Is Upper Extremity or Lower Extremity Function More Important for Patient Satisfaction? An Analysis of 24-Month Outcomes from the QOD Cervical Spondylotic Myelopathy Cohort

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Study Design: Retrospective analysis of a prospective, multicenter registry.

Objective: To assess whether upper or lower limb mJOA improvement more strongly associates with patient satisfaction after surgery for cervical spondylotic myelopathy (CSM).

Summary of Background Data: The modified Japanese Orthopaedic Association (mJOA) is commonly used to assess functional status in patients with CSM. Patients present with upper and/or lower extremity dysfunction, and it is unclear whether improvement in one and/or both symptoms drives postoperative patient satisfaction.

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Methods: This study utilizes the prospective Quality Outcomes Database (QOD) CSM data set. Clinical outcomes included mJOA and North American Spine Society (NASS) satisfaction. The upper limb mJOA score was defined as upper motor plus sensory mJOA, and the lower limb mJOA as lower motor plus sensory mJOA. Ordered logistic regression was used to determine whether upper or lower limb mJOA was more closely associated with NASS satisfaction, adjusting for other covariates.

Results: Overall, 1141 patients were enrolled in the QOD CSM cohort. In all, 780 had both preoperative and 24-month mJOA scores, met inclusion criteria, and were included for analysis. The baseline mJOA was 12.1 ± 2.7, and postoperatively, 85.6% would undergo surgery again (NASS 1 or 2, satisfied). Patients exhibited mean improvement in both upper (baseline:3.9 ± 1.4 vs. 24 mo:5.0 ± 1.1, $P < 0.001$) and lower limb mJOA (baseline:3.9 ± 1.4 vs. 24 mon:4.5 ± 1.5, $P < 0.001$); however, the 24-month change in the upper limb mJOA was greater (upper:1.1 ± 1.6 vs. lower:0.6 ± 1.6, $P < 0.001$). Across 24-month NASS satisfaction, the baseline upper and lower limb mJOA scores were similar ($p_{upper} = 0.28$, $p_{lower} = 0.092$). However, as satisfaction decreased, the 24-month change in upper and lower limb mJOA decreased as well ($p_{upper} < 0.001$, $p_{lower} < 0.001$). Patients with NASS scores of 4 (lowest satisfaction) did not demonstrate significant differences from baseline in upper or lower limb mJOA ($P > 0.05$). In ordered logistic regression, NASS satisfaction was independently associated with upper limb mJOA improvement (OR = 0.81; 95% CI: 0.68-0.97; $P = 0.019$) but not lower limb mJOA improvement (OR = 0.84; 95% CI: 0.70-1.0; $P = 0.054$).

Conclusions: As the magnitude of upper and lower mJOA improvement decreased postoperatively, so too did patient satisfaction with surgical intervention. Upper limb mJOA improvement was a significant independent predictor of patient satisfaction, whereas lower limb mJOA improvement was not. These findings may aid preoperative counseling, stratified by patients' upper and lower extremity treatment expectations.

Level of Evidence: Level—III.

Key Words: cervical myelopathy, mJOA, upper limb dysfunction, lower limb dysfunction, functional status, satisfaction, QOD, quality outcomes database

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Cervical spondylotic myelopathy (CSM) is the most common spinal cord disorder in the United States for adults over age 55.[1] Cumulative degenerative changes in the cervical spine lead to spinal cord compression and sensorimotor dysfunction. The hallmark signs of CSM are upper extremity dysfunction and lower extremity dysfunction,[2] with other common symptoms including decrements in manual dexterity, gait imbalance, neck pain,[3] and bowel and bladder incontinence.[4] To prevent neurologic deterioration, surgical treatment in the form of anterior, posterior, or combined decompression is often performed for patients with progressive CSM.[4–6]

The modified Japanese Orthopaedic Association (mJOA) scale is the most commonly used measure to assess functional status in patients with CSM.[7,8] Patients are evaluated based on self-reported metrics of motor and sensory dysfunction of the upper and lower limbs as well as bladder dysfunction. mJOA can be obtained preoperatively to establish baseline myelopathy severity, as well as postoperatively to assess operative efficacy.

Few studies have examined how functional improvement directly relates to patient satisfaction, another key postoperative measure. The limited literature surrounding this question has established a positive correlation between change in overall mJOA score and standardized measures of patient satisfaction in patients with CSM.[9–11] However, these studies did not segregate the individual associations between upper and lower limb mJOA scores and satisfaction, and there exist few published comparisons of any elements of upper versus lower limb presentation amongst CSM patients. A study by Funaba et al focusing on radiological factors has associated neck stiffness and anterior spondylolisthesis with patients who express more severe lower extremity dysfunction than upper.[12] Another study from Fudo et al has established an association between change in upper limb function during hospitalization and overall functional status 1 year after laminoplasty.[13] Upper limb function was additionally found to improve faster than lower limb function, both perioperatively and postoperatively. Most recently, Friesen et al found less recovery in the lower mJOA subscore than the upper mJOA subscore, particularly in severe patients.[14]

There remains a dearth of knowledge surrounding the course of upper and lower limb symptoms in a surgical context, and particularly a lack of understanding on how improvement in specific upper versus lower limb dysfunction correlates with patient satisfaction. Further insight into this relationship may aid in preoperative counseling regarding upper and lower extremity function and identify if one is tied more closely to patient satisfaction postoperatively. To this end, we use the Quality Outcomes Database CSM data set to analyze the association of upper and lower limb function on patient satisfaction following surgical treatment for CSM.

