JNS SPINE

CLINICAL ARTICLE

Patient-reported outcome trajectories the first 24 months after surgery for cervical spondylotic myelopathy: a Quality Outcomes Database study

Daniel Zeitouni, MD,[1] Sarah E. Johnson, MBBS,[2] Sufyan Ibrahim, MBBS,[2] Erica F. Bisson, MD, MPH,[3] Praveen V. Mummaneni, MD, MBA,[4] Regis W. Haid Jr., MD,[5] Andrew K. Chan, MD,[6] Dean Chou, MD,[6] Michael Y. Wang, MD, MBA,[7] John J. Knightly, MD,[8] Scott Meyer, MD,[8] Oren N. Gottfried, MD,[9] Christopher I. Shaffrey, MD,[9] Michael S. Virk, MD, PhD,[10] Kai-Ming G. Fu, MD, PhD,[10] Mark E. Shaffrey, MD, MPH,[11] Paul Park, MD,[12] Kevin T. Foley, MD,[12] Cheerag D. Upadhyaya, MD, MBA, MSc,[13] Eric A. Potts, MD,[14] Jay D. Turner, MD, PhD,[15] Juan S. Uribe, MD,[15] Luis M. Tumialán, MD, PhD,[15] Domagoj Coric, MD,[1] Mohamad Bydon, MD,[2] and Anthony L. Asher, MD[1]

[1]Neuroscience Institute, Carolina Neurosurgery & Spine Associates, Carolinas Healthcare System, Charlotte, North Carolina; [2]Department of Neurologic Surgery, Mayo Clinic, Rochester, Minnesota; [3]Department of Neurosurgery, University of Utah, Salt Lake City, Utah; [4]Department of Neurosurgery, University of California, San Francisco, California; [5]Atlanta Brain and Spine Care, Atlanta, Georgia; [6]Department of Neurosurgery, Columbia University Irving Medical Center, New York, New York; [7]Department of Neurological Surgery, University of Miami, Florida; [8]Atlantic Neurosurgical Specialists, Morristown, New Jersey; [9]Department of Neurosurgery, Duke University, Durham, North Carolina; [10]Department of Neurological Surgery, Weill Cornell Medical Center, New York, New York; [11]Department of Neurosurgery, University of Virginia, Charlottesville, Virginia; [12]Department of Neurosurgery, Semmes Murphey Clinic, University of Tennessee, Memphis, Tennessee; [13]Department of Neurosurgery, University of North Carolina, Chapel Hill, North Carolina; [14]Department of Neurological Surgery, Goodman Campbell Brain and Spine, Indianapolis, Indiana; and [15]Department of Neurosurgery, Barrow Neurological Institute, Phoenix, Arizona

OBJECTIVE Cervical spondylotic myelopathy (CSM) shows varying levels of improvement after surgical treatment. While some patients improve soon after surgery, others may take months to years to show any signs of improvement. The goal of this study was to evaluate postoperative improvement, patient-reported outcomes, and patient satisfaction up to 2 years after surgical treatment for CSM, which will help optimize the current treatment strategies and effectively manage patient expectations.

METHODS This was a retrospective study of prospectively collected data using the Quality Outcomes Database. The primary outcomes of interest were achievement of the minimal clinically important difference (MCID) for the numeric rating scale for neck and arm pain, modified Japanese Orthopaedic Association, Neck Disability Index, and EQ-5D scores and postoperative satisfaction (North American Spine Society scale). Early and sustained improvement was defined as MCID achievement in at least one patient-reported outcome measure (PROM) at the 3-, 12-, and 24-month follow-ups. Transient improvement was defined as MCID achievement only at the 3-month and/or 12-month follow-up but not at the 24-month follow-up. Late improvement was defined as MCID achievement in at least one PROM only at the 24-month follow-up.

RESULTS There were 630 patients included in the comparative analysis. A total of 463 (73.5%) patients achieved early and sustained improvement, 105 (16.7%) patients experienced transient improvement with subsequent decline, 25 (4.0%) patients reported late improvement, and 37 (5.9%) patients did not report any clinically meaningful improvement after surgery. Patients with an anterior approach were more likely to be in the early and sustained improvement group. African

ABBREVIATIONS ASA = American Society of Anesthesiologists; COPD = chronic obstructive pulmonary disease; CSM = cervical spondylotic myelopathy; MCID = minimal clinically important difference; mJOA = modified Japanese Orthopaedic Association; NASS = North American Spine Society; NDI = Neck Disability Index; NRS = numeric rating scale; PROM = patient-reported outcome measure; QOD = Quality Outcomes Database; SES = socioeconomic status.

SUBMITTED March 23, 2024. **ACCEPTED** September 25, 2024.
INCLUDE WHEN CITING Published online January 10, 2025; DOI: 10.3171/2024.9.SPINE24351.

American patients (OR 2.98, 95% CI 1.14–7.76; p = 0.03) were more likely to report late improvement when compared with White patients. The overall satisfaction rate at the 24-month follow-up was 87.8%.

