Myelopathic signs and functional outcome following cervical decompression surgery: a proposed myelopathy scale

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OBJECTIVE Cervical spondylotic myelopathy (CSM) is the most common cause of spinal cord dysfunction in adults. In spite of this, the impact of the changes in myelopathic signs following cervical decompression surgery and their relationship to functional outcome measures remains unclear. The main goals of our study were to prospectively assess changes in myelopathic signs with a functional outcome scale (the modified Japanese Orthopaedic Association [mJOA] scale) following cervical decompression surgery and to objectively test a proposed new myelopathy scale (MS).

METHODS Between 2008 and 2011, 36 patients with CSM were observed following cervical decompression surgery. Patient data including mJOA and MS scores were prospectively collected and analyzed preoperatively and at 1 year after surgery.

RESULTS In this cohort, reflex, Babinski, and proprioception signs showed statistically significant improvement following surgery at 1 year ($p = < 0.001$, $p = 0.008$, and $p = 0.015$, respectively). A lesser degree of improvement was observed with the Hoffman sign ($p = 0.091$). No statistically significant improvement in clonus occurred ($p = 0.368$). There was a significant improvement in mJOA ($p \leq 0.001$) and MS ($p \leq 0.001$) scores at 1 year compared with the preoperative scores. The results showed an inverse correlation between MS and mJOA scores both pre- and postoperatively (Spearman's correlation coefficient = -0.202 preoperatively and -0.361 postoperatively).

CONCLUSIONS Improvement in myelopathic signs was noted following cervical decompression surgery in patients with CSM. The newly devised MS scale demonstrated these findings, and the new MS scale correlates with improvement in mJOA scores in this patient cohort.

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KEY WORDS cervical spondylosis; functional outcome; myelopathy; scale; cervical decompression surgery

CERVICAL spondylotic myelopathy (CSM) is a clinico-radiological entity resulting from narrowing of the cervical spinal canal from degenerative changes with subsequent compression of the cervical cord. It is by far the most common cause of myelopathy in the cervical spine.^{1,3,4} It is characterized by a series of complex long-tract signs and symptoms. CSM may present with an indolent course or may follow a more detrimental progressive course.^{9,14} In spite of the fact that CSM is the most common cause of myelopathy of the cervical spine, there is a paucity of information in the literature regarding changes in myelopathic signs following cervical decompression surgery and the comparison of the impact of these

changes in a patient's myelopathic signs to actual changes in functional outcome. Although a variety of functional outcome instruments have been used for assessing patients with CSM, to our knowledge there is no known objective myelopathic scale that evaluates patients with CSM based solely on myelopathic signs.⁶ Numerous scales to assess myelopathy have been suggested in the literature.^{2,5,7,8,12,13} The Myelopathy Disability Index, modified Japanese Orthopaedic Association (mJOA) scale, Prolo-score scale, Cooper scale, and others have all been used. The common theme shared by these scales is the degree of subjectivity inherent in each scale and the lack of use of myelopathic signs.

ABBREVIATIONS CSM = cervical spondylotic myelopathy; mJOA = modified Japanese Orthopaedic Association; MS = myelopathy scale.

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Some researchers have recommended the use of functional (subjective) outcome scales in the assessment of patients undergoing surgery for CSM, because such scales have proven to be valid and reliable.^{6,16} The need to have a more definitive objective assessment tool that would further aid in the surgical decision-making process for cervical myelopathy has led us to the creation of the myelopathy scale (MS; Fig. 1). When we designed this scale, we took into consideration 3 fundamental prerequisites: user-friendliness, simplicity, and comprehensibility. Hence, the main objective of the current study was to observe changes in myelopathic signs on an individual basis and as part of this newly devised scale. These changes were compared with a widely accepted functional outcome scale, the modified Japanese Orthopaedic Association (mJOA) scale, which assesses motor and gait function for patients with CSM (Table 1).

