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Validation of a novel scoring system (Cervical Surgical Score) for the management of degenerative cervical myelopathy

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ABSTRACT

Background: Degenerative Cervical Myelopathy (DCM) is the leading cause of spinal cord dysfunction globally. Surgical intervention is often recommended for moderate to severe cases, but the optimal surgical approach remains debated.
Objective: This study aims to validate the novel Cervical Surgical Score (CSS) for managing DCM, aiding surgical decision-making.
Methods: A prospective study was conducted in Carlo Besta institute (Milan) from a consecutive series, enrolling 113 patients undergoing surgery for DCM from January 2022 to February 2023. This cohort was compared with 106 patients from a retrospective cohort treated between 2019 and 2021.
Results: A total 219 patients (113 prospective, 106 retrospective) were included. The prospective group had an average age of 59.6 years (61 % males), and the retrospective group, 60.7 years (69 % males). The mean CSS score (calculated based on age, level of cervical pathologies, level of myelopathy, extension, site and type of compression, cervical alignment and mJOA) was 12.3 for prospective and 13.18 for retrospective groups. Most prospective cases used an anterior approach compared to retrospective group (88,5 % vs 48.1 %). At two years, neurological recovery (last follow-up mJOA-preoperative mJOA)/(18−preoperative mJOA × 100) was higher in prospective group (68 % vs. 54 %). CSS concordance linked to better recovery rates at one and two years (45 % and 66 % vs. 29 % and 47 %; $p < 0,001$). High-expertise surgeons (defined based on case-load evaluation scale) achieved higher CSS concordance (64 %) than medium (31 %) and low-expertise surgeons (0 %).
Conclusion: The CSS is a reliable tool for optimizing surgical strategies for DCM, enhancing decision-making, and improving patient outcomes.

1. Introduction

Decision-making in the treatment of Degenerative Cervical Myelopathy (DCM) presents one of the most intricate challenges in modern spinal surgery (Wilson et al., 2017). The leading cause of spinal cord dysfunction globally, DCM encompasses a broad range of degenerative conditions that affect the cervical spine (Witiw et al., 2017; Pedro et al., 2024; Wilson et al., 2023). The impact is particularly severe among older adults, and dramatically reduces life expectancy as well as quality of life, while imposing a staggering economic burden of over £681.6 million annually (Davies et al., 2023).

The management of DCM is complicated by several variables, such as natural history, heterogeneous etio-pathogenesis, medical frailty and anatomical findings of the disease (Yoshimatsu et al., 2001; Hirayama et al., 2023). Surgical intervention is the suggested option for clinically relevant cases, especially where moderate to severe symptoms or escalating neurological deficits are present (Tetreault et al., 2017). In literature there are several recommendations and algorithms that provide comprehensive surgical indications, analyzing the critical role of disease severity and individual patient factors (Rodrigues-Pinto et al., 2022; Parthiban et al., 2019; Fehlings et al., 2017). However, determining the optimal surgical approach remains an unsolved and complex issue. This

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lack of consensus underscores the patient's need for a specific tool supporting the surgical decision-making process (Hejrati et al., 2022).

To address these knowledge gaps, our team has developed a specific scoring system known as the Cervical Surgical Score (CSS) (Costa et al., 2024). It is a tool designed to simplify and enhance decision-making by evaluating key clinical and radiological factors to determine the best surgical approach for each patient. The CSS assesses eight critical parameters: age, number of pathological levels, levels of radiological myelopathy, extent and type of compression, site of compression, cervical alignment, and the grade of clinical myelopathy. Each parameter is assigned a numerical value, enabling a stratified assessment that guides treatment decisions. Specifically, the CSS provides clear recommendations based on the total score: an anterior approach is suggested for scores between 5 and 12, a posterior approach for scores between 17 and 23, and all surgical options are considered for scores in the "grey zone" of 13–16. Preliminary results show that the CSS offers high concordance in straightforward cases and significantly improves guidance in complex scenarios, making it a reliable tool for defining optimal surgical strategies for DCM patients (Costa et al., 2024).

Validating this tool, holds the potential of empowering clinicians to make more informed, personalized surgical decisions, based on a comprehensive and systematic analysis of individual patient factors, thus promoting a more precise and patient-centered approach in cervical spine surgery.

