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Factors Affecting Surgical Outcomes in Cervical Spondylotic Myelopathy: A Retrospective Study

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ABSTRACT

Introduction: To determine the factors that may affect surgical outcomes in patients with cervical spondylotic myelopathy (CSM) by evaluating consecutive patients at our institution.

Methods: Medical charts of the patients were reviewed retrospectively between 2012 and 2019. The modified Japanese Orthopedic Association scale and the postoperative functional recovery (PFR) rate were used to assess the clinical outcomes and benefits of surgical intervention. Demographics, clinical presentations, radiological variables, and surgical techniques were evaluated.

Results: A total of 98 patients with CSM with a mean age of 55.4±10.7 years were included. Fifty (51.0%) patients were male. A good preoperative functional status ($p=0.001$, $R_2=0.22$), female sex ($p=0.008$, $R_2=0.07$), short preoperative period ($p=0.007$, $R_2=0.074$), and dynamic compression on more than one dynamic magnetic resonance imaging phase ($p=0.001$, $R_2=0.115$) were associated with good surgical outcomes and a higher PFR rate. No significant differences were found in the PFR rate and the complications among all surgical approaches ($p>0.05$).

Conclusion: Demographic, clinical, and radiological factors, such as sex, preoperative functional status, preoperative clinical course, and number of dynamic compression phases, can impact surgical outcomes in CSM. Early diagnosis is very critical and extremely important in reducing persistent neurological deficits associated with CSM. We recommend early surgical intervention for patients with CSM to obtain good surgical outcomes.

Keywords: Cervical spine, myelopathy, spondylosis, corpectomy, stabilization

Introduction

Cervical spondylotic myelopathy (CSM) is the most common cause of spinal cord injury in the advanced age population that leads to spinal cord dysfunction (1). Joint-related spinal cord compression develops later, as ligament hypertrophy often happens gradually. Patients who present with severe myelopathy are indicated for surgical intervention to prevent clinical worsening (2). Spinal cord deformations caused by CSM are treated either anteriorly or posteriorly or by two-stage combined surgery. The anterior approach includes discectomy and/or corpectomy with fusion, which can be performed more easily to relieve compression on the spinal cord caused by herniations, osteophytes, and hypertrophic ligaments. The posterior approach typically includes foraminotomy, laminectomy, fusion with laminectomy, and laminoplasty.

Although some evidence indicates that most patients with CSM recover after surgery, the basic clinical and imaging factors that predict surgical outcome have not been established (3). Pre-surgical magnetic resonance imaging (MRI) may predict postoperative functional recovery levels in CSM. Age, duration of symptoms, and baseline score for the modified Japanese Orthopedic Association (mJOA) scale appear to correlate with postoperative functional scores. A recent systematic analysis identified important limitations in the current medical literature that prevent formal recommendations regarding the use of prognostic factors in treatment algorithms (4). The main limitations were that the mJOA scale is not used and the disregard of factors that confuse the functional status when evaluating patients prospectively.

In this retrospective study, we determined the factors that may affect the surgical outcomes of patients with CSM by evaluating 98 patients consecutively operated at our institution.

Methods

The medical charts of patients with CSM operated consecutively at our institution between 2012 and 2019 were reviewed retrospectively. Demographics, clinical presentations, radiological variables, and surgical techniques were evaluated. Our study was approved by the Clinical

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Research Ethics Committee of University of Health Sciences Turkey, Fatih Sultan Mehmet Training and Research Hospital under a decision number (approval number: 2020/3).

Verbal and written consent were obtained from all patients who agreed to participate in this study.

Study Population and Criteria

The inclusion criteria of the study were age 18 years or older, symptomatic CSM with at least one clinical sign of myelopathy, imaging compatible with cervical cord compression, and no previous cervical spine surgery. The exclusion criteria were being asymptomatic, having an active infection, neoplastic disease, rheumatoid arthritis, ankylosing spondylitis, and concomitant symptomatic lumbar stenosis. In addition, patients lost to follow-up were excluded from the study. The surgical criteria were persistent or recurrent radiculopathy, progressive neurological deficit, and static neurological deficit with severe radicular pain (5).

Out of 107 patients screened, 9 were excluded. Of these 9 patients, 2 were asymptomatic, 2 had symptomatic lumbar spinal stenosis, and 5 were lost to follow-up. The final analysis evaluated the data of 98 patients.

Clinical Evaluation

Clinical evaluation was conducted for patients suffering various symptoms, such as gait disturbance, bilateral upper extremity paresthesia, Lhermitte phenomenon, pyramidal motor deficits, hand muscle atrophy, positive Hoffman's sign, stable basal skin reflex plantar responses, lower extremity spasticity, and broad-based unsteady gait that were supported by radiological evidence of compression on the spinal cord in the cervical region.

