Examination of the Economic Burden of Frailty in Patients With Adult Spinal Deformity Undergoing Surgical Intervention

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BACKGROUND: With increasing interest in cost optimization, costs of adult spinal deformity (ASD) surgery intersections with frailty merit investigation.
OBJECTIVE: To investigate costs associated with ASD and frailty.
METHODS: Patients with ASD (scoliosis ≥20°, sagittal vertical axis [SVA] ≥5 cm, pelvic tilt ≥ 25°, or thoracic kyphosis ≥ 60°) with baseline and 2-yr radiographic data were included. Patients were severely frail (SF), frail (F), or not frail (NF). Utility data were converted from Oswestry Disability Index to Short-Form Six-Dimension. Quality-adjusted life years (QALYs) used 3% rate for decline to life expectancy. Costs were calculated using PearlDiver. Loss of work costs were based on SRS-22rQ9 and US Bureau of Labor Statistics. Accounting for complications, length of stay, revisions, and death, cost per QALY at 2 yr and life expectancy were calculated.
RESULTS: Five hundred ninety-two patients with ASD were included (59.8 ± 14.0 yr, 80% F, body mass index: 27.7 ± 6.0 kg/m^2, Adult Spinal Deformity-Frailty Index: 3.3 ± 1.6, and Charlson Comorbidity Index: 1.8 ± 1.7). The average blood loss was 1569.3 mL, and the operative time was 376.6 min, with 63% undergoing osteotomy and 54% decompression. 69.3% had a posterior-only approach, 30% combined, and 0.7% anterior-only. 4.7% were SF, 22.3% F, and 73.0% NF. At baseline, 104 were unemployed losing $971.38 weekly. After 1 yr, 62 remained unemployed losing $50 508.64 yearly. With propensity score matching for baseline SVA, cost of ASD surgery at 2 yr for F/SF was greater than that for NF ($81 347 vs $69 722). Cost per QALY was higher for F/SF at 2 yr than that for NF ($436 473 vs $430 437). At life expectancy, cost per QALY differences became comparable ($58 965 vs $58 149).
CONCLUSION: Despite greater initial cost, F and SF patients show greater improvement. Cost per QALY for NF and F patients becomes similar at life expectancy.

KEY WORDS: Economics, Frailty, Spinal deformity, Cost-effectiveness, QALY, Utility gained

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ABBREVIATIONS: ASD, adult spinal deformity; **ASD-FI,** Adult Spinal Deformity-Frailty Index; **CC,** complications/comorbidities; **CCI,** Charlson Comorbidity Index; **F,** frail; **LL,** lumbar lordosis; **LOS,** length of stay; **MCC,** major complications/comorbidities; **MCID,** minimal clinically important difference; **NF,** not frail; **ODI,** Oswestry Disability Index; **PI,** pelvic incidence; **PI-LL,** pelvic incidence and lumbar lordosis; **PT,** pelvic tilt; **SF,** severely frail; **SRS-22,** Scoliosis Research Society Outcomes Questionnaire; **SVA,** sagittal vertical axis; **TK,** thoracic kyphosis

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Adult spinal deformity (ASD) is a multifaceted disease that affects patients across a broad spectrum from minimal symptoms to severely debilitating pain because of spondylosis, stenosis, and postural imbalance.[1,2] Corrective surgery for ASD can require lengthy intervention that increases in invasiveness with degree of deformity severity.[3] In addition, patient age plays a critical role in determining the surgical plan and magnitude of ASD surgery.[3]

Traditionally, age has been considered a nonmodifiable risk factor. However, because an increasing number of variables are found to influence the aging process, it has become proportionately necessary to characterize the increasingly complex components of age. The differentiation between

chronological and physiological age, often referred to as frailty, substantiates the use of age as an analytical component when predicting mortality and adverse events.[4-6] As "a medical syndrome with multiple causes and contributors that is characterized by diminished strength, endurance, and reduced physiologic function that increases an individual's vulnerability for developing increased dependency and/or death, " frailty proves to be an important preoperative consideration.[7-11]

The Adult Spinal Deformity-Frailty Index (ASD-FI), which was shown by Miller et al[12] to be strongly associated with greater risk of major complications, proximal junctional kyphosis, pseudoarthrosis, deep wound infection, wound dehiscence, reoperation, and longer hospital stay, incorporates frailty into a relevant context for patients undergoing elective surgery to correct ASD. Stratification of these patients as not frail (NF), frail (F), and severely frail (SF) using the ASD-FI scale allows for a more thorough analysis of frailty's effects on operative outcomes and costs.[13]

