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Correlation of the Modified Japanese Orthopedic Association With Functional and Quality-of-Life Outcomes After Surgery for Degenerative Cervical Myelopathy: A Quality Outcomes Database Study

BACKGROUND: The modified Japanese Orthopedic Association (mJOA) score is a widely used and validated metric for assessing severity of myelopathy. Its relationship to functional and quality-of-life outcomes after surgery has not been fully described.
OBJECTIVE: To quantify the association of the mJOA with the Neck Disability Index (NDI) and EuroQol-5 Dimension (EQ-5D) after surgery for degenerative cervical myelopathy.
METHODS: The cervical module of the prospectively enrolled Quality Outcomes Database was queried retrospectively for adult patients who underwent single-stage degenerative cervical myelopathy surgery. The mJOA score, NDI, and EQ-5D were assessed preoperatively and 3 and 12 months postoperatively. Improvement in mJOA was used as the independent variable in univariate and multivariable linear and logistic regression models.
RESULTS: Across 14 centers, 1121 patients were identified, mean age 60.6 ± 11.8 years, and 52.5% male. Anterior-only operations were performed in 772 patients (68.9%). By univariate linear regression, improvements in mJOA were associated with improvements in NDI and EQ-5D at 3 and 12 months postoperatively (all $P < .0001$) and with improvements in the 10 NDI items individually. These findings were similar in multivariable regression incorporating potential confounders. The Pearson correlation coefficients for changes in mJOA with changes in NDI were −0.31 and −0.38 at 3 and 12 months postoperatively. The Pearson correlation coefficients for changes in mJOA with changes in EQ-5D were 0.29 and 0.34 at 3 and 12 months.
CONCLUSION: Improvements in mJOA correlated weakly with improvements in NDI and EQ-5D, suggesting that changes in mJOA may not be a suitable proxy for functional and quality-of-life outcomes.

KEY WORDS: Cervical myelopathy, Decompression, Fusion, Disability, Quality of life

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Degenerative cervical myelopathy (DCM) is the most common etiology of spinal cord dysfunction in adults.[1] Extrinsic compression of the cord by degenerated disks, ligaments, and osseous structures may lead to neuronal loss by a variety of vascular and inflammatory mechanisms, manifesting as aberrancies in strength, sensation, dexterity, balance, and sphincter function. Despite the high prevalence of DCM, its natural history has been imprecisely characterized, with a wide range of rates of deterioration reported in extant retrospective studies.[1,2] Severe or progressive disease can be managed with decompression with or without instrumented fusion, which can halt neurological decline and improve function in well-selected patients.[3,4]

The modified Japanese Orthopedic Association (mJOA) scale[5] is a validated, disease-specific, investigator-administered tool that is widely used to assess the severity of myelopathy.[6] The scale

ABBREVIATIONS: COPD, chronic obstructive pulmonary disease; **DCM,** degenerative cervical myelopathy; **EQ-5D,** EuroQol-5 Dimension; **mJOA,** modified Japanese Orthopedic Association; **NDI,** Neck Disability Index; **PCC,** Pearson correlation coefficient; **QOD,** Quality Outcomes Database.

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includes subscores for upper extremity motor function, lower extremity motor function, upper extremity sensation, and urinary function; the sum of these subscores ranges from 0 to 18, with lower scores representing increasing severity of disease. Despite the prominence of the mJOA in determining surgical candidacy and assessing the efficacy of surgery, its relationship to functional and quality-of-life outcomes is incompletely known. These patient-reported outcomes are increasingly viewed as markers of the value and quality of care, and there is merit in understanding the interplay between objective and subjective measures. This study's aim was to quantify the association of the mJOA with the Neck Disability Index (NDI)[7] and the EuroQol-5 Dimension (EQ-5D)[8,9] after surgery for DCM using a large, multicenter database. We hypothesized that changes in the mJOA would correlate with changes in the NDI and EuroQol-5 Dimension (EQ-5D) at 3 and 12 months postoperatively.

METHODS

This study was approved by the University of Michigan Institutional Review Board. Patients completed informed consent, and the final data set was devoid of identifiable patient information.

