

Original Article

The impact of preoperative neurological symptom severity on postoperative outcomes in cervical spondylotic myelopathy

ABSTRACT

Study Design: The study design is a retrospective cohort study.

Objective: To compare patient-reported outcomes between patients with mild versus moderate-to-severe myelopathy following surgery for cervical spondylotic myelopathy (CSM).

Summary of Background Data: Recent studies have demonstrated that decompression for CSM leads to improved quality of life when measured by patient-reported outcomes. However, it is unknown if preoperative myelopathy classification is predictive of superior postoperative improvements.

Materials and Methods: A retrospective review of patients treated surgically for CSM at a single institution from 2014 to 2015 was performed. Preoperative myelopathy severity was classified according to the modified Japanese Orthopaedic Association (mJOA) scale as either mild (≥ 15) or moderate-to-severe (< 15). Other outcomes included neck disability index (NDI), 12-item short-form survey (SF-12), and visual analog scale (VAS) for arm and neck pain. Differences in outcomes were tested by linear mixed-effects models followed by pairwise comparisons using least square means. Multiple linear regression determined whether any baseline outcomes or demographics predicted postoperative mJOA.

Results: There were 67 patients with mild and 50 patients with moderate-to-severe myelopathy. Preoperatively, patients with moderate-to-severe myelopathy reported significantly worse outcomes compared to the mild group for NDI, Physical Component Score (PCS-12), and VAS arm ($P = 0.031$). While both groups experienced improvements in NDI, PCS-12, VAS Arm and Neck after surgery, only the moderate-to-severe patients achieved improved mJOA (+3.1 points, $P < 0.001$). However, mJOA was significantly worse in the moderate-to-severe when compared to the mild group postoperatively (-1.2 points, $P = 0.017$). Both younger age ($P = 0.017$, β -coefficient = 0.05) and higher preoperative mJOA ($P < 0.001$, β -coefficient = 0.37) predicted higher postoperative mJOA.

Conclusions: Although patients with moderate-to-severe myelopathy improved for all outcomes, they did not achieve normal absolute neurological function, indicating potential irreversible spinal cord changes. Early surgical intervention should be considered in patients with mild myelopathy if they seek to prevent progressive neurological decline over time.

Keywords: Cervical spondylosis, modified Japanese Orthopaedic Association, myelopathy, patient-reported outcomes

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INTRODUCTION

Cervical spondylotic myelopathy (CSM) is a progressive disorder associated with spinal cord dysfunction resulting in loss of motor function, abnormal reflexes, and gait imbalance, among other symptoms.^[1-3] Optimal timing for the treatment of CSM remains controversial as the natural history of the disease can be unpredictable, ranging from stepwise deterioration and progressive disability to periods of disease quiescence.^[4,5]

Conventionally, it was believed that surgical decompression prevented the progression of myelopathic symptoms without necessarily improving neurologic function.^[6,7] However, recent studies have since demonstrated that decompression for CSM leads to improved quality of life when measured by patient-reported outcomes.^[8-14] Fehlings *et al.*, prospectively examined the effect of surgical treatment in patients with varying degrees of cervical myelopathy severity and found that patients with mild, moderate, and severe disease all demonstrated improvements in functional and clinical outcomes at 1-year follow-up.^[8] These observations, however, exposed the need for elucidating the differences in preoperative myelopathy classification and their utility for predicting postoperative success.

This study's primary aim was to investigate whether patients with moderate-to-severe myelopathy undergoing surgery for CSM experienced greater improvements across the various health-related quality of life (HRQOL) outcomes at 1-year follow-up in comparison to patients with mild myelopathy. We hypothesized that while improvement in neurological symptoms varies according to baseline myelopathy scores, surgery for CSM may be warranted despite the degree of severity, based on the recovery in other patient-derived outcomes. We ultimately sought to elucidate the relationship between preoperative modified Japanese Orthopaedic Association (mJOA) score and perioperative change in patient-reported postoperative outcomes after surgery.

MATERIALS AND METHODS

Study design and data collection

A retrospective review of consecutive patients undergoing surgery for CSM between 2014 and 2015 was performed. Patients were identified from a single, large orthopedic practice with multiple fellowship-trained orthopedic spine surgeons. Cervical myelopathy was diagnosed based on clinical findings including loss of dexterity, ataxia, bowel and/or bladder symptoms, as well as corresponding physical examination and concomitant compression of the spinal cord on advanced imaging studies. Key inclusion criteria were age 18 years or older at the time of surgery, no prior

cervical spine surgery, and a completed preoperative mJOA survey. Only those with at least 1-year worth of outcomes follow-up (defined as greater than or equal to 12-months after the date of index surgery) were included in this study. Patients with trauma, tumor, infection or those who presented to the emergency department with central cord syndrome were excluded. IRB approval was obtained before the start of data collection.

