical community largely remains uneducated regarding the reasons for ASD-associated disability. Accordingly, many in the medical community as well as third party payers remain unaware of viable treatment options available for patients with ASD as evidenced by a growing body of literature indicating that a substantial number of patients with ASD treated nonoperatively report minimal improvement in quality of life.[7–18]

Analysis of the different types of treatments that are provided for a specific disease state offers insight to the impact the disease state has upon quality of life. Treatment choices also reflect the patient and physician perceived severity of the disease state. Consequently, evaluation of the type of treatment provided to patients with ASD may provide some information to the clinical and radiographical features that best correlate with disability. A retrospective analysis by Glassman *et al*[19] demonstrated that patients treated operatively (OP) had greater back pain, greater leg pain, and larger scoliosis than patients treated nonoperatively (NON), whereas NON were older and had greater comorbidities. Bess *et al*[20] reported that younger OP with ASD had larger scoliosis but similar disability compared with age-matched NON, whereas older OP with ASD reported greater baseline disability than NON but had similar sagittal and coronal plane spinal deformities. These studies provide useful information regarding the clinical and radiographical parameters that motivate types of treatment for ASD, however both studies are limited by retrospective study designs and relatively small patient cohorts. The objectives of this study were to (1) compare the baseline HRQOL and radiographical differences between OP and NON with ASD in a large, prospective multicenter, consecutive cohort of patients with ASD who had no prior history of spine surgery, and (2) evaluate for age-associated differences that exist between the OP and NON cohorts including differences in disability and treatment preferences.

MATERIALS AND METHODS

Data for this study were extracted from a prospective, multicenter, database of consecutively enrolled patients with ASD. Eleven participating sites located within the United States enrolled patients with ASD into the database for this study. Institutional review board approval was obtained at each participating institution prior to patient enrollment into the database. Inclusion criteria for enrollment into the database are: patient age more than 18 years, adult degenerative or adult idiopathic spinal deformity, and minimum one of the following: scoliosis more than 20°, thoracic kyphosis more than 60°, pelvic tilt more than 25°, and/or SVA more than 5 cm. An additional inclusion criterion for this study was no history of previous spine surgery. Exclusion criteria for the database include spinal deformity secondary to neuromuscular, syndromic, autoimmune, and infectious tumor, or post-traumatic conditions. Baseline demographic, radiographical, and HRQOL parameters that were obtained upon patient enrollment into the database were evaluated. Radiographical evaluation consisted of regional coronal and sagittal Cobb angle measurements, including maximal scoliosis, thoracic kyphosis (Cobb angle between the superior endplate of T4 and the inferior endplate of T12), thoracolumbar kyphosis (Cobb angle between the superior endplate of T10 and the inferior endplate of L2), lumbar lordosis (LL; Cobb angle between the superior endplate of T12 and the superior endplate of S1), and maximal kyphosis. Sagittal spinopelvic parameters evaluated included SVA (distance from the C7 plumb line to posterior superior corner sacrum), pelvic tilt (PT; angle formed between lines drawn from the midpoint of the superior endplate of S1 to the center of the bicoxofemoral axis and the vertical), sacral slope (angle formed between the line drawn along the superior endplate of S1 and the horizontal), pelvic incidence (PI; angle formed between lines drawn from the perpendicular of the midpoint of the superior endplate of S1 and a line drawn between the midpoint of the superior endplate of S1 and the center of the bicoxofemoral axis), and the PI/lumbar lordosis mismatch (difference between PI and LL; PI-LL), as described in the earlier text.[16,18,21] All radiographical measurements were obtained using a centralized process in which patient radiographs were downloaded from PACS systems (Dicom format; NEMA, Rosslyn, VA) or digitized through a Vidar scanner (Vidar Systems Corp., Herndon, VA) with 75-dpi resolution and 12 gray levels. All radiographical measurements were obtained by the same individual, who has a PhD in biomechanics, using Spineview software (Surgiview, Paris, France), a validated, computer-based tool that enables quantitative measurements of the spine and pelvis. HRQOL outcome questionnaires administered to all patients included the Scoliosis Research Society-22r questionnaire, Oswestry Disability Index, and Short Form-36 Health Survey (SF-36). Patients were divided into those selecting operative (OP) or nonoperative (NON) treatment upon initial enrollment into the study. None of the OP had been initially enrolled and treated as NON. This study was a prospective, observational study, therefore, upon enrollment into the study, the indications and decision making for operative or nonoperative treatment was nonstandardized and made according to the informed consent process between the patient and the surgeon. Patients were stratified according to age into 3 groups; age less than 50 years (G1), age 50 to 65 years (G2), and age more than 65 years (G3). Baseline, pretreatment demographic, radiographical, and HRQOL values were compared between treatment groups and age groups.

