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The Additional Economic Burden of Frailty in Adult Cervical Deformity Patients Undergoing Surgical Intervention

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Summary of Background Data. The influence of frailty on economic burden following corrective surgery for the adult cervical deformity (CD) is understudied and may provide valuable insights for preoperative planning.

Objective. To assess the influence of baseline frailty status on the economic burden of CD surgery

Study Design. Retrospective cohort.

Materials and Methods. CD patients with frailty scores and baseline and two-year Neck Disability Index data were included. Frailty score was categorized patients by modified CD frailty index into not frail (NF) and frail (F). Analysis of covariance was used to estimate marginal means adjusting for age, sex, surgical approach, and baseline sacral slope, T1 slope minus cervical lordosis, C2–C7 angle, C2–C7 sagittal vertical axis. Costs were derived from PearlDiver registry data. Reimbursement consisted of a standardized estimate using regression analysis of Medicare payscales for services within a 30-day window including length of stay and death. This data is representative of the national average Medicare cost differentiated by complication/comorbidity outcome, surgical approach, and revision status. Cost per quality-adjusted life-year (QALY) at two years was calculated for NF and F patients.

Results. There were 126 patients included. There were 68 NF patients and 58 classified as F. Frailty groups did not differ by overall complications, instance of distal junctional kyphosis, or reoperations (all $P > 0.05$). These groups had similar rates of radiographic and clinical improvement by two years. NF and F had similar overall cost ($36,731.03 *vs.* $37,356.75, $P = 0.793$), resulting in equivocal costs per QALYs for both patients at two years ($90,113.79 *vs.* $80,866.66, $P = 0.097$).

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Conclusion. F and NF patients experienced similar complication rates and upfront costs, with equivocal utility gained, leading to comparative cost-effectiveness with NF patients based on cost per QALYs at two years. Surgical correction for CD is an economical healthcare investment for F patients when accounting for anticipated utility gained and cost-effectiveness following the procedure.

Key words: cervical deformity, spine, frailty, cost-effectiveness, clinical outcomes, QALY

Level of Evidence. III.

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Frailty, a concept that contextualizes physiological reserves and potential for recovery from surgery, has gained increased acceptance as an important prognostic factor for mortality and adverse events across many surgical fields, including adult spinal deformity.[1–7]

In the context of cervical deformity (CD) corrective surgery, several indices have been developed to quantify frailty, with higher frailty scores indicating an increased risk of major complications.[8–10] Additional studies have shown there is a relationship between CD frailty score and odds of experiencing postsurgical complications.[10] Despite experiencing a perioperative complication, many patients will still go on to derive substantive benefit from the CD surgery. Others, however, may experience a deleterious shift in their recovery trajectory and never fully recover or fail to reach an optimal outcome. Furthermore, ongoing disability and healthcare requirements may add to the already extensive expenditures associated with the index CD correction.

With an increased emphasis on stewardship of healthcare resources in the current fiscal environment, it is appropriate to consider factors that may influence the cost-effectiveness of CD surgery.[11,12] By individualizing surgical plans that account for the intersection of frailty, severity of deformity and procedural costs, surgeons may be better able to optimize patient outcomes while minimizing low-value care. However, the ultimate impact different levels of frailty can have on the cost-effectiveness of CD surgery has yet to be adequately explored.

In this context, we sought to conduct a cost-effectiveness analysis accounting for patient frailty, using multicenter registry data for patients who underwent surgical correction for CD. We hypothesized that surgery for frail (F) patients would be less cost-effective than procedures performed on not frail (NF) individuals.

MATERIALS AND METHODS

Study Design and Inclusion Criteria

As previously published, the current database comprises 13 distinct centers across the United States, contributing consecutively enrolled, consented patient data with institutional review board approval to a prospectively enrolled adult CD database that the present study utilized via retrospective analysis.[13,14] These patients were initially identified for database inclusion by meeting at least one of the following radiographic parameter criteria: cervical kyphosis (C2–C7 cobb angle $>10°$), C2–C7 sagittal vertical axis (cSVA) >4 cm, chin-brow vertical angle $>25°$, or T1 slope minus cervical lordosis (TS–CL) $>10°$. Patients that were included in the present study also had baseline and up to two-year data from the Neck Disability Index (NDI) questionnaire, as well as a baseline frailty score.