CONCLUSIONS These findings indicate that 73.5% of patients achieve early and sustained improvement, and 87.8% of patients are satisfied with surgery 24 months postoperatively.

https://thejns.org/doi/abs/10.3171/2024.9.SPINE24351

KEYWORDS patient-reported outcomes; cervical spine; outcome kinetics; outcome trajectories; patient satisfaction

Cervical spondylotic myelopathy (CSM) is a degenerative disease in which nearby structures lead to compression of the cervical spinal cord. It is the most common cause of spinal cord injury, and the symptoms often go unrecognized by patients. Myelopathy presents with a variety of symptoms, which include neck and shoulder pain, gait disturbances, hyperreflexia, bladder and bowel dysfunction, reduced hand dexterity, and clonus. Surgical decompression prevents further disease progression and potentially improves functionality.[1,2] While pain and numbness can quickly improve after decompression of the spinal cord, the ability and timing of motor improvement is unclear. Some studies have demonstrated that neurological improvement is most significant the first 3 months postoperatively and plateaus at 6 months.[3,4] A previous Quality Outcomes Database (QOD) study determined the trajectory of the 1st year postoperatively, also finding that the majority of patients improved in the first 3 months.[5] Patients with severe myelopathy showed the greatest improvement after 3 months but never reached the functionality that those with less severe disease achieved.

Previous studies have attempted to determine characteristics of patients most likely to improve from decompression. Some studies have demonstrated that elderly patients significantly improve after decompression and that diabetes can impair recovery.[6,7] Studies have shown mixed results when determining the effect of BMI and obesity on surgical outcomes.[8,9]

The goal of this study was to determine the trajectory of patients who underwent a surgical decompression for CSM over the first 2 years postoperatively, as well as their satisfaction rate at the 2-year follow-up. In addition, we assessed for variables that contribute to early versus late improvement of symptoms. To our knowledge, this is the largest cohort of patients with CSM followed for 2 years after decompression.

Methods

Data Source and Patient Cohort

The CSM cohort of the QOD includes 1141 patients who underwent cervical spine surgery for CSM across 14 high-enrolling sites of the original QOD.[10] Criteria for enrollment were a score < 17 on the modified Japanese Orthopaedic Association (mJOA) questionnaire at baseline and myelopathy as the primary indication for surgery.[11] Elective cases solely due to degenerative underlying pathologies were enrolled in this database, while operative cases due to infection, trauma, or tumor were excluded. Patients were followed up in person or via telephone for the completion of patient-reported outcome measures (PROMs) at the 3-, 12-, and 24-month follow-up periods. This study's cohort included 630 patients with available PROMs at the 3-, 12-, and 24-month time points, that is, the numeric rating scale (NRS) for neck and arm pain, mJOA, Neck Disability Index (NDI), and EQ-5D (measured in quality-adjusted life-years) scores. IRB approval was obtained by the participating sites during development of the QOD registry. Because this registry contains de-identified patient information, no additional IRB approval or consent was required.

Outcomes of Interest

The primary outcome of interest was the achievement of the minimal clinically important difference (MCID) for NRS neck pain, NRS arm pain, mJOA, NDI, and EQ-5D scores and achievement of postoperative satisfaction. The NRS pain scales range from 0 to 10, with higher scores indicating a greater intensity of pain. Myelopathy was considered mild with mJOA scores of 15–17, moderate with mJOA scores of 12–14, and severe with mJOA scores of 0–11.[12] The NDI consists of 10 sections designed to evaluate the effect of neck pain on the patient's functionality.[13] In this registry, NDI percentage scores (ranging from 0 to 100) are captured, with higher scores indicating greater disability. The MCIDs for NRS neck pain, NRS arm pain, NDI, and EQ-5D scores were defined as a 30% decrease from baseline.[14] The MCID for the mJOA score was calculated based on the CSM severity at baseline, as previously described.[15] Satisfaction with surgery was measured based on the 4-point North American Spine Society (NASS) scale: 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"; and 4) "I am the same or worse than before treatment."[16] Patients were considered satisfied if they had a score of 1 or 2.[16]

Patients were divided into four groups based on their trajectory of outcome achievement; early and sustained improvement was defined as MCID achievement in at least one PROM at the 3-, 12-, and 24-month follow-ups. Transient improvement was defined as MCID achievement only at the 3-month and/or 12-month follow-up but not at the 24-month follow-up. Late improvement was defined as MCID achievement in at least one PROM only at the 24-month follow-up. The no-improvement group consisted of patients who did not achieve an MCID at any time point.

Baseline and Perioperative Variables

Demographic variables, comorbidities, clinical characteristics, and surgical variables were also included for each group. These variables included age, sex, race, BMI, insurance payor, educational level, preoperative employment status, socioeconomic status (SES) index, workers' compensation status, smoking status, medical comorbidities (multiple sclerosis, diabetes mellitus, depression, anxiety, coronary artery disease, osteoarthritis, chronic obstructive pulmonary disease [COPD]), baseline symptoms and symptom duration, American Society of Anesthesiologists (ASA) grade, presence of dynamic instability, number of treated segments, surgical approach, discharge disposition, and reoperation status.