Clinical variables that were investigated for prognosis included age, sex, symptom duration (preoperative clinical course), and initial functional status (preop mJOA). The mJOA scale and postoperative functional recovery (PFR) rate were used to evaluate the clinical outcomes and the benefits of surgical intervention (6).

Imaging Analysis

Imaging analysis was performed by two neuroradiologists with standard 300% magnification Sante DICOM Viewer Pro v. made using 11.7.3 64-bit software. After a reasonable interval, the two neuroradiologists repeated the measurements, following the same protocol and using the same computer unit and software.

MRIs were analyzed based on three parameters: 1) the cross-sectional area at the maximum compression level of the spinal cord; 2) the spinal cord signal intensity on the T1- and T2-weighted MRI sequences; and 3) the number of compression levels.

Sagittal plane alignment was calculated using the Harisson posterior tangent method on standing scoliosis (whole spine) radiographs that were taken from 3 feet (~90 cm) distance. The alignment was measured by finding the angulation created by intersecting the tangents drawn between the posterior edges of both C2 and C7 bodies (7) (Figure 1). The patients were divided into two groups according to the spinal cord cross-sectional area on the axial sequences based on cut-off values reported previously (0.76 cm^2) (8-10). The surface measurement at the narrowest level of the spinal cord at the maximum compression level (in cm^2) was obtained on axial T2-weighted sequences (Figure 2).

Functional Evaluation

The preoperative and 12th postoperative month evaluations were performed using the mJOA functional disability scale. The PFR rate was calculated using the pre- and postoperative mJOA scores via the formula by Hirabayashi et al. (11):

PFR rate = [postoperative mJOA - preoperative mJOA/Normal value (18) - preoperative mJOA] ×100.

The postoperative functional evaluation was conducted at 12-month intervals, to allow the optimum time for recovery after CSM therapy (12,13).

Surgery

Surgical decompression of the cervical spine was performed in all patients. The suitable approach, number of cervical levels to be treated,

Figure 1. Diagram of Harrison's posterior tangent method

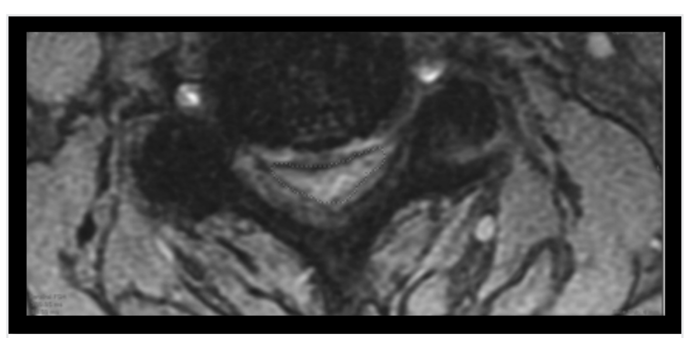

Figure 2. Axial section area measurement using 64-bit Sante DICOM Viewer Pro v. 11.7.3 software

and fixation option were decided according to the CSM treatment algorithms. Three approaches were applied, namely, anterior, posterior, or combined approaches.

The anterior approach included discectomy and/or corpectomy with fusion. In the anterior cervical approach, anterior discectomy is performed up to three levels to remove the disks or osteophytes pressing on the spinal cord to relieve compression on the spinal cord. Then, a graft for interbody fusion is placed in the disk space (2,14). This technique has become a preferred method since it limits the defect by removing less bony structures (14,15).

The posterior approach included laminectomy, fusion with laminectomy, and laminoplasty. To reduce post-laminectomy kyphosis, laminectomy alone is no longer performed in treating CSM. Fusion with laminectomy includes posterior decompression and stabilization, which prevents kyphosis and instability in the late postoperative period. In stabilization, fusion to the facet joint space should be planned with instrumentation. Laminoplasty is performed to prevent the development of postoperative kyphosis and to maintain neck movement.

Postoperative Course

The patients that postoperatively showed no recovery or improvement were reassessed to rule out the non-spondylotic causes of myelopathy (16). Straight and dynamic cervical radiographs, computed tomography (CT) images, and MRI with axial, coronal, and sagittal sequences were thus obtained.

Statistical Analysis

All variables with normal distributions were analyzed using descriptive statistics. The relationships among continuous variables were evaluated using Spearman's correlation and univariate linear regression analysis. The t-test was used when a variable was continuous, while the other was categorical. For categorical data, the chi-square test was used.

The Mann-Whitney U test was used to analyze the relationship between categorized variables and changes in postoperative score and recovery rate since these scores did not follow the Gaussian distribution. Values were reported as mean ± standard error of the mean.

A multiple linear regression model was calculated using forward stepwise regression. Univariate analysis was performed to identify statistically and clinically significant variables for evaluation in exploratory data analysis. SPSS version 21 (IBM Corp. Armonk, NY, USA) was used for statistical analysis, and $p<0.05$ was considered statistically significant.

