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## Trajectory of Improvement in Myelopathic Symptoms From 3 to 12 Months Following Surgery for Degenerative Cervical Myelopathy

**BACKGROUND:** Degenerative cervical myelopathy (DCM) is a progressive disease resulting from cervical cord compression. The modified Japanese Orthopaedic Association (mJOA) is commonly used to grade myelopathic symptoms, but its persistent postoperative improvement has not been previously explored.

**OBJECTIVE:** To utilize the Quality Outcomes Database (QOD) to evaluate the trajectory of outcomes in those operatively treated for DCM.

**METHODS:** This study is a retrospective analysis of prospectively collected data. The QOD was queried for patients undergoing elective surgery for DCM. Patients were divided into mild ( $\geq 14$ ), moderate (9-13), or severe ( $< 9$ ) categories for their baseline severity of myelopathic symptoms (mJOA scores). A parsimonious multivariable logistic regression model was fitted with 2 points improvement on mJOA from 3- to 12-mo follow-up as the outcome of interest.

**RESULTS:** A total of 2156 patients who underwent elective surgery for DCM and had complete 3- and 12-mo follow-up were included in our analysis. Patients improved significantly from baseline to 3-mo on their mJOA scores, regardless of their baseline mJOA severity. After adjusting for the relevant preoperative characteristics, the baseline mJOA categories had significant impact on outcome of whether a patient keeps improving in mJOA score from 3 to 12 mo postsurgery. Patient with severe mJOA score at baseline had a higher likelihood of improvement in their myelopathic symptoms, compared to patients with mild mJOA score in.

**CONCLUSION:** Most patients achieve improvement on a shorter follow-up; however, patients with severe symptoms keep on improving until after a longer follow-up. Preoperative identification of such patients helps the clinician settling realistic expectations for each follow-up timepoint.

**KEY WORDS:** Cervical spine, Degenerative cervical myelopathy, Modified Japanese Orthopaedic Association, Adult spine surgery, Trajectory of improvement

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**D**egenerative cervical myelopathy (DCM) is a progressive disease that affects the discs, facet joints, and surrounding soft tissues causing stenosis and, ultimately, compression of the spinal cord. The resulting myelopathy requires surgical decompression to

halt disease progression and improve functionality.<sup>1,2</sup> DCM is the most common cause of spinal cord impairment in adults. The incidence of DCM-related hospitalizations has been estimated at 4.04/100 000 person-years, with surgically treated DCM estimated at 1.6 per 100 000 inhabitants.<sup>3,4</sup> With an aging population, the prevalence of DCM is expected to increase in the United States. In order to set realistic expectations in the preoperative settings, it is imperative for surgeons to discuss treatment options and the postoperative trajectory of functional improvement with patients.

**ABBREVIATIONS:** BMI, Body mass index; DCM, Degenerative cervical myelopathy; mJOA, Modified Japanese Orthopaedic Association; QOD, Quality outcomes database; rms, Regression modeling strategies; REDCap, Research electronic data capture

DCM is a well-studied disease process because of its high prevalence, functional manifestations (weakness, hand dysfunction, and gait impairment), and numerous surgical options. The optimal surgical approach is based on cervical sagittal alignment, number of pathological levels, and the degree of anterior or posterior compression.<sup>5-7</sup> Early decompression has been found to significantly improve functional outcomes<sup>8</sup> in both younger (<65 yr) and older (>75 yr) patients.<sup>9</sup> However, there is a paucity of literature that describes the natural history of recovery following surgical decompression, especially in the postsurgical period of 3 mo to 12 mo. Most of the studies that do exist examine small numbers of patients with high levels of heterogeneity within the cohorts.<sup>10,11</sup>

This study utilizes the Quality Outcomes Database (QOD) to evaluate the trajectory of outcomes in patients treated surgically for DCM. We hypothesize that patients with different severities of preoperative myelopathic symptoms will show different patterns of symptom improvement between the 3- and 12-mo postoperative period.