Study Design and Patient Population

The cervical module of the multicenter, prospectively collected Quality Outcomes Database was queried and reviewed retrospectively. Patients older than 18 years who underwent single-stage surgery for DCM between January 2016 and December 2018 were included. Revisions and operations for infection, trauma, and tumor were excluded. The mJOA, NDI (total score and individual subscores), and 3-level EQ-5D scores were obtained preoperatively and at 3 and 12 months postoperatively.

The mJOA scale[5] is scored from 0 to 18, with higher scores indicating decreasing severity of myelopathy. The total score is calculated by assessment of upper extremity motor function, lower extremity motor function, and urinary function. Mild myelopathy was defined as mJOA 15 to 17, moderate as mJOA 12 to 14, and severe as mJOA 0 to 11.[6] The NDI[7] is scored from 0 to 100, with lower scores representing better function. The total score is generated by summation of values from 10 sections: pain intensity, personal care, lifting, reading, headaches, concentration, work, driving, sleeping, and recreation. The EQ-5D preference-based health state is derived from self-assessments of mobility, self-care, performance of usual activities, pain and discomfort, and anxiety and depression. Health state scores range from less than 0 (where 0 is equivalent to death, and negative values represent states worse than death) to 1 (representing full health).[8,9]

TABLE 1. Baseline Characteristics of the Cohort

	n = 1121
Age in y (mean ± SD)	60.6 ± 11.8
Male	588 (52.5%)
BMI in kg/m^2 (mean ± SD)	30.1 ± 6.4
ASA	
Class 1	22 (2.1%)
Class 2	488 (46.9%)
Class 3	510 (49%)
Class 4	20 (1.9%)
Diabetes	236 (21.1%)
Coronary artery disease	105 (9.4%)
Peripheral vascular disease	40 (3.6%)
Chronic kidney disease	47 (4.2%)
Osteoarthritis	317 (28.3%)
Anxiety	206 (18.4%)
Depression	244 (21.8%)
Parkinson disease	5 (0.5%)
Multiple sclerosis	18 (1.6%)
COPD	77 (6.9%)
Current smoker	197 (17.9%)
White race	860 (76.8%)
College graduate	404 (37.5%)
Private insurance	567 (50.6%)
Worker's compensation	21 (1.9%)
Employed and working	433 (38.7%)
Outside activities	909 (81.3%)
Home activities	996 (90.4%)
Any motor deficit	692 (61.7%)
Radicular motor deficit	334 (29.8%)
Radicular pain	501 (44.7%)
Radicular numbness	657 (58.6%)
Neck pain	707 (63.1%)
Micturition dysfunction	375 (33.6%)
Independently ambulatory	916 (81.7%)
Listhesis	256 (24.9%)
Symptom duration in mo (mean ± SD)	2.5 ± 0.8
Myelopathy severity	
Mild	243 (21.7%)
Moderate	445 (39.7%)
Severe	433 (38.6%)

ASA, American Society of Anesthesiologists; BMI, body mass index; COPD, chronic obstructive pulmonary disease.

Statistical Analysis

Descriptive data were analyzed with univariate methods. Continuous variables were described with the mean and standard deviation. Categorical variables were described with frequency and percent. Improvements in mJOA, NDI, and EQ-5D at 3 and 12 months postoperatively were calculated relative to baseline. Univariate and multivariable regression analyses were performed with NDI and EQ-5D changes as dependent variables and changes in mJOA as the independent variable. Multivariable regression incorporated potential risk factors such as age, sex, body mass index, race,

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TABLE 2. Operative Details for the Cohort

Anterior approach (n = 772)	
Anterior cervical diskectomy and fusion	745 (96.5%)
Corpectomy	92 (11.9%)
Arthroplasty	37 (4.8%)
Posterior approach (n = 349)	
Laminectomy	310 (88.8%)
Laminoplasty	45 (12.9%)
Dorsal arthrodesis	253 (72.5%)

All patients underwent either anterior-only or posterior-only operations.

anxiety, depression, American Society of Anesthesiologists (ASA) physical status, college education, private insurance, preoperative employment status, preoperative motor deficit, preoperative ability to ambulate independently, and surgical approach. The Pearson correlation coefficient (PCC) was also calculated for the association of the changes in mJOA with changes in NDI, NDI subscores, and EQ-5D. A *P* value of less than .05 was considered significant. Normality of data distribution was assessed with the histogram. Missing data were handled with listwise deletion.