MATERIALS AND METHODS

Patient Cohort

This study was a retrospective analysis of the prospectively collected Quality Outcomes Database (QOD) Cervical Spondylotic Myelopathy data set. Patients undergoing elective surgery for CSM were enrolled between January 2016 and December 2018 from 14 high-enrolling sites in the QOD.[15–34] Previous studies have documented the QOD data collection and patient enrollment criteria in detail. Institutional review board approval (Columbia University IRB #AAAU5620) was received for this study, and the data set did not include identifiable patient information.

The QOD CSM data set includes adult patients (over 18 y old) with a primary diagnosis and surgical indication of cervical myelopathy, though co-occurring indications (ie, radiculopathy) were allowed for inclusion.

TABLE 1. NASS Satisfaction Criteria

NASS patient satisfaction	Score	Description
	1	The treatment met my expectations.
	2	I did not improve as much as I had hoped, but I would undergo the same treatment for the same outcome.
	3	I did not improve as much as I had hoped, and I would not undergo the same treatment for the same outcome.
	4	I am the same or worse than before treatment.

Only patients with an mJOA score under 17 were included. Exclusion criteria included spinal infection, tumor, fracture, traumatic dislocation, deformity, or neurological paralysis due to preexisting spine disease or injury.

Variables of Interest

A range of patient characteristics were documented by this database, including demographics, comorbidities, clinical, and surgical characteristics. Outcomes are recorded longitudinally at baseline, 3, 12, and 24 months, and include mJOA, NASS patient satisfaction, Neck Disability Index, EQ-5D, VAS-neck pain, and VAS-arm pain.

The primary outcomes of this study were mJOA and NASS patient satisfaction, assessed at 24 months postoperatively. The North American Spine Society (NASS) patient satisfaction index was scored from 1 to 4, with lower scores representing increased satisfaction following surgery (Table 1). mJOA was scored on a scale of 0 to 17, with lower scores indicating more severe myelopathy (Table 2). The mJOA subcategories were used to calculate upper limb mJOA and lower limb mJOA subscores. The extremity subscores were the composite of the mJOA function and sensation sections as follows, resulting in a range from 0 to 6.

$$Upper Limb mJOA = Upper Extremity Function + Upper Extremity Sensation,$$

$$Lower Limb mJOA = Lower Extremity Function + Lower Extremity Sensation.$$

"Full recovery" of mJOA, lower extremity mJOA, or upper extremity mJOA was defined as patients reaching a full score following surgery (either 17 or 6). In addition, the mJOA recovery rate was calculated using the Hirabayashi method by means of the following formula.[35]

$$Recovery Rate(\%) = \frac{(Postoperative mJOA - Preoperative mJOA)}{(17 - Preoperative mJOA)} \times 100.$$

Statistical Analysis

Categorical variables were calculated as frequencies and proportions (%), and continuous variables as means ± SD. For univariate analysis, two-sample *t*-tests and one-way ANOVA were used for continuous variables, and Pearson's χ^2 tests for categorical variables as appropriate. Fisher exact test was implemented for categorical data when any expected value was less than 5. Multivariable analysis was conducted by means of ordered logistic regression to determine significant factors contributing most to NASS satisfaction.

All statistical analysis was conducted using Python 3.9.16 (Python Software Foundation). The "missingpy"

TABLE 2. mJOA Criteria

mJOA subcategory	Score	Description
Upper extremity function	4	Able to feed myself with no difficulty in both hands
	3	Able to use a knife and fork with slight difficulty
	2	Able to use a knife and fork with much difficulty
	1	Unable to use both hands for a knife, but I am able to eat using a fork or spoon with 1 hand
	0	Unable to feed myself
Lower extremity function	4	No problem walking
	3	Lack of stability and smooth gait (walking in a smooth manner)
	2	Can walk up and down stairs with the support of a handrail
	1	Can walk on a flat surface with a cane or walker
	0	Unable to walk
Upper extremity sensation	2	No loss of feelings in my hands and arms
	1	Mild loss of feeling in my hand or arm
	0	Severe loss of feeling in my hand or arm, loss of pain, touch, or sensation
Lower extremity sensation	2	No loss of feeling in my legs
	1	Mild loss of feeling in my legs
	0	Severe loss of feeling in my legs
Sensation—trunk	2	No loss of feeling in my body
	1	Mild loss of feeling in my body
	0	Severe loss of feeling in my body
Bladder function	3	No problems with urinating or peeing
	2	Mild difficulty because of problems with initiating or getting started or problems with urinating either too frequently or hardly ever
	1	Severe difficulty because of feeling of residual urine or retaining urine even after voiding or because of straining to go or just dribbling when urinating
	0	Cannot urinate, void, or pee