2. Material and METHODS

The Institutional Review Board of the Fondazione RCCS Istituto Neurologico Carlo Besta in Milan approved a prospective study to validate the Cervical Surgical Score (CSS – Fig. 1). This study aims to aid surgeons in selecting the appropriate surgical approach for complex degenerative cervical pathology by objectively evaluating various clinical and radiological parameters.

Patients who underwent surgery for degenerative cervical myelopathy (DCM) at the institution between January 2022 and February 2023 were prospectively enrolled. Patients were evaluated in a Spine Surgery outpatient clinic, where a specific surgical recommendation was made. Upon admission to the Spine Surgery Unit, patients underwent routine clinical and radiological examinations, including magnetic resonance imaging (MRI) and cervical X-ray, with additional computed tomography (CT) and cervical dynamic X-ray as needed. Outcomes of the prospective cohort were compared with those of a retrospective cohort of patients who had undergone surgery at the same institution between 2019 and 2021.

2.1. Surgeon expertise stratification

To demonstrate the efficacy of the CSS in clinical practice, it is crucial to stratify results based on the varying expertise of the surgeons. Therefore, we propose to stratifying surgical expertise based on individual caseloads obtained by literature analysis on learning curves for common cervical spine procedures.

For posterior approaches (eg. laminectomy with screw placement) Yoshimoto et al. (2009) analyzed the learning curve of cervical pedicle screw placement under fluoroscopy across three categories of 100 screw positions each. Screw perforations decreased significantly after more than 200 screws had been placed, with performance improving later in the learning curve.

For the anterior cervical approach, Mayo et al. (2016) evaluated the learning curve for ACDF procedures performed by surgeons immediately post-fellowship. Their analysis of 374 patients concluded that operative proficiency is achieved after at least 60 ACDF cases. In contrast, there is no specific learning curve for cervical corpectomies (ACCF), but Hartmann et al. (2016) stratified surgeon expertise based on the number of procedures performed per year, with non-experts performing fewer than 5 in several years and experts performing more than 5.

Based on this evidence, we propose a case-load-based scoring system to stratify surgeon expertise in DCM into three categories: ACDF (1 point: <60; 2 points: 60–250; 3 points: >250); ACCF (1 point: <5 in 10 yrs; 2 points: <10 in 10 yrs; 3 points: >10 in 10 yrs); Posterior approach

Cervical Surgical Score Flowchart

Parameters	Value	Points
Age	≤70 years >70 <80 years ≥ 80 years	1 2 3
N° of level/s (disc) of cervical pathology/ies	1 2 3 ≥4	1 2 3 5
N° of level/s of radiological myelopathy	0 1 2 ≥3	0 1 2 3
Extension of Compression	Disc level Disc and vertebral body	1 2
Predominance of Site of Compression/s	Anterior Both Posterior	1 2 3
Type of Compression	"Soft" "Hard" or calcified	1 2
Cervical Alignment	Kyphotic Neutral Lordotic	0 1 2
Grade of Clinical Myelopathy (mJOA)	None Mild (15-18) Moderate (12-14) Severe (≤11)	0 1 2 3