Statistical Analysis

Descriptive statistics are reported as means and standard deviations for continuous variables or frequencies and percentages for categorical variables. The independent Student t-test and Pearson's chi-square test were performed for univariate analyses of continuous and categorical variables, respectively. ANOVA was performed when the association between categorical and continuous variables was investigated. A multivariable logistic regression model was created to evaluate the baseline risk factors associated with transient and late improvement, with the early and sustained improvement group as a reference. For the multivariable model, variables were selected if $p < 0.20$ on univariate analysis and/or clinical relevance. The covariates used in this analysis were age, sex, BMI, race, ambulation dependence, baseline radicular arm pain, surgical approach, and number of levels treated. Results were considered statistically significant at $p < 0.05$. Statistical analyses were performed using R software (version 4.2.2, R Foundation for Statistical Computing).[17]

Results

A total of 630 patients who underwent surgery for CSM were included in this study. The mean age was 61.7 ± 11.3 years, and 47.6% of the cohort was female. The mean BMI was 30.1 ± 6.4. Patients excluded from this study due to inadequate follow-up at all three time points were younger (aged 61.7 vs 59.2 years, $p < 0.01$), were less likely to have Medicare and more likely to have private or no insurance ($p < 0.01$), and had a higher NDI score ($p < 0.01$). Of the 630 patients included in the study, 463 (73.5%) patients achieved early and sustained improvement, 105 (16.7%) patients experienced transient improvement with a subsequent decline, 25 (4.0%) patients reported late improvement, and 37 (5.9%) patients did not report any clinically meaningful improvement after surgery. There were no significant differences between the four groups with respect to age, BMI, insurance payor, level of education, SES index, preoperative employment or workers' compensation status, and medical comorbidities such as multiple sclerosis, diabetes mellitus, depression, anxiety, coronary artery disease, osteoarthritis, or COPD. There were no significant differences in terms of ambulation dependence, listhesis/dynamic instability, or ASA grade between the four groups.

The mean number of operated levels was highest in the no-improvement group ($p = 0.02$), while the early and sustained group had the lowest rate of reoperation ($p = 0.05$). Patients with transient or late improvement were more likely to have a symptom duration > 3 months ($p < 0.01$). Patients who achieved early and sustained improvement were more likely to have an anterior surgical approach (69.5% vs 66.7% vs 60.0% vs 43.2%, $p < 0.01$) as well as severe myelopathy (39.5% vs 24.8% vs 36.0% vs 21.6%, $p < 0.01$). Baseline characteristics are outlined in Table 1. Patient-reported outcomes at baseline and 3, 12, and 24 months of follow-up are reported in Table 2. The rates of MCID achievement at the 3-, 12-, and 24-month follow-up time points are outlined in Table 3.

In the multivariable model to identify baseline risk factors for transient improvement and late improvement, patients with early and sustained improvement were used as the reference group. African American patients (reference: White patients) (OR 2.98, 95% CI 1.14–7.76; $p = 0.03$) were found to be more likely to report late improvement (Table 4). There were no significant predictors for transient improvement.

At the 24-month follow-up, postoperative satisfaction with surgery (NASS score) was collected for 623 of 630 patients. The overall patient satisfaction rate was 87.8% (NASS score of 1 or 2). Patients who reported early and sustained improvement had significantly higher rates of satisfaction (93.4% vs 70.5% vs 78.3% vs 73%, $p < 0.01$) (Fig. 1). Line graphs depicting NRS neck pain, NRS arm pain, mJOA, NDI, and EQ-5D scores at baseline and at follow-up time points stratified by outcome trajectory (early and sustained improvement, transient improvement, late improvement, no improvement) are demonstrated in Fig. 2.

Discussion

Decompression is effective in halting the progression of CSM and improving symptoms associated with it. Understanding both how we can improve the outcomes of these patients and the predictors of improvement is essential to counsel patients and manage patient expectations. In this study, 73.5% of patients achieved early and sustained improvement, and an additional 4.0% achieved late improvement. Patients with early and sustained improvement were more likely to have an anterior surgical approach, and patients with early and sustained as well as late improvement were more likely to have severe myelopathy at baseline.

Previous studies have demonstrated the significance of surgical approach (anterior vs posterior) and severity of myelopathy on whether a patient achieves an MCID.[5,18] One study demonstrated that patients undergoing an anterior approach for decompression and fusion were more likely to achieve a significant improvement in NDI score.[18] In our cohort, there was a greater proportion of anterior approaches in the early and sustained improvement group. A previous QOD study demonstrated that patients with severe myelopathy were more likely to continue improving 1 year postoperatively.[5] Patients in the early and sustained group as well as the late improvement group were more likely to have severe myelopathy in our cohort ($p < 0.01$) (Table 1).

