

Greater improvement in Neck Disability Index scores in women after surgery for cervical myelopathy: an analysis of the Quality Outcomes Database

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OBJECTIVE There is a high prevalence of cervical myelopathy that requires surgery; as such, it is important to identify how different groups benefit from surgery. The American Association of Neurological Surgeons launched the Quality Outcomes Database (QOD), a prospective longitudinal registry, that includes demographic, clinical, and patient-reported outcome data to measure the safety and quality of neurosurgical procedures. In this study, the authors assessed the impact of gender on patient-reported outcomes in patients who underwent surgery for cervical myelopathy.

METHODS The authors analyzed 1152 patients who underwent surgery for cervical myelopathy and were included in the QOD cervical module. Univariate comparison of baseline patient characteristics between males and females who underwent surgery for cervical spondylotic myelopathy was performed. Baseline characteristics that significantly differed between males and females were included in a multivariate generalized linear model comparing baseline and 1-year postoperative Neck Disability Index (NDI) scores.

RESULTS This study included 546 females and 604 males. Females demonstrated significantly greater improvement in NDI score 1 year after surgery ($p = 0.036$). In addition to gender, the presence of axial neck pain and insurance status were also significantly predictive of improvement in NDI score after surgery ($p = 0.0013$ and $p = 0.0058$, respectively).

CONCLUSIONS Females were more likely to benefit from surgery for cervical myelopathy compared with males. It is important to identify gender differences in postoperative outcomes after surgery in order to deliver more personalized and patient-centric care.

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KEYWORDS cervical myelopathy; gender; QOD; NDI

ABBREVIATIONS DCM = degenerative cervical myelopathy; GLM = generalized linear model; NDI = Neck Disability Index; QOD = Quality Outcomes Database.

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DEGENERATIVE cervical myelopathy (DCM) is one of the most common causes of nontraumatic spinal cord injury globally.^{1,2} The incidence and prevalence rates of DCM in North America are estimated to be at least 41 and 605 cases per million persons, respectively, though these values are likely underestimates.¹ Furthermore, the number of surgical procedures for DCM has dramatically increased over the last 20 years, with greater proportions of older patients who have comorbidities.^{3–5} Identifying the factors that predict postoperative outcomes would optimize patient selection and clinical management.

Prospective clinical registries are powerful tools for pinpointing these prognostic factors.^{6–10} The Quality Outcomes Database (QOD) is a prospective longitudinal multicenter registry that was launched to measure the safety and quality of neurosurgical procedures.¹¹ The QOD has become the largest North American spine registry to date and has catalyzed important insights on the factors that influence patient-reported outcomes, such as return to work and satisfaction.^{11–13} Registry-based data have highlighted the impact of socioeconomic and demographic characteristics, such as gender, on surgical outcomes of DCM.^{14,15}

The prevalence and nature of DCM are known to differ between men and women.^{16–18} Nevertheless, the impact of gender on patient-reported outcomes in patients undergoing surgery for cervical myelopathy is still under investigation. The Neck Disability Index (NDI) score, a patient-reported measure of how neck pain affects life, is a commonly used outcome measure that has demonstrated robust responsiveness and reliability.^{19–21} Using the QOD cervical module, we created a multivariate generalized linear model comparing the baseline and 1-year postoperative NDI scores of male and female patients who underwent surgery for cervical myelopathy across the 14 participating sites. We also assessed other patient demographic, comorbidity, symptom, and social factors that were predictors of NDI improvement after surgery.

Methods

We analyzed 1152 patients who underwent surgery for cervical myelopathy in the QOD cervical module. QOD is a prospective longitudinal registry comprising demographic, clinical, and outcome data for neurosurgical procedures across multiple high-volume neurosurgical and orthopedic spine centers in the United States. Fourteen sites were represented in the cervical module for surgical procedures within the query period from database inception through October 7, 2021.

A univariate comparison of the baseline patient characteristics between males and females who underwent surgery for CSM was performed using the two-sided Wilcoxon rank-sum test. Baseline characteristics that significantly differed between males and females were included in a multivariate generalized linear model (GLM) comparing baseline and 1-year postoperative NDI scores. Of note, if the QOD data for a given patient did not include gender, the subsequent demographic, clinical, and outcome data were not included in either the univariate or multivariate analyses.