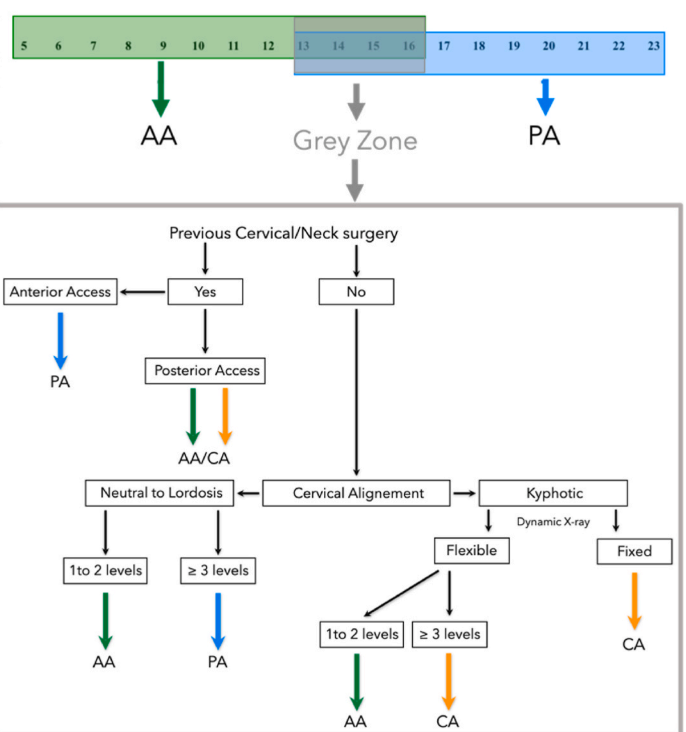

Fig. 1. Summary of cervical surgical score flowchart.

including screw placement or simple laminectomy (1 point: <200; 2 points: 200–300; 3 points: >300). More specifically, based on this scoring system we defined Low-experienced surgeon (fewer than 5 points); Medium-experienced surgeon (5–7 points) and High-experienced surgeon (more than 7 points).

2.2. Study objective

Our primary objective is to evaluate the utility of the CSS (Cervical Surgical Score) in guiding surgeons towards optimal surgical approaches for DCM (Degenerative Cervical Myelopathy) patients, validating its scoring system, and assessing its impact on surgical outcome. To achieve this, we compared data from both prospectively and retrospectively enrolled patient groups.

In addition, we aim to investigate whether there are differences in rates of revision surgery, complications, and hospital stays between patients whose surgical approach aligns with CSS recommendations (in both prospective and retrospective cohorts) and those whose treatment deviates from them. Secondly, we seek to explore potential variations in clinical outcomes based on adherence to CSS recommendations and stratifying it based on the expertise level of the surgeons involved.

2.3. Study assessment

Patients were screened in outpatient clinics by neurosurgeons based on specific inclusion (adults over 18 years of age diagnosed with degenerative cervical myelopathy requiring surgical intervention) and exclusion criteria. Specifically, exclusion criteria encompassed inability to undergo cervical MRI for any reason, conditions that could potentially confound preoperative clinical evaluations, severe preoperative neurocognitive deficits not related to DCM, specific diseases requiring particular surgical indications, and a history of previous cervical surgery for traumatic or oncological pathologies.

During hospitalization, all patients underwent a comprehensive preoperative assessment, which included reviewing medical records and obtaining informed consent. Preoperative data collection covered symptoms, comorbidities, mJOA score (Tetreault et al., 2017), gait disturbances, neck and arm visual analog scale (VAS) (Cha et al., 2019), Neck Disability Index (NDI) (Vernon, 2008), Nurick score, details of previous cervical surgeries, clinical myelopathy grade, and cervical alignment determined by lateral cervical XR.

Moreover, intraoperative data were recorded for all patients including the type of surgical approach, procedure duration, and any intraoperative complications.

During post-surgery hospitalization, assessments included clinical outcomes and complications, with complications measured using the Landriel Scoring System (Ibaez et al., 2011). The need for further examinations, such as cervical CT scans, was evaluated along with details of non-routine discharges and duration of hospital stay. Orthostatic postoperative cervical X-rays were performed to rule out early postoperative complications. One and two-year follow-up data regarding clinical-neurological evaluations, neurological recovery rate (Hirabayashi et al., 1981) and cervical MRI information was recorded and collected.

2.4. Statistics

All analyses were conducted using the IBM SPSS Statistics Version 19 software package (SPSS, Inc., Somers, NY, USA) and Python for SPSS. Descriptive statistics were reported in terms of absolute numbers and percentages for categorical variables and means with standard deviations (SDs) for continuous (numerical) variables. Correlations within a cohort were evaluated using Spearman's rank correlation coefficient rho. Given the disparity in sample sizes, the significance of discrepancies between variables across cohorts was determined using t-tests and t-statistics for continuous variables and with chi-square tests for categorical variables.

To account for potential confounding factors, outcome-dependent variables between cohorts (prospective vs. retrospective, concordant vs. discordant) were adjusted using analysis of Covariance (ANCOVA), incorporating the "Surgeon Score Expertise" and "Surgeon Expertise Level" covariates.