Data Collection and Radiographic Parameters

We abstracted demographic [age, body mass index (BMI), biological sex, Charlson Comorbidity Index], surgical (levels fused, operative time, length of stay, surgical approach, performance of decompressions, and osteotomies), and clinical (complications, reoperations) data. Complication assessments were made based on a review of imaging, patient reports, and clinical follow-up data also contained in the dataset. NDI results were collected at baseline and follow-up intervals by the individual centers and were accessed via a multicenter registry.

Full-length free-standing lateral spine radiographs (EOS or 36-inch cassette if unavailable) were collected and assessed at baseline and follow-up. Radiographic images were analyzed using SpineView® (ENSAM; Laboratory of Biomechanics, Paris, France) software.[15–17]

Frailty Categorization

Patient frailty scores, determined at baseline, were categorized based on the modified CD frailty index.[9] NF patients had a score that was ≤ 0.3. F patients had scores that were >0.3.

Utility Calculation

Utility data was calculated via the difference between baseline and 2-year NDI scores after converting to Short-Form 6 Domains.[18] The utilities were then transformed into quality-adjusted life-years (QALYs) and characterized as QALYs gained. QALYs were discounted at an annual 3% rate as recommended by the World Health Organization to account for the decline in function associated with aging.

Cost Calculation

PearlDiver data was utilized to calculate national average Medicare costs using job order cost accounting ("charge analysis") for cervical procedures. We used mean costs associated with procedures based on 2018 adult CD diagnosis-related groups. We also accounted for costs associated with the occurrence of complications and comorbidities, major complications and comorbidities, and revisions according to CMS.gov manual definitions.[19] Two-year reimbursement consisted of a standardized estimate using regression analysis of Medicare payscales 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 complications and comorbidities, major complications and comorbidities, length of stay, revisions, and death, cost per QALY at two-year follow-up was calculated.[20–24]

Statistical Analysis

We used analysis of covariance to establish estimated marginal means for complication rates and NDI improvement from baseline to two years adjusting for age, sex, surgical approach, baseline deformity (sacral slope, TS–CL, C2–C7, cSVA), and baseline disability (NDI). Costs per QALY were calculated at two years for patients in the different frailty groups (NF and F). Statistical tests were performed using SPSS software (v21.0; IBM Corp., Armonk, NY).

RESULTS

Patient Demographics

Of 169 patients, we identified 126 patients were eligible for inclusion. The mean age of the cohort was 61.6 ± 10.0 years, and 65% of the cohort was female. The mean BMI of the cohort was 28.93 ± 7.6 kg/m^2. The mean Charlson Comorbidity Index total score was 0.94 ± 1.3. By surgical approach, 18.3% of the cohort had an anterior-only approach, 48.4% had a posterior-only approach, and 33.3% underwent a combined approach. Overall, 84.7% of patients underwent a surgery that included an osteotomy, 16.4% were a major osteotomy.

Frailty Groupings

Separating patients by baseline modified CD frailty index, 68 patients were NF, 51 were F, and seven were severely frail. F and severely frail patients were grouped into the frail group. Their baseline characteristics are compared in Table 1.

TABLE 1. Baseline Characteristics and Disability of Frailty Groups

	Mean ± SD		
	Not Frail	Frail	*P*
Age	63.0 ± 8.8	60.0 ± 11.0	0.087
Sex (female) (%)	56	76	0.018
BMI	27.4 ± 5.3	30.6 ± 9.2	0.026
CCI	0.72 ± 1.02	1.20 ± 1.50	0.055
Frailty	0.199 ± 0.074	0.415 ± 0.078	< 0.001
Osteoporosis (%)	14.7	20.7	0.382
Baseline HRQLs			
EQ-5D	0.773	0.697	< 0.001
NDI	40.6	56.4	< 0.001

BMI indicates body mass index; CCI, Charlson Comorbidity Index; EQ-5D, EuroQol-5 Dimension; HRQL, health-related quality of life; NDI, Neck Disability Index.

Baseline Demographics and Disability

The NF patients had lower BMI and were more often male, but the two groups did not differ in age or Charlson Comorbidity Index (both $P > 0.05$). The NF group had significantly lower baseline scores in both NDI and EuroQol-5 Dimension (both $P < 0.001$, Table 1).