## METHODS

The QOD is a national multicenter registry that prospectively enrolls patients undergoing elective spine surgery. As of April 2017, over 37 000 patients from 82 participating sites across the United States were enrolled in the QOD spine modules, including over 4000 patients undergoing cervical spine surgery. The sites enroll patients continuously or on a prespecified rotating cycle ensuring unbiased enrolment into the registry.<sup>12</sup> Patients undergoing cervical spine surgery for the diagnosis of stenosis (foraminal or central), instability, disc herniation, or adjacent segment disease are eligible for inclusion in the QOD registry. Exclusion criteria include patients with a diagnosis of spinal infection, tumor, fracture, traumatic dislocation, deformity, neurological paralysis due to pre-existing spine disease or injury, and those who are less than 18 years of age, or incarcerated. For this study, we identified patients undergoing elective surgery for DCM. Specifically, patients were selected for inclusion in the current study if one of their predominant symptoms/indications for cervical spine surgery was myelopathy and if 3-mo and 1-yr follow-up data were available (N = 2156).

The QOD project is designated as a nonresearch clinical quality improvement effort and is based on existing federal guidelines exempted from IRB review. Data were collected through the standard QOD process. Electronic medical records were reviewed to gather data for variables such as age, gender, race, body mass index (BMI), comorbid conditions, symptom duration, and surgical approach. Data for other variables such as smoking status, workers' compensation, and liability insurance were collected via self-administration during a clinic visit, by email or telephone interviews by an independent data coordinator who was not directly involved with clinical care. Patients with myelopathy also completed the modified Japanese Orthopaedic Association (mJOA) score. The mJOA score has been shown to be a valid and responsive measure of functional status and effectiveness of surgery in patients presenting with DCM.<sup>13</sup> The mJOA score is a multidimensional scale and assesses upper as well as lower extremity and bladder dysfunction in patients with DCM, and is the standard scale for DCM grading in

the Western population.<sup>13</sup> The 3- and 12-mo postsurgical mJOA scores were compared for each patient, and a 2-point improvement was defined as meeting a clinically meaningful threshold.<sup>14</sup> The severity of preoperative myelopathic symptoms was categorized as mild (mJOA  $\geq$  14), moderate (mJOA = 9-13), or severe (mJOA < 9). All of these data were stored in a national aggregate database (Research Electronic Data Capture [REDCap]) through a secure, password-protected, web-based portal.

## Statistical Analysis

Descriptive statistics including mean and standard deviation for continuous variables and frequency and proportion for categorical variables were reported. Finally, a parsimonious multivariable logistic regression model was fitted with a 2-point reduction in the mJOA from 3- to 12-mo follow-up as the outcome of interest. The independent variable was preoperative mJOA category, and other covariates included age, gender, race, BMI, worker's compensation, liability compensation, current smoking status, history of diabetes, anxiety, depression, symptom duration, and surgical approach. For continuous predictors such as age and BMI, the odds ratio was computed when the variable was set to its 75th percentile vs its 25th percentile. We used Wald statistics to determine the relative importance of the various predictors with respect to improvement in mJOA. The analysis was conducted using R 3.1.2 (R Foundation for Statistical Computing, Vienna, Austria) and the rms (Regression Modeling Strategies) package 16, with a significance value of 0.05.<sup>15,16</sup>

## RESULTS

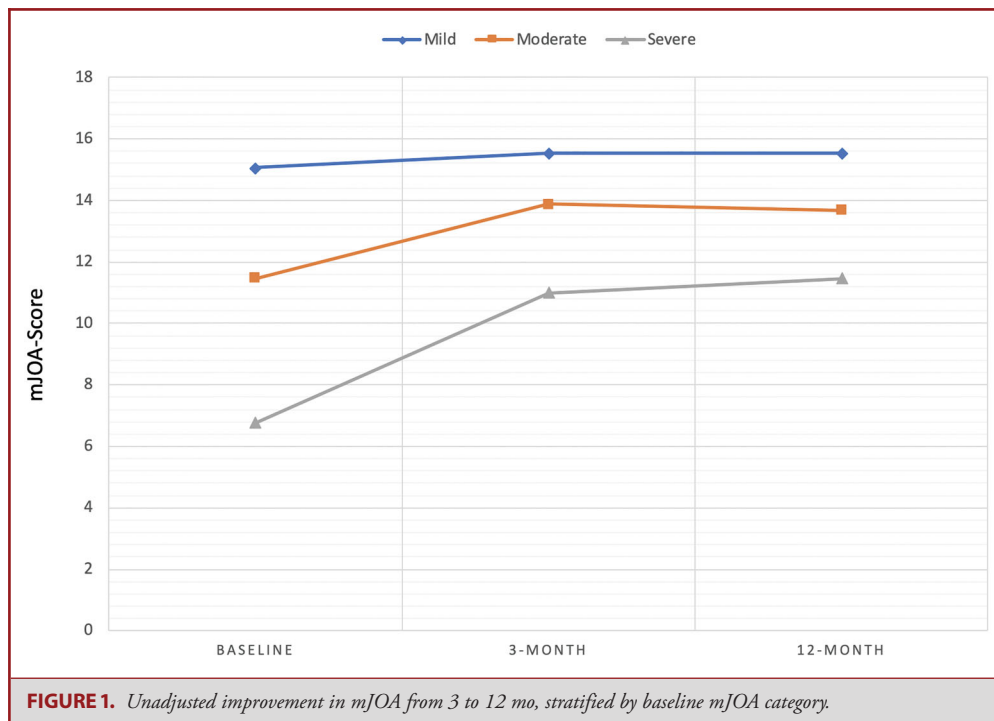
A total of 4196 patients who underwent surgery for DCM were enrolled into the cervical module of the registry and were eligible for 12-mo follow-up. Among all, 2156 patients who had completed 3- and 12-mo follow-up were included in our analysis (Table). The average age of the study cohort was 69.7 yr of age, and 48% were female. A total of 259 (12%) patients had symptoms for less than 3 mo, 831 (38.5%) had them for 3 to 12 mo, 966 (44.8%) had them for over 12 mo, and 100 (4.6%) had an unknown preoperative duration of symptoms. A total of 1621 (75.2%) patients underwent anterior decompression, 477 (22.1%) underwent posterior decompression, and 58 (2.7%) required a 2-stage procedure. The study cohort had 892 (41.4%) patients with mild, 1045 (48.5%) with moderate, and 219 (10.2%) with severe baseline mJOA scores.