This adjustment ensured that the results were appropriately controlled for the surgeon's expertise executing the procedures. Statistical significance was established at p-value less than 0.05 for all tests.

3. RESULTS

3.1. Clinical demographical and surgical data among prospective and retrospective patients

A total of 219 patients including both retrospective and prospective cohort were analyzed. Specifically, the prospective cohort included 113 patients recruited over two years. The mean age was 59.6 ± 12.4 years, with 61 % males and 39 % females. Clinical and radiological preoperative data with CSS parameters of prospective and retrospective cohort are summarized in Table 1. Regarding intraoperative data, in the prospective cohort surgical approaches were mostly anterior (100/113–88.5 %), followed by posterior (12/113–10.6 %) and combined (1/113–0.9 %). Specifically, anterior surgeries included ACDF (90/100 - 90 %) and ACCF (10/100 - 10 %), while posterior included laminectomies without fusion (5/12–41.6 %), with fusion (6/12–50 %), and one (1/12–8.4 %) open-door laminoplasty. Mean length of surgical operation was 79.8 ± 41.9 min, with hospital stays averaging of 3.27 ± 6.15 days. The mean CSS score was 12.3 ± 3.01, with, due to the design of this study, 100 % concordance to the CSS.

The retrospective cohort included 106 patients enrolled from January 2019 to October 2021. The mean age was 60.7 ± 12.7 years, with 69 % males and 31 % females. Clinical and radiological preoperative data with CSS parameters are summarized in Table 1. A mean surgical experience score of 4.65 ± 1.35 was registered among this cohort. Surgeries were executed by low-experienced surgeon in 59 cases, by moderately experienced in 37 cases, and by highly experienced in 10 cases. The mean CSS score was 13.18 ± 3.15, with 72.7 % concordance between chosen approach and CSS indication. Among all cases retrospectively treated, surgical approaches were anterior in 48 % (51/106) of cases and posterior in 52 % (55/106). Anterior surgeries included ACDF (47/51–92 %), ACCF (2/51- 4 %), and CDR (2/51- 4 %). Posterior surgeries included Laminectomy Without Fusion (LWOF; 49/55–89 %), laminectomies with fusion - preferably with screw in lateral mass - (1/55 - 2 %), open-door laminoplasties (1/55 - 2 %), and other approaches (2 hemilaminectomy and 2 foraminotomy) (7 %). Mean length of surgical operation was 105.3 ± 36.4 min, with hospital stays averaging 3.87 ± 2.37 days. Figs. 2–5 presents different case examples of CSS application.

3.2. Comparison between prospective and retrospective cohorts

Comparison between prospective and retrospective cohorts did not show many statistically significant differences, suggesting that the cohorts are well-matched for comparative analysis (Table 1).

Specifically, the main differences were reported in longer lengths of surgery in the retrospective cohort, likely due to a higher incidence of posterior surgical approaches or different surgical expertise among the two cohorts. Moreover, the prospective cohort experienced fewer complications, with only three cases reported (two requiring reoperation due to mispositioned screw-fixed cages and one case of urinary infection managed with antibiotics) compared to 17 complications reported in the retrospective cohort (with 12 cases requiring revision surgery).

Outcome data was analyzed based on one and two-year follow-up evaluations. The 1-year follow-up showed a better postoperative neurological recovery rate in the prospective vs retrospective cohort (49 % ± 30.9 % vs 43.4 % ± 34.2 %; p-value >0,05). However, the Nurick

Table 1
Summary of clinical demographical and surgical data in prospective and retrospective cohorts.