Methods

Demographic Data

Inclusion criteria for the study were adult patients 18 years and older, with CSM secondary to degenerative etiologies, who underwent cervical decompression surgery performed by the authors (S.E. and E.K.). Exclusion criteria were patients with isolated cervical radiculopathy, concurrent neurological conditions (i.e., stroke/cerebrovascular accidents, spinal epidural lesions [tumor, abscess, or hematoma], spinal tumor [primary or secondary], brain tumor, multiple sclerosis, normal pressure hydrocephalus, syringomyelia, and peripheral neuropathy), prior cervical spine surgery, cervical deformity, and trauma patients. Thus, the prospective cohort included patients with CSM who underwent cervical decompressive surgery at Hamilton General Hospital, McMaster University, over a 3-year period from June 2008 to May 2011. Assessments both preoperatively and 1-year postoperatively were performed by the authors (S.E. and E.K.).

Surgical Treatment

A full range of surgical options both anteriorly and posteriorly were used. The choice and the recommendation of the approach were based on the severity of the pathology and the number of levels involved, at the discretion of the authors (S.E. and E.K.). Anterior approaches (corpectomy, single- or multilevel anterior cervical discectomy), posterior approaches (laminectomy, laminectomy with instrumentation-fusion, and expansive laminoplasty) and combined approaches were used. In this study, expansive cervical laminoplasty was the most frequently used technique (30 patients, 83.3%).

Clinical Evaluation

Eligible patients were assessed prospectively by the authors independently at the Neurosurgery Spine Clinic at Hamilton General Hospital, McMaster University, over a 3-year period. To assess the severity of myelopathy, our newly proposed MS and the mJOA scale were used. The maximum score for the mJOA scale is 17. The MS is a 10-point score scale (0–10) based on 5 fundamental signs

The Myelopathy Scale

Exam date (mm/dd/yyyy):

Patient's name:

Age:

Sex:

Hospital Record Number:

	Negative	Positive (Unilateral)	Positive (Bilateral)
Hoffman sign			
Babinski sign			
Reflexes (brisk)			
Clonus			
Proprioception			

Values

- ☐ Negative = 0 point
- ☐ Unilateral = 1 point
- ☐ Bilateral = 2 points
- ☐ Maximal score = 10 points
- ☐ Minimal score = 0 points

Total score:

FIG. 1. Proposed MS. This scale is based on 5 basic myelopathic signs (Hoffman, Babinski, reflexes, proprioception, and clonus): a score of 0 if the sign is absent, 1 if unilateral, and 2 if bilateral. The maximum score is 10 and minimum is 0.

of myelopathy (Hoffman sign, Babinski sign, reflexes, proprioception, and clonus). A score of zero was given if the sign is absent, 1 if unilateral, and 2 if bilateral. The higher the scoring grade, the worse the degree of myelopathy. Reflexes were judged to be brisk and abnormal if they were graded ≥ 3 on a scale from 0 to 4.

The clinical diagnosis and the decision for surgical intervention were based on clinical assessment and radiological evidence using MRI at the discretion of the authors. Myelopathy was assessed preoperatively and 1-year postoperatively. Both scales were used to assess the degree of clinical and symptomatic improvement postoperatively, and both scales were compared with each other.

Statistical Analysis

Descriptive statistics were collected. Categorical variables were reported as frequencies, relative frequencies, and continuous variable means with standard deviations, or medians with minimums and maximums if not normally distributed. Categorical variables were compared using

TABLE 1. Modified JOA scale by Keller et al., 1993

Criterion	Clinical Situation	Points*
Motor function upper extremity	Paralysis	1
	Fine motor function massively decreased	2
	Fine motor function decelerated	3
	Discreet weakness in hands or proximal arm	4
	Normal function	5
Motor function lower extremity	Unable to walk	1
	Need walking aid on flat floor	2
	Need handrail on stairs	3
	Able to walk w/o walking aid, but inadequate	4
	Normal function	5
Sensory	Upper extremity/lower extremity/trunk	
	Apparent sensory loss	1
	Minimal sensory loss	2
	Normal function	3
Bladder function	Urinary retention	1
	Severe dysfunction	2
	Mild dysfunction	3
	Normal function	4

* Total score 0–17.

the chi-square or Fisher exact test whenever appropriate, and continuous variables using independent-sample t-tests or Wilcoxon rank-sum tests if not normally distributed. The paired t-test was used to compare the preoperative values to the postoperative values of the mJOA scale and MS. Statistical significance was defined as $p < 0.05$. Results are reported as mean change with 95% confidence intervals (CIs). Spearman's correlation coefficient and p value were used to test the strength of the correlation between the mJOA scale and MS. All statistical analyses were performed using SPSS (version 20.0, IBM).