RESULTS

Our query of the Quality Outcomes Database cervical module yielded 1,121 unique adult patients across 14 centers who underwent single-stage surgery for DCM between January 2016 and December 2018. The mean age ± SD was 60.6 ± 11.8 years, 52.5% of patients were male, and 76.8% were of White race (Table 1). Anterior-only operations were performed in 772 patients (68.9%), and posterior-only operations were in 349 patients (31.1%; Table 2). No combined anterior and posterior procedures were performed. Among patients who underwent an anterior approach, anterior cervical diskectomy and fusion was performed in 96.5%, corpectomy in 11.9%, and arthroplasty in 4.8%. Among those who underwent a posterior approach, laminectomy was performed in 88.8% and laminoplasty in 12.9%. Posterior arthrodesis was performed in 72.5% (Table 2).

The mean mJOA ± SD scores at baseline, 3 months postoperatively, and 12 months postoperatively were 12.0 ± 2.8 (n = 1121), 13.9 ± 2.6 (n = 914), and 13.8 ± 2.8, respectively (n = 801; Table 3, Figure 1). The mean NDI ± SD scores at baseline, 3 months postoperatively, and 12 months postoperatively were 38.3 ± 20.8 (n = 1117), 23.1 ± 17.9 (n = 942), and 20.4 ± 19.4 (n = 807; Table 3, Figure 2). The mean EQ-5D ± SD scores at baseline, 3 months postoperatively, and 12 months postoperatively were 0.6 ± 0.2 (n = 1029), 0.7 ± 0.2 (n = 899), and 0.7 ± 0.2 (n = 761; Table 3, Figure 3). By univariate regression, improvements in mJOA were associated with improvements in NDI and EQ-5D at 3 and 12 months postoperatively (all $P < .0001$). In addition, improvements in mJOA were associated with improvements in each of the 10 NDI items individually. Multivariable regression incorporating potential confounders yielded similar results.

The PCCs for changes in mJOA and changes in NDI were −0.31 (95% CI −0.37 to −0.25) and −0.38 (95% CI −0.44 to −0.32) at 3 and 12 months postoperatively (Table 4, Figure 4). Among those with mild baseline myelopathy, PCCs for changes in mJOA and changes in NDI were −0.23 (95% CI −0.36 to −0.10) and −0.31 (95% CI −0.44 to −0.17) at 3 and 12 months postoperatively. Among those with moderate baseline myelopathy, PCCs for changes in mJOA and changes in NDI were −0.30 (95% CI −0.39 to −0.21) and −0.42 (95% CI −0.50 to −0.32) at 3 and 12 months postoperatively. Among those with severe baseline myelopathy, PCCs for changes in mJOA and changes in NDI were −0.28 (95% CI −0.37 to −0.18) and −0.34 (95% CI −0.44 to −0.23) at 3 and 12 months postoperatively. PCCs for changes in mJOA with changes in NDI subdomains ranged from −0.13 to −0.23 at 3 months postoperatively and −0.17 to −0.30 at 12 months postoperatively. The PCCs for changes in mJOA with changes in EQ-5D were 0.29 (95% CI 0.23-0.35) and 0.34 (95% CI 0.27-0.40) at 3 and 12 months postoperatively (Table 4, Figure 5). Among those with mild baseline myelopathy, PCCs for changes in mJOA and changes in EQ-5D were 0.25 (95% CI 0.11-0.39) and 0.40 (95% CI 0.25-0.52) at 3 and 12 months postoperatively. Among those with moderate baseline myelopathy, PCCs for changes in mJOA and changes in EQ-5D were 0.31 (95% CI 0.21-0.40) and 0.38 (95% CI 0.28-0.47) at 3 and 12 months postoperatively. Among those with severe baseline myelopathy, PCCs for changes in mJOA and changes in EQ-5D were 0.27 (95% CI 0.16-0.37) and 0.26 (95% CI 0.15-0.37) at 3 and 12 months postoperatively. These correlations were similar when restricting analyses to patients undergoing laminectomy or laminoplasty at 3 or more levels.