Because cost is a substantial obstacle for many in determining whether to seek or accept medical treatment, it is important to understand the costs associated with surgery, as high financial burden has been shown to be associated with increased therapeutic nonadherence, psychological distress, and social difficulties while contributing to diminished physical health, self-esteem, and exposure to resources.[14,15] Cost-effectiveness as it pertains to surgical outcomes can be calculated by comparing cost, which includes those of the initial surgery, postoperative complications, outpatient healthcare encounters, revisions, and medical-related readmissions, with the quality-adjusted life years (QALYs) gained from the intervention. This study aims to examine the potential differences in cost per QALY across patient frailty categories to determine the effect of frailty on cost utility.

METHODS

Study Design and Inclusion and Exclusion Criteria

This study was a retrospective cohort review of a prospective multicenter ASD database. Patients were enrolled consecutively with Institutional Review Board approval, and informed consent was obtained from 13 centers across the United States. Database inclusion criteria consisted of patients older than 18 yr with at least one of the following radiographic measures: sagittal vertical axis (SVA) >5 cm, Cobb angle >20°, pelvic tilt (PT) >25°, and/or thoracic kyphosis (TK) >60°. Operative ASD patients who met database inclusion criteria with no history of fusions and radiographic and health-related quality-of-life data at baseline and a 2-yr follow-up were analyzed.

Data Collection and Radiographic Parameters

Demographic, clinical, and operative data were recorded with standardized data collection forms. Demographic information included age, body mass index (BMI), biological sex, and Charlson Comorbidity Index (CCI). Surgical parameters complied were levels fused, operative time, length of stay (LOS), surgical approach, performance of decompressions, and osteotomies. An assessment of complications was made based on review of imaging and clinical follow-up. Study coordinators on site at each center aided with data collection, allowing the database to further undergo routine auditing to certify accuracy. Patient-reported outcome measures were prospectively collected at baseline and follow-up intervals and included the following: Short Form-36 (SF-36) questionnaire, Scoliosis Research Society Outcomes Questionnaire (SRS-22), and the Oswestry Disability Index (ODI). To evaluate improvement in outcomes, minimal clinically important difference (MCID) thresholds were used based on published values in the literature for SF-36 (4.9), ODI (12.8), SRS-Pain (0.587), SRS-Mental (0.42), SRS-Activity (0.375), and SRS-Appearance (0.8).

Full-length free-standing lateral spine radiographs (36-in cassette) were collected and assessed at baseline and follow-up intervals. Radiographic images were analyzed using SpineView (ENSAM, Laboratory of Biomechanics) software according to standardized and validated techniques previously published in the literature. Spinopelvic radiographic parameters measured were PT, pelvic incidence (PI), SVA, TK (T4-12), lumbar lordosis (LL, T12-S1), and mismatch between pelvic incidence and lumbar lordosis (PI-LL).

Cost Calculation

The PearlDiver database was used to calculate costs using job order cost accounting ("charge analysis"). Reflecting both Medicare reimbursement and private insurance, the PearlDiver data are one 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. According to CMS.gov, manual definitions for revisions, complications/comorbidities (CC), and major complications/comorbidities (MCC) were used. Regression analysis of Medicare pay scales for the services recorded within a 30-d window was used to estimate 2-yr reimbursement costs. Cost per QALY at 2-yr follow-up and life expectancy were calculated while accounting for LOS, CC, MCC, revisions, and death.

Indirect costs associated with loss of work were calculated based on response to SRS-22rQ9 and by estimating loss of average weekly earnings based on the average weekly income from the US Bureau of Labor Statistics. Patients who were categorized as returning to work identified as either "Disabled" or "Unemployed" using chart review at baseline but had a change in work status to "Employed" at follow-up. Those who were already retired were not included when identifying those who returned to work.

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Utility Calculation

Utility data were calculated converting ODI to Short-Form Six-Dimension based on a published conversion methodology in the literature.[16-18] As an assessment of outcome, quality-adjusted life years (QALYs) were used by QALYs gained calculated using the following equation:

$$\text{QALYs gained} = (Q^{i} - Q)\frac{1 - \exp^{-rL}}{r}.$$

As a measure of health-related quality of life, 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). Quality-adjusted life years used a 3% discount rate as recommended by the World Health Organization to account for residual decline in life expectancy. 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 men (76.9 yr) and women (81.6 yr) were manually selected for life expectancy.