	Prospective Cohort	Retrospective Cohort	p-value
Count	113	106	–
Age	59.62 ± 12.37	60.77 ± 12.68	0.5
Sex	69/44	73/33	0.8
ASA Score	1.31 ± 0.71	1.38 ± 0.74	0.49
Charlson	2.73 ± 1.06	2.08 ± 1.76	**0.01**
Duration of Symptoms (days)	563.10 ± 737.98	735.34 ± 991.14	0.14
Neck VAS	4.24 ± 2.54	4.51 ± 2.74	0.5
Arm VAS	4.23 ± 2.26	3.52 ± 2.77	0.74
NDI	25 % ± 16 %	0.28 ± 0.17	0.41
Nurick Scale	2.94 ± 1.17	3.11 ± 1.17	0.15
mJOA	13.10 ± 2.35	12.64 ± 2.33	0.46
mJOA Grade			
Mild	32	25	0.82
Moderate	56	48	0.65
Severe	25	33	0.42
Symptoms Type			
Pain (D)	79	70	0.45
Paresthesias (P)	53	78	0.07
Motor Issues (M)	66	63	0.72
Sphincteric Issues (S)	18	19	0.61
Levels of Cervical Pathology			0.44
1 level	45	41	
2 level	35	31	
3 level	26	25	
4+ level	7	9	
Extent of Compression			0.72
Disk	60	54	
Disk + vertebral body	53	52	
Predominance of Compression			0.37
Anterior	90	56	
Both	18	34	
Posterior	5	16	
Cervical Alignment			0.07
Kyphosis	38	18	
Lordosis	65	44	
Neutral	10	43	
Type of Compression			0.09
Soft	49	26	
Hard	64	79	
Previous Cervical Surgery	13	8	0.32
CSS	12.34 ± 3.02	13.18 ± 3.15	0.11
Duration of Surgery (min)	79.82 ± 41.97	105.29 ± 36.43	**0.0003**
Length of Stay (days)	3.27 ± 6.15	3.87 ± 2.37	0.44
Surgeon Experience	L = 0; M = 0; H = 100	L = 55; M = 37; H = 10	–
Type of Approach			0.06
Anterior	100	51	–
ACDF	90	47	–
ACCF	10	2	–
CDR	0	2	–
Posterior	12	55	–
LWOF	5	49	–
LWF	6	1	–
LP	1	1	–
Combined	1	0	–
Complications	3	16	**0.04**

Score showed a statistically significant improvement, with the prospective cohort improving by 2.08 ± 1.35 points compared to 1.05 ± 1.85 points in the retrospective cohort (t-statistic: −2.49, p-value = 0.0003). At the 2-year follow-up, a significant difference in post-operative neurological recovery rates was observed between the prospective and retrospective cohorts (68 % ± 33 % vs. 54 % ± 36 %), with a t-statistic of 3.64 (p-value = 0.0003). Further outcome details for each cohort are summarized in Table 2.

3.3. Comparison between CSS concordant vs CSS discordant cohorts

A comparative analysis was conducted to assess the differences between patients whose surgical indications were concordant with the CSS indication (Concordant Cohort) and those whose indications were discordant (Discordant Cohort). The analysis revealed no statistically significant differences in preoperative data between the two cohorts, as detailed in Table 3. However, significant differences were noted in the types of surgical approaches used. In the concordant cohort, 88 % of surgeries were anterior, while only 12 % were posterior. Conversely, in the discordant cohort, 90 % of surgeries were posterior, and only 10 % were anterior; reporting a statistically significant difference in surgical approach chosen among the two cohorts (chi-square: 40.42; p-value = 0.004).

Interestingly, significant differences were observed in the outcomes of patients who followed CSS recommendations compared to those who did not. At the one-year follow-up, the neurological recovery rate was 45 ± 32 % for the concordant cohort and 29 ± 26 % for the discordant cohort (t-statistic: 3.64, p-value = 0.0003). Moreover, at the two-year follow-up, the recovery rate was 66 ± 32 % for the concordant cohort versus 47 ± 33 % for the discordant cohort, also statistically significant (t-statistic = 4.46, p-value< 0.0001). Statistically significant improvements were also observed in Neck VAS, Arm VAS, and NDI scores, both relative and absolute, as detailed in Table 4. Although the return-to-work rate was slightly higher in the concordant cohort (84 % versus 75 %), this difference was not statistically significant (p-value = 0.2). However, there was a significant difference in the return to activity rate, with 76 % in the concordant cohort compared to 57 % in the discordant cohort (p-value = 0.015). Lastly, the 2-year MRI evaluation showed a reduction in myelopathic signal in 78 % of cases in the concordant group compared to 52 % in the discordant group (p-value = 0.04).