DISCUSSION

The mJOA is widely used to assess severity of myelopathy and evaluate the efficacy of surgical intervention. Although the postoperative mJOA score has been shown to correlate with patient satisfaction after surgery for cervical spondylotic myelopathy,[10] its

TABLE 3. Mean mJOA, NDI, and EQ-5D at Baseline, 3 Months Postoperatively, and 12 Months Postoperatively

	Baseline	3 mo postoperative	12 mo postoperative
mJOA, mean ± SD (n)	12 ± 2.8 (n = 1121)	13.9 ± 2.6 (n = 914)	13.8 ± 2.8 (n = 801)
NDI, mean ± SD (n)	38.3 ± 20.8 (n = 1117)	23.1 ± 17.9 (n = 942)	20.4 ± 19.4 (n = 807)
EQ-5D, mean ± SD (n)	0.6 ± 0.2 (n = 1029)	0.7 ± 0.2 (n = 899)	0.7 ± 0.2 (n = 761)

mJOA, modified Japanese Orthopedic Association; NDI, Neck Disability Index.

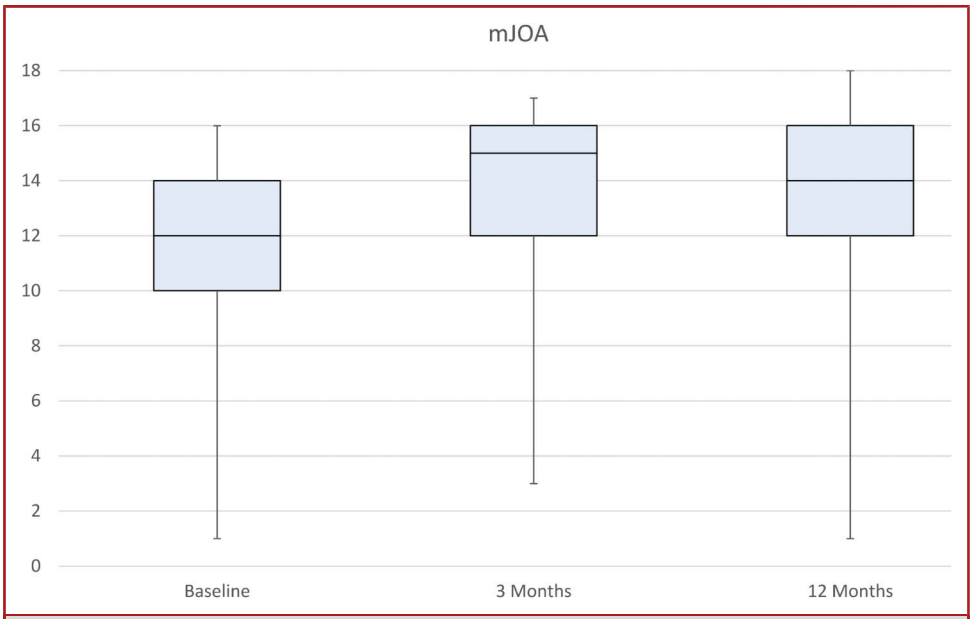

FIGURE 1. *Boxplots showing minimum, Q1, median, Q3, and maximum mJOA values at baseline and 3 and 12 months postoperatively. mJOA, modified Japanese Orthopedic Association.*

relationship to functional and quality-of-life outcomes has not yet been satisfactorily demonstrated. Indeed, sparse literature has examined the associations between objective, myelopathy-specific measures and subjective, patient-reported outcomes. In this large, multicenter study, we have shown that changes in mJOA correlate weakly with changes in NDI and EQ-5D in adult patients undergoing single-stage surgery for DCM.

Lubelski et al[11] retrospectively studied 119 patients who underwent surgery for DCM at a single center and examined relationships among several myelopathy-specific measures (mJOA and Nurick), functional and psychosocial outcomes (Pain Disability Questionnaire [PDQ]) and Patient Health Questionnaire [PHQ]-9), and a quality-of-life outcome (EQ-5D). They found moderate correlation between the mJOA and PDQ as well as the mJOA and EQ-5D. Weak