For the first multivariate GLM, univariate predictors

that were significant at a level of $p < 0.20$, in addition to gender, were included to predict differences in composite NDI scores 12 months postoperatively. For the variables that were significant in this multivariate GLM, we completed a subanalysis to compare postoperative NDI scores between the gender distributions of the respective variables. A second GLM was built to predict the influence of gender on all NDI subcomponents 12 months postoperatively. The outcomes of the GLM are reported as t-statistic (number of subjects) and p value. Both univariate and multivariate analyses were conducted using the MATLAB functions `ranksum` and `fitglm`, respectively (MATLAB version R2020b).

Finally, we conducted a propensity-matched univariate analysis with XLSTAT to examine whether matching baseline patient characteristics between male and female patients would account for any differences in 12-month postoperative NDI scores. Similar to the first univariate analysis, clinical predictors were significant at a level of $p < 0.20$ for inclusion in subsequent GLMs.

Results

Our study population included 1150 patients, including 546 females and 604 males who underwent surgery for cervical myelopathy. We extracted clinicodemographic and outcome variables from the QOD cervical module. We first compared male and female patients on the basis of demographic and preoperative clinical characteristics. In addition to gender, male and female cohorts differed (univariate $p < 0.20$, rank-sum test) in 11 areas including age, medical and psychiatric comorbidities, preoperative radicular and myelopathic symptoms, and insurance and education status (Table 1).

We included these 12 patient variables, also comprising gender, as covariates in a multivariate GLM (see *Methods*) designed to predict the difference in composite NDI scores 12 months postoperatively. Our model significantly predicted postoperative NDI ($F [693] = 2.33$, $p = 5.4 \times 10^{-4}$). Moreover, despite controlling for all differing clinicodemographic variables in the model, we found that gender significantly modulated NDI outcomes ($t [693] = -2.10$, $p = 0.036$) (Table 2), with females experiencing significantly greater reduction in NDI score than males (mean \pm SEM females 9.64 ± 0.56 , males 7.38 ± 0.53) (Fig. 1). In addition to female gender, the other patient factors that significantly predicted improved NDI score were more severe preoperative axial neck pain ($t [693] = -3.21$, $p = 0.0013$) and possessing either Medicare or private insurance rather than no insurance ($t [693] = -2.77$ and $p = 0.0058$, and $t [693] = -2.75$ and $p = 0.0062$, respectively).

Next, we examined whether there were gender differences in postoperative 12-month NDI improvement based on presence/absence of axial neck pain, as well as based on insurance status (Table 3). Women in the groups without ($p = 0.043$) and with ($p = 0.023$) axial neck pain had greater NDI score improvement. Both genders with the presence of axial neck pain had greater improvement in postoperative NDI score as compared with those without pain. Women in both the Medicare ($p = 0.027$) and private insurance ($p = 0.0031$) subgroups also had greater

TABLE 1. Comparison of clinicodemographic characteristics between male and female cervical spondylotic myelopathy patients

Predictor	T-Statistic*	p Value
Age†	3.05	0.0023
BMI	0.33	0.74
Smoking†	-1.30	0.20
Diabetes	1.17	0.24
CAD†	3.85	1.2e-4
Anxiety†	-5.09	3.6e-7
Depression†	-6.28	3.4e-10
Radicular pain†	-4.09	4.3e-5
Axial pain†	-4.28	1.8e-5
Motor	0.44	0.66
Sensory	-0.36	0.72
Motor deficit†	1.45	0.15
Ambulatory	-1.03	0.30
ASA class	-0.10	0.92
Insurance†	-1.31	0.19
Ethnicity	-1.04	0.30
Education†	2.15	0.032
Employment†	-2.79	0.0052

ASA = American Society of Anesthesiologists Physical Status Classification System; CAD = coronary artery disease.

* Positive values indicate greater values for males.

† These predictors were included in the multivariate model because univariate comparison between genders (with the rank-sum test) yielded $p < 0.20$.

NDI score improvement. Both genders had greater NDI improvement with private insurance as compared with Medicare.

We additionally built a separate GLM to predict the influence of gender on all NDI subcomponents 12 months postoperatively. Notably, females experienced greater improvement across all subcomponents, though no subcomponent differed significantly (Table 4). Female improvement outpaced that of males primarily in the domains of reading ($p = 0.082$), headache ($p = 0.074$), and work ($p = 0.093$).

After propensity matching of the baseline clinical variables, 331 female and 331 male patients were available for univariate analysis. There were no variables in the univariate analysis that met the criteria for inclusion in the multivariate analysis (i.e., $p < 0.2$) (Table 5).