TABLE 1. Characteristics of patients undergoing surgery for CSM

	Early & Sustained Improvement (n = 463)	Transient Improvement (n = 105)	Late Improvement (n = 25)	No Improvement (n = 37)	p Value
Age, yrs	61.62 (11.21)	61.90 (12.02)	61.20 (10.79)	61.76 (11.64)	0.99
Female sex	227 (49.0)	47 (44.8)	12 (48.0)	14 (37.8)	0.55
BMI	29.89 (6.34)	31.41 (6.73)	31.36 (6.03)	28.86 (5.90)	0.06
Insurance payor					0.25
Medicaid	29 (6.3)	4 (3.8)	2 (8.0)	6 (16.2)	
Medicare	191 (41.3)	49 (46.7)	11 (44.0)	14 (37.8)	
Private	233 (50.3)	50 (47.6)	11 (44.0)	17 (45.9)	
Uninsured	0 (0.0)	1 (1.0)	0 (0.0)	0 (0.0)	
VA/government	10 (2.2)	1 (1.0)	1 (4.0)	0 (0.0)	
Educational level					0.32
Graduate	178 (38.4)	44 (41.9)	8 (32.0)	13 (35.1)	
High school or less	196 (42.3)	43 (41.0)	14 (56.0)	14 (37.8)	
Postgraduate	69 (14.9)	14 (13.3)	1 (4.0)	10 (27.0)	
Prefer not to answer/NA	20 (4.3)	4 (3.8)	2 (8.0)	0 (0.0)	
Race					0.09
White	364 (81.3)	78 (75.7)	16 (66.7)	33 (89.2)	
African American	67 (15.0)	21 (20.4)	8 (33.3)	2 (5.4)	
Other	17 (3.8)	4 (3.9)	0 (0.0)	2 (5.4)	
SES index	53.32 (5.17)	53.18 (5.31)	53.24 (4.68)	52.47 (5.20)	0.81
Preop employment status					0.38
Employed	177 (38.2)	31 (29.5)	5 (20.8)	16 (43.2)	
Employed on short-term leave	35 (7.6)	10 (9.5)	2 (8.3)	2 (5.4)	
Unemployed	251 (54.2)	64 (61.0)	17 (70.8)	19 (51.4)	
Workers' compensation	7 (1.5)	2 (1.9)	1 (4.2)	0 (0.0)	0.64
Multiple sclerosis	7 (1.5)	2 (1.9)	1 (4.0)	1 (2.7)	0.79
Smoking	74 (16.0)	11 (10.5)	5 (20.0)	6 (16.2)	0.47
Diabetes mellitus	97 (21.0)	25 (23.8)	7 (28.0)	9 (24.3)	0.77
Depression	103 (22.2)	24 (22.9)	6 (24.0)	10 (27.0)	0.92
Anxiety	90 (19.4)	24 (22.9)	5 (20.0)	8 (21.6)	0.88
Coronary artery disease	49 (10.6)	7 (6.7)	5 (20.0)	4 (10.8)	0.25
Osteoarthritis	140 (30.2)	31 (29.5)	8 (32.0)	11 (29.7)	>0.99
COPD	29 (6.3)	5 (4.8)	5 (20.0)	4 (10.8)	**0.03**
ASA grade					0.67
I	9 (2.0)	1 (1.0)	0 (0.0)	0 (0.0)	
II	215 (48.8)	40 (40.4)	10 (40.0)	19 (54.3)	
III	209 (47.4)	55 (55.6)	15 (60.0)	15 (42.9)	
IV	8 (1.8)	3 (3.0)	0 (0.0)	1 (2.9)	
Dependent ambulation	88 (19.0)	16 (15.2)	8 (32.0)	6 (16.2)	0.27
Radicular motor deficit	140 (30.2)	38 (36.2)	5 (20.0)	10 (27.0)	0.37
Radicular arm pain	221 (47.7)	52 (49.5)	8 (32.0)	10 (27.0)	**0.04**
Symptom duration					**<0.01**
<3 mos	74 (29.0)	6 (10.7)	1 (6.3)	5 (27.8)	
>3 mos	181 (71.0)	50 (89.3)	15 (93.8)	13 (72.2)	
Myelopathy severity					**<0.01**
Mild	101 (21.8)	25 (23.8)	6 (24.0)	5 (13.5)	
Moderate	179 (38.7)	54 (51.4)	10 (40.0)	24 (64.9)	
Severe	183 (39.5)	26 (24.8)	9 (36.0)	8 (21.6)	
Listhesis/dynamic instability	137 (33.3)	31 (33.0)	9 (37.5)	13 (37.1)	0.94

CONTINUED ON PAGE 5 »

» CONTINUED FROM PAGE 4

TABLE 1. Characteristics of patients undergoing surgery for CSM

	Early & Sustained Improvement (n = 463)	Transient Improvement (n = 105)	Late Improvement (n = 25)	No Improvement (n = 37)	p Value
Surgical approach					**<0.01**
Anterior	322 (69.5)	70 (66.7)	15 (60.0)	16 (43.2)	
Posterior	141 (30.5)	35 (33.3)	10 (40.0)	21 (56.8)	
No. of levels treated	3.36 (1.28)	3.44 (1.27)	3.44 (1.16)	4.08 (1.80)	**0.02**
Nonroutine discharge	49 (10.6)	21 (20.0)	3 (12.0)	6 (16.7)	0.06
90-day readmission	25 (5.4)	4 (3.8)	0 (0.0)	5 (13.5)	0.08
Reop	31 (6.7)	15 (14.3)	3 (12.0)	7 (18.9)	0.05

NA = not available; VA = Veterans Affairs.
Values are given as number of patients (%) or mean (SD) unless otherwise indicated. Boldface type indicates statistical significance.