Results

In this prospective cohort study, 47 patients met the strict inclusion criteria and were enrolled. Thirty-six patients completed a 1-year postoperative follow-up period (Table 2). Eleven patients were lost to follow-up at 1 year. Long-term duration of myelopathic symptoms (> 3 years) was reported in 24 patients (66.7%). Cervical laminoplasty was the most commonly used procedure in our study (30 patients, 83.3%). The mean age ($\pm$ SD) of the patients was 63.0 ± 13.2 years. There were 28 males (77.8%) and 8 females (22.2%). Thirty-two patients (88.9%) were retired at the time of presentation. The MRI stenosis severity based on radiological evaluation was as follows: mild in 0 patients (0%), moderate in 4 patients (11.1%), and severe in 32 patients (88.9%; Table 3). A statistically significant change postoperatively at 1 year compared with preoperatively was noted with the following myelopathic signs: reflexes, Babinski sign, and proprioception signs ($p = < 0.001$, $p = 0.008$, and $p = 0.015$, respectively). There was an improvement in Hoffman's sign postoperatively, although it did not reach a statistical level of significance (p

$= 0.091$). No statistically significant improvement with the clonus sign was noted ($p = 0.368$; Tables 4 and 5).

We also noticed a statistically significant improvement in the degree of myelopathy based on the postoperative mJOA scale score at 1 year compared with the preoperative mJOA scale score. The mean postoperative mJOA scale score at 1 year improved by 2.8 ± 1.6 points (95% CI 2.2–3.3 points) compared with the mean preoperative mJOA score ($p < 0.001$), and the mean percentage change in mJOA scale score was 29.8% and in MS score was 38.7%, indicating a significant degree of improvement in myelopathy based on this functional outcome scale following cervical surgical decompression. Similarly, our MS score showed a statistically significant degree of improvement following surgery at 1 year, with a mean difference of -1.9 ± 1.7 points (95% CI -2.4 to -1.3) at 1 year ($p < 0.001$), indicating as well a statistically significant improvement. There was a small and nonsignificant inverse correlation between preoperative mJOA scale and MS scores (Spearman's correlation coefficient -0.202 , $p = 0.238$), and a similar observation was also noted for the correlation between postoperative mJOA scale and MS scores (-0.361 , $p = 0.031$; Tables 6–8).

In 29 (80.6 %) of the 36 patients, there was an improvement in the scores of both scales at 1 year postoperatively. Five (13.9%) of 36 patients improved on the mJOA scale and did not change on the MS. Two (5.6%) of 36 patients demonstrated no change on either scale. Of note, 2 patients experienced recurrence of severe myelopathy that required reoperation. One was due to a motor vehicle accident 8 months after surgery, and the other patient experienced a clinical neurological decline. The reoperations were excluded from the statistical analysis.

Discussion

One of the challenges in evaluating success following cervical decompression surgery for patients with CSM has been the reliance on outcome measures and scales that are largely dependent on the surgeon or patient's subjective impression of outcome.⁶ Several scales used to assess patients with myelopathy are discussed in the literature. These scales rely on subjective recording of patient's symptoms and overall functionality. CSM is a condition that relies on objective myelopathic signs for diagnosis; however, to date, no known study has examined the correlation between functional outcome and myelopathic signs following cervical decompression surgery.⁶ Our current study was essentially designed to address this question.