Outcome measurements

Baseline myelopathy status was classified based on preoperative mJOA score as mild (mJOA \geq 15), moderate (mJOA = 12–14), or severe (mJOA < 12).^[7,8,15,16] The mJOA scale is a validated means to assess degenerative cervical myelopathy relative to (1) motor dysfunction in the upper extremities, (2) motor dysfunction in the lower extremities, (3) sensory dysfunction in the upper extremities, and (4) dysfunction related to micturition.^[15] HRQOL outcome measures included 12-Item short form survey (SF-12), neck disability index (NDI), and visual analog scale for the neck (VAS neck) and arm (VAS arm) pain.^[15,17-20] The SF-12 is a patient-reported outcome measure that globally assesses mental and physical functioning. Both the mental (MCS-12) and physical (PCS-12) component scores of the SF-12 were included in this study. NDI, which is reported on a 100-point scale, is a patient questionnaire that evaluates the degree that neck pain affects patients' quality of life. Lastly, the VAS neck and arm pain scores are based on an 11-point numeric rating scale from zero (no pain) to ten (worst pain imaginable). All patient-reported outcomes were prospectively collected in the clinic, remotely via telephone, or by using the web-based application Outcomes Based Electronic Research Database (OBERD, Universal Research Solutions, Columbia, MO).^[21]

Statistical analysis

Data were evaluated for normality by visualization and computing the skewness and kurtosis. Normally distributed data were summarized by the mean \pm standard deviation; otherwise, data were summarized by median and interquartile range. Differences in preoperative outcomes among the three mJOA severity groups were tested by one-way analysis of variance or Kruskal–Wallis tests. If differences were detected ($P < 0.1$), *post hoc* pairwise comparisons with Bonferroni correction were used to differentiate between groups. Excluding mJOA, no differences were observed for preoperative HRQOL outcomes between patients with moderate and severe myelopathy [Table 1]. Therefore, the two cohorts were combined and denoted as “moderate-to-severe” myelopathy for further comparative analysis.

Baseline comparisons between the “mild-” and “moderate-to-severe” groups were performed for sex,

Table 1: Differences in preoperative patients reported outcomes grouped by mJOA

	Mild (n=67)	Moderate (n=37)	Severe (n=13)	P*			
				Overall	Mild vs. mod	Mild vs. sev	Mod vs. sev
mJOA	17 [15,18]	14 [13, 14]	10 [7, 11]	<0.001	<0.001	<0.001	0.032
NDI	28.5 (17.6)	39.5 (19.8)	44.0 (16.7)	0.002	0.012	0.018	1.000
PCS-12	36.9 (8.3)	32.9 (7.7)	27.4 (6.0)	<0.001	0.043	<0.001	0.100
VAS Arm	4.0 [0.7, 7.5]	7.0 [3.5, 8.8]	6.2 [5.0, 7.2]	0.064	0.039	0.307	1.000
MCS-12	52.9 [44.4, 59.2]	46.5 [38.1, 57.9]	43.0 [39.1, 59.6]	0.205	0.147	0.449	1.000
VAS Neck	3.3 [0.4, 7.0]	5.0 [3.0, 7.5]	3.4 [1.0, 8.0]	0.246	0.141	1.000	0.736

*Differences in preoperative patient-reported outcomes across the three original mJOA groups (mild, moderate, severe) were tested with one-way ANOVA or Kruskal-Wallis tests, as appropriate. Significant $P < 0.05$ are reported for the overall cohort, mild versus moderate (mod), mild versus severe (sev), and moderate versus severe myelopathy

age, body mass index (BMI), number of levels fused, type of surgery (anterior fusion, posterior fusion, combined anterior and posterior fusion, laminoplasty alone), and length of follow-up. Categorical variables were tested using Chi-square tests, while continuous variables were tested using Mann–Whitney U or *t*-tests.