Statistical analysis was performed using SPSS (software package for statistical analysis, IBM Corporation, Armonk, New York). Means were compared using the Student *t* test and analysis of variance. In comparisons of multiple groups simultaneously requiring analysis of variance, a Bonferroni

post hoc test was performed to control for family-wise error rate. Categorical variables were compared using the Fisher exact test.

RESULTS

Demographic Data

Of the 793 patients enrolled into the database, 497 had no history of previous spine surgery and were evaluated for this study. Mean age for all 497 patients evaluated was 50.4 years, mean BMI was 25.6, and mean Charlson Comorbidity Index (CCI) was 0.9. OP (n = 156) were older (53.3 *vs.* 49.0 yr), had greater BMI (26.8 *vs.* 25.1), and similar CCI (0.8 *vs.* 1.0) compared with NON (n = 341), respectively ($P < 0.05$; Table 1). Stratification according to age demonstrated BMI and CCI progressively increased with increasing age (Table 2). Stratification according to age and treatment type demonstrated similar BMI and CCI between age stratified treatment groups (Table 3).

Radiographical Data

The mean maximum scoliosis for all patients in the study was 45.3° (SD = 18.3°), mean SVA for all patients was 19.9 mm (SD = 58.1), and mean PT for all patients was 18.8° (SD = 10.2°). OP had greater maximal scoliosis (49.4° *vs.* 43.3°), greater SVA (33.2 mm *vs.* 13.7 mm), and greater PI-LL (6.6° *vs.* 3.1°) than NON, respectively ($P < 0.05$). Stratification by age demonstrated progressive worsening of spinopelvic alignment with increasing age, including increased SVA, increased PT, and increased PI-LL ($P < 0.05$; Table 2). Conversely, the 2 youngest age groups had greater scoliotic deformity (G1 = 44.0°, G2 = 50.3°) than the oldest age group (G3 = 38.5°, $P < 0.05$). Stratification according to age and treatment demonstrated that OP had greater maximal scoliosis than NON in the 2 youngest groups (G1 and G2), however the maximal scoliosis was the same for OP and NON in the oldest age group (Table 3). Sagittal spinopelvic alignment was similar between OP and NON in the 2 youngest age groups (G1 and G2), whereas OP had larger mean SVA than NON in the oldest age group (G3; $P < 0.05$). Comparing age-associated radiographical changes within the treatment groups demonstrated progressive age-associated worsening of all measured sagittal spinopelvic parameters with increasing age for both OP and NON, including SVA, PT, and PI-LL.

Health-Related Quality of Life

Evaluation according to type of treatment demonstrated OP reported worse HRQOL for all measured parameters except for the mental component of the SF-36 ($P < 0.05$; Table 1).

TABLE 1. Operative *Versus* Nonoperative Treatment; Demographic, Radiographical, and Health-Related Quality of Life Values

	Nonoperative	Operative	*P*
Total no. of patients	341	156	
Age, mean (SD), yr	49.0 (16.9)	53.3 (16.6)	<0.05
BMI mean (SD)	25.1 (5.7)	26.8 (7.5)	<0.05
Charlson Comorbidity Index	1.0	0.8	0.3
SVA, mean (SD), mm	13.7 (52.2)	33.2 (67.3)	<0.05
PT, mean (SD),°	18.4 (10.5)	19.5 (9.5)	NS
PI-LL, mean (SD),°	3.1 (17.3)	6.6 (17.9)	<0.05
Maximum scoliosis, mean (SD)°	43.3 (17.7)	49.4 (18.8)	<0.05
ODI, mean (SD)	22.8 (16.5)	36.4 (19.6)	<0.05
SF-36 PCS, mean (SD)	43.3 (10.1)	35.1 (11.3)	<0.05
SF-36 MCS, mean (SD)	50.39 (11.0)	47.9 (11.7)	NS
SRS-22 function, mean (SD)	3.55 (0.72)	3.1 (0.73)	<0.05
SRS-22 pain, mean (SD)	3.1 (0.72)	2.6 (0.64)	<0.05
SRS-22 image, mean (SD)	3.51 (0.77)	2.9 (0.84)	<0.05
SRS-22 mental health, mean (SD)	3.95 (0.73)	3.66 (0.79)	<0.05
SRS-22 satisfaction, mean (SD)	3.61 (0.92)	3.01 (0.91)	<0.05
SRS-22 total, mean (SD)	3.54 (0.66)	3.03 (0.64)	<0.05