Overall, 77.5% of our cohort (73.5% early and sustained improvement, 4.0% late improvement) achieved an MCID at the 24-month follow-up, and 87.8% of patients were satisfied with surgery at the 24-month follow-up (Fig. 1). These outcomes are more favorable than those of previous studies, which have suggested that 30% of patients do not improve with surgery and are unsatisfied.[19] The difference in outcomes seen in this study could be attributed to the use of MRI, improvement in diagnosing myelopathy, or improvements in surgical technique. The

TABLE 2. PROMs at baseline and 3, 12, and 24 months of follow-up

	Early & Sustained Improvement (n = 463)	Transient Improvement (n = 105)	Late Improvement (n = 25)	No Improvement (n = 37)	p Value
NRS arm pain score					
Baseline	5.13 (3.36)	4.47 (3.57)	3.84 (3.89)	2.68 (3.66)	**<0.01**
3 mos	1.80 (2.52)	2.90 (3.20)	3.80 (3.37)	2.86 (3.24)	**<0.01**
12 mos	1.76 (2.48)	3.29 (3.15)	3.76 (3.22)	2.68 (3.19)	**<0.01**
24 mos	1.61 (2.56)	4.57 (3.26)	2.28 (3.02)	2.27 (3.48)	**<0.01**
NRS neck pain score					
Baseline	5.31 (3.17)	4.82 (3.48)	4.20 (3.24)	3.30 (3.45)	**<0.01**
3 mos	2.15 (2.42)	3.75 (2.98)	4.36 (2.25)	3.70 (3.07)	**<0.01**
12 mos	2.01 (2.49)	4.26 (3.23)	4.16 (3.01)	3.24 (3.01)	**<0.01**
24 mos	1.80 (2.41)	4.69 (3.09)	2.48 (2.77)	3.03 (3.53)	**<0.01**
mJOA score					
Baseline	11.97 (2.82)	12.76 (2.38)	12.36 (2.66)	12.81 (1.93)	**0.02**
3 mos	14.44 (2.14)	13.77 (2.57)	12.17 (2.55)	12.86 (2.25)	**<0.01**
12 mos	14.57 (2.17)	12.91 (2.56)	11.80 (3.06)	13.11 (2.57)	**<0.01**
24 mos	14.64 (2.27)	12.29 (2.76)	13.58 (2.86)	13.30 (2.82)	**<0.01**
NDI score					
Baseline	38.53 (19.51)	34.77 (23.21)	36.88 (21.51)	25.43 (24.38)	**<0.01**
3 mos	18.30 (15.14)	26.49 (19.88)	37.12 (19.51)	30.06 (19.69)	**<0.01**
12 mos	15.28 (15.66)	29.24 (20.51)	31.28 (20.99)	24.54 (21.95)	**<0.01**
24 mos	15.34 (16.13)	33.26 (18.88)	18.00 (15.52)	23.42 (24.35)	**<0.01**
EQ-5D score*					
Baseline	0.56 (0.21)	0.59 (0.23)	0.59 (0.18)	0.67 (0.22)	**<0.01**
3 mos	0.77 (0.19)	0.69 (0.22)	0.59 (0.19)	0.64 (0.21)	**<0.01**
12 mos	0.78 (0.18)	0.66 (0.19)	0.62 (0.19)	0.68 (0.23)	**<0.01**
24 mos	0.78 (0.20)	0.59 (0.23)	0.78 (0.14)	0.70 (0.25)	**<0.01**

Values are given as mean (SD) unless otherwise indicated. Boldface type indicates statistical significance.
* Measured in quality-adjusted life-years.

TABLE 3. Rates of MCID achievement at 3, 12, and 24 months of follow-up

	Early & Sustained Improvement (n = 463)	Transient Improvement (n = 105)	Late Improvement (n = 25)	No Improvement (n = 37)
NRS arm pain score MCID				
3 mos	309 (67.5)	45 (42.9)	3 (12.0)	3 (8.1)
12 mos	313 (68.5)	38 (36.2)	3 (12.0)	4 (10.8)
24 mos	310 (69.4)	22 (21.2)	11 (44.0)	7 (18.9)
NRS neck pain score MCID				
3 mos	324 (70.3)	35 (33.3)	4 (16.0)	5 (13.5)
12 mos	329 (71.7)	28 (26.7)	5 (20.0)	8 (21.6)
24 mos	327 (72.8)	19 (18.3)	17 (68.0)	13 (35.1)
mJOA score MCID				
3 mos	306 (66.7)	45 (43.3)	2 (8.3)	5 (13.5)
12 mos	318 (69.6)	28 (27.2)	5 (20.0)	8 (21.6)
24 mos	287 (70.2)	16 (16.3)	14 (58.3)	13 (35.1)
NDI score MCID				
3 mos	340 (73.4)	42 (40.0)	1 (4.0)	3 (8.1)
12 mos	362 (78.7)	37 (35.2)	7 (28.0)	8 (21.6)
24 mos	368 (80.0)	21 (20.0)	19 (76.0)	11 (29.7)
EQ-5D score MCID				
3 mos	197 (44.1)	20 (19.6)	1 (4.0)	2 (5.4)
12 mos	195 (44.3)	20 (19.4)	2 (8.0)	2 (5.4)
24 mos	196 (44.4)	11 (10.8)	10 (40.0)	4 (10.8)

Values are given as number of patients (%).

early and sustained group had a significantly lower reoperation rate (Table 1). Patients with late improvement of their symptoms had steady improvement in all patient-reported outcomes but did not achieve an MCID until 24 months postoperatively (Fig. 2, Table 2).

This study exhibits the same limitations commonly associated with registry-based research. This study was limited to patients in our database with 3, 12, and 24 months of follow-up. The study is limited by the variables collected in the database, and imaging characteristics are not currently included in the registry.[20] Preoperative imaging characteristics and operative reports would be especially helpful to better understand the radiographic outcomes of patients and demonstrate adequate decompression postoperatively.