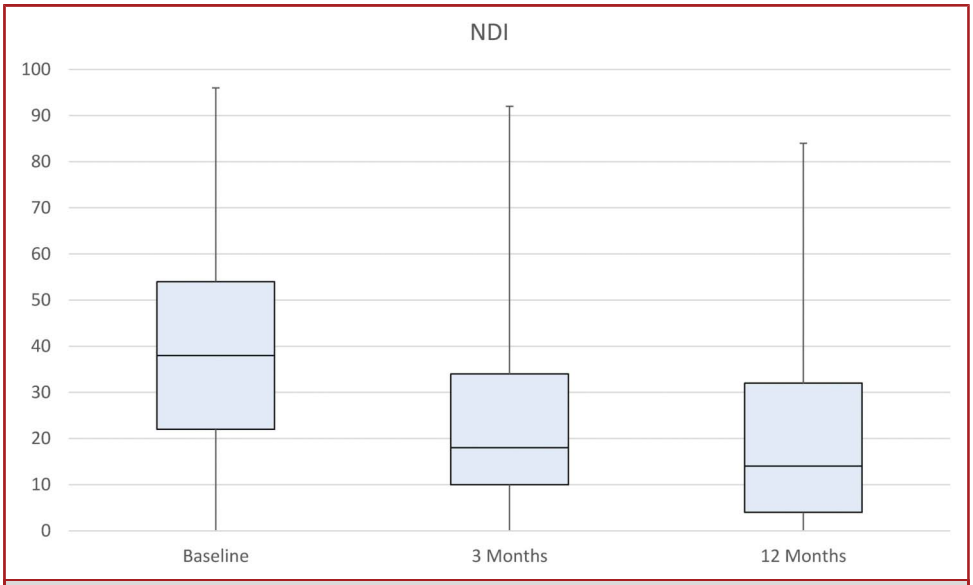

FIGURE 2. *Boxplots showing minimum, Q1, median, Q3, and maximum NDI values at baseline and 3 and 12 months postoperatively. NDI, Neck Disability Index.*

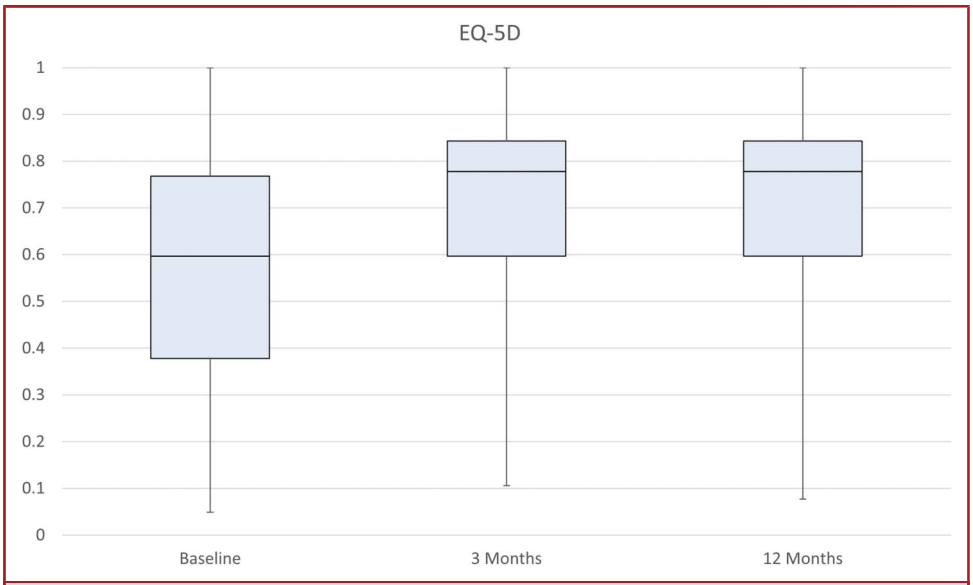

FIGURE 3. *Boxplots showing minimum, Q1, median, Q3, and maximum EQ-5D values at baseline and 3 and 12 months postoperatively.*

correlation was found between the mJOA and PHQ-9. The NDI was not included in this study. Although the NDI was originally developed to assess disability because of neck pain, not myelopathy, it remains the most widely used functional patient-reported outcome for patients with cervical spine disorders[12] and has been validated for evaluating the efficacy of cervical spine surgery.[13,14] Furthermore, only 42 of the 119 patients in this study completed both the preoperative and postoperative mJOA assessments, which limits their ability to assess responsiveness of the metric. The authors do acknowledge having to combine both the preoperative and postoperative scores of the various measures to increase their sample.