BMI indicates body mass index; SVA, sagittal vertical axis; PT, pelvic tilt; PI-LL, difference between pelvic incidence and lumbar lordosis; ODI, Oswestry Disability Index; SF-36 PCS, Short Form-36 physical component score; SF-36 MCS, Short Form-36 mental component score; SRS-22, Scoliosis Research Society Outcomes Score; SD, standard deviation; NS, not significant.

TABLE 2. Age Group Stratification; Demographic, Radiographical, and Health-Related Quality of Life Values

	G1	G2	G3	*P*
Total no. of patients	208	187	102	
Age, mean (SD), yr	33.3 (9.5)	57.3 (4.2)	71.7 (5.5)	<0.05; all groups
BMI, mean (SD)	25.1 (7.1)	25.2 (4.9)	27.6 (6.8)	<0.05; 1, 3 and 2, 3
Charlson Comorbidity Index	0.4	0.8	1.7	<0.05; all groups
SVA, mean (SD) mm	−7.5 (40.8)	18.3 (43.8)	80.3 (67)	<0.05; all groups
PT, mean (SD)°	13.3 (8.5)	20.5 (8.8)	26.9 (9.0)	<0.05; all groups
PI-LL mismatch, mean (SD)°	−4.3 (4.6)	5.7 (15.8)	18.9 (15.5)	<0.05; all groups
Maximum Cobb angle, mean (SD),°	44.0 (15.5)	50.3 (18.8)	38.5 (19.5)	<0.05; all groups
ODI, mean (SD)	19.1 (14)	31.0 (20)	35.9 (17)	<0.05; 1, 2 and 1, 3
SF-36 PCS, mean (SD)	45.6 (9.9)	39.5 (10.7)	33.1 (10.1)	<0.05; all groups
SF-36 MCS, mean (SD)	49.7 (10.2)	48.1 (12.5)	51.4 (10.9)	NS
SRS-22 function, mean (SD)	3.57 (0.7)	3.3 (0.8)	3.24 (0.7)	<0.05; 1, 2 and 1, 3
SRS-22 pain, mean (SD)	3.14 (0.7)	2.80 (0.7)	2.77 (0.8)	<0.05; 1, 2 and 1, 3
SRS-22 image, mean (SD)	3.54 (0.8)	3.11 (0.9)	3.17 (0.8)	<0.05; 1, 2 and 1, 3
SRS-22 mental health, mean (SD)	3.99 (0.7)	3.75 (0.8)	3.80 (0.6)	<0.05; 1, 2
SRS-22 satisfaction, mean (SD)	3.59 (0.9)	3.40 (1)	3.13 (0.9)	<0.05; 1, 3
SRS-22 total, mean (SD)	3.57 (0.6)	3.27 (0.8)	3.21 (0.6)	<0.05; 1, 2 and 1, 3

G1, indicates <50 yr; G2, 50–65 yr; G3, >65 yr; BMI, body mass index; SVA, sagittal vertical axis; PT, pelvic tilt; PI-LL, difference between pelvic incidence and lumbar lordosis; ODI, Oswestry Disability Index; SF-36 PCS, Short Form-36 physical component score; SF-36 MCS, Short Form-36 mental component score; SRS-22, Scoliosis Research Society Outcomes Score; SD, standard deviation.

Stratification according to age demonstrated progressive age-associated worsening of HRQOL scores for all measures except for the mental component of the SF-36 ($P < 0.05$; Table 2). Stratification according to treatment and age demonstrated OP reported worse HRQOL across all age groups for all measured HRQOL values except for 2 measures; mental component of the SF-36 and the Scoliosis Research Society-22r questionnaire questionnaires for which only OP within the G2 age group reported worse scores than NON ($P < 0.05$; Table 3).