TABLE 4. Multivariable analyses demonstrating factors associated with early improvement and subsequent decline and late improvement at 24-month follow-up

	Transient Improvement*			Late Improvement*		
	OR	95% CI	p Value	OR	95% CI	p Value
Age: ≤61 yrs	0.98	0.62–1.55	0.93	0.92	0.38–2.25	0.86
Sex: Male	1.16	0.74–1.79	0.52	0.83	0.36–1.93	0.67
BMI: ≥29	1.52	0.97–2.37	0.07	1.65	0.69–3.95	0.26
Race: Black	1.37	0.77–2.42	0.28	2.98	1.14–7.76	**0.03**
Race: other	1.06	0.34–3.28	0.92	—	—	—
Dependent ambulation	0.72	0.39–1.32	0.29	1.32	0.50–3.47	0.57
Radicular arm pain	1.07	0.68–1.69	0.78	0.48	0.19–1.25	0.13
Approach: posterior	1.20	0.68–2.12	0.53	1.20	0.41–3.47	0.74
Levels: 3	0.99	0.56–1.76	0.98	1.09	0.35–3.38	0.89
Levels: ≥4	1.08	0.59–1.97	0.80	1.11	0.34–3.65	0.86

— = there were no patients with other race in the late improvement group.
Boldface type indicates statistical significance.
* Reference: early and sustained improvement.

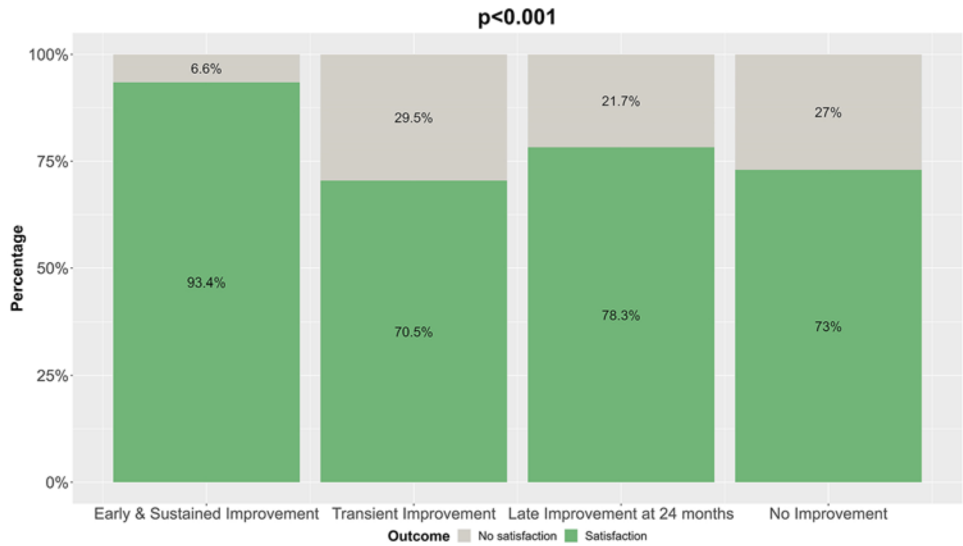

FIG. 1. Comparison of satisfaction rates based on outcome trajectory at the 2-year follow-up. Figure is available in color online only.

Conclusions

Surgical decompression for CSM is an effective treatment, with 77.5% of patients reporting clinically meaningful improvement in at least one patient-reported outcome at 24 months of follow-up and a 87.8% satisfaction rate at 24 months postoperatively. Patients with early and sustained improvement were more likely to have an anterior surgical approach and severe myelopathy at baseline. African American patients were more likely to experience late improvement when compared with White patients.

Acknowledgments

This research was supported by the NeuroPoint Alliance (NPA) and the Neurosurgery Research & Education Foundation (NREF). The NPA is a 501(c)(6) affiliate nonprofit organization of the American Association of Neurological Surgeons (AANS) dedicated to the improvement of the quality of care in neurosurgi-