TABLE 3. Baseline Characteristics of Study Cohort

Patient-reported outcomes	n = 780
Age (y), mean ± SD	61.2 ± 11.3
Female, n (%)	374 (47.9)
BMI, mean ± SD	29.9 ± 6.3
Caucasian Race, n (%)	615 (78.9)
Not Hispanic or Latino, n (%)	743 (95.3)
≥ 4 y of college-level education, n (%)	464 (61.7)
Employed or employed and on leave, n (%)	365 (46.8)
Insurance, n (%)	
Medicare	301 (38.6)
Medicaid	50 (6.4)
Private	407 (52.2)
Uninsured	4 (0.5)
Comorbidities	
Diabetes mellitus, n (%)	164 (21.0)
Coronary artery disease, n (%)	81 (10.4)
Peripheral vascular disease, n (%)	39 (5.0)
Anxiety, n (%)	161 (20.6)
Depression, n (%)	177 (22.7)
Arthritis, n (%)	230 (29.5)
Predominant location of pain, n (%)	
Neck	267 (34.2)
Arm	139 (17.8)
Neck and Arm	214 (27.4)
No Pain	160 (20.5)
Patient subjective presentation of symptoms	
Radicular deficit, n (%)	216 (27.7)
Radicular arm pain, n (%)	329 (42.2)
Numbness, n (%)	439 (56.3)
Neck pain, n (%)	467 (59.9)
Myelopathy, n (%)	744 (95.4)
Symptom duration, n (%)	
< 3 mo	94 (12.1)
3–12 mo	269 (34.5)
> 12 mo	334 (42.8)
Participation in outside activities, n (%)	665 (85.5)
Motor deficit at baseline, n (%)	471 (60.4)
Independently ambulatory, n (%)	635 (81.4)
ASA Grade, n (%)	
1	11 (1.5)
2	364 (48.9)
3	357 (48.0)
4	12 (1.6)
Patient-reported outcomes	
Baseline NDI, mean ± SD	37.3 ± 21.1
Baseline VAS-neck pain, mean ± SD	5.1 ± 3.3
Baseline VAS-arm pain, mean ± SD	4.8 ± 3.5
Baseline mJOA, mean ± SD	12.1 ± 2.7
Baseline EQ-VAS, mean ± SD	59.7 ± 21.7
Baseline EQ-5D, mean ± SD	0.6 ± 0.2
Mean levels operated, mean ± SD	2.6 ± 1.5
Procedure breakdown, n (%)	
ACDF	426 (54.6)
ACCF	82 (10.5)
CDR	23 (2.9)
Laminectomy w/ fusion	164 (21.0)
Laminectomy w/o fusion	47 (6.0)
Laminoplasty	38 (4.9)

package was used to conduct MissForest imputation of missing values. Statistical significance was defined as an alpha of 0.05.

RESULTS

Overall, 1141 patients were enrolled in the QOD CSM cohort. In all, 780 patients with both baseline and 24-month mJOA scores met inclusion criteria and comprised our study cohort. Overall demographic characteristics of this study cohort are described in Table 3. The mean age of patients was 61.2 ± 11.3 y, 374 (47.9%) were female, and the mean BMI was 29.9 ± 6.3. In all, 78.9% of patients were of Caucasian race, and 61.7% completed at least 4 years of college education. Approximately 38.6% and 52.2% of patients utilized Medicare and private insurance, respectively. For clinical characteristics, 95.4% of patients had subjective complaints of myelopathy at baseline. In addition, more patients had symptoms lasting over 12 months (42.8%) than less than 3 months (12.1%) or between 3 and 12 months (34.5%). The average mJOA of the cohort at baseline was 12.1 ± 2.7, representing a moderate level of severity.

Mean 24-month Clinical Outcomes

Table 4 illustrates the average mJOA and NASS satisfaction of this study cohort. Most patients (85.6%) achieved a NASS score of 1 or 2, indicating that they would undergo the surgery again. The mean mJOA score improved significantly from the baseline score of 12.1 ± 2.7 to 14.0 ± 2.7 at 24 months ($P < 0.001$). The 24-month recovery rate was 25.6% ± 92.7%, and 145 (18.6%) patients achieved full recovery of mJOA. Upper extremity mJOA scores averaged 3.9 ± 1.4 at baseline, increasing significantly to 5.0 ± 1.1 at 24 months ($P < 0.001$). There were 310 (39.7%) patients who achieved full recovery of upper extremity mJOA after 24 months. Lower extremity mJOA scores averaged 3.9 ± 1.4 at baseline, increasing to 4.5 ± 1.5 at 24 months ($P < 0.001$). In all, 267 (34.2%) patients achieved full recovery of lower extremity mJOA after 24 months. The magnitude of the 24-month upper mJOA change was significantly greater than the lower change (upper:1.1 ± 1.6 vs. lower:0.6 ± 1.6, $P < 0.001$).

Univariate Analysis of Factors Associated with Preoperative and 24-month mJOA

At baseline, patients younger than 65 had greater lower extremity mJOA scores than patients 65 and older (4.0 ± 1.4 vs 3.7 ± 1.4; $P = 0.005$). Patients with Medicare/Medicaid had significantly lower upper limb mJOA (3.8 ± 1.5 vs. 4.0 ± 1.3, $P = 0.036$) and lower limb mJOA (3.6 ± 1.4 vs. 4.2 ± 1.4, $P < 0.001$) than patients with private insurance. Patients presenting with neck pain as a primary indication for surgery had the lowest mean upper limb mJOA (neck pain: 3.1 ± 1.6, myelopathy: 3.9 ± 1.4, radiculopathy: 3.9 ± 1.3; $P = 0.015$). No significant differences in baseline upper or lower limb mJOA scores were seen across gender, BMI, ethnicity, education, and symptom duration.