Whitmore et al[15] performed a multicenter, prospective study of 103 patients who underwent surgery for DCM because of spinal cord compression at 2 or more levels and assessed the correlation of various outcome measures. Strong correlations were demonstrated between the mJOA and NDI as well as the mJOA and EQ-5D. They state that missing data were omitted from analysis, although they do not seem to disclose how many patients at each time point had incomplete measures. They excluded patients with "significant active health-related comorbidity," which was defined as ASA class 3 or higher. Although this also serves to increase the homogeneity of their study population, it excludes a large proportion of patients for whom the results of this study could be informative. The incidence of DCM increases with age and with accrual of other disease processes. Over 50% of the patients in our study had an ASA class of 3 or 4. Patient selection may help explain the difference in the strength of correlations between their data and ours. Furthermore, although they showed significant changes within all metrics from baseline to 1 year postoperatively, they did not examine how the changes correlated among the metrics. The authors also seem to have simultaneously analyzed scores from different time points when performing their correlation. We find it more illustrative to analyze correlations individually at predefined intervals, as convalescence across domains can change at different rates.

McGregor et al[16] conducted a retrospective study of 78 patients who underwent surgery for DCM and examined the relationships among American Spine Injury Association, mJOA, NDI, Nurick, and Short-form 36-item (SF-36) scores. Notably, their inclusion

TABLE 4. Pearson Correlation Coefficients for Changes in mJOA vs Changes in NDI and EQ-5D at 3 and 12 Months Postoperatively (all $P < .0001$)

	Pearson correlation coefficient (95% CI)	
	3 mo postoperative	12 mo postoperative
Change in mJOA vs change in NDI	−0.31 (−0.37 to −0.25)	−0.38 (−0.44 to −0.32)
Change in mJOA vs change in EQ-5D	0.29 (0.23-0.35)	0.34 (0.27-0.40)

mJOA, modified Japanese Orthopedic Association; NDI, Neck Disability Index.