For statistical comparisons, the patients were divided into two age groups (≥65 years and <65 years), and the preoperative clinical course was accepted as short if the duration of symptoms ≤12 months and long (chronic) if it >12 months (17). The study analyzed a relatively small sample size, and were data obtained from a single center. All cut-off values were obtained from larger data sets reported in the literature.

Results

The demographic, clinical, and radiological characteristics of the patients are summarized in Table 1. Seventy patients underwent an

Table 1. Patient demographics and clinical variables of the investigated patients

Demographics and clinical variables	Patients (%)
Preoperative clinical course (months)	16.4±12.9
Age (years)	55.4±10.7
<65	79 (80.6%)
≥65	19 (19.4%)
Sex	
Male	50 (51.0%)
Female	48 (49.0%)
Severity of CSM (mJOA scores)	
Mild (mJOA >15)	48% (47)
Moderate (mJOA 12-14)	39.8% (39)
Severe (mJOA <12)	12.2% (12)
Cross-sectional area of the spinal cord (mean ± SD)	0.76±0.022
<0.76 cm^2	49% (48)
≥0.76 cm^2	51% (50)
Anatomical level of stenosis	
C2-C3	5% (5)
C3-C4	32% (32)
C4-C5	66% (65)
C5-C6	87% (86)
C6-C7	53% (52)
Number of segments with spinal compression	
1	5% (5)
2	49% (48)
≥3	46% (45)
Myelopathic etiologies	
OPLL	31% (30)
Spondylosis	75% (73)
Calcified disk herniation	33% (33)
Hypertrophic ligamentum flavum	25% (25)
Subluxation	5% (5)
The number of myelopathy etiology number	
1	33% (33)
2	59% (57)
>3	8% (8)
Cervical alignment	
Lordosis	36% (35)
Neutral	51% (50)
Kyphosis	13% (13)
Dynamic pressure	
Present	62% (61)
Absent	38% (37)
Surgical approach	
Anterior	72% (70)
Posterior	21% (21)
Combined	7% (7)

mJOA: modified Japanese Orthopedic Association anterior decompressive approach (discectomy, corpectomy, and fusion instrumentation), 21 underwent a posterior decompressive approach (laminectomy and fusion with posterior instrumentation), and 7 underwent a combined approach. In all cases, the spinal cord was confirmed to be sufficiently decompressed on CTs conducted in the early postoperative period and assessed by two experienced neuroradiologists. No patients were reoperated due to insufficient decompression.

Postoperative Complications

Cerebrospinal fluid (CSF) fistula was reported in 4 patients (3 posterior approach, 1 anterior approach), which was treated with primary suture fibrin sealants (17). No patient was reoperated for the CSF fistula. Unilateral C5 paralysis occurred in two patients. One patient underwent a posterior approach, and the paralysis manifested late, on the 15th postoperative day. The symptoms completely resolved with conservative treatment. The second patient underwent an anterior approach, and the paralysis was identified early. Unfortunately, the patient did not improve. Anterior displacement of the graft and plate-screw system was observed in the early control radiographs of three patients who underwent an anterior approach. Both cases were followed closely, and, eventually, fusion occurred without any malalignment. Salivary fistula related to esophageal perforation occurred in one patient. Oral feeding was stopped, and the symptoms resolved after 20 days.

Factors Affecting the Preoperative mJOA Score

The results of the univariate analysis of the relationship between the aforementioned demographic, clinical, and radiological characteristics of the patients and their preoperative mJOA scores are presented in Table 2.

Age: The preoperative mean mJOA score of patients >65 years old was 14.32±0.19, whereas those >65 years old was 12.68±0.50. The younger patient group showed better functional status, and the relationship between the preoperative mJOA score and age group was significant (p=0.001).

Symptom duration: The mean preoperative mJOA score of patients with a short preoperative clinical course (symptom duration <12 months) was 14.39±0.23, whereas that of patients with chronic symptoms (symptom duration >12 months) was 13.3±0.31. As the symptom duration increased, the mJOA score worsened (p=0.007).