3.4. Correlation between surgical expertise, CSS and outcome

Comparison between concordant vs discordant groups revealed a notable disparity in surgical expertise. Specifically, the concordant cohort had a mean surgical expertise score of 7.32 ± 2.24, compared to 4.14 ± 0.96 in the discordant cohort (p-value = 0.003).

Furthermore, within the concordant group, 64 % (n = 121) of procedures were performed by high-expertise surgeons, 15 % (n = 29) by medium-expertise surgeons, and 21 % (n = 40) by low-expertise surgeons. Conversely, in the CSS-discordant group, 0 % of procedures were performed by high-expertise surgeons, 31 % by medium-expertise surgeons, and a striking 69 % of procedures were performed by low-expertise surgeons, as defined by our Surgeon Expertise Level. This discrepancy between cohorts was statistically significant suggesting that medium- and high-expertise surgeons are significantly more likely to adhere to CSS indications in their clinical practice (chi-square = 10.5, p-value = 0.00003). Table 5 summarizes comparisons between CSS concordant vs CSS discordant groups, subcategorized based on surgeon expertise level.

Covariate analyses (ANCOVA) and t-tests on the concordant and discordant populations was carried out to determine the impact of the "surgical expertise level" covariate on the outcome data obtained. Table 6 summarizes the significant outcome discrepancies between the concordant and discordant cohorts for the low and medium expertise sub-groups, as there were no high-expertise surgeons in the discordant group for comparison. Specifically, these adjusted analyses demonstrate that while some differences in outcomes can be attributed to varying levels of surgical expertise, the CSS significantly enhances the decision-making process and leads to significantly better outcomes, especially among less experienced surgeons. This is particularly evident in the low-experienced surgeon subgroup, where statistical significance is preserved across all outcome discrepancies.

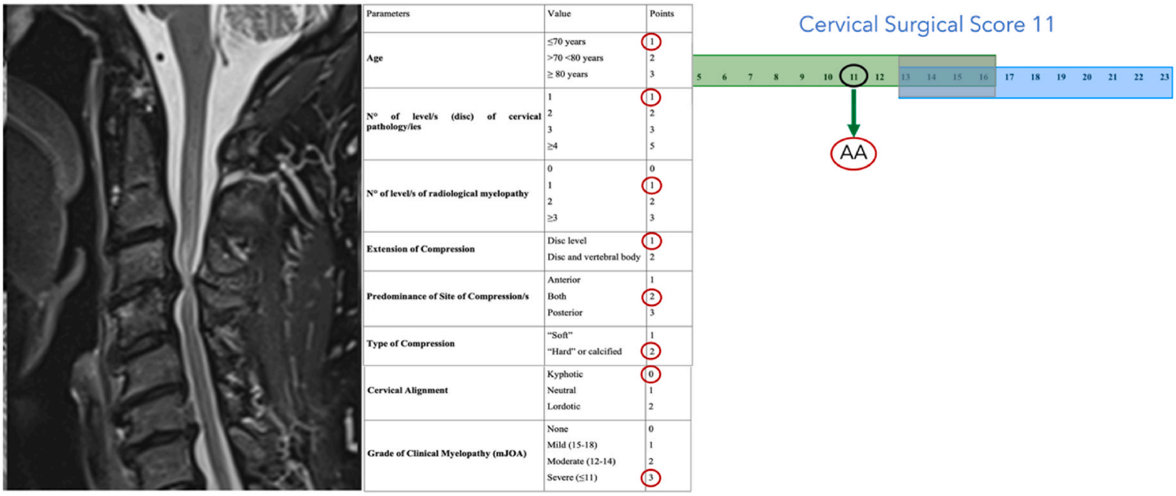

Fig. 2. Case example of CSS application in case of single level C3-C4 DCM treated with anterior approach.