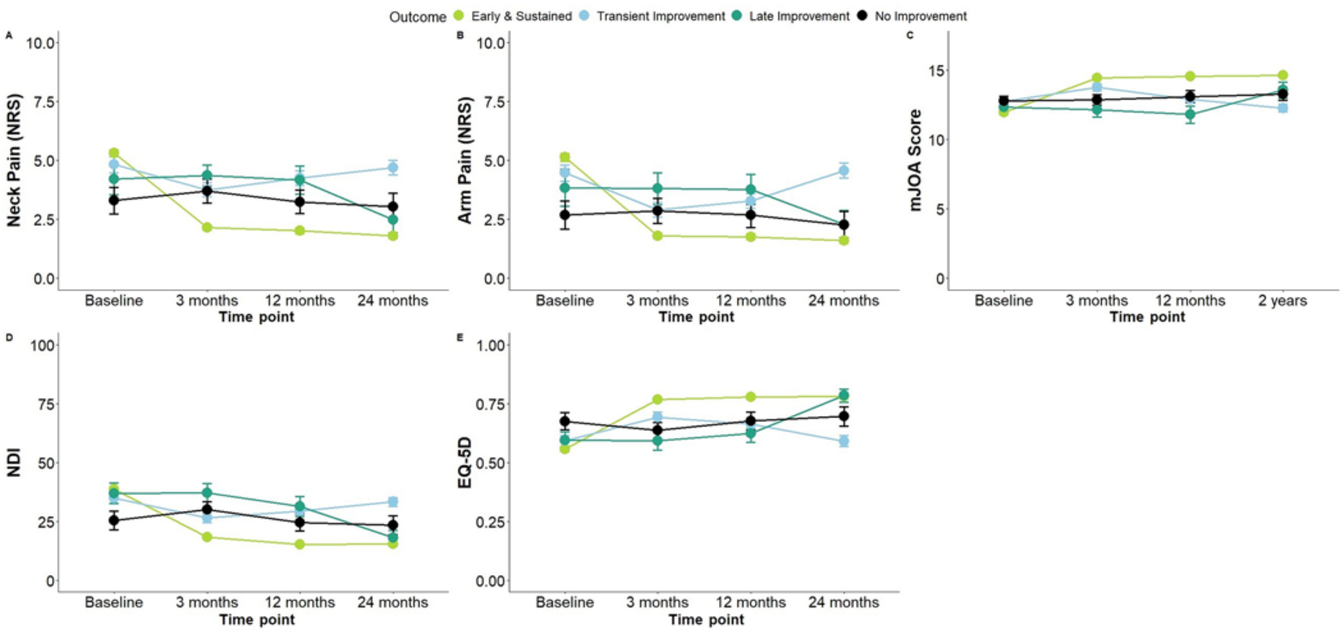

FIG. 2. Line graphs depicting NRS neck pain (**A**), NRS arm pain (**B**), mJOA (**C**), NDI (**D**), and EQ-5D (**E**) scores at baseline and at follow-up time points stratified by outcome trajectory (early and sustained improvement, transient improvement, late improvement, no improvement). Figure is available in color online only.

cal practice via the institution of national quality registries, such as the one utilized for this study. The NREF is the philanthropic arm of the AANS and has financially supported the creation and maintenance of the QOD. The Spine Section is a neurosurgical community aiming at advancing spine and peripheral nerve patient care through education, research, and advocacy.

References

1. Fehlings MG, Wilson JR, Kopjar B, et al. Efficacy and safety of surgical decompression in patients with cervical spondylotic myelopathy: results of the AOSpine North America prospective multi-center study. *J Bone Joint Surg Am*. 2013; 95(18):1651-1658.
2. Kalsi-Ryan S, Karadimas SK, Fehlings MG. Cervical spondylotic myelopathy: the clinical phenomenon and the current pathobiology of an increasingly prevalent and devastating disorder. *Neuroscientist*. 2013;19(4):409-421.
3. Cheung WY, Arvinte D, Wong YW, Luk KD, Cheung KM. Neurological recovery after surgical decompression in patients with cervical spondylotic myelopathy–a prospective study. *Int Orthop*. 2008;32(2):273-278.
4. Evaniew N, Coyle M, Rampersaud YR, et al. Timing of recovery after surgery for patients with degenerative cervical myelopathy: an observational study from the Canadian Spine Outcomes and Research Network. *Neurosurgery*. 2023;92(2): 271-282.
5. Khan I, Archer KR, Wanner JP, et al. Trajectory of improvement in myelopathic symptoms from 3 to 12 months following surgery for degenerative cervical myelopathy. *Neurosurgery*. 2020;86(6):763-768.
6. Pedro KM, Alvi MA, Hejrati N, Moghaddamjou A, Fehlings MG. Elderly patients show substantial improvement in health-related quality of life after surgery for degenerative cervical myelopathy despite medical frailty: an ambispective analysis of a multicenter, international data set. *Neurosurgery*. 2024;94(6):1122-1131.
7. Kusin DJ, Ahn UM, Ahn NU. The influence of diabetes on surgical outcomes in cervical myelopathy. *Spine (Phila Pa 1976)*. 2016;41(18):1436-1440.
8. Wilson JR, Tetreault LA, Schroeder G, et al. Impact of elevated body mass index and obesity on long-term surgical outcomes for patients with degenerative cervical myelopathy: analysis of a combined prospective dataset. *Spine (Phila Pa 1976)*. 2017;42(3):195-201.
9. Basques BA, Khan JM, Louie PK, et al. Obesity does not impact clinical outcome but affects cervical sagittal alignment and adjacent segment degeneration in short term follow-up after an anterior cervical decompression and fusion. *Spine J*. 2019;19(7):1146-1153.
10. Asher AL, Sammak SE, Michalopoulos GD, et al. Time trend analysis of database and registry use in the neurosurgical literature: evidence for the advance of registry science. *J Neurosurg*. 2021;136(6):1804-1809.
11. Chan AK, Shaffrey CI, Gottfried ON, et al. Cervical spondylotic myelopathy with severe axial neck pain: is anterior or posterior approach better? *J Neurosurg Spine*. 2022;38(1):42-55.
12. Tetreault L, Kopjar B, Nouri A, et al. The modified Japanese Orthopaedic Association scale: establishing criteria for mild, moderate and severe impairment in patients with degenerative cervical myelopathy. *Eur Spine J*. 2017;26(1):78-84.
13. Vernon H, Mior S. The Neck Disability Index: a study of reliability and validity. *J Manipulative Physiol Ther*. 1991;14(7): 409-415.
14. Khan I, Pennings JS, Devin CJ, et al. Clinically meaningful improvement following cervical spine surgery: 30% reduction versus absolute point-change MCID values. *Spine (Phila Pa 1976)*. 2021;46(11):717-725.
15. Tetreault L, Nouri A, Kopjar B, Côté P, Fehlings MG. The minimum clinically important difference of the modified Japanese Orthopaedic Association scale in patients with degenerative cervical myelopathy. *Spine (Phila Pa 1976)*. 2015; 40(21):1653-1659.
16. Daltroy LH, Cats-Baril WL, Katz JN, Fossel AH, Liang MH. The North American Spine Society Lumbar Spine Outcome Assessment Instrument: reliability and validity tests. *Spine (Phila Pa 1976)*. 1996;21(6):741-749.
17. R: a language and environment for statistical computing. R Foundation for Statistical Computing. Accessed November 6, 2024. https://www.R-project.org
18. Wilkerson CG, Sherrod BA, Alvi MA, et al. Differences in patient-reported outcomes between anterior and posterior approaches for treatment of cervical spondylotic myelopathy: a Quality Outcomes Database analysis. *World Neurosurg*. 2022;160:e436-e441.
19. Rowland LP. Surgical treatment of cervical spondylotic myelopathy: time for a controlled trial. *Neurology*. 1992;42(1): 5-13.
20. Gliklich RE, Leavy MB, Dreyer NA, eds. *Registries for Evaluating Patient Outcomes: A User's Guide*. 4th ed. AHRQ Publication No. 19(20)-EHC020. Agency for Healthcare Research and Quality; 2020. Accessed November 6, 2024. https://effectivehealthcare.ahrq.gov/products/registries-guide-4th-edition/users-guide