Statistical Analysis

Patients were stratified into 3 categories according to the ASD-FI: (1) NF, (2) F, and (3) SF. Independent sample *t*-tests and chi-squared analysis compared demographic, radiographic, health-related quality-of-life, and surgical data among the cohorts. Statistical significance was set to $P < .05$. Statistical tests were performed using SPSS software (v21.0, IBM).

RESULTS

Patient Demographics

Five hundred ninety-two patients with operative ASD met the inclusion criteria. The mean patient age was 59.8 ± 14.0 yr, with a BMI of 27.7 ± 6.0 kg/m^2, CCI of 1.8 ± 1.7, and ASD-FI of 3.3 ± 1.6, with 80% of patients being female. Overall, 4.7% of patients were categorized as SF, 22.3% as F, and 73.0% as NF (Table 1).

Surgical Characteristics

Patients had a mean level fused of 11.4 ± 4.4, an estimated blood loss of 1569 ± 1486 mL, a LOS of 7.9 ± 4.5 d, and an operative time of 376 ± 133 min. Overall, 69.3% of patients had a posterior-only approach, 30% combined approach, and 0.7% anterior-only; 63% underwent an osteotomy; and 54% had a decompression performed (Table 1).

Baseline Radiographic and Clinical Profile

Radiographically at baseline, patients present with a mean PT of 24.4 ± 10.8, PI-LL of 16.1 ± 21.1, SVA of 63.9 ± 72.4, and T1PA of 22.9 ± 13.1. According to SRS-Schwab Classification, 29.1% of patients were ++ for PT, 29.4% ++ for SVA, and 39.2% ++ for PI-LL. For health-related quality of life at baseline, patients had a mean ODI of 43.6 ± 17.6, PCS of 31.7 ± 9.9, SRS-Activity of 2.9 ± 0.88, SRS-Pain of 2.4 ± 0.84, SRS-Appearance of 2.4 ± 0.74, SRS-Mental of 3.4 ± 0.94, SRS-Satisfaction of 2.8 ± 1.1, and SRS-Total of 2.8 ± 0.6.

Preoperative and Postoperative Radiographic Alignment

At baseline, F/SF patients compared with NF patients had significantly greater PT (26.9 vs 23.4, $P < .001$), PI-LL (23.9 vs 13.2, $P < .001$), SVA (97.3 vs 51.8, $P < .001$), and a lower L1-S1 (31.4 vs 41.2, $P < .001$). Two years after index surgery, F/SF patients showed significantly greater improvement in PI-LL, LL (L1-S1), and TK (T4-T12) relative to NF patients (Table 2).

Differences in Postoperative Morbidity Between NF and F Groups

F patients experienced more reoperations by 2 yr (33% vs 25%, $P = .046$) and had a higher amount of major complications (37% vs 23%, $P = .001$). There were no major differences in minor complications (38% vs 36%, $P = .632$).

TABLE 1. Cohort Demographics and Surgical Characteristics by Frailty Status

Patient/surgical characteristics	NF	F/SF	*P*
Patient demographics			
Age (yr)	58.18 ± 14.97	64.35 ± 9.02	<.001
Female	81%	76%	.251
BMI (kg/m^2)	26.22 ± 5.12	31.82 ± 6.31	<.001
CCI	1.19 ± 1.30	3.34 ± 1.82	<.001
Surgical characteristics			
Levels fused	10.87 ± 4.22	11.87 ± 3.87	.031
Estimated blood loss (mL)	1448.91 ± 1301.07	1895.57 ± 1865.51	.001
LOS (d)	7.56 ± 4	8.86 ± 5.3	.002
Operative time (min)	363.92 ± 131.65	411.04 ± 134.26	<.001
Anterior-only approach	0.5%	1.3%	.300
Posterior-only approach	69.4%	68.7%	.871
Combined approach	30.1%	30.0%	.983
Osteotomy	64%	61%	.499
Decompression	49%	66%	<.001

BMI, body mass index; CCI, Charlson Comorbidity Index; F, frail; LOS, length of stay; NF, not frail; SF, severely frail.