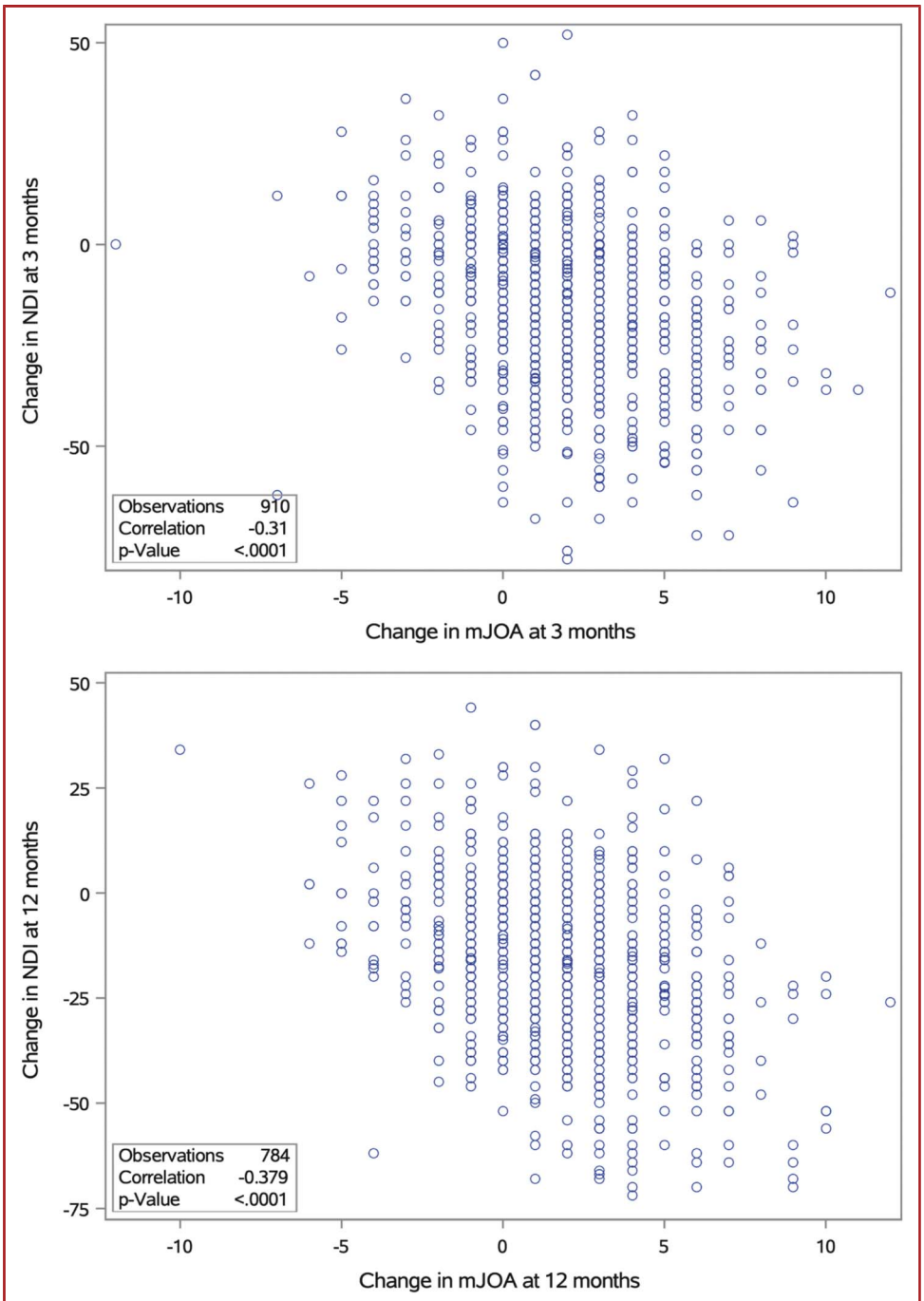

FIGURE 4. *Scatter plots of change in mJOA against change in NDI at 3 and 12 months postoperatively. mJOA, modified Japanese Orthopedic Association; NDI, Neck Disability Index.*

criteria stipulated T2-weighted intramedullary signal change, which may have restricted their population to patients at higher risk for a worse postoperative outcome.[17,18] They found moderate correlation between the mJOA and NDI at the preoperative and 6 months postoperative time points but no significant correlation between the change in mJOA and change in NDI at 6 months postoperatively. The change in mJOA correlated moderately with the change in SF-36 physical component but not the mental component at 6 months