After 24 months, patients presenting with a longer symptom duration at had worse upper limb mJOA (< 3 mo: 5.4 ± 0.9, 3–12 mo: 5.0 ± 1.1, > 12 mo: 4.9 ± 1.2; $P < 0.001$) and lower limb mJOA scores (< 3 mo: 4.7 ± 1.6, 3–12 mo: 4.6 ± 1.4, > 12 mo: 4.3 ± 1.5; $P < 0.001$). Patients on Medicare/Medicaid had significantly worse lower limb mJOA scores at 24 months, as compared with patients on private

TABLE 4. Mean mJOA, mJOA Subscore, and NASS Satisfaction at Baseline and 24 Months Postoperatively

mJOA outcomes	n = 780
mJOA	
Baseline mJOA score	12.1 ± 2.7
24-month mJOA score	14.0 ± 2.7
24-month mJOA change	1.9 ± 3.1
24-month recovery rate	25.6% ± 92.7%
24-month full recovery	145 (18.6)
Upper extremity mJOA	
Baseline upper mJOA Score	3.9 ± 1.4
24-month upper mJOA Score	5.0 ± 1.1
24-month upper mJOA Change	1.1 ± 1.6
24-month upper mJOA full recovery	310 (39.7)
Lower extremity mJOA	
Baseline lower mJOA Score	3.9 ± 1.4
24-month lower mJOA Score	4.5 ± 1.5
24-month lower mJOA Change	0.6 ± 1.6
24-month lower mJOA full recovery	267 (34.2)
NASS satisfaction	
24-Month NASS score 1 or 2	668 (85.6)

insurance (4.3 ± 1.6 vs 4.6 ± 1.4, $P = 0.004$). There were additionally significant differences in 24-month lower limb mJOA scores based on the primary indication for surgery. Those with neck pain as a primary indication had the lowest 24-month lower limb mJOA (neck pain: 3.9 ± 1.5, myelopathy: 4.5 ± 1.5, radiculopathy: 4.6 ± 1.4; $P = 0.033$). There were no significant differences in 24-month upper or lower limb mJOA scores across age, gender, BMI, ethnicity, or education level (Table 5).

The change in upper extremity mJOA over 24 months remained significantly different across symptom duration, with greater symptom duration showing decreased improvement (< 3 mo:1.5 ± 1.6, 3–12 mo:1.1 ± 1.6, > 12 mo:0.9 ± 1.5; $P = 0.004$). However, there were no significant differences in lower limb mJOA change based on symptom duration (< 3 mo:0.6 ± 1.9, 3–12 mo:0.6 ± 1.6, > 12 mo:0.5 ± 1.5; $P = 0.67$). In addition, there were no significant differences in upper or lower mJOA change based on insurance or primary indication (Table 5).

mJOA Outcomes Stratified by NASS Satisfaction Level

Table 6 shows overall mJOA, upper extremity mJOA, and lower extremity mJOA across cohorts based on the four 24-month NASS satisfaction levels. When stratifying patients by their satisfaction levels reported 24 months following surgery, we found mJOA scores at baseline to be significantly different across the groups (NASS 1:12.3 ± 2.7, NASS 2:11.9 ± 2.9, NASS 3:11.4 ± 2.7, NASS 4:11.6 ± 2.8; $P = 0.031$). The baseline upper limb mJOA scores were not significantly different across satisfaction levels (N1:4.0 ± 1.4, N2:3.9 ± 1.4, N3:3.6 ± 1.6, N4:3.9 ± 1.4; $P = 0.28$). Similarly, baseline lower limb mJOA scores were similar across all 4 satisfaction levels (N1:4.0 ± 1.5, N2:3.9 ± 1.3, N3:3.6 ± 1.2, N4:3.6 ± 1.4; $P = 0.092$).

Patients reporting lower satisfaction with surgery at 24 months demonstrated significantly lower 24-month mJOA scores (N1:14.7 ± 2.4, N2:13.6 ± 2.4, N3:12.2 ± 2.9, N4:11.5 ± 2.7; $P < 0.001$). The 24-month change in mJOA was similarly lower in less-satisfied patients ($P < 0.001$), with patients reporting a NASS satisfaction of 4 (lowest satisfaction) reporting a negative average change in mJOA (ie, functional worsening) after 24 months (−0.1 ± 3.1). The number of patients making a full recovery after 24 months was significantly higher in patients with a NASS score of 1 (N1:25.2%, N2:5.9%, N3:2.7%, N4:1.5%; $P < 0.001$).