DISCUSSION

The incidence of ASD is rising in conjunction with the increasing age of the population.[22] Consequently, physicians are increasingly being called upon to evaluate and treat ASD. Physicians and health care providers must become cognizant of the most appropriate treatment for patients with ASD to facilitate the best possible treatment. patients with ASD, however, present with varying severities of spinal deformity and report varying amounts of disability, therefore, the primary challenge to evaluating the patient with ASD with pain is to accurately identify the source(s) of pain. Understanding the baseline clinical and radiographical characteristics of patients with ASD, who have no prior history of surgery, may help define the associated disabilities that emanate from the patients' spinal deformities. In turn then, the evaluation of the treatment choices opted by the same cohort of patients with ASD may allow for delineation of the radiographical parameters that are intrinsically most associated with pain, disability, and patient dissatisfaction, without being confounded by a history of previous spine surgery. This study demonstrates that patients who opt for surgical treatment are uniformly more disabled than patients treated nonoperatively, regardless of age. However, the radiographical parameters associated with pain and disability are different for different patient age groups. The magnitude of scoliosis seems to be associated with pain, disability, and a preference for surgical treatment in younger patients with ASD, whereas sagittal malalignment seems to drive pain, disability, and surgical treatment for older patients with ASD.

A substantial amount of research has been devoted toward understanding if and why patients with ASD are more disabled than the general population. In what was ostensibly a pivotal series of investigations on ASD, Weinstein *et al*[4,5] reported on the long-term outcome of untreated adult idiopathic scoliosis (termed late-onset idiopathic scoliosis; LIS). The authors reported that at 50-year follow-up, patients with untreated LIS report no more back pain than the general population,

TABLE 3. Group Stratification According to Age and Treatment; Demographic, Radiographical, and Health-Related Quality of Life Values

	G1 NON/OP	G2 NON/OP	G3 NON/OP	*P*
Total no. of patients	157/51	122/65	62/40	NS
Age (STD)	33.4/33.2	57.7/57.8	71.7/71.6	NS
BMI (STD)	24.8/25.8	24.7/26.1	26.6/29.2	<0.05 G3
Charlson Comorbidity Index	0.4/0.4	0.9/1.1	1.5/1.9	NS
SVA (STD) mm	−7.9/−6.1	16.2/22/4	66.4/100.6	<0.05 G3
PT (STD)°	13.1/13.9	20.6/20.2	27.6/25.8	NS
PI-LL mismatch (STD)°	−4.5/−3.8	4.7/7.6	19.1/18.8	NS
Maximum Cobb angle (STD),°	42.2/49.9	47.2/56.0	38.9/37.9	<0.05 G1, G2
ODI (STD)	17.4/24.1	25.4/ 41.4	31.0/43.8	<0.05 G1, G2, G3
SF-36 PCS (STD)	46.6/42.3	42.5/33.8	36.3/27.5	<0.05 G1, G2, G3
SF-36 MCS (STD)	49.7/49.8	50/44.4	51.2/51.7	<0.05 G2
SRS-22 function (STD)	3.65/3.35	3.5/2.9	3.38/2.99	<0.05 G1, G2, G3
SRS-22 pain (STD)	3.25/2.82	2.9/2.42	2.93/2.48	<0.05 G1, G2, G3
SRS-22 image (STD)	3.61/3.34	3.4/2.6	3.43/2.73	<0.05 G1, G2, G3
SRS-22 mental health (STD)	4.03/3.86	3.89/3.47	3.82/3.73	<0.05 G2
SRS-22 satisfaction (STD)	3.71/3.21	3.64/2.96	3.31/2.81	<0.05 G1, G2, G3
SRS-22 total (STD)	3.65/3.32	3.48/2.9	3.38/2.95	<0.05 G1, G2, G3

NON indicates nonoperative treatment; OP, operative treatment; G1, <50 yr; G2, 50–65 yr; G3, >65 yr; BMI, body mass index; SVA, sagittal vertical axis; PT, pelvic tilt; PI-LL, difference between pelvic incidence and lumbar lordosis; ODI, Oswestry Disability Index; SF-36 PCS, Short Form-36 physical component score; SF-36 MCS, Short Form-36 mental component score; SRS-22, Scoliosis Research Society Outcomes Score; NS, not significant STD, standard deviation.