Given that CSM is largely defined based on the fundamental signs of myelopathy, we attempted in this study to find out how myelopathic signs change over time following surgery and what is the relationship of these changes to functional outcome. Nurick et al. classified myelopathy into 6 grades (Grades 0–5), but this grading system only assesses disabilities focused at the lower extremities. We contend that the mJOA scoring system is a more thorough system for assessing the degree of cervical myelopathy, because it includes evaluation of the upper and lower limbs, as well as sensory and bladder function.¹⁷

In our study, the degree of CSM was evaluated according to the mJOA scale prior to surgery and at the final

TABLE 2. Baseline patient characteristics

Case No.	Age (yrs), Sex	Duration of Myelopathy at Presentation (yrs)	Preop mJOA Score	Postop mJOA Score at 1 Yr	Preop MS	Postop MS at 1 Yr
1	76, M	>3	16	16	6	6
2	66, M	>3	13	14	6	6
3	56, M	>3	10	12	6	5
4	75, M	<1	9	14	4	4
5	42, M	<1	9	12	5	5
6	64, F	1–3	11	15	5	2
7	77, M	>3	5	8	10	8
8	77, M	>3	8	12	4	4
9	43, M	>3	11	15	7	6
10	62, M	>3	9	13	4	0
11	52, M	<1	12	14	6	5
12	73, M	>3	12	13	6	4
13	80, F	>3	7	13	6	2
14	65, M	>3	10	13	5	4
15	45, M	1–3	12	16	5	2
16	67, M	>3	9	13	10	5
17	48, M	1–3	12	15	10	5
18	60, M	>3	14	15	6	2
19	70, M	>3	12	14	2	0
20	77, M	>3	12	15	4	0
21	42, M	1–3	12	14	3	2
22	73, M	<1	12	15	4	0
23	50, M	1–3	13	16	4	2
24	78, M	>3	9	11	5	5
25	52, M	1–3	10	11	7	6
26	65, M	<1	15	15	1	4
27	54, M	>3	8	15	4	2
28	39, M	>3	15	16	4	2
29	52, F	>3	9	12	3	2
30	75, M	>3	10	14	6	3
31	70, F	>3	10	12	2	0
32	73, F	>3	12	16	3	0
33	47, F	1–3	14	16	4	3
34	81, F	>3	13	14	6	4
35	59, F	>3	13	15	4	2
36	83, M	>3	5	9	7	5

follow-up assessment. The mJOA scale score determines the clinical and functional status of patients by evaluating upper limb (4 points), lower limb (4 points), sensory (6 points), and urinary bladder function (3 points).¹¹ However, the mJOA scale score has been shown to have a variable degree of fluctuation of at least 1 point with interobserver and intraobserver rating differences.¹⁷ Also, the mJOA scale relies heavily on a patient's subjective feedback and does not involve objective examination of myelopathic signs.

The diagnosis of myelopathy is based on the presence of myelopathic signs in conjunction with supportive imaging findings. There was no indication for postoperative MRI,

as the practice in our center is not routinely performed except when there is neurological deterioration postoperatively. Two of our patients experienced a degree of worsening postoperatively (1 of them due to a motor vehicle accident), and both obtained postoperative MRI as part of the evaluation workup. Because of this, we have attempted to develop an MS that directly integrates the basic signs of myelopathy. This differentiates our scale from previously used scales. The future question to answer is whether a myelopathic scale based on myelopathic signs can contribute to our clinical assessment and management of patients. If our scale can be correlated with improvement in functional outcome as assessed by the mJOA scale, our scale

TABLE 3. Patient demographics

Variable	Value (%)
No. of patients	36
Mean age $\pm$ SD (yrs)	63.0 $\pm$ 13.2
Age group (yrs)	
18–50	8 (22.2)
51–75	20 (55.6)
>75	8 (22.2)
Sex	
Male	28 (77.8)
Female	8 (22.2)
MRI severity	
Mild	0 (0)
Moderate	4 (11.1)
Severe	32 (88.9)

may be used as a tool to predict patient outcome following cervical decompression surgery.

Our study showed a statistically significant improvement in the degree of myelopathy as shown in our results with improvement in both myelopathic scales. These results may prompt health care practitioners to look for, or even expect, a lessening or resolution of myelopathic signs when judging the success of treatment.

Approximately 95% of our patients had preoperative gait abnormalities, 85% had severe cervical spinal cord compression, and about 65% had retained their motor strength of at least 4/5 in all muscle groups tested (based on the Medical Research Council scale).