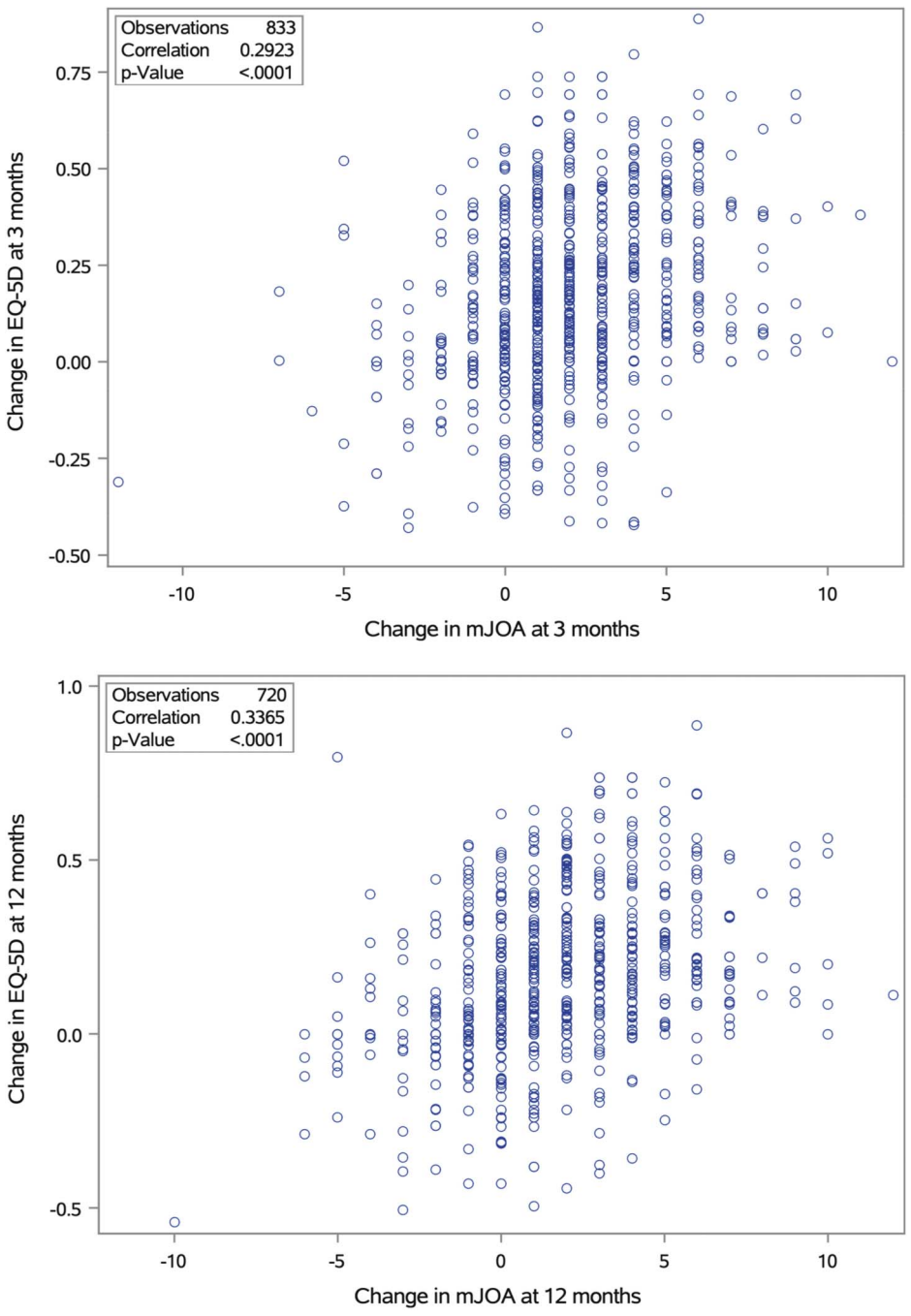

FIGURE 5. *Scatter plots of change in mJOA against change in EQ-5D at 3 and 12 months postoperatively. mJOA, modified Japanese Orthopedic Association.*

postoperatively. These findings are in line with ours, although we have the advantage of a larger patient population, more time points, and follow-up to 12 months postoperatively.

Key Results and Interpretation

To the best of our knowledge, this is the largest study to assess the correlation between mJOA and functional and quality-of-life

outcomes. Despite the widespread use of the mJOA as an assessment of myelopathy severity and informally as an assessment of physical function in patients with DCM, we found it to correlate weakly with changes in NDI and EQ-5D at 3 and 12 months postoperatively. Although it is preferable for a disease-specific metric to correlate with functional and quality-of-life outcomes, the clinical heterogeneity of DCM poses a challenge for description by any single-outcome measure. Our results suggest overlap between mJOA and NDI and mJOA and EQ-5D, the mJOA does not fully encapsulate either. The objective and relatively narrow scope of the mJOA—focusing on motor, sensory, and micturition function—may help explain its low correlation with subjective and broad nature of NDI and EQ-5D. Further efforts will be necessary to reduce the administrative burden of multiple questionnaires that are completed, transcribed, and analyzed for clinical and research purposes. We anticipate that modifications will be made to existing measures and new ones developed to more precisely describe myelopathy and correlate with global health status. As the need to procure multiple outcome measures persists, phone and e-mail administration of the JOA and NDI have been demonstrated to be valid with strong reliability and internal consistency.[19] The use of such ancillary means of data capture may increase efficiency of clinic visits and improve rates of questionnaire completion.

Limitations

The limitations of our study include its retrospective nature, although the data were collected prospectively. Although our inclusion criteria of imaging findings and comorbidities are less stringent than those of studies referenced above, we think this makes our study pragmatic and more reflective of common clinical practice. Furthermore, the large sample size and multicenter cooperation increase the generalizability of our results. Although our type I error rate remained unadjusted despite multiple comparisons, a demonstration of lack of significance to our correlations would only serve to strengthen our conclusion.

CONCLUSION

Changes in the mJOA correlate weakly with changes in NDI and EQ-5D at 3 and 12 months after surgery for DCM, suggesting that the mJOA is not a suitable proxy for patient-reported functional and quality-of-life outcomes.

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