TABLE 2. Cohort Radiographic Measurements by Frailty Status

	NF	F/SF	*P*
Baseline			
PT	23.41 ± 10.90	26.99 ± 10.25	<.001
PI	54.84 ± 12.69	55.29 ± 11.23	.693
PI-LL	13.16 ± 20.72	23.92 ± 20.11	<.001
L1-S1	41.67 ± 21.16	31.37 ± 20.44	<.001
SVA	97.31 ± 75.42	51.85 ± 67.37	<.001
TK (T4-T12)	−35.28 ± 19.31	−33.40 ± 18.39	.288
Sacral slope	29.19 ± 14.12	31.95 ± 12.75	.030
TS-CL	17.79 ± 11.10	19.16 ± 12.66	.219
Cervical lordosis (C2-C7)	11.10 ± 15.93	12.40 ± 16.97	.407
cSVA	28.19 ± 14.23	31.21 ± 15.86	.034
C2-T3	10.27 ± 17.21	12.75 ± 18.04	.140
2 yr postsurgery			
PT	21.04 ± 13.31	23.33 ± 9.57	.015
PI	54.93 ± 12.77	55.38 ± 11.60	.695
PI-LL	1.84 ± 17.76	7.52 ± 14.03	<.001
L1-S1	53.08 ± 13.74	47.87 ± 14.85	<.001
SVA	19.47 ± 50.82	56.63 ± 50.02	<.001
TK (T4-T12)	−43.07 ± 16.18	−46.43 ± 16.56	.026
Sacral slope	31.53 ± 13.45	36.13 ± 12.23	<.001
TS-CL	20.33 ± 10.93	23.02 ± 12.01	.010
Cervical lordosis (C2-C7)	11.19 ± 16.37	13.04 ± 15.63	.216
cSVA	30.08 ± 14.13	34.79 ± 13.81	<.001
C2-T3	5.95 ± 16.97	9.93 ± 17.47	.012

F, frail; NF, not frail; PI, pelvic incidence; PI-LL, pelvic incidence and lumbar lordosis; PT, pelvic tilt; SF, severely frail; SVA, sagittal vertical axis; TK, thoracic kyphosis.

Health-Related Quality-of-Life Scores

F and SF patients presented at baseline with a significantly higher ODI (54.1 vs 39.8) and lower PCS (26.4 vs 33.7), SRS-Activity (2.4 vs 3.1), SRS-Pain (2.1 vs 2.5), SRS-Appearance (2.1 vs 2.5), SRS-Mental (3.2 vs 3.6), and SRS-Total (2.5 vs 2.9, all $P < .001$). At 1-yr postoperatively, F/SF patients showed a significantly greater degree of improvement in ODI (20.0 vs 15.5, $P = .007$), SRS-Activity (0.80 vs 0.59, $P = .007$), and SRS-Total (1.0 vs 0.89, $P = .046$). In addition, F/SF patients met MCID for SRS-Activity at significantly higher rates relative to NF patients at 1-yr follow-up (77% vs 63.4%, $P = .011$). At 2 yr, there were no significant differences between the cohorts on meeting MCID for ODI, PCS, SRS-Activity, SRS-Pain, SRS-Appearance, or SRS-Mental (all $P > .05$) (Table 3).

Distribution of Patients Who Improved, Remained the Same, and Deteriorated According to Frailty Category

One hundred eighty-six patients (30%) improved, 389 patients (63%) remained the same, and 22 (3.6%) increased in frailty.

Financial Burden of ASD

At baseline, 104 patients with ASD were classified as unemployed experiencing an average weekly earnings loss of $971.38. After 1 yr postoperatively, 62 patients remained unemployed experiencing an overall average loss of $50 508.64 yearly income.

Additional Financial Burden of Frailty

With propensity score matching for baseline SVA to account for the initial level of deformity, the average cost of ASD surgery at 2-yr follow-up for F/SF patients was greater compared with that of NF ($81 347 vs $69 722). Furthermore, the cost per QALY was similar for F/SF patients at 2 yr compared with that for NF ($436 473 vs $430 437). If utility gained is sustained to life expectancy, the cost per QALY differences between F/SF and NF become more comparable ($58 965 vs $58 149) (Table 4).

DISCUSSION

The goal of this study was to investigate the additional direct and indirect costs that frailty can compound for patients who suffer from ASD and undergo surgical intervention. To the authors' knowledge, there are no studies that have analyzed the intersections of frailty, surgical correction for ASD, and their economic impact on the patient.