For extremity subscores, patients with lower satisfaction exhibited lower 24-month upper limb mJOA (N1:5.2 ± 1.0, N2:4.8 ± 1.2, N3:4.5 ± 1.3, N4:4.0 ± 1.2; $P < 0.001$) and lower limb mJOA (N1:4.7 ± 1.4, N2:4.3 ± 1.4, N3:3.7 ± 1.4, N4:3.4 ± 1.5; $P < 0.001$). Only patients reporting NASS scores of 4 did not demonstrate a significant difference in 24-month upper limb mJOA as compared with their baseline scores (24 mo:4.0 ± 1.2 vs. baseline:3.9 ± 1.4, $P = 0.65$). Twenty-four–month lower limb mJOA was not significantly different from baseline for patients with NASS scores of 3 (24 months:3.7 ± 1.4 vs. baseline:3.6 ± 1.2, $P = 0.69$) and NASS scores of 4 (24 mo:3.4 ± 1.5 vs. baseline:3.6 ± 1.4, $P = 0.55$).

The change in upper limb mJOA after 24 months also decreased with lower satisfaction (N1:1.2 ± 1.5, N2:0.9 ± 1.7, N3:0.9 ± 1.9, N4:0.1 ± 1.5; $P < 0.001$). Similarly, the 24-month change in lower limb mJOA was lower in patients reporting lower satisfaction (N1:0.7 ± 1.7, N2:0.4 ± 1.5, N3:0.1 ± 1.5, N4:-0.2 ± 1.5; $P < 0.001$). Only patients with a NASS score of 4 demonstrated a negative 24-month change in lower limb mJOA (ie, 24-month values worse than baseline on average). The cohorts with higher satisfaction at 24 months had more patients reach full recovery of upper limb mJOA (N1:49.0%, N2:25.7%, N3:24.3%, N4:7.6%; $P < 0.001$) and lower limb mJOA (N1:41.9%, N2:23.7%, N3:13.5%, N4:10.6%; $P < 0.001$).

Table 7 compares the distribution of 24-month NASS satisfaction scores between patients with versus without improvement in mJOA scores. Patient without 24-month improvement in mJOA had fewer patients willing to undergo surgery again than patients with 24-month improvement in mJOA, via NASS scores of 1 or 2 (no improvement:74.8% vs. improvement:90.4%, $P < 0.001$). Patients without improvement in upper extremity mJOA were also less likely to have NASS scores of 1 or 2 (no improvement:79.4% vs improvement:89.2%, $P < 0.001$), as were patients without improvement in lower extremity mJOA (no improvement:81.7% vs improvement:89.6%, $P = 0.002$). Even so, most patients who did not show functional improvement still reported satisfaction with surgery. A NASS score of 1 (most satisfied) was seen among a majority of patients without improvement in mJOA (51.3%), upper mJOA (56.1%), and lower mJOA (61.0%).

Multivariable Predictor Analysis

Ordered logistic regression was used for multivariable analysis to determine the significant factors

TABLE 5. Demographic Comparison of 24-Month mJOA Outcomes in Patients With Cervical Spondylotic Myelopathy

Demographic groups	Baseline upper limb mJOA	Baseline lower limb mJOA	24-Month upper limb mJOA	24-Month lower limb mJOA	Change in upper limb mJOA	Change in lower limb mJOA
Age						
> = 65	3.9 ± 1.4	3.7 ± 1.4	5.0 ± 1.2	4.4 ± 1.5	1.1 ± 1.7	0.7 ± 1.7
< 65	4.0 ± 1.4	4.0 ± 1.4	5.0 ± 1.1	4.5 ± 1.5	1.1 ± 1.5	0.5 ± 1.6
P	0.82	**0.005***	0.99	0.44	0.95	0.13
Gender						
Male	4.0 ± 1.4	3.9 ± 1.4	5.0 ± 1.1	4.5 ± 1.5	1.0 ± 1.6	0.5 ± 1.6
Female	3.9 ± 1.4	3.9 ± 1.5	5.0 ± 1.1	4.5 ± 1.5	1.1 ± 1.6	0.6 ± 1.7
P	0.41	0.52	0.68	0.72	0.64	0.41
BMI						
> = 30	3.9 ± 1.4	3.9 ± 1.4	5.0 ± 1.1	4.5 ± 1.5	1.1 ± 1.6	0.6 ± 1.6
< 30	3.9 ± 1.5	4.0 ± 1.4	5.0 ± 1.1	4.6 ± 1.5	1.1 ± 1.7	0.6 ± 1.6
P	0.72	0.25	0.73	0.16	0.56	0.81
Ethnicity						
Hispanic or Latino	3.7 ± 1.4	3.7 ± 1.6	4.8 ± 1.3	3.9 ± 1.8	1.1 ± 1.6	0.2 ± 1.7
Not Hispanic or Latino	3.9 ± 1.4	3.9 ± 1.4	5.0 ± 1.1	4.5 ± 1.5	1.1 ± 1.6	0.6 ± 1.6
P	0.43	0.41	0.35	0.06	0.98	0.33
Education						
High School or Less	3.9 ± 1.4	3.8 ± 1.4	4.9 ± 1.1	4.4 ± 1.5	1.1 ± 1.5	0.6 ± 1.6
Some College or More	4.0 ± 1.4	4.0 ± 1.4	5.1 ± 1.1	4.6 ± 1.5	1.1 ± 1.6	0.6 ± 1.6
P	0.44	0.16	0.17	0.16	0.94	0.93
Insurance						
Medicare/Medicaid	3.8 ± 1.5	3.6 ± 1.4	4.9 ± 1.2	4.3 ± 1.6	1.1 ± 1.7	0.6 ± 1.7
Private	4.0 ± 1.3	4.2 ± 1.4	5.1 ± 1.1	4.6 ± 1.4	1.0 ± 1.5	0.4 ± 1.5
P	**0.036***	**< 0.001***	0.18	**0.004***	0.43	0.08
Symptom Duration						
< 3 mo	3.9 ± 1.6	4.0 ± 1.5	5.4 ± 0.9	4.7 ± 1.6	1.5 ± 1.6	0.6 ± 1.9
3–12 mo	4.0 ± 1.4	4.0 ± 1.4	5.0 ± 1.1	4.6 ± 1.4	1.1 ± 1.6	0.6 ± 1.6
> 12 mo	4.0 ± 1.3	3.8 ± 1.4	4.9 ± 1.2	4.3 ± 1.5	0.9 ± 1.5	0.5 ± 1.5
P	0.75	0.26	**< 0.001***	**0.029***	**0.004†**	0.67
Primary indication						
Radiculopathy	3.9 ± 1.3	4.1 ± 1.4	5.0 ± 1.1	4.6 ± 1.4	1.1 ± 1.6	0.5 ± 1.5
Myelopathy	3.9 ± 1.4	3.9 ± 1.4	5.0 ± 1.1	4.5 ± 1.5	1.1 ± 1.6	0.6 ± 1.6
Neck Pain	3.1 ± 1.6	4.1 ± 1.3	4.8 ± 1.3	3.9 ± 1.5	1.7 ± 2.0	-0.2 ± 1.6
P	**0.015***	0.055	0.748	**0.033***	0.15	0.07