Baseline Radiographic Alignment and Surgical Details

Baseline differences in radiographic parameters are indicated in Table 2. There no differences seen in TS–CL, cervical lordosis, T1 slope, C2 slope, C2–T3, McGregor's slope, or cSVA at baseline between the two frailty groups (all $P > 0.05$). Table 2 highlighted the surgical details between frailty groups. F patients did not differ from NF patients in any surgical details, except undergoing significantly less major osteotomies (8.6% *vs.* 22.1%, $P = 0.035$).

Radiographic Outcomes

The radiographic outcomes between NF and F groups is depicted in Table 3. There were no significant differences in the two-year measurements for each radiographic parameter. However, F patients had equivocal rates of meeting their Roussouly target (60% *vs.* 48%, $P = 0.224$) and being proportioned in Global Alignment and Proportion (51% *vs.* 30%, $P = 0.088$) by two years compared with NF.

Rates of Complications by Frailty

Frailty groups did not differ by the rate of any complication or instance of distal junctional kyphosis. There were no significant differences in specific rates of overall medical, cardiac, infection, and neurological complications ($P > 0.05$), as displayed in Table 3. However, when examining major complications in each category, F patients had significantly higher major neurological complications (12.1% *vs.* 2.9%, $P = 0.048$) while trending towards higher rates of major cardiac (8.6% *vs.* 2.9%, $P = 0.13$) and overall major complications (29.3% *vs.* 17.7%, $P = 0.12$). Of note, there were six patients in the NF group who underwent reoperation, whereas only one patient in the F group underwent reoperation (8.8% *vs.* 1.7%, $P = 0.070$).

Frailty Cost and QALY Outcomes

There was no significant difference in improvement in NDI between the two time points (NF: 15.1 *vs.* frail: 18.1, $P = 0.413$; Table 4). Following adjustment for all included covariates, F patients had similar utility gained from baseline to two years (change: 0.238) relative to NF patients (change: 0.210, $P = 0.605$). This translated to F patients experiencing similar gains in QALYs at two years (0.462 *vs.* 0.408, $P = 0.605$). NF and F groups had similar total surgical costs at two years ($36,731.03 *vs.* $37,356.75, respectively), resulting in equivocal costs per QALY for both groups at two years ($90,113.79 *vs.* $80,866.66, $P = 0.097$; Table 4).

TABLE 2. Baseline Radiographics and Surgical Details by Frailty

	Mean ± SD		
	Not Frail	Frail	P
TS–CL	37.2 ± 18.3	40.1 ± 23.7	0.476
C2–C7 lordosis	−6.0 ± 21.9	−9.6 ± 21.9	0.399
T1 slope	40.8 ± 19.1	36.4 ± 19.8	0.261
C2–T3	−17.5 ± 22.3	−18.0 ± 24.4	0.917
C2 slope	37.2 ± 20.5	39.8 ± 24.4	0.536
McGregor's slope	5.2 ± 13.7	2.5 ± 12.3	0.295
cSVA	48.2 ± 23.9	42.7 ± 25.1	0.243
GAP score	3.37	3.64	0.623
Mismatched in Roussouly (%)	60	54.3	0.535
Surgical details			
EBL (mL)	878	712	0.269
Operative time (min)	546	548	0.986
No. levels fused	7.8 ± 4.4	7.6 ± 3.5	0.777
Approach	Anterior: 0.21, Posterior: 0.47, Combined: 0.32	Anterior: 0.16, Posterior: 0.50, Combined: 0.34	0.774
Length of stay	5.6 ± 3.6	8.1 ± 10.5	0.092
Procedures performed (%)			
Decompressions performed	50	62	0.177
Osteotomies performed	50	55	0.566
Major osteotomies performed	22.1	8.6	0.035
Undergoing revision	25.0	22.4	0.737

cSVA indicates C2–C7 sagittal vertical axis; EBL, estimated blood loss; GAP, Global Alignment and Proportion; TS–CL, T1 slope minus cervical lordosis.

Case Example

For reference, a severely frail patient receiving a cervical fusion surgery achieving greater than average improvement in utility gained (change in NDI from baseline to two years) is modeled in Table 5, along with baseline and two-year radiographs in Figures 1–4.