Differences in patient-reported outcomes between groups over time were tested by linear mixed-effects models for age, myelopathy severity, time, and group-by-time interaction with repeated measures on time and subject-level random intercept. Model residuals were examined for normality on a Q-Q plot. From the mixed-effects model, pairwise comparisons using least-square means with Bonferroni correction tested for differences within each group over time and between groups at each time-point. Results were summarized by the model estimates with 95% confidence intervals (CIs). Finally, multiple linear regression analysis determined whether any preoperative outcomes or baseline demographics predicted postoperative mJOA. Statistical significance was determined at $\alpha = 0.05$. All statistical analyses were performed using R software (Version 3.6.1; The R Foundation for Statistical Computing Platform; Vienna, Austria).

RESULTS

Preoperative outcomes according to modified Japanese Orthopaedic Association classification

There were 117 patients that met inclusion criteria. Table 1 summarizes preoperative outcomes initially stratified by mild, moderate, and severe myelopathy. NDI was significantly higher among patients with moderate myelopathy ($P = 0.012$) and severe myelopathy ($P = 0.018$) compared to patients with mild myelopathy. PCS-12 exhibited a similar pattern with the moderate ($P = 0.043$) and severe ($P < 0.001$) groups reporting worse scores than the mild group. VAS arm was significantly higher in the moderate than the mild group ($P = 0.039$). As previously mentioned, because no there was no difference in preoperative outcomes between the moderate and severe patients, the two cohorts were combined (moderate-to-severe) for further analysis.

Baseline characteristics of cohort

Baseline demographics for mild and moderate-to-severe groups are shown in Table 2. Preoperatively, there were 67 (57.3%) patients with mild myelopathy, and 50 (42.7%) with moderate-to-severe myelopathy (37 moderate, 13 severe). Mean age was 55.8 ± 11.9 years, and mean BMI was 29.9 ± 6.4 . Patients with moderate-to-severe myelopathy were significantly older (60.3 vs. 52.4 years, $P < 0.001$). Median follow-up was 23.0 (12.9, 23.4) months with 100% of patients having at least 1-year follow-up. Notably, 53.0% of patients in the cohort had at least 2-years of outcomes follow-up. There was a longer follow-up observed in the moderate-to-severe group (23.1 vs. 19.8 months, $P = 0.031$). After calculating Pearson's correlation coefficient between the length of follow-up and outcomes, only MCS-12 and PCS-12 exhibited weakly positive correlations of 0.24 ($P = 0.019$) and 0.17 ($P = 0.099$), respectively, in relation to follow-up length. There was no significant correlation between length of follow-up and changes in mJOA scores ($P = 0.363$).

Overall, anterior cervical discectomy and fusion (ACDF) was the most common procedure (88 patients), followed by posterior cervical discectomy and fusion (16 patients), combined anterior and posterior procedure (eight patients), and laminoplasty alone (five patients) [Table 2]. There were no significant differences in the number of levels fused or in the surgical approach between myelopathy groups. Three (3) patients underwent revision surgery during the follow-up period. Initial procedures, myelopathy severity status, and corresponding revisions surgeries for the three patients were as follows:

1. Primary: C3-7 ACDF; moderate myelopathy revision: C6-T1 laminoforaminotomies on postoperative day (POD) 185 for worsening radiculopathy
2. Primary: C3-7 laminectomies with posterolateral fusion and placement of segmental instrumentation; severe myelopathy revision: C2 laminectomy on POD 485 for cervical stenosis
3. Primary: C3-7 ACDF; moderate myelopathy revision: Anterior C5 and C6 corpectomy, revision of prior

C3-C7 ACDF, and addition of posterior spinal fusion instrumentation from C2-T2 on POD 11 due to failure of the anterior plate with resultant cervical kyphosis.

Changes in outcomes after surgery

Due to the significant difference in age between the two myelopathy severity groups, age was included in the mixed effect models. Estimates from the pairwise comparisons are summarized in Tables 3 (overtime within groups) and 4 (between groups within time). A positive value indicates an increase from preoperative to postoperative score in Table 3 and that the moderate-to-severe group reported greater scores than the mild group in Table 4.

Absolute preoperative and postoperative scores are summarized for each group in Table 3. Overall, patients in both the mild and moderate-to-severe myelopathy groups experienced significant improvements across all HRQOL measurements as a result of surgery. Both groups reported significant improvement in NDI, PCS-12, VAS arm, and VAS neck. Only the moderate-to-severe group reported significant improvement in mJOA ($P < 0.001$) and MCS-12 ($P = 0.014$).