Disclosures

Dr. Bisson reported personal fees from Stryker, Medtronic, and MiRus; and stock in nView, Proprio, and See All outside the submitted work. Dr. Mummaneni reported personal fees from DePuy Synthes, Globus, BK Medical, Brainlab, and SI-Bone; grants from ISSG, AO Spine, NIH, PCORI, SLIP II, Pacira, DoD, and NREF; stock in Discgenics; and royalties from Springer Publisher and Thieme Publisher outside the submitted work. Dr. Chou reported personal fees from Globus, Medtronic, and Orthofix outside the submitted work. Dr. Wang reported personal fees from DePuy Synthes, NuVasive, Spineology, Stryker, and Pacira; and stock in Kinesiometrics, ISD, and Medical Device Partners during the conduct of the study. In addition, Dr. Wang had a patent for DePuy Synthes with royalties paid from the University of Miami. Dr. C. Shaffrey reported personal fees from Medtronic, NuVasive/Globus, SI-Bone, and Proprio outside the submitted work. Dr. Virk reported consulting fees from DePuy Synthes, stock in OnPoint Surgical, and grants from NIH/NINDS outside the submitted work. Dr. Fu reported personal fees from Stryker, Atec, Bioventus, and DePuy outside the submitted work. Dr. Park reported royalties from Globus; personal fees from Globus, NuVasive, Medtronic, DePuy, and Accelus; and grants from Cerapedics, ISSG, SI-Bone, DePuy, and SMISS outside the submitted work. Dr. Foley reported royalties and consulting fees from Medtronic; and stock in Medtronic, Discgenics, DuraStat, NuVasive, RevBio, Spine Wave, Vori Health, and Curiteva outside the submitted work. In addition, Dr. Foley had a patent for multiple patents with royalties paid from Medtronic. Dr. Potts reported royalties and consulting fees from Medtronic and ownership of SeeAll AI outside the submitted work. Dr. Turner reported grants and personal fees from Atec, SeaSpine, and SI-Bone outside the submitted work. Dr. Uribe reported personal fees from Atec and SI-Bone outside the submitted work. Dr. Coric reported personal fees from Spine Wave, Medtronic, Globus Medical, Stryker, and Acellus outside the submitted work. Dr. Asher reported personal fees from Globus outside the submitted work.

Author Contributions

Conception and design: Bydon, Zeitouni, Johnson, Chan, Knightly, CI Shaffrey, Virk, Potts, Uribe. Acquisition of data: Johnson, Ibrahim, Bisson, Mummaneni, Chan, Wang, Knightly, CI Shaffrey, Virk, Fu, ME Shaffrey, Park, Foley, Upadhyaya,

Potts, Coric, Asher. Analysis and interpretation of data: Zeitouni, Johnson, Ibrahim, Haid, Chan, Knightly, Virk, Coric. Drafting the article: Zeitouni, Johnson, Ibrahim. Critically revising the article: Zeitouni, Bisson, Haid, Chan, CI Shaffrey, ME Shaffrey, Foley, Turner, Tumialán. Reviewed submitted version of manuscript: Bydon, Johnson, Bisson, Mummaneni, Haid, Chan, Chou, Wang, Meyer, Gottfried, CI Shaffrey, Virk, Fu, ME Shaffrey, Park, Foley, Upadhyaya, Potts, Turner, Tumialán, Coric, Asher. Approved the final version of the manuscript on behalf of all authors: Bydon. Statistical analysis: Johnson, Ibrahim. Administrative/technical/material support: Potts. Study supervision: Bydon, Bisson, Mummaneni, Haid, Meyer, CI Shaffrey.

Supplemental Information

Previous Presentations

The abstract of this paper was presented at the 2024 AANS/CNS Section on Disorders of the Spine and Peripheral Nerves Meeting, Las Vegas, NV, February 21–24, 2024.

Correspondence

Mohamad Bydon: Mayo Clinic, Rochester, MN. bydon.mohamad@mayo.edu.