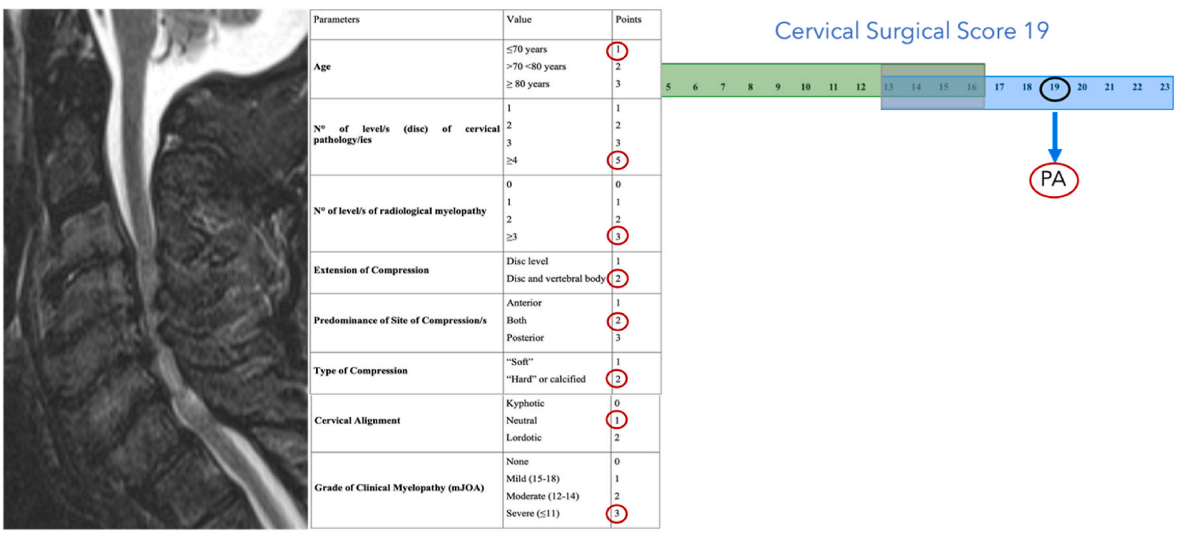

Fig. 3. Case example of CSS application in case of multiple level C3-C7 DCM treated with posterior approach.

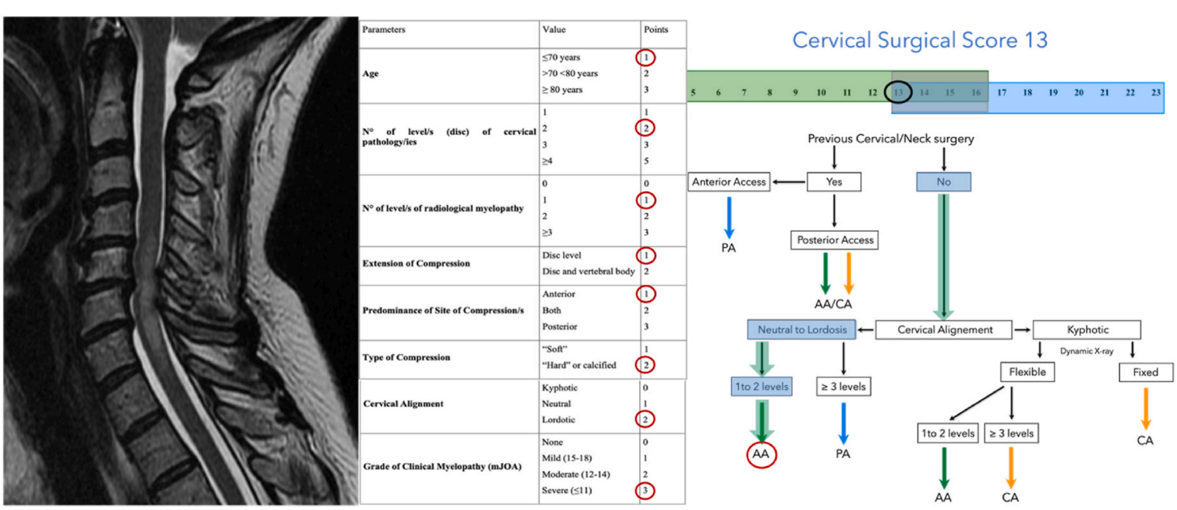

Fig. 4. Case example of CSS application in case of multiple level C5-C7 DCM in "grey zone" treated with anterior approach.