Table 2: Patient demographics overall and grouped by myelopathy severity

	Mild (n=67)	Moderate-to-severe (n=50)	Between groups (P) ¹
Female Sex	29	21	1.000
Age	52.4 (11.3)	60.3 (11.2)	<0.001
BMI	29.0 (5.52)	31.0 (7.37)	0.118
Months follow-up	19.8 [12.8;23.2]	23.1 [16.4;23.9]	0.031
No. levels fused	2 [2;3]	3 [2;4]	0.267
Approach			
Anterior	54	34	0.291
Posterior	8	8	
Anterior/Posterior	4	4	
Laminoplasty	1	4	

Baseline comparisons between the two myelopathy classification groups (mild versus moderate-to-severe) tested for differences in gender, age, BMI, number of levels fused, type of surgery, and length of follow-up in months. ¹Categorical variables were tested using Chi-square tests while continuous variables were tested using t-tests or Mann-Whitney U tests, as appropriate.

Table 3: Changes in outcome scores over time grouped by myelopathy severity

Outcome	Mild				Moderate-to-severe			
	Pre	Post	Estimate ¹	P	Pre	Post	Estimate ¹	P
mJOA	17 [15,18]	17 [16, 18]	+0.4 [-0.4, 1.1]	0.726	13 [11, 14]	16 [13, 18]	+3.1 [2.3, 4.0]	<0.001
NDI	28.5 (17.6)	16.0 (18)	-11.8 [-18.4, -5.2]	<0.001	40.7 (19.0)	19.9 (17.6)	-20.4 [-28.0, -12.7]	<0.001
PCS-12	36.9 (8.3)	44.6 (8.9)	+7.9 [4.4, 11.5]	<0.001	31.5 (7.7)	40.7 (9.8)	+9.6 [5.4, 13.7]	<0.001
VAS Arm	4.0 [0.7, 7.5]	0.8 [0.0, 2.7]	-2.3 [-3.7, -0.9]	<0.001	6.6 [3.6, 8.8]	1.8 [0.0, 4.4]	-3.4 [-5.0, -1.8]	<0.001
MCS-12	52.9 [44.4, 59.2]	57.1 [48.4, 60.4]	+1.8 [-2.6, 6.1]	1.000	46.1 [38.2, 58.1]	55.8 [47.6, 60.1]	+5.7 [0.6, 10.7]	0.014
VAS Neck	3.3 [0.4, 7.0]	1.1 [0.0, 4.1]	-1.6 [-2.9, 0.4]	0.003	4.4 [2.0, 7.7]	1.4 [0.0, 2.5]	-2.9 [-4.3, -1.4]	<0.001

Preoperative and postoperative scores for each mJOA group are reported as mean or median as appropriate. Using a mixed effects model controlling for patient age at time of surgery, pairwise comparisons with Bonferroni correction tested for differences within each myelopathy classification group over time. ¹Estimates from the pairwise comparisons are reported with the 95% confidence interval and adjusted P. Positive values for the estimate indicate an increase in score values from preoperatively to postoperatively.

Differences in outcomes between myelopathy classification groups

Preoperatively, the moderate-to-severe group reported significantly worse outcomes compared to the mild group for NDI (+14.3, $P < 0.001$), PCS-12 (-4.5, $P = 0.031$), and VAS Arm (+2.0, $P = 0.005$) [Table 4 and Figure 1]. Postoperatively, mJOA was the only outcome that remained significantly worse in the moderate-to-severe group compared to the mild group ($P = 0.017$) [Table 4 and Figure 2]. Median mJOA scores after surgery were 17 and 16 for the mild and moderate-to-severe groups, respectively [Table 3].

A multiple linear regression model was constructed to predict postoperative mJOA. Both greater preoperative mJOA ($P < 0.001$, β -coefficient = 0.37, 95% CI: 0.22, 0.53) and younger age ($P = 0.017$), β -coefficient = -0.05, 95% CI:-0.08, -0.01) predicted greater mJOA at final follow-up.

DISCUSSION

It has been conventionally understood that the utility of surgery for CSM lies not in improving myelopathy, but instead in halting disease progression. For this reason, the treatment

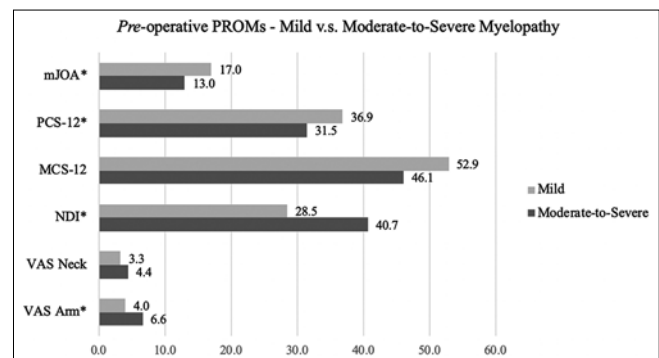


Figure 1: Comparison of preoperative patient reported outcome measures between patients with mild versus moderate-to-severe myelopathy. Modified Japanese Orthopaedic Association, PCS-12, MCS-12 = higher is better. Neck disability index, visual analog scale neck, visual analog scale arm = lower is better. * $P < 0.05$ when comparing outcomes between the two myelopathy groups