Table 2. Factors affecting the preoperative modified Japanese Orthopedic Association score

	Mean preoperative mJOA score	95% CI	p	R^2
Age group			0,0011*	0,118
<65	14,32	13.9-14.7		
>65	12.68	11.6-13.7		
Sex			0.0242*	0.052
Male	14.44	14.0-14.88		
Female	13.58	12.98-14.18		
Duration of symptoms			0.007*	0.073
<12 months	14.39	13.93-14.84		
>12 months	13.33	12.70-13.97		
MRI signal properties			0.0261	0.005
Normal T1/normal T2	14.75	13.64-15.86		
Normal T1/hyperintense T2	13.78	10.89-15.91		
Hypointense T1/hyperintense T2	13.40	11.78-15.78		
Cross-sectional area of the spinal cord (cm^2)			0.117	0.025
<0.76 cm^2	13.75	13.14-14.36		
>0.76 cm^2	14.24	13.36-14.75		
Number of segments with spinal compression			0.007*	0.072
1	13.00	10.68-15.32		
2	14.81	14.43-15.20		
>3	13.24	11.19-15.29		
Cervical alignment			0.881	0.00
Lordosis	13.71			
Neutral	14.12			
Kyphosis	14.31			
Dynamic pressure			0.827	0.001
Present	13.97	13.51-14.42		
Absent	14.05	13.36-14.75		

mJOA: modified Japanese Orthopedic Association, CI: Confidence interval, MRI: Magnetic resonance imaging, PFR: Postoperative functional recovery

Sex: The average preoperative mJOA value for women in the study group was 14.4±0.22, whereas for men it was 13.6±0.3. Although no difference was found between the sexes in terms of symptom duration (p=0.567) and age grouping (p=0.504), a significant difference was found in preoperative mJOA scores (p=0.029). The preoperative functional neurological status of the male sex was significantly better.

MRI signal properties: The preoperative mJOA scores of patients with MRI signal changes were significantly lower than those with normal T1 and T2 signal intensity (p=0.026).

Several compression segments: The mJOA score was found to be significantly lower in the group with compression in 3 or more segments (p=0.007). No significant difference was found compared to 1 or 2 compression groups in terms of mJOA scores.

Other variables: Significant relationships of the cross-sectional surface measurements of the spinal cord (p=0.117), presence of dynamic pressure (p=0.827), and cervical sagittal alignment characteristics (p=0.881) with preoperative mJOA score were not observed.

Factors Affecting the Postoperative Functional Outcomes (PFR rates)

Preoperative functional status: A highly significant relationship was observed between the preoperative mJOA score groups and the degree of postoperative functional improvement (p=0.000, R^2=0.22). Patients with a higher mJOA (i.e., good preoperative functional status) had better surgical outcomes.

Age: No significant relationship was found between age and the PFR rate (p=0.153, R^2=0.021). The PFR rate was higher (69.3% vs. 59.9%) in the younger group (<65 years) than in the older group (≥65 years). However, the difference was not significant.

Sex: A significant difference was found between the sexes in terms of functional improvement. The postoperative recovery rate of the female sex was better (p=0.008 and R^2=0.07).

The duration of symptoms: Patients presenting with signs and symptoms for a shorter period (<12 months) had higher PFR values (p=0.007, R^2=0.074).

Dynamic compression: According to the classification system defined previously using cervical dynamic MRI, the PFR rates of the cases with one or more phase changes in the compression phase were significantly higher (p=0.001, R^2=0.115).

Other variables: No significant statistical relationship was found between the spinal cord cross-sectional area, MRI signal characteristics, the number of segments with compression, cervical alignment, or surgical approach with the degree of functional improvement. No significant correlation was found between cervical sagittal alignment and functional status before (p=0.881, R^2=0.00) or after surgery (p=0.185, R^2=0.021) (Table 3).

Multiple linear regression analysis was performed to predict the PFR rate according to the preoperative mJOA score and the presence of dynamic compression. A high preoperative mJOA score (>15), with the presence of dynamic compression, was identified as a significant predictor of the PFR rate. The two variables accounted for 28% of the variance in the PFR rate. Both variables can thus separately predict the PFR rate (p<0.05). The predictive values of a high mJOA score and the presence of dynamic compression were β=0.42 and β=0.32, respectively.

Factors Affecting the Change in mJOA Scores

Preoperative functional status: A significant statistical relationship was observed between the preoperative mJOA score and change in mJOA (ΔmJOA) score or PFR (p=0.000, R^2=0.217). The ΔmJOA is higher in patients with a lower preoperative mJOA score (Table 4).

Age: The ΔmJOA was higher in the older (≥65 years) group, and the difference between the age groups was statistically significant (p=0.042, R^2=0.042).

Several compression segments: The ΔmJOA in the group with three or more compression segments was significantly higher (p=0.000, R^2=0.078).

Dynamic compression: In the presence of dynamic compression, the difference in the mJOA score between the pre- and postoperative periods were significantly higher in the group with dynamic compression than in the group without (p=0.000, R^2=0.163).

The type of surgical approach: According to the type of surgical approach, the improvement in mJOA score was significantly higher in those who underwent a posterior or combined approach than in those who underwent an anterior approach alone (p=0.000, R^2=0.167).

Other variables: The effect of sex, symptom duration, MRI signal characteristics, spinal cord cross-sectional area, and cervical sagittal alignment on ΔmJOA could not be demonstrated (Table 4).