Finally, to examine whether operative approaches may have influenced these results, we compared the 12-month NDI and baseline scores of the laminoplasty and laminectomy subgroups. We found no differences in NDI scores at baseline (mean \pm SD 35.22 ± 18.34 for the laminoplasty subgroup and 35.24 ± 21.36 for the laminectomy subgroup, $p = 0.96$) or 12 months postoperatively (20.86 ± 18.46 for the laminoplasty subgroup and 22.45 ± 20.09 for the laminectomy subgroup, $p = 0.77$).

Discussion

Here, in our analysis of 1152 patients who underwent

TABLE 2. Relationships between patient clinicodemographic variables and 12-month postoperative improvement in NDI score

Variable*	T-Statistic†	p Value
Female gender‡	-2.10	0.036
Axial pain‡	-3.21	0.0013
Medicare insurance‡	-2.77	0.0058
Private insurance‡	-2.75	0.0062

* Only includes covariates that were significant ($p < 0.05$) in the multivariate GLM.

† A negative t-statistic indicates a greater association with reduction in 12-month NDI score.

‡ Significant ($p < 0.05$) predictors of 12-month postoperative NDI score.

surgery for cervical myelopathy, we demonstrated that females had a significantly greater improvement than men in NDI scores 1 year after surgery. The presence of axial neck pain, as well as Medicare or private insurance, was also significantly predictive of improvement in NDI scores after surgery. In the multivariate analysis, female gender was also independently and most strongly associated with improvement in NDI scores at 12 months postoperatively. This held true when conducting gender-based subgroup analysis based on axial neck pain and insurance status, too.

Although several studies have shown sex-based differences in the biomechanical characteristics of the cervical spine, as well as in the prevalence rates of DCM, sex-based differences in surgical outcomes for cervical myelopathy have been equivocal. Tetreault et al. demonstrated via meta-analysis of 16 studies that gender was not a significant predictor of outcome for degenerative cervical spondylotic myelopathy, whereas preoperative severity and duration of symptoms were predictors.²² However, more recent papers have suggested sex-based differences in cervical spinal alignment,²³ in addition to more positive outcomes for

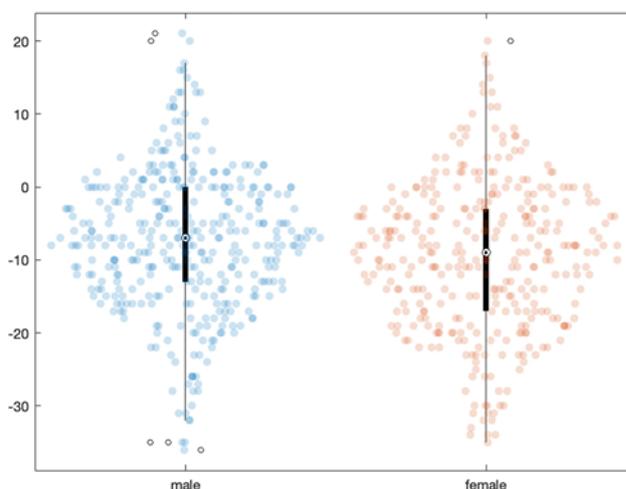


FIG. 1. Difference in total NDI scores at 1 year relative to baseline for male and female cervical spondylotic myelopathy patients. The center line indicates the 25th–75th percentile for difference between baseline and 1-year NDI scores for males and females, respectively. Open circles represent outliers.

TABLE 3. Relationships between previously significant clinicodemographic variables and gender and 12-month postoperative improvement in NDI score

Variable	Postop NDI Improvement*		T-Statistic†	p Value
	Females	Males		
Axial neck pain				
Absent‡	7.94 (123)	5.39 (193)	-2.02	0.043
Present‡	10.40 (270)	8.84 (246)	-2.27	0.023
Medicare insurance‡	9.26 (164)	6.96 (186)	-2.21	0.027
Private insurance‡	10.19 (189)	7.56 (211)	-2.96	0.0031

* Presented as t-statistic (number of patients).

† A negative t-statistic indicates a greater association with reduction in 12-month NDI score in females.

‡ Significant (p < 0.05) according to the multivariate generalized linear model.

females after surgery for degenerative cervical myelopathy. Such findings include the more likely achievement of minimum clinically important difference on the modified Japanese Orthopaedic Association scale,²⁴ decreased risk of reoperation relative to males,²⁵ and increased receipt of > 3-level fusion and anterior-only approach.²⁶ Given our negative results after propensity matching, it is apparent that postoperative NDI improvements for females could also be due to gender-associated clinical demographic characteristics.