Statistical significant cutoff of $P < 0.05$ are in bold.
*Difference in upper/lower limb mJOA score between demographic subgroup was statistically significant ($P < 0.05$).
†Difference in the upper/lower limb mJOA change between demographic subgroup was statistically significant ($P < 0.05$).

contributing most to patient satisfaction at 24 months. We found that 24-month NASS satisfaction was independently associated with upper limb mJOA change (OR:0.81, 95% CI: 0.68–0.97, $P = 0.019$). Lower limb mJOA change was not a statistically significant independent predictor of patient satisfaction (OR: 0.84, 95% CI: 0.70–1.0, $P = 0.054$).

DISCUSSION

Patients diagnosed with cervical myelopathy may present with both upper and lower extremity impairments ranging from weakness, numbness, issues with manual dexterity, and gait instability. To our knowledge, this is the first study to date that directly compares upper extremity and lower extremity status in relation to satisfaction with surgical treatment for CSM. We utilized the QOD CSM data set to investigate whether upper or lower extremity mJOA was more highly associated with patient satisfaction. Patients with lower levels of satisfaction following surgery were found to have comparatively lower improvements in both upper limb and lower limb mJOA after 24 months. In multivariable predictor analysis, we found that only upper limb mJOA change was independently predictive of patient satisfaction. The association between lower limb mJOA change and patient satisfaction was not independently significant.

In our study, ~69.4% of patients show improvement in mJOA functional status, with 18.6% reaching a "fully recovered" asymptomatic state. 63.8% show improvement in upper limb function and 49.5% in lower limb function, with 39.7% and 34.2% reaching a "fully recovered" asymptomatic state in each respective domain. These results are consistent with Friesen et al's cohort of 53 patients with degenerative cervical myelopathy, which similarly found greater recovery in the upper extremity mJOA than the lower.[14] Our study also found that most patients (85.6%) were satisfied with surgery. This is generally consistent with prior literature showing similar rates of satisfaction, including 77% satisfied after 2 years in a cohort of 288 patients and 80% satisfied after an average follow-up of 9.3 years in a cohort of 69 patients.[10,36]

Patient satisfaction has remained a crucial postoperative outcome of interest even among the wide array

TABLE 6. Post-operative mJOA Outcomes Stratified by 24-Month NASS Satisfaction Level

24-month mJOA outcomes	NASS 1 (n = 516)	NASS 2 (n = 152)	NASS 3 (n = 37)	NASS 4 (n = 66)	*P* value
mJOA					
Baseline mJOA score	12.3 ± 2.7	11.9 ± 2.9	11.4 ± 2.7	11.6 ± 2.8	0.031**
24-Month mJOA score	14.7 ± 2.4	13.6 ± 2.4	12.2 ± 2.9	11.5 ± 2.7	< 0.001**
24-Month mJOA change	2.3 ± 3.1	1.7 ± 3.0	0.8 ± 3.2	-0.1 ± 3.1	< 0.001**
24-month recovery rate	38.9% ± 88.7%	10.6% ± 90.2%	-8.4% ± 95.4%	-27.2% ± 103.9%	< 0.001**
24-month No. Full recovery	130 (25.2)	9 (5.9)	1 (2.7)	1 (1.5)	< 0.001**
mJOA Upper Limb					
Baseline upper limb function score	4.0 ± 1.4	3.9 ± 1.4	3.6 ± 1.6	3.9 ± 1.4	0.28
24-month upper limb function score	5.2 ± 1.0	4.8 ± 1.2	4.5 ± 1.3	4.0 ± 1.2	< 0.001**
24-month upper limb function change	1.2 ± 1.5	0.9 ± 1.7	0.9 ± 1.9	0.1 ± 1.5	< 0.001**
24-month No. Full recovery	253 (49.0)	39 (25.7)	9 (24.3)	5 (7.6)	< 0.001**
mJOA Lower Limb					
Baseline lower limb function score	4.0 ± 1.5	3.9 ± 1.3	3.6 ± 1.2	3.6 ± 1.4	0.092
24-month lower limb function score	4.7 ± 1.4	4.3 ± 1.4	3.7 ± 1.4	3.4 ± 1.5	< 0.001**
24-month lower limb function change	0.7 ± 1.7	0.4 ± 1.5	0.1 ± 1.5	-0.2 ± 1.5	< 0.001**
24-month No. full recovery	216 (41.9)	36 (23.7)	5 (13.5)	7 (10.6)	< 0.001**