Table 4: Differences in preoperative and postoperative outcomes between myelopathy groups

Outcome	Moderate-to-severe versus mild myelopathy			
	Preoperative		Postoperative	
	Estimate ¹	P	Estimate ¹	P
mJOA	-4.0 [-4.9, -3.0]	<0.001	-1.2 [-2.3, -0.1]	0.017
NDI	14.3 [4.9, 23.7]	<0.001	5.7 [-4.4, 15.9]	0.535
PCS-12	-4.5 [-8.9, -0.0]	0.031	-2.9 [-7.8, 2.0]	0.481
VAS Arm	2.0 [0.4, 3.6]	0.005	0.9 [-0.9, 2.7]	0.797
MCS-12	-5.1 [-10.9, 0.7]	0.079	-1.2 [-7.5, 5.1]	1.000
VAS Neck	1.2 [-0.3, 2.7]	0.114	0.2 [-1.6, 1.7]	1.000

Differences in each patient-reported outcome between mJOA classification groups over time were tested by linear mixed effects models for age, group, time, and the group by time interaction with repeated measures on time and subject-level random intercept and controlling for patient age at time of surgery. From the mixed effects model, pairwise comparisons with Bonferroni correction tested for differences between groups at each time-point. ¹Estimates from the pairwise comparisons are reported with the 95% confidence interval and adjusted P. A positive coefficient indicates that the moderate-to-severe group reported higher scores than the mild group.

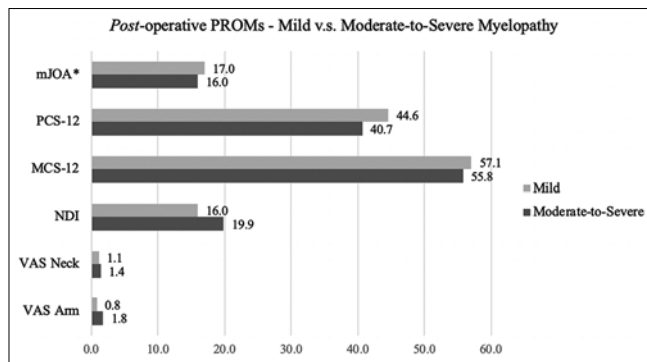


Figure 2: Comparison of postoperative patient reported outcome measures between patients with mild versus moderate-to-severe myelopathy. Modified Japanese Orthopaedic Association, PCS-12, MCS-12 = higher is better. Neck disability index, visual analog scale neck, visual analog scale arm = lower is better. *P < 0.05 when comparing outcomes between the two myelopathy groups

algorithm for CSM often differs between patients with mild and those with moderate-to-severe myelopathy; the premise being that patients with mild myelopathy have less to gain neurologically.^[22] This observation can be attributed to the ceiling effect, where patients with mild myelopathy can only improve 1–3 points on the mJOA given the questionnaire’s inherent limit.^[8,23] However, neurological improvement after surgery must also take into account other outcomes desired by patients, including physical and psychological well-being.^[24]

The most current clinical guidelines for managing cervical myelopathy were published by Fehlings *et al.*,^[25] for patients with moderate or severe CSM, there was a strong recommendation for surgical intervention based on the moderate quality of evidence.^[25] Comparatively, for patients with mild myelopathy, there was a weak recommendation based on poor evidence to offer either surgery or a trial

of structured rehabilitation.^[25] Our results corroborate the current literature that those with moderate-to-severe myelopathy have worse preoperative symptoms at baseline and have more to gain postoperatively.^[8,23,26-28] Khan *et al.*, while studying the trajectory of postoperative neurological improvements in patients with CSM, concluded that in the short term (3 months) all patients, regardless of preoperative mJOA severity, improved significantly. However, only patients with severe findings exhibited progressive improvement over the longer term (12 months), while mild and moderate patients appeared to plateau.^[23] Our results were comparable, as patients with worse symptoms achieved statistically significant improvement among all six outcome measures with larger deltas, while those with mild symptoms had fewer and smaller improvements. However, our findings demonstrate that patients with CSM, regardless of myelopathy severity, ultimately achieved better outcome scores at 1-year follow-up. Those with mild myelopathy in this cohort maintained significantly better mJOA scores than more severe counterparts after 1-year, despite the ceiling effect.