Because the definition of frailty continues to adapt to an aging population, it is important to maintain its identity as a descriptor of vulnerability.[19] Frailty has been positively correlated with incidence of mortality, LOS, and total cost of surgery across medical subspecialties.[20] Within this niche, greater patient frailty as assessed by the ASD-FI metric was associated with suboptimal health-related quality of life after surgery.[12]

TABLE 3. Cohort Health-Related Quality-of-Life Scores by Frailty Status

	NF	F/SF	*P*
Baseline			
ODI	39.77 ± 15.6	54.06 ± 16.7	<.001
PCS	33.66 ± 7.7	26.37 ± .47	<.001
SRS-Activity	3.08 ± 0.06	2.43 ± 0.63	<.001
SRS-Pain	2.52 ± .059	2.07 ± 0.04	<.001
SRS-Appearance	2.53 ± 0.052	2.14 ± 0.04	<.001
SRS-Mental	3.56 ± 0.071	3.16 ± 0.035	<.001
SRS-Total	2.92 ± 2.5	2.47 ± 0.63	<.001
Difference 2 yr postsurgery and at baseline			
ODI	−20.0 ± 0.85	−15.5 ± 1.5	.007
PCS	8.32 ± 0.49	9.61 ± 0.83	.204
SRS-Activity	0.59 ± 0.04	0.80 ± 0.06	.007
SRS-Pain	1.00 ± 0.05	1.18 ± 0.09	.059
SRS-Appearance	1.29 ± 1.0	1.32 ± 0.072	.757
SRS-Mental	0.43 ± 0.82	0.55 ± 0.07	.122
SRS-Total	0.89 ± 0.71	1.01 ± 0.054	.046

F, frail; NF, not frail; ODI, Oswestry Disability Index; SF, severely frail; SF-36, Short Form-36 questionnaire; SRS-22, Scoliosis Research Society Outcomes Questionnaire.

TABLE 4. Cost Data by Frailty Status, With Cost per QALY at 2 yr and Life Expectancy

	NF	F/SF
Average total cost	$69 722	$81 347
Cost per QALY at 2 yr	$430 437	$436 473
Cost per QALY at life expectancy	$58 149	$58 965

F, frail; NF, not frail; QALY, quality adjusted life year; SF, severely frail.

Previous literature by Reid et al[21] demonstrated that SF patients are the least likely to achieve substantial clinical benefit in most health-related quality-of-life domains after ASD surgery, when compared to NF or F patients. The authors additionally concluded that F patients improved more in the same measures compared with NF patients, demonstrating the potential inconsistencies of increasing frailty on surgical outcome by this metric.

In addition, Smith et al[22] have previously shown that although elderly patients are at increased risk of complications when undergoing corrective surgery for adult scoliosis, these patients also have a significant margin of improvement in pain and disability. Our findings are consistent with this literature in showing the postoperative radiographic, functional, and clinical benefits that F and SF patients experience after operative treatment. We have additionally demonstrated that despite an increased initial cost, the improvement in quality of life for F/SF patients makes the costs similar to those of NF patients. Furthermore, our propensity score matching for baseline deformity exhibited that when modeled out to life expectancy, the cost per QALY differences between F/SF and NF become comparable. Thus, we can see that the gap between F/SF and NF patients in cost per QALY lessens over time. This study validated the findings of the investigation by Brown et al[23] because the results maintained a greater improvement in ODI among F/SF patients. The studies are also similar in finding higher mean total cost of intervention among F/SF patients; however, the high patient-reported outcome improvement among F/SF patients in this study resulted in a less striking difference in cost per QALY data. Being powered by larger sample size and extended follow-up, this study is unique in that it allowed for a better picture of cost differences between frailty cohorts. It is important to consider that a higher frailty index indicates a higher risk for complications, which was seen with our F population when compared with NF patients. These increased complications would have directly contributed to a higher cost for the F population.

Limitations

We appreciate several limitations to this study. First, the collection of data was conducted in a prospective manner, but the retrospective design of our study could introduce bias. Furthermore, although the use of a multicenter database may increase the generalizability and clinical application of our findings, errors may result during the data entry process. In addition, a limitation of our analysis is that the calculation of frailty incorporates health-related quality of life, which may be a confounding variable in the associations. Moreover, because of the multisurgeon and multicenter nature of the database, there is a deficiency of homogeneity behind selection of patients undergoing surgical treatment.

CONCLUSION

The complexity of ASD in presentation and corrective treatment lends itself to significant scrutiny on the cost-effectiveness of surgical intervention. Although previous literature has demonstrated that F and SF patients have significant margin of benefit with surgical intervention, the economic impact on treating this cohort of patients has been understudied. To the best of our knowledge, this study is the first to exemplify that F and SF patients with ASD not only experience a significant improvement in quality of life with surgical intervention, but the cost per QALY is also comparable with treating NF patients when modeled out to life expectancy.

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