Multiple linear regression analysis was performed to predict postoperative ΔmJOA according to preoperative mJOA score and the presence of dynamic compression. A moderate preoperative mJOA score (12-14) and dynamic compression are significant predictors of postoperative ΔmJOA. The two variables together explain 28% of the ΔmJOA variance. Both variables can independently predict mJOA (p<0.05). A medium mJOA score (ß=0.37) and the presence of dynamic compression (ß=0.34) could predict ΔmJOA. No significant differences were found in the PFR rate and the complications among all approaches (p=0.196 and p=0.21, respectively).

Discussion

The prognosis of CSM is most significantly affected by age at diagnosis, symptom duration (preoperative clinical course), and the severity of myelopathy. Age was reported in most previously published studies as a prognostic factor for patients with CSM (18). Some authors have shown that the prognosis and surgical outcomes were better in younger patients (<60 years) (8,19-21). This may be related to the length of the preoperative clinical course. An international consensus study showed that age >65 years is an unfavorable prognostic factor for CSM (22). We found no significant relationship between age and postoperative functional outcomes (PFR rate). However, female sex was a good prognostic factor in our study.

Several previous studies have shown that patients with CSM who had a longer preoperative clinical course (i.e., longer symptom durations) have

Table 3. Factors affecting the postoperative functional outcomes (PFR rates)

	Mean PFR	95% CI	p	R^2
The preoperative mJOA score			0.001*	0.22
Mild (mJOA >15)	76.59	69.77-83.41		
Moderate (12> mJOA >14)	65.29	59.10-71.49		
Severe (mJOA <12)	38.74	19.19-58.28		
Age group			0.153	0.021
<65	69.27	63.67-74.87		
>65	59.93	46.95-72.91		
Sex			0.008*	0.070
Male	60.88	52.51-69.25		
Female	74.31	68.92-79.70		
Duration of symptoms			0.007*	0.074
<12 months	72.72	66.87-78.57		
>12 months	58.40	49.17-67.63		
MRI signal properties			0.120	0.025
Normal T1/normal T2	70.62	61.37-79.87		
Normal T1/hyperintense T2	67.55	61.45-73.65		
Hypointense T1/hyperintense T2	51.00	0.48-101.5		
Cross-sectional area of the spinal cord (cm^2)			0.711	0.001
<0.76 cm^2	69.42	61.57-77.26.		
>0.76 cm^2	65.58	58.74-72.42		
Number of segments with spinal compression			0.392	0.021
1	54.83	24.46-85.19		
2	68.95	63.19-77.50		
>3	65.79	57.84-73.74		
Cervical alignment			0.185	0.021
Lordosis	60.68	53.87-71.29		
Neutral	70.09	62.54-77.63		
Kyphosis	70.49	57.66-83.32		
Dynamic pressure			0.001*	0.115
Present	74.16	69.26-79.06		
Absent	54.61	46.18-66.65		
Surgical approach			0.196	0.021
Anterior	69.80	63.50-76.11		
Posterior	61.54	51.57-71.50		
Combined	61.78	38.21-85.35		

mJOA: modified Japanese Orthopedic Association, CI: Confidence interval, MRI: Magnetic resonance imaging, PFR: Postoperative functional recovery

a poorer prognosis (22-24), with that of Yamazaki et al. (25) and Chagas et al. (19) defining a long clinical course as longer than 1 and 2 years, respectively. Karpova et al. (8) suggest that the duration of symptoms was related to the preoperative functional status, but it did not affect the postoperative outcome. We found that a short preoperative period was an independent factor associated with good surgical outcomes and a higher PFR rate in our patients.

Some studies have reported that myelopathic findings have also been associated with changes in the cross-sectional area on axial and signal intensity on T1 and T2 sequences (8,26). Some authors suggest that, although the cross-sectional area of the spinal cord does not indicate CSM severity, it can determine the surgical prognosis (8-10). Fukishima et al. (27) reported a critical value of 0.45 cm^2 for the spinal cord cross-sectional area on the axial sequences and suggested that irreversible functional impairment would begin below this value. In this study, the number of cases with a critical value ≤0.45 cm^2 was quite low. Therefore, the 0.76 cm^2 value, which is the arithmetic mean of the whole group, was taken as the critical value of the cross-sectional area for statistical comparisons. The different values obtained may be related to the software used for area measurement.