Sphincter abnormalities were found in 20% of patients. One patient (Case 26) of our 36 surgically treated patients demonstrated postoperative worsening of MS scores at 1 year. This patient's MS score increased by 3 points and required a second surgery after 1 year. Interestingly, this patient's mJOA scale score was the same pre- and postoperatively at 1 year. Five patients had no change in MS score (13.9%), which interestingly coincided with improvement in the mJOA scale scores, while there was an agreement

TABLE 4. Frequency of preoperative and postoperative myelopathic signs

Signs	Negative (%)	Unilateral (%)	Bilateral (%)
Preop			
Reflexes	1 (2.8)	5 (13.9)	30 (83.3)
Proprioception	24 (66.7)	8 (22.2)	4 (11.1)
Clonus	31 (86.1)	2 (5.6)	3 (8.3)
Hoffman	8 (22.2)	6 (16.7)	22 (61.1)
Babinski	10 (27.8)	7 (19.4)	19 (52.8)
Postop (1 yr)			
Reflexes	12 (33.3)	9 (25.0)	15 (41.7)
Proprioception	34 (94.4)	1 (2.8)	1 (2.8)
Clonus	33 (91.7)	2 (5.6)	1 (2.8)
Hoffman	14 (38.9)	7 (19.4)	15 (41.7)
Babinski	20 (55.6)	7 (19.4)	9 (25.0)

TABLE 5. Changes in postoperative myelopathic signs 1 year postoperatively

Preop Signs	1-Yr Postop (%)			p Value
	Negative	Unilateral	Bilateral	
Reflexes				<0.001
Negative	1 (2.8)	0	0	
Unilateral	3 (8.3)	2 (5.6)	0	
Bilateral	8 (22.2)	7 (19.4)	15 (41.7)	
Proprioception				0.015
Negative	23 (63.9)	1 (2.8)	0	
Unilateral	8 (22.2)	0	0	
Bilateral	3 (8.3)	0	1 (2.8)	
Clonus				0.368
Negative	30 (83.3)	1 (2.8)	0	
Unilateral	1 (2.8)	1 (2.8)	0	
Bilateral	2 (5.6)	0	1 (2.8)	
Hoffman				0.091
Negative	7 (19.4)	0	1 (2.8)	
Unilateral	2 (5.6)	3 (8.3)	1 (2.8)	
Bilateral	5 (13.9)	4 (11.1)	13 (36.1)	
Babinski				0.008
Negative	10 (27.8)	0	0	
Unilateral	3 (8.3)	3 (8.3)	1 (2.8)	
Bilateral	7 (19.4)	4 (11.1)	8 (22.2)	

in improvement in both myelopathic signs and functional outcome following surgical decompression between the 2 scales of 30 patients (83.3%) with a strength of agreement (kappa) of 0.160 (Table 9).

The overall improvement in MS scores was statistically significant ($p < 0.001$). Furthermore, when we broke down the MS into its basic components, we found that the following signs had statistically significant improvement: reflexes ($p < 0.001$), proprioception ($p = 0.015$), and Babin-

TABLE 6. Pre- and postoperative mJOA and MS scores

Variable	Mean $\pm$ SD	95% CI
Preop		
mJOA	10.9 $\pm$ 2.6	5–16
MS	5.1 $\pm$ 2.1	1–10
1-Yr Postop		
mJOA	13.7 $\pm$ 2.0	8–16
MS	3.3 $\pm$ 2.1	0–8
Change from preop (mean difference)		
mJOA	2.8 $\pm$ 1.6	2.2–3.3
MS	–1.9 $\pm$ 1.7	–2.4 to –1.3
Percentage change*		
mJOA	29.8 $\pm$ 22.4	(0–87.5)
MS	38.7 $\pm$ 40.5	(–100† to 100)

* Percentage change = (Postop score – Preop score/Preop score) $\times$ 100% (absolute value was used).

† One patient had a –100% change in score and “became worse,” because of a naturally declining condition.