DISCUSSION

As government and third-party payers in the United States continue to emphasize value-based care, the determination of cost-effectiveness for various procedures serves a critical role in spine surgery.[20,24] Frailty is a complex spectrum disorder with numerous etiologies.[25] Cervical deformity surgery is widely known to be associated with a large initial healthcare expenditures and a high rate of complications.[21,26,27] Moreover, previous studies have shown frailty is commonly present among the population necessitating surgical correction for CD.[28,29] While it is generally accepted that frailty is an important risk factor for adverse events following CD surgery, it is equally vital to define the influence of this spectrum disorder on costs of care. The present study sought to evaluate the additional financial burden associated with frailty in the setting of CD surgery.

Our results indicate corrective surgery for patients with a higher frailty score was just as cost-effective as similar interventions for individuals deemed NF. Patients who were classified as F tended to experience greater improvements in NDI scores when compared with NF individuals. Overall, surgical expenditures and associated costs were relatively similar between the two groups. The complication rates were also similar in many regards, except for seeing significantly more reoperations occur in the NF group and higher major neurological complications for the F group, demonstrating equivocal cost-effectiveness profiles across the frailty spectrum. In previous literature, however, we have seen F patients incur

TABLE 3. Two-year Radiographic Outcomes and Complication Rates by Frailty

	Mean ± SD		
	Not Frail	Frail	*P*
TS–CL	29.2 ± 11.6	25.7 ± 14.0	0.319
C2–C7 lordosis	7.2 ± 12.5	12.4 ± 15.3	0.165
T1 slope	36.3 ± 15.6	37.5 ± 17.1	0.774
C2–T3	−2.1 ± 13.5	2.2 ± 14.7	0.257
C2 slope	27.1 ± 12.0	24.3 ± 14.4	0.433
McGregor's slope	−3.7 ± 9.2	−6.3 ± 9.0	0.261
cSVA	39.8 ± 18.3	39.7 ± 16.9	0.984
GAP proportioned (%)	30	51	0.088
Met Roussouly target (%)	48	60	0.224
2-yr complication rates (%)			
DJK	7.4	12.1	0.381
Medical	14.7	8.6	0.288
Cardiac	1.5	5.2	0.262
Neurological	7.4	12.1	0.373
Major	11.8	12.1	0.958
Minor	14.7	17.2	0.701
SICU admission	62	71	0.296
Reoperation	8.8	1.7	0.070

cSVA indicates C2–C7 sagittal vertical axis; DJK, distal junctional kyphosis; SICU, surgical intensive care unit; TS–CL, T1 slope minus cervical lordosis.

TABLE 4. Cost and QALY Data by Frailty Status

Parameters	Baseline	2 yr
Cervical lordosis (C2–C7)	−52.5	31.0
TS–CL	110.0	28.9
C2 slope	80.2	23.2
Utility analysis	Patient	Cohort average
Utility gained	0.30	0.21
QALYs gained at 2 yr	0.58	0.41
Complications	None (no reoperation, DJK, major or minor comp)	

DJK indicates distal junctional kyphosis; QALY, quality-adjusted life-year; TS–CL, T1 slope minus cervical lordosis.

significantly higher complications following CD surgery.[9] While this may be due to our smaller patient cohort, we can speculate at least that surgeons are better at optimizing the realignment goals for patients with higher frailty. Particularly, significantly more major osteotomies were performed in the NF cohort, despite their similar severity in deformity at baseline. Although a multicenter, multisurgeon database makes it difficult to discern the surgical planning behind the correction of each deformity, we hypothesize this instance may serve as the surgeons in our database taking a more conservative approach to minimize complications and poor outcomes in the highly frail populations.

Conversely, previous studies have shown that F patients experienced greater improvement in overall health state than patients who were NF.[30] This is possibly due to the traditionally lower "starting point" that F patients have at baseline compared with their NF counterparts, which results in a quantitatively larger potential for improvement. A similar phenomenon could have been observed here among F patients. Although F patients differed significantly from the other group in both baseline and two-year neck disability, their improvement during that time period was similar to the NF group, even when accounting for baseline deformity, disability, and age. This indicates F patients reap similar benefits from CD corrective surgery compared with their peers, despite an increased comorbidity profile.