Table 4. Factors affecting the change in modified Japanese Orthopedic Association score scores (ΔmJOA)				
	ΔmJOA	95% CI	p	R^2
Preoperative mJOA score			0.001*	0.217
Mild (>15)	1.85	2.68-3.31		
Moderate (12-14)	3.00	1.47-4.36		
Severe (<12)	2.91	1.65-2.04		
Age group			0.042	0.042
<65	2.31	2.07-2.55		
>65	2.94	2.15-3.74		
Sex			0.327	0.01
Male	2.32	1.93-2.70		
Female	2.56	2.25-2.87		
Duration of symptoms			0.83	0.00
<12 months	2.42	2.12-2.71		
>12 months	2.47	2.01-2.92		
MRI signal properties			0.274	0.038
Normal T1/normal T2	2.25	1.87-2.62		
Normal T1/hyperintense T2	2.56	2.25-2.87		
Hypointense T1/hyperintense T2	1.60	(-0.06)-3.26		
Cross-sectional area of the spinal cord (cm^2)			0.115	0.016
<0.76 cm^2	2.60	2.21-2.99		
>0.76 cm^2	2.28	1.97-2.58		
Number of segments with spinal compression			0.006*	0.078
1	2.4	1.28-3.51		
2	2.10	1.81-2.39		
>3	2.80	2.38-3.21		
Cervical alignment			0.731	0.002
Lordosis	2.48	2.04-2.92		
Neutral	2.44	2.09-2.79		
Kyphosis	2.30	1.63-2.97		
Dynamic pressure			0.001*	0.163
Present	2.81	2.51-3.12		
Absent	1.8	1.46-2.15		
Surgical approach			0.001*	0.167
Anterior	2.12	1.88-3.26		
Posterior	3.28	2.60-3.96		
Combined	3.00	2.07-3.92		

mJOA: modified Japanese Orthopedic Association, CI: Confidence interval, MRI: Magnetic resonance imaging

The severity of symptoms in CSM is evaluated using disability indexes, mJOA score, and Nurick's score. Most articles suggest that poor baseline functional status scores are associated with a worse prognosis (18,22). In contrast, no index has been established to provide a reliable preoperative assessment of the functional status (18). The JOA score and its modifications are most frequently used to assess functional status during the presentation. Tetreault et al.'s (22) review found that an mJOA score ≥12 indicated a good prognosis. Su et al. (20) concluded that preoperative mJOA scores increased preoperative signal intensities on MRI, and age are independent factors that significantly affect the disease prognosis and surgical outcomes. In our study, we found a highly significant relationship between the preoperative mJOA score and PFR rate.

A few studies have investigated the relationship between cervical sagittal balance (C2-C7 SVA) and the severity of myelopathy. Although the cervical translational sequence is associated with the mJOA score, the cervical C2-C7 Cobb angle (lordosis/kyphosis) did not correlated with the mJOA score (28). Tang et al. (29) found that the surgical outcomes of patients who underwent posterior cervical fusion were correlated with C2-C7 SVA. However, the study only included postoperative patients and represents a mixed set of indications, including primary cervical deformity. In our study, cervical sagittal posture measurements were made using the posterior tangent method (7). Our findings showed no significant correlation between cervical sagittal alignment and functional status either pre- or postoperatively.

Eck et al. (30) showed that accelerated degenerative changes and increased stress load may lead to adjacent segment disease after anterior cervical fusion surgery. As the degeneration progresses, the disk space becomes narrower, and hyperplasia begins in the facet and Luschka joints. The formation of osteophytes and further bone bridges occurs on the anterior and/or posterior edges of the vertebral body. The intervertebral disk activity decreases or even disappears. This situation is equivalent to "auto fusion." Due to this "auto fusion" at the CSM level, adjacent segments undergo accelerated degeneration and a compensatory increase in mobility, resulting in cervical segmental instability. CSM and subaxial cervical instability may be different stages of cervical degenerative disease, and subaxial cervical instability occurs after CSM (31). In our study, the compression on the spinal cord is mostly dynamic (62%); thus, we assumed that limited segmental movement persists, the duration of compression is not full-time, the CSM process is not long enough to result in auto fusion, and rigid formations that will limit segmental movement (bridge osteophytes, facets, and ligament hypertrophy) have not yet occurred. Consequently, the signs and symptoms of CSM may be reversible. Our findings indicate no correlation between the presence of dynamic compression and preoperative mJOA; however, the PRF rate was significantly higher in the group with dynamic compression.

Patients who have benefited in the early period after surgery or whose condition has at least been stabilized by surgery may undergo late-term regression of neurological functions. Slightly more than half of the patients who underwent anterior surgery and up to a third of the patients who underwent laminectomy in the late-term controls showed improvement according to their preoperative status. Reasons for delayed recovery or postoperative worsening include inadequate decompression of the spinal cord, progression of spondylosis in untreated areas, soft disk herniation, kyphotic deformity, and post-laminectomy membrane formation, misdiagnosis of the cause of myelopathy, and advanced age. Severe and long-term loss of neurological function were listed among irreversible pathologies that include high-level involvement and atrophy in the spinal cord (32). Hirabayashi and Satomi (32) studied 35 patients who had undergone laminoplasty for multiple-level spondylosis and found that 54% showed improved symptoms and preserved long-term canal width. In our study, fusion laminectomy was performed in patients who underwent a posterior approach. No differences were found in the PFR rate and the complications among all approaches in our patients.