TABLE 7. Comparison of pre- and postoperative mean mJOA and MS scores*

Score Comparison	Mean Difference	SD	95% CI	p Value
Postop & preop mJOA	2.8	1.6	2.3–3.3	<0.001
Postop & preop MS	–1.9	1.7	–2.4 to –1.3	<0.001

* Statistical analysis was performed using the paired-samples t-test.

ski's sign ($p = 0.008$). A lesser degree of improvement was seen with Hoffman's sign ($p = 0.091$), and no improvement occurred with clonus ($p = 0.368$). The improvement in these 3 myelopathic signs corresponded to the improvement in mJOA scale scores, even though the correlation between the 2 scales was not robust.

In our study, when we tested the strength of correlation between our MS and the mJOA scale, it was noted that there is a weak degree of inverse correlation between the 2 scales, even though both scales showed statistically significant improvement postoperatively at 1 year. This appears to show that functional improvement as demonstrated by an increased score on the mJOA scale depends to some extent on patients having fewer myelopathic signs as shown by the decreased score on our MS. The degree to which one depends on the other appears to be mildly correlated. Further studies with larger numbers of patients will need to be conducted to determine whether functional improvement as assessed by scales such as the mJOA would require a lessening of myelopathic signs. However, it is possible that patients can improve functionally following cervical decompressive surgery but nonetheless be left with residual signs of myelopathy.

Other researchers have compared myelopathy scales with other neurological tests. Schön¹⁵ compared sensory evoked potentials with the lower European Myelopathy Scale (EMS). Lyu et al.¹⁰ studied the degree of correlation between the nonmodified version of the JOA scoring system with that of sensory evoked potentials. Both of these studies also found a weak degree of correlation when they tested these modalities against each other, which is consistent with our finding of the weak correlation between the 2 scales we tested.

TABLE 9. Agreement between mJOA and MS*

MS Outcome	mJOA Score			Measure of Agreement (kappa)
	Worsened	No Change	Improved	
MS				0.160
Worsened	0	1 (2.7%)	0	
No change	0	0	5 (13.9%)	
Improved	0	0	30 (83.3%)	

* Worsened, improved, or no change from preoperative score. Percentages based on $n = 36$.

An interesting finding in our study was noted upon examining patients who completed a 2-year postoperative follow-up interval (12 patients). All of these patients continued to show improvement in mJOA scores by at least 1 point at the 2-year follow-up compared with 1 year follow-up. Of these 12 patients, only 3 improved by at least 1 point on the MS scores, and 9 patients had no further improvement in the scores at 2 years compared with scores at 1 year. This interesting observation leads one to question whether functional outcome can continue to improve after 1 year following surgery even though myelopathic sign resolution will level off after 1 year.

Limitations of the Study

This study has several limitations. It has a relatively small number of patients and was conducted at a single center. However, we are presenting unique findings of myelopathy not previously reported in the literature.

Conclusions

Our newly devised MS showed a statistically significant improvement at postoperative Year 1, which is consistent with the improvement noted with the mJOA scale score. This study could form the basis for further testing of myelopathy pre- and postoperatively following cervical decompression surgery. Further studies should be conducted in an effort to better understand the relationship between

TABLE 8. Correlation between pre- and postoperative mJOA and MS scores using Spearman correlation coefficient

Assessment	Preop mJOA Score	Postop mJOA Score	Preop MS	Postop MS
Preop mJOA				
Correlation coefficient	1	0.745	–0.202	–0.147
p value	—	<0.001	0.238	0.392
Postop mJOA				
Correlation coefficient	0.745	1	–0.269	–0.361
p value	<0.001	—	0.113	0.031
Preop MS				
Correlation coefficient	–0.202	–0.269	1	0.733
p value	0.238	0.113	—	<0.001
Postop MS				
Correlation coefficient	–0.147	–0.361	0.733	1
p value	0.392	0.031	<0.001	—

improvements in myelopathic signs and functional outcome. Further studies and evaluation of our proposed MS will allow us to possibly validate the scale through more vigorous testing, including interobserver reliability.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Kachur, El-Zuway. Acquisition of data: Kachur, El-Zuway. Analysis and interpretation of data: all authors. Drafting the article: Kachur, El-Zuway. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Kachur. Statistical analysis: Farrokhvar. Study supervision: Kachur, El-Zuway.

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