and concluded that "untreated LIS causes little physical impairment other than back pain and cosmetic concerns." Although this study was a monumental effort at the time, the study conclusions have become a mantra for physicians treating ASD and third party payers. A greater understanding of ASD has been acquired since the reports by Weinstein *et al*, and, importantly, a consistent finding that has emerged is that, although the LIS population investigated by Weinstein *et al* is a portion of the ASD population, it does not represent the diversity of the ASD population as a whole. This finding is best represented by the subpopulation of patients with ASD who have minimal scoliosis, but have sagittal spinopelvic malalignment, including elevated SVA, elevated PT and increased PI/LL mismatch. Sagittal spinopelvic malalignment has repeatedly been demonstrated to correlate with pain and disability, whereas the magnitude of the scoliotic curvature has been previously reported to play a minor role toward pain and disability.[1,15–18,23,24] Unfortunately, the studies by Weinstein *et al* did not include evaluation of the lateral radiographs in their study populations, consequently, the patients with ASD who may report the greatest amount of pain and disability were not evaluated or identified by the Weinstein studies. Our findings concur that, within the general ASD population, there is a subpopulation of patients with ASD who are relatively less symptomatic. Accordingly, we also found that the patients who are less symptomatic are more apt to choose nonoperative treatment. However, although pain and disability seem to be the underlying theme that drives surgical treatment for ASD, our findings also indicate that ASD cannot be distilled down to a solitary radiographical phenomenon that is associated with disability or treatment preference across all age groups. OP in this study reported more pain and disability across all age groups. We also found that patients with ASD reported worsening HRQOL with increasing age and, accordingly, demonstrated worsening sagittal spinopelvic malalignment with increasing age. However, the OP in the younger age groups reported greater disability and had greater scoliosis than the NON, but demonstrated similar sagittal spinopelvic alignment to NON. Therefore, contrary to the findings by Weinstein *et al*, there is a subset of patients with ASD with primarily scoliotic deformities who also report pain, disability, and poor quality of life. Further research must delineate the reasons for reported pain associated with scoliosis especially in the younger ASD population.

This study has several limitations, including no standardization of treatment and no analysis of treatment outcomes.

We sought to evaluate why patients chose specific treatments, not the outcomes of those treatments. We recognize the critical value for treatment outcomes, and as the current dataset matures we will evaluate the associated changes in HRQOL outcome scores according to treatment and for the treatments most effective for each age group and deformity. The cost and complications associated with treatment must be evaluated, as well as the satisfaction associated with treatment. These outcomes are also not assessed in this study and will be part of the future analyses of this dataset. Importantly, the design of this investigation was a prospective, observational study, therefore, the indications for patient treatment and the treatment provided to the patients in this study were not standardized. Consequently, this study is unable to indicate the treatments that are most appropriate for each patient.

CONCLUSION

Evaluation of a large cohort of consecutive patients with ASD who had no prior history of spine surgery, demonstrated that the treatment choice for ASD (operative or nonoperative) seems to be motivated by the severity of the patients' reported disability. Patients who opted for surgical treatment consistently reported greater baseline disability than patients treated nonoperatively, regardless of age. Therefore, this reported disability is likely secondary to ASD and is not simply an aging phenomenon, or a reflection of comorbidities. Contrary to previous reports, scoliosis can be associated with substantial pain and disability, especially in younger patients with ASD, and it is likely that the reported pain and disability associated with scoliosis in the younger ASD population motivates treatment. Therefore, the surgical treatment of ASD is not simply based on cosmesis or purely radiographical findings. Consistent with previous reports, however, we did find that sagittal malalignment is associated with greater disability in the older ASD populations and seems to motivate treatment. Treating physicians must focus on patient reported pain and disability and correlate patient symptoms with specific radiographical findings to elucidate the best treatment options for each patient with ASD. Future research is needed on standardization of operative and nonoperative treatment for ASD and associated treatment outcomes.

➢ Key Points

- ❑ OP with ASD report worse HRQOL than NON for all age groups.
- ❑ Disability and operative treatment for younger patients with ASD seems to be motivated by scoliosis.
- ❑ Disability and operative treatment for older patients with ASD seems to be motivated by sagittal spinopelvic malalignment.

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