Study Limitations

This study had some limitations. First, the sample size studied was relatively small (n=98), which included patients treated surgically at our hospital and met our study criteria. Thus, the patients evaluated are unrepresentative of the population of the Asian part of İstanbul. Furthermore, the nature of the study is retrospective, the follow-up period is relatively short, and the findings only represent the experience of a single center. Further randomized prospective studies involving larger samples from multiple centers that sufficiently represent a geographical area with a sufficiently long follow-up period must improve the generalizability of our findings.

Conclusion

Demographic, clinical, and radiological factors, such as sex, preoperative functional status, preoperative clinical course, and the number of dynamic compression phases can impact the surgical outcomes in CSM. Early diagnosis is extremely important in reducing persistent neurological deficits associated with CSM. Early surgical intervention often has good results. The data of this study should be used to discuss the possible consequences of surgery and properly manage patient expectations in CSM. These expectations need to be met, given the increasing importance of patient satisfaction in the performance-based health system.

Ethics Committee Approval: Our study was approved by the Clinical Research Ethics Committee of University of Health Sciences Turkey, Fatih Sultan Mehmet Training and Research Hospital under a decision number (approval number: 2020/3).

Informed Consent: Verbal and written consent were obtained from all patients who agreed to participate in this study.

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References

1. Montgomery DM, Brower RS. Cervical spondylotic myelopathy. Clinical syndrome and natural history. Orthop Clin North Am 1992; 23: 487-93.
2. Smith GW, Robinson RA. The treatment of certain cervical-spine disorders by anterior removal of the intervertebral disc and interbody fusion. J Bone Joint Surg Am 1958; 40-A: 607-24.
3. Tavares S, Costa GG, Galego O, Pereira R. Can Morphometric Analysis of Cervical Spondylotic Myelopathy Be a Tool for Surgical Outcome Prediction? Int J Spine Surg, 2021; 15: 718-23.
4. Holly LT, Matz PG, Anderson PA, Groff MW, Heary RF, Kaiser MG, et al. Clinical prognostic indicators of surgical outcome in cervical spondylotic myelopathy. J Neurosurg Spine 2009; 11: 112-8.
5. Zileli M. Recommendations of WFNS Spine Committee. Neurospine 2019; 16: 383-5.
6. Mastronardi L, Elsawaf A, Roperto R, Bozzao A, Caroli M, Ferrante M, et al. Prognostic relevance of the postoperative evolution of intramedullary spinal cord changes in signal intensity on magnetic resonance imaging after anterior decompression for cervical spondylotic myelopathy. J Neurosurg Spine 2007; 7: 615-22.
7. Harrison DE, Harrison DD, Cailliet R, Troyanovich SJ, Janik TJ, Holland B. Cobb method or Harrison posterior tangent method: which to choose for lateral cervical radiographic analysis. Spine (Phila Pa 1976) 2000; 25: 2072-8.