mJOA recovery rate was calculated according to the Hirabayashi method.
**Difference was statistically significant ($P < 0.05$).

of available patient-reported outcomes (PROs). As a direct measure of the patients' perception of the care they received, satisfaction is a particularly subjective, complex amalgamation of many factors including baseline characteristics, inter-personal relationships, and expectations going into surgery.[37] Beyond reflective use by the individual patient and surgeon, patient satisfaction metrics are increasingly used by researchers, patient advocates, and governing agencies for quality improvement initiatives.[38,39] Reimbursement from Medicare and Medicaid is now affected by patient satisfaction, as further incentive for hospitals.[39–41] There are clear clinical and economic consequences tied to patient satisfaction following surgical procedures.

Prior studies have investigated patient satisfaction with CSM surgery, often in relation to other PROs. Squires et al found in an analysis of 2023 patients with cervical myelopathy from the Michigan Spine Surgery Improvement Collaborative (MSSIC) that both change in mJOA and change in PROMIS PF were strongly related to patient satisfaction ($P < 0.001$).[10] Zaki et al reports correlations between outcome questionnaires and patient satisfaction from our QOD CSM cohort.[11] NASS satisfaction was negatively correlated with mJOA at 3 months ($r = -0.287$, $P < 0.001$) and 24 months ($r = -0.38$, $P < 0.001$). Among the surveys assessed (mJOA, NDI, NRS-Neck Pain, NRS-Arm Pain, EQ-5D), mJOA was surprisingly found to be the least correlated with NASS at both 3 and 12 months. We were thus interested in breaking down the relationship between patient satisfaction and the distinct sub-elements of the mJOA, particularly those for upper versus lower extremity.

Limited existing literature directly compares upper versus lower extremity function in the context of CSM. Our results follow a prior study by Fudo et al analyzing 104 patients undergoing laminoplasty for CSM, which found upper limb function [assessed by grip strength, Simple Test for Evaluating Hand Function (STEF)] to improve faster than lower limb function (assessed by timed up and go test, 10-m. walk, time to stand on 1 leg) immediately after surgery.[13] The group found an association between changes in the upper limb during hospitalization

TABLE 7. 24-Month NASS Satisfaction Level Across Patients With versus Without Improvement in mJOA Outcomes

	mJOA		Upper mJOA		Lower mJOA	
	No improvement (n = 238)	**Improvement (n = 542)**	**No improvement (n = 282)**	**Improvement (n = 498)**	**No improvement (n = 394)**	**Improvement (n = 386)**
7a. NASS 1 or 2 (would undergo again)						
1 or 2	178 (74.8)	490 (90.4)	224 (79.4)	444 (89.2)	322 (81.7)	346 (89.6)
3 or 4	60 (25.2)	52 (9.6)	58 (20.6)	54 (10.8)	72 (18.3)	40 (10.4)
P value	< 0.001		< 0.001		0.002	
7b. NASS levels						
1 (most satisfied)	120 (51.3)	396 (73.7)	157 (56.1)	359 (73.1)	238 (61.0)	278 (73.0)
2	58 (24.8)	94 (17.5)	67 (23.9)	85 (17.3)	84 (21.5)	68 (17.8)
3	17 (7.3)	20 (3.7)	16 (5.7)	21 (4.3)	23 (5.9)	14 (3.7)
4 (least satisfied)	39 (16.7)	27 (5.0)	40 (14.3)	26 (5.3)	45 (11.5)	21 (5.5)
P value	< 0.001		< 0.001		0.001	

"No Improvement" was classified as a 24-month change in outcomes score < = 0.

with 1-year postoperative JOA. Surgical outcome was solely measured through JOA, and satisfaction was not recorded in this study. Our study also aligns with Friesen et al, which found in a cohort of 53 patients with degenerative cervical myelopathy that diminished recovery was observed in the lower extremity mJOA subscore as compared with upper extremity.[14] Our study builds upon these 2 studies by providing longer-term outcomes at 24 months, a larger patient cohort, and the inclusion of a patient satisfaction metric. Including our study, the existing literature suggests that upper limb mJOA is modestly more responsive to surgery than lower limb mJOA.