Our findings suggest that patients do not achieve normal function by simply deferring surgery until the onset of moderate-to-severe myelopathy and intervening sooner may potentially preserve higher neurological function. The length of time between mild and moderate-to-severe CSM can be progressive, stepwise, or stagnant, thus patients’ response to nonoperative treatment is classically unpredictable.^[4,13,29-34] Patients with more severe symptoms are more likely to have greater cord compression, which has been intimately linked to irreversible spongiform change, grey matter necrosis, cavitation, and other cellular-level abnormalities observed in histological studies.^[35,36] Furthermore, Wada *et al.*,’ formative study of CSM magnetic resonance images, demonstrated that T2 signal intensity changes in the intramedullary canal were indicative of permanent damage and correlated with worse outcomes.^[37] While those with mild myelopathy certainly have less to gain secondary to the ceiling effect, they also have much more to lose in outcomes and cord morphology as they wait for the natural history of their disease to take hold. We suggest that the degree of myelopathy alone should not be the guiding principle for determining whether or not a patient is a candidate for surgery.

When determining surgical indications, we advocate for a more patient-centered approach that weighs the risks and benefits of operative intervention and the totality of symptoms experienced from CSM. Despite efforts to standardize patients’ subjective experiences, contemporary reviews have largely concluded that no single measurement is predictive for all cases of CSM.^[28,38,39] McGregor *et al.*, in a recent prospective

study, attempted to correlate patient-derived myelopathy scores based on mJOA and physician-derived scores based on the American Spine Injury Association (ASIA) summary physical exam.^[24] While they found that patients experienced improvements in disability and physical function after surgery, mJOA and ASIA were weakly correlated.^[24] Their findings exemplify how patients' perception of their disease can be incongruent with their surgeons' perception. Altogether, the present study and evidence from the literature suggest that treatment optimization for CSM requires shared decision making that weighs objective clinical findings, subjective patient experience, potentially irreversible sequelae from pursuing conservative management, and risks of surgical intervention.^[8,24,26-28,40]

Our study is not without limitations. For instance, about 22% of patients were lost to follow-up during the 1-year period of this cohort, which is comparable to previous studies.^[41-43] In addition, while the levels operated on were similar across groups, no data was collected as to the specific components used in each case. There is growing literature that certain low-profile implants may exert a stronger effect size on patient outcomes than previously thought.^[44] The generalizability of this study may also be limited by the potential confounding between preoperative neurological function and age as shown on regression analysis. The effect of age on outcomes was more evident at the extremes (<40 or >70 years of age) but insignificant between the ages of 40 and 70. Another potential limitation is the absence of a control group, but our intent was to make a direct comparison within patients diagnosed with CSM based on the severity of symptoms and not normal subjects. Fehlings *et al.*, have even proposed that the use of controls in prospective studies involving patients with CSM may be confounded by the number of patients that potentially deteriorate and end up being surgical candidates.^[8] We also recognize that the similarities in postoperative MCS-12 scores between the myelopathy groups could be attributed to the longer length of follow-up observed in the moderate-to-severe cohort. Finally, due to few patients with severe myelopathy (mJOA <12), and the similarities observed in functional and pain scores, patients with severe CSM had to be grouped with those who presented with moderate symptoms for comparative analysis. Thus, the results of our study may not be specifically generalizable to patients with severe myelopathy.

CONCLUSION

The present study builds on current evidence evaluating the relationship between the severity of preoperative cervical myelopathy and postoperative patient-reported outcomes.

Currently, there is no consensus on managing patients with mild myelopathy, whereas surgical intervention is recommended for patients with moderate-to-severe disease. This study indicates that when compared to those with moderate-to-severe CSM, patients with mild myelopathy maintain closer to normal neurologic function and significant improvements in other quality of life, disability, and pain-related outcome measures when treated surgically. Patients with moderate-to-severe myelopathy, who are likely to have greater irreversible spinal cord changes, do not achieve normal absolute function even after surgery. As such, early surgical intervention should be strongly considered in patients with mild myelopathy if they seek to benefit from the observed recovery in HRQOL outcome measures and forego potentially irreversible sequelae from progressive cervical degeneration.

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Conflicts of interest

There are no conflicts of interest.

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