8. Karpova A, Arun R, Davis AM, Kulkarni AV, Massicotte EM, Mikulis DJ, et al. Predictors of surgical outcome in cervical spondylotic myelopathy. Spine (Phila Pa 1976) 2013; 38: 392-400.
9. Chikuda H, Seichi A, Takeshita K, Matsunaga S, Watanabe M, Nakagawa Y, et al. Acute cervical spinal cord injury complicated by preexisting ossification of the posterior longitudinal ligament: a multicenter study. Spine 2011; 36: 1453-8.
10. Nouri A, Tetreault L, Zamorano JJ, Dalzell K, Davis AM, Mikulis D, et al. Role of magnetic resonance imaging in predicting surgical outcome in patients with cervical spondylotic myelopathy. Spine 2015; 40: 171-8.
11. Hirabayashi K, Miyakawa J, Satomi K, Maruyama T, Wakano K. Operative results and postoperative progression of ossification among patients with ossification of cervical posterior longitudinal ligament. Spine (Phila Pa 1976) 1981; 6: 354-64.
12. 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: 273-8.
13. Furlan JC, Kalsi-Ryan S, Kailaya-Vasan A, Massicotte EM, Fehlings MG. Functional and clinical outcomes following surgical treatment in patients with cervical spondylotic myelopathy: a prospective study of 81 cases. J Neurosurg Spine 2011; 14: 348-55.
14. Cloward RB. The anterior approach for removal of ruptured cervical disks. J Neurosurg 1958; 15: 602-17.
15. Kanna RM, Perambuduri AS, Shetty AP, Rajasekaran S. A Randomized Control Trial Comparing Local Autografts and Allografts in Single Level Anterior Cervical Discectomy and Fusion Using a Stand-Alone Cage. Asian Spine J 2021; 15: 817-24.
16. Ghogawala Z, Terrin N, Dunbar MR, Breeze JL, Freund KM, Kanter AS, et al. Effect of Ventral vs Dorsal Spinal Surgery on Patient-Reported Physical Functioning in Patients With Cervical Spondylotic Myelopathy: A Randomized Clinical Trial. JAMA 2021; 325: 942-51.
17. Fehlings MG, Ibrahim A, Tetreault L, Albanese V, Alvarado M, Arnold P, et al. A global perspective on the outcomes of surgical decompression in patients with cervical spondylotic myelopathy: results from the prospective multicenter AOSpine international study on 479 patients. Spine (Phila Pa 1976) 2015; 40: 1322-8.
18. Zileli M, Maheshwari S, Kale SS, Garg K, Menon SK, Parthiban J. Outcome Measures and Variables Affecting Prognosis of Cervical Spondylotic Myelopathy: WFNS Spine Committee Recommendations. Neurospine 2019; 16: 435-47.
19. Chagas H, Domingues F, Aversa A, Vidal Fonseca AL, de Souza JM. Cervical spondylotic myelopathy: 10 years of prospective outcome analysis of anterior decompression and fusion. Surg Neurol 2005; 64 Suppl 1: S1: 30-5; discussion S1:35-6.
20. Su N, Fei Q, Wang B, Li D, Li J, Meng H, et al. Long-term outcomes and prognostic analysis of modified open-door laminoplasty with lateral mass screw fusion in treatment of cervical spondylotic myelopathy. Ther Clin Risk Manag 2016; 12: 1329-37.
21. Suzuki A, Misawa H, Simogata M, Tsutsumimoto T, Takaoka K, Nakamura H. Recovery process following cervical laminoplasty in patients with cervical compression myelopathy: prospective cohort study. Spine (Phila Pa 1976) 2009; 34: 2874-9.
22. Tetreault LA, Karpova A, Fehlings MG. Predictors of outcome in patients with degenerative cervical spondylotic myelopathy undergoing surgical treatment: results of a systematic review. Eur Spine J 2015; 24 Suppl 2: 236-51.
23. Tracy JA, Bartleson JD. Cervical spondylotic myelopathy. Neurologist 2010; 16: 176-87.
24. Li XY, Lu SB, Sun XY, Kong C, Guo MC, Sun SY, et al. Clinical and magnetic resonance imaging predictors of the surgical outcomes of patients with cervical spondylotic myelopathy. Clin Neurol Neurosurg 2018; 174: 137-43.
25. Yamazaki T, Yanaka K, Sato H, Uemura K, Tsukada A, Nose T. Cervical spondylotic myelopathy: surgical results and factors affecting outcome with special reference to age differences. Neurosurgery 2003; 52: 122-6; discussion 126.
26. Rao A, Soliman H, Kaushal M, Motovylyak O, Vedantam A, Budde MD. Diffusion tensor imaging in a large longitudinal series of patients with cervical spondylotic myelopathy correlated with long-term functional outcome. Neurosurgery 2018; 83: 753-60.
27. Fukushima T, Ikata T, Taoka Y, Takata S. Magnetic resonance imaging study on spinal cord plasticity in patients with cervical compression myelopathy. Spine 1991; 16(10 Suppl): S534-8.
28. Smith JS, Lafage V, Ryan DJ, Shaffrey CI, Schwab FJ, Patel AA, et al. Association of myelopathy scores with cervical sagittal balance and normalized spinal cord volume: analysis of 56 preoperative cases from the AOSpine North America Myelopathy study. Spine (Phila Pa 1976) 2013; 38: S161-70.
29. Tang JA, Scheer JK, Smith JS, Deviren V, Bess S, Hart RA, et al. The impact of standing regional cervical sagittal alignment on outcomes in posterior cervical fusion surgery. Neurosurgery 2015; 76 Suppl 1: S14-21; discussion S21.
30. Eck JC, Humphreys SC, Lim TH, Jeong ST, Kim JG, Hodges SD, et al. Biomechanical study on the effect of cervical spine fusion on adjacent-level intradiscal pressure and segmental motion. Spine (Phila Pa 1976) 2002; 27: 2431-4.
31. Lu K, Gao X, Tong T, Miao D, Ding W, Shen Y. Clinical Predictors of Surgical Outcomes and Imaging Features in Single Segmental Cervical Spondylotic Myelopathy with Lower Cervical Instability. Med Sci Monit 2017; 23: 3697-705.
32. Hirabayashi K, Satomi L. Operative procedure and results of expansive open-door laminoplasty. Spine (Phila Pa 1976) 1988; 13: 870-6.