Of note, comparing outcomes across the aforementioned studies is difficult due to the variety of clinical metrics used to assess for successful outcome after surgery for cervical myelopathy. The NDI is a long-used 10-item questionnaire for assessing how neck pain affects a patient’s daily life, in addition to providing a self-rating of disability.²⁷ Over the past couple of decades, the reliability and validity of this self-assessment for evaluating disability from neck pain has been demonstrated not only in the United States^{28,29} but also widely internationally, having been translated to over 20 languages.^{30–33} Thus, utilization of this metric across the many institutions that have contributed patient outcomes for this data set provides a broad, valid characterization of how female gender is predictive of better improvement after surgery for cervical myelopathy.

TABLE 4. Influence of gender on postoperative 12-month NDI subcomponent scores

NDI Subcomponent	T-Statistic*	p Value
Pain intensity	-0.21	0.83
Personal care	-1.51	0.13
Lifting	-0.022	0.98
Reading	-1.74	0.082
Headache	-1.79	0.074
Concentration	-1.57	0.12
Work	-1.68	0.093
Driving	-0.66	0.51
Sleeping	-0.53	0.60
Recreation	-0.54	0.59

* A negative t-statistic indicates a greater association with reduction in the 12-month NDI subcomponent score for females.

There were many limitations to this study, first related to the conclusions drawn from analyzing a multicenter registry. We were limited in the length of outcome for comparison (12 months), and we needed to group all surgical procedures for cervical myelopathy together to enable greater statistical power—in other words, we did not separate on the basis of anterior versus posterior versus combined approaches, number of levels of laminectomy, or number of levels of fusion. Longer term study of NDI outcomes for this cohort, in addition to future studies studying subcohorts based on surgical approach, will be needed for more robust and specific conclusions, respectively. Additionally, we did not have access to the radiographic parameters of each patient (e.g., flexion-extension

TABLE 5. Propensity-matched comparison of clinicodemographic characteristics between male and female cervical spondylotic myelopathy patients

Predictor	T-Statistic*	p Value†
Age	-0.44	0.66
BMI	-1.02	0.31
Smoking	0.00	>0.99
Diabetes	0.18	0.85
CAD	-0.56	0.58
Anxiety	0.31	0.76
Depression	-0.59	0.56
Radicular pain	1.01	0.31
Axial pain	0.082	0.93
Motor	0.29	0.77
Sensory	0.47	0.64
Motor deficit	0.24	0.81
Ambulatory	0.00	>0.99
ASA	0.59	0.56
Insurance	0.30	0.77
Ethnicity	0.28	0.78
Education	-0.092	0.93
Employment	0.44	0.66

* Positive values indicate greater values for males.

† No predictor in the propensity-matched univariate comparison between genders met p < 0.20 (rank-sum test).

instability, sagittal alignment angles) for further assessment of whether cervical spine alignment itself differed between the female and male populations included in this study, in addition to possible associations with reduction in NDI score.

While the findings of this study are limited as detailed above, here we have provided one of the largest comprehensive, multicenter analyses thus far and have analyzed the outcomes after surgery for cervical myelopathy on the basis of clinicodemographic variables, particularly those obtained using a patient-filled questionnaire for assessment of changes in disability 12 months after surgery. Importantly, we found that identification of gender, insurance status, and preoperative pain could play a particular role in predicting which patients may benefit most from surgical intervention for cervical myelopathy.

Conclusions

Females are more likely to benefit from surgery for cervical myelopathy compared with males. It is important to identify gender differences in postoperative outcomes after surgery in order to deliver more personalized and patient-centric care.

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Disclosures

Dr. Bisson reported personal fees from Stryker, Medtronic, and MiRus; and stock from Proprio and nView outside the submitted work. Dr. Chou reported personal fees from Globus, Orthofix, and Medtronic outside the submitted work. Dr. Glassman reported personal consulting fees from Medtronic, K2M/Stryker, and DePuy outside the submitted work; and is the chair of the American Spine Registry. Dr. Foley reported royalties, multiple patents with royalties paid, consulting fees, advisory board participation, and stock ownership from Medtronic; and stock ownership from DiscGenics, Accelus, Companion Spine, DuraStat, RevBio, NuVasive, Tissue Differentiation Intelligence, True Digital Surgery, Vori Health, and Spine Wave outside the submitted work. Dr. C. Shaffrey reported consulting fees for advisory board participation, royalties, and stock from NuVasive; consulting fees for advisory board participation and stock from Proprio; and consult-

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Supplemental Information

Previous Presentations

Portions of this work were presented at the 2023 AANS Annual Meeting, Los Angeles, CA, April 21–24, 2023.

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