Prior work analyzing the impact of frailty on cost-effectiveness among adult spinal deformity patients found that F and severely frail patients had a lower cost per QALY than NF counterparts at both two-year follow-up and life expectancy.[20,21] Our findings indicated a somewhat similar trend. These disparate conclusions could result from the fact that the nature of cost-effectiveness in spinal deformity may be relatable between the thoracolumbar and cervical regions. This trend, however, may not continue into the longer term towards life expectancy. Although we could have amortized the QALYs gained up to average life expectancy within simulations associated with our own analysis, recent discussion has rendered the conversion of two-year improvement to life expectancy utility inadmissible.[31,32] Future studies should target longer term follow-up to evaluate the durability of the outcomes present in our findings.

In a similar sense, due to a low number of patients with severe frailty, we were unable to parse out the differences

TABLE 5. Cost Analysis Case Example

Metric	Not Frail	Frail	*P*
NDI improvement BL to 2 yr	15.1	18.1	0.413
Total surgical cost at 2 yr ($)	36,731.03	37,356.75	0.793
QALYs gained at 2 yr	0.408	0.462	0.605
Cost per QALY at 2 yr ($)	90,113.79	80,866.66	0.097

BL indicates baseline; NDI, Neck Disability Index; QALY, quality-adjusted life-year.

FIGURE 1. Baseline lateral cervical radiograph.

FIGURE 3. Two-year lateral cervical radiograph.

FIGURE 2. Baseline lateral full-spine radiograph.

FIGURE 4. Two-year lateral full-spine radiograph.

between the specific frailty categories. This delineation would be clinically significant to target because, although these patients often have the highest baseline disability and deformity, the severely frail population do not often achieve the same proportion of their potential for improvement when compared with their F and NF counterparts reminiscent of a "ceiling" effect.[10,28] Future research is needed to analyze these subgroups for potential differences in complication rates, clinical and radiographic outcomes, as well as their overall impact on cost and cost-effectiveness.

Alongside this observation, we recognize several potential limitations. The population under study may be prone to the selection, indication, and expertise bias, given our utilization of this multicenter registry as a substrate. We also cannot identify or control for, errors that may occur during the data entry process and are limited to consider factors routinely collected by the participating centers. While 126 patients is a relatively large sample of CD patients, there may still be restricted clinical variation within the cohort as a whole as well as with respect to frailty profiles within the population. Our statistical models are designed to adjust for confounders associated with frailty and not to generate estimates of the influence of other risk factors on cost-effectiveness in CD surgery. In this setting, it is also important to note that we are not comparing surgical intervention for CD to nonoperative measures, which may have even less favorable cost-benefit profiles. The use of generalized national cost estimates derived from PearlDiver may also mean that the findings may not be translatable to all clinical contexts and healthcare environments. Further, more granular testing in larger and more diverse samples remains to be performed. Finally, as cost-effectiveness analysis, we caution against the use of this work to deny patients surgery or define who may or may not undergo CD correction. There may still be F patients to benefit substantially from surgical correction of CD, even if the procedure is not as cost-effective as it might be for NF individuals.

Nonetheless, we believe that our results have important information for clinicians, hospital administrators, and third-party payers. Foremost, surgical correction for CD is a reasonable healthcare investment for properly indicated F patients, irrespective of frailty status, when one considers the anticipated utility gained, along with the cost-benefit. Second, F patients who present at baseline, when optimized, may realize benefits in terms of similar improvements in HRQLs and cost-effectiveness for their procedures alongside their NF peers. Finally, in the event that F patients cannot be improved and still necessitate surgical intervention, lower intensity approaches, if practicable, might result in the quality of life benefits with a more favorable cost-effectiveness profile.

CONCLUSION

In this analysis, F patients had a similar complication rate and a similar total cost. Likewise, F patients saw equivocal improvement in HRQLs following surgery when compared with NF individuals. This resulted in comparative costs per QALY for F and NF patients alike at two years. Therefore, given their relative utility gained and cost-effectiveness, CD corrective surgery provides a clinical and economical benefit in the F population.

➢ Key Points

- ❑ F patients had slightly higher complication rates overall but had less reoperation rates compared with NF patients in this cohort.
- ❑ F patients trended towards greater clinical improvement in terms of NDI by two years.
- ❑ The overall cost did not differ between the two frailty groups.
- ❑ Ultimately, these outcomes generated equivocal cost-effectiveness between F and NF patients following adult cervical deformity surgery.

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