Our results may speak to the higher specificity of upper extremity symptoms to cervical spondylotic myelopathy compared with lower limb symptoms. When considering a differential diagnosis for patients presenting with upper limb sensorimotor disturbance, especially when combined with neck and arm pain,[42] CSM remains a chief consideration. Additional considerations include cervical spondylosis without myelopathy, cervical radiculopathy without myelopathy, or peripheral etiologies.[43,44] Lower limb weakness or numbness, however, may overlap with a greater array of potential diagnoses, including disorders of the brain, cervical spine, thoracic spine, and lumbar spine—in addition to peripheral etiologies. Given the primary goal of CSM surgery is to alleviate neural compression of the cervical spine, we hypothesize that upper extremity symptoms are more often appropriately diagnosed and treated. This may drive the closer association we observe between upper extremity functional improvement and postoperative satisfaction. A study by Hilton et al examined the initial clinical assessments of a cohort of 43 patients with cervical myelopathy, stratified by specialization of the practioner (general practioners, specialists, and spinal surgeons) rendering the initial assessment.[45] In the primary assessments conducted by general practitioners, upper limb paresthesia was the most commonly reported symptom (65%), followed by lower limb weakness (43%) and neck pain (43%). In subsequent assessments made by a spinal surgeon, upper limb paresthesia remained the most commonly reported symptom (65%), but there were decreased documentations of lower limb weakness (33%). Significant differences were found in the reporting of symptoms, including limb pain, objective limb weakness, hyperreflexia, and lower limb spasticity ($P < 0.005$). The variable prevalence and/or ascertainment of upper and lower extremity dysfunction in cervical myelopathy may impact discussions about patient expectations and general perceptions of the efficacy of surgical treatment.

It is important to note that though the only statistically independent predictor for 24-month NASS satisfaction was upper limb mJOA improvement ($P = 0.019$), lower limb mJOA was also near the established alpha level of 0.05 ($P = 0.054$). We thus concluded, based on our specific predictor analysis, that the lower limb was not significantly associated with outcome. This statistical difference may not be clinically significant and could reflect an issue with power. Since the use of the individual mJOA components as "subscores" has not been validated, we cannot definitively claim whether small differences in the changes in mJOA subscores are clinically relevant. However, given that our study is conducted using the largest CSM registry data set to date,[46] it is currently the best attempt at a predictor analysis. Future studies may conduct similar analyses on larger sample sizes to further investigate this hypothesis, potentially expanding to other measures of upper/lower extremity function and patient satisfaction.

Study Limitations

This study is limited by its retrospective study design, though data was prospectively collected. The primary "outcome" of this study was NASS patient satisfaction, a measure of patient expectation that is inherently subjective and not solely influenced by the achievement of surgical outcomes. To this point, prior work has found satisfaction levels to differ following spine surgery despite the procedures being similarly clinically effective.[47] Surgeons may also differ in their setting of patient expectations prior to operation, which may lead to heterogeneity in what constitutes a certain satisfaction level. If surgeons counsel variably about the propensity for upper versus lower extremity improvement postoperatively, then NASS patient satisfaction scores may differ without any difference in the objective goal of surgical decompression. In addition, the patient cohort represented in this study was one with, on average, moderate myelopathy. It is thus unclear whether our findings may fully extend to a population with more severe or mild myelopathy.

Our study operationalizes the mJOA scale to assess upper limb and lower limb dysfunction, which is one of the most widely used tools for the assessment of functional status in CSM. The mJOA scale is a quantitative metric of functional disability severity that is responsive, convergently valid, and divergently valid.[7] Though the use of the individual components of the mJOA has not been specifically validated in the past, there is precedent in its segregated analysis to compare against specific upper/lower functional assessments or simply provide a higher level of granularity.[14,48–52] However, this tool is not a complete nor detailed characterization of the upper limb or lower limb dysfunction experienced by a patient. Like NASS satisfaction, it relies largely on the subjective perception/report of the patient. Our use of NASS satisfaction could also be limiting, as the score consists of only 4 levels that may not capture the full breadth of postoperative patient satisfaction. However, we analyze NASS satisfaction as both a 4-level variable (assessing for ordinal effect) and a 2-level variable (assessing whether patients would undergo surgery again) to provide further insight into postoperative satisfaction.[53]

Future work seeking to confirm the relative importance of upper versus lower limb status in patients with CSM may aim to use more objective clinical assessments. For upper limb function, this includes more sensitive measures of strength, sensation, and/or dexterity—such as the 10-second test,[48] STEF,[49] or the Graded Redefined

Assessment of Strength, Sensibility, and Prehension–Version Myelopathy (GRASSP-M).[50] For lower limb function, this may include assessments such as the enhanced gait variability index or 10-step tandem gait test.[51,52] The NIH Toolbox motor battery (NIHTBM) is an additional assessment of neurological deficits related to both the upper and lower limb.[54]

CONCLUSION

In patients operated for CSM, increased patient satisfaction with surgical intervention was associated with both increased magnitudes of upper and lower limb mJOA improvement. Patients with the lowest satisfaction levels did not show any mean significant differences in 24-month upper or lower limb mJOA scores compared with baseline. In multivariable predictor analysis, upper limb mJOA improvement was independently associated with patient satisfaction when adjusting for other confounding variables. This independent significant association was not observed for lower limb mJOA and satisfaction. Our findings may aid surgeons in preoperative counseling to understand the relative importance of upper versus lower extremity treatment expectations for patients.

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