A total of 405 (18.8%) patients showed at least a 2-point improvement in their mJOA scores between the 3- and 12-mo postoperative time points. In the unadjusted paired-sample *t*-test analysis, patients improved significantly from baseline to 3-mo on their mJOA scores, regardless of their baseline mJOA severity. However, only patients with severe baseline mJOA demonstrated statistically significant improvements in mJOA from 3- to 12-mo. The unadjusted improvement in mJOA scores from baseline to 3-mo and then on to 12-mo, stratified by baseline mJOA category, is represented using a line chart in Figure 1.

In the multivariable logistic regression analysis, after adjusting for relevant patient and surgery-specific characteristics, baseline

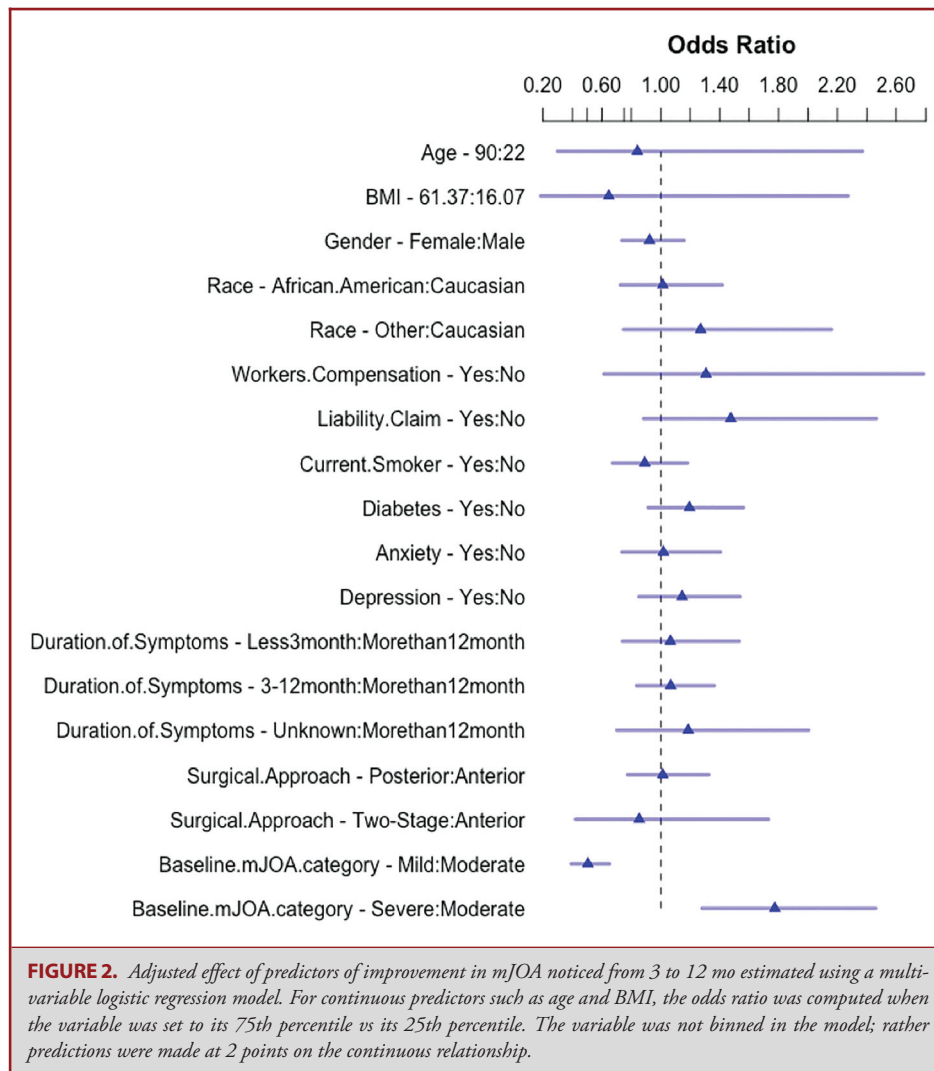
**TABLE. Patient Characteristics**

	Total (N = 2156)	Improved mJOA		P value
		Yes (405)	No (1751)	
Age	69.73 ± 7.63	60.74 ± 8.47	60.73 ± 7.41	.984
Gender: Female	1032 (47.9)	187 (46.2)	845 (48.3)	.483
<b>Race</b>				.242
African American	270 (12.5)	56 (13.8)	214 (12.2)	
Caucasian	1800 (83.5)	328 (81.0)	1472 (84.1)	
Other	86 (4.0)	21 (5.2)	65 (3.7)	
BMI	29.29 ± 8.04	29.31 ± 4.26	29.29 ± 4.04	.931
Workers compensation	41 (1.9)	10 (2.5)	31 (1.8)	.467
Liability claim	83 (3.9)	23 (5.8)	60 (3.5)	.045
Current smoker	447 (20.7)	84 (20.7)	363 (20.7)	1.000
Diabetes	451 (20.9)	99 (24.4)	352 (20.1)	.063
Anxiety	429 (19.9)	89 (22.0)	340 (19.5)	.284
Depression	544 (25.3)	115 (28.4)	429 (24.6)	.124
<b>Duration of symptoms</b>				.844
<3 mo	259 (12.0)	49 (12.1)	210 (12.0)	
3 to 12 mo	831 (38.5)	157 (38.8)	674 (38.5)	
>12 mo	966 (44.8)	177 (43.7)	789 (45.1)	
Unknown	100 (4.6)	22 (5.4)	78 (4.5)	
<b>Surgical approach</b>				.525
Anterior	1621 (75.2)	297 (73.3)	1324 (75.6)	
Posterior	477 (22.1)	98 (24.2)	379 (21.6)	
Two-stage	58 (2.7)	10 (2.5)	48 (2.7)	
<b>Baseline mJOA</b>				<.001
Mild	892 (41.4)	108 (26.7)	784 (44.8)	
Moderate	1045 (48.5)	225 (55.6)	820 (46.8)	
Severe	219 (10.2)	72 (17.8)	147 (8.4)	



**FIGURE 1.** Unadjusted improvement in mJOA from 3 to 12 mo, stratified by baseline mJOA category.

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mJOA categories had a significant impact on predicting whether a patient’s mJOA continued to improve from 3 to 12 mo after surgery (Figure 2). Patients with severe (mJOA < 9) and moderate (mJOA = 9-13) preoperative myelopathic symptoms had a higher likelihood of improvement during this period of time, compared to patients with mild preoperative myelopathic symptoms (mJOA ≥ 14).

## DISCUSSION

### Key Results and Interpretation

Surgical management of DCM effectively halts the progression of disease, and improves patients’ functional status and quality of life. It is important to have a thorough understanding of DCM epidemiology, pathology, surgical options, and outcomes in order to effectively communicate expectations and treatment

strategies to patients. In our cohort, preoperative myelopathy severity (measured by mJOA score) was found to be a significant predictor of a 2-point mJOA score improvement between the 3- and 12-mo postoperative time points. When comparing the preoperative mJOA score to the 3-mo postsurgical mJOA score, a significant improvement was demonstrated across the entire study cohort. However, this improvement continued during 3- to 12-mo only for those patients with severe myelopathy as identified by preoperative mJOA scores. In regard to their mJOA scores, the patients in mild myelopathy group improved to a lesser extent in the early postoperative follow-up and the patients maintained the achieved mJOA score value to longer follow-up. In other words, in the mild myelopathic group preoperative mJOA values limit the room for improvement and the surgery is aimed to prevent worsening of the myelopathic symptoms.

The risks for intraoperative complications and postoperative outcomes in patients with DCM differ with disease severity. Severe cord compression puts the patient at risk for neurological complications and refractory loss of functionality. In such cases, intraoperative strategies may differ with an increased focus on positioning, blood pressure management, and use of neurological monitoring, all to ensure adequate perfusion of the spinal cord. Similarly, the severity of preoperative myelopathy necessitates more intensive postoperative care. Patients with severe preoperative myelopathy may require postoperative inpatient rehabilitation, whereas patients with mild myelopathy are typically discharged home. Any combination of the aforementioned perioperative factors may alter the trajectory of a patient's outcome depending on their disease severity. Tetreault et al<sup>17</sup> performed a systematic review and similarly found that increased duration of symptoms and more severe baseline myelopathy were predictive of poorer outcomes. Other studies have identified age, smoking status, broad-based unstable gait, psychological comorbidities, baseline mJOA score, and baseline transverse area of the cord on magnetic resonance imaging impacting long-term improvement in mJOA.<sup>18,19</sup> Before undergoing decompression for DCM, patients are likely to inquire about the possibility of clinically meaningful improvement. The results of our study shed further light on the postoperative trajectory of patients with DCM and can inform such discussions.

Patients with severe preoperative symptoms continue to have some residual symptoms on their long-term follow-up. In our study, the majority of patients had achieved significant improvement in their mJOA score by the 3-mo postoperative mark. However, a nontrivial proportion of patients continued to improve between 3- and 12-mo follow-up. Patients with severe myelopathy have the potential to continue to improve from 3 to 12 mo and, as such, should be encouraged to continue and stimulate the neural pathways on their own and through directed therapy to achieve maximal medical improvement. On the other hand, we demonstrated that patients with mild preoperative symptoms of myelopathy are unlikely to improve in a clinically meaningful way beyond 3 mo. Understanding the postoperative trajectory of mJOA score improvement is an important aspect of surgical care and may help guide the utility of various postoperative treatment strategies such as discharge disposition, postoperative clinical care plan, and physical therapy.

### Limitations and Generalizability

Any analysis is limited by the variables that are used to fit the model. Certain variables such as postoperative complications, residual or recurrent cervical compression, and postoperative imaging findings that may impact the patients' trajectory of improvement in mJOA scores were not captured in the registry and were not included in the model. However, mJOA is, in fact, considered one of the most relevant and important determinants of functionality and health status in DCM patients. Additionally, the postoperative improvement in mJOA scores is lower in

patients with mild disease because of the associated ceiling effect; however, in our study, the baseline ceiling effect was only noted at 3.6%, which is insignificant. In such patients, the preoperative mJOA present a set ceiling for improvement in myelopathy, and the surgery is aimed to halt the disease progression and improve symptoms of pain and numbness. Despite the aforementioned limitations, utilizing robustly collected prospective data from across the United States, we believe that our results are generalizable to a reasonable degree.

## CONCLUSION

In this cohort of patients with DCM who were treated with decompression, the majority improved from baseline to the 3-mo postoperative mark regardless of baseline patient characteristics, including severity of myelopathy. However, severe baseline myelopathy was the only preoperative patient characteristic found to be predictive of improvement beyond 3 mo. Although severely myelopathic patients will not improve to the point of matching their counterparts with mild baseline myelopathy, they are more likely to improve in the subacute period following decompression.

### Disclosures

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## COMMENT

The authors present a straightforward and well-executed study of improvement after surgical treatment of degenerative cervical myelopathy. Using the QOD, 2156 patients were identified that met all study criteria, including complete 3- and 12-month follow-up. The results showed that all patient groups, regardless of whether their preoperative mJOA score classified them as having mild, moderate, or severe myelopathy, improved by the predefined MCID at 3 months. Interestingly, those with severe myelopathy were more likely to see additional improvement between 3 and 12 months.

These results are potentially very beneficial to practicing spinal surgeons. Patient questions regarding prognosis are prevalent and often difficult to answer. Figure 1, in particular, might be very helpful in facilitating informed consent. The large number of patients, accrued in a real-world practice environment, greatly enhances generalizability.

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