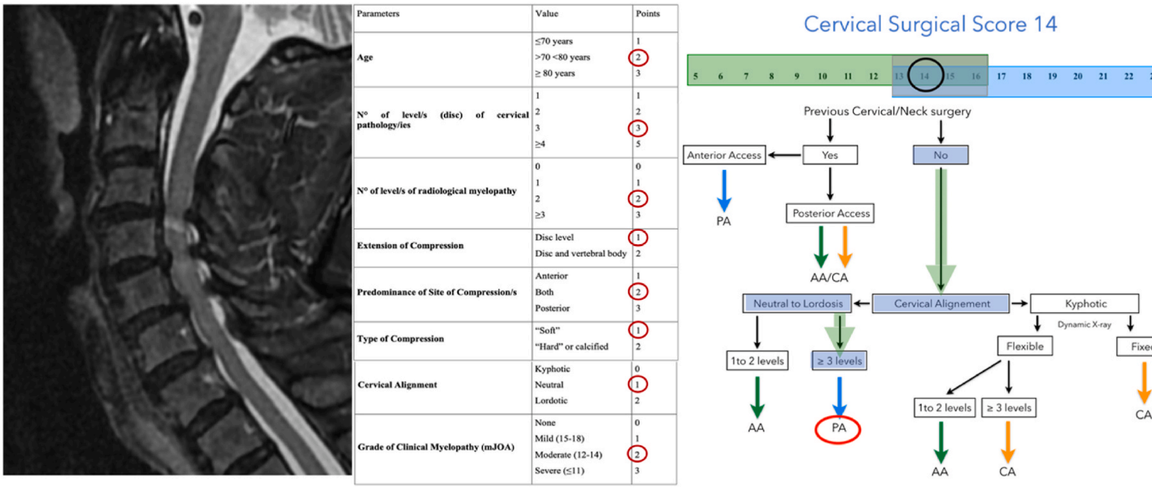

Fig. 5. Case example of CSS application in case of multiple level C5-C7 DCM in "grey zone" treated with posterior approach.

Table 2
Comparison between prospective and retrospective cohort.

	Prospective Cohort				Retrospective Cohort				
	Pre-op	1-year FU	2-years FU	Improvement at last FU	Pre-op	1-year FU	2-year FU	Improvement at last FU	p-value
Patients	113	113	113	/	106	102	96		
mJOA	13.10 ± 2.35	15.35 ± 2.31	16.3 ± 2.03	3.28 ± 2.07	12.64 ± 2.33	15.02 ± 2.05	15.59 ± 1.97	2.95 ± 1.97	**0.0003**
Nurick	2.94 ± 1.17	1.56 ± 1.16	0.86 ± 1.17	2.08 ± 1.35	3.11 ± 1.17	2.19 ± 1.39	2.06 ± 1.49	1.05 ± 1.85	**0.0003**
Neck VAS	4.24 ± 2.54	/	1.84 ± 1.55	2.4 ± 2.22	4.51 ± 2.74	/	2.19 ± 2.05	2.32 ± 2.85	0.08
Arm VAS	4.23 ± 2.26	/	1.76 ± 1.91	2.47 ± 2.43	3.52 ± 2.77	/	1.96 ± 2.02	1.56 ± 2.35	0.32
NDI	25 % ± 16 %	/	10.2 % ± 9.8 %	14.8 % ± 13 %	28.6 % ± 17.7 %	/	13.6 % ± 11.7 %	15 % ± 17 %	**0.007**
Return To Work	/	/	84 % ± 16 %	/	/	/	80 % ± 20 %	/	0.14
Return To Activity	/	/	76 % ± 24 %	/	/	/	71 % ± 31 %	/	0.11
MRI Myelopathy Reduction	/	/	/	/	/	/	72 %	/	–

4. Discussion

The choice of the more appropriate surgical approach for DCM patients remains a subject of ongoing debate, predominantly based on the individual surgeon experience and center-specific protocols. Despite extensive literature on the topic, no single surgical technique has been unequivocally proven superior (Fehlings et al., 2013; Nagashima et al., 2011; Croci et al., 2022; Moghaddamjou et al., 2020; Kato et al., 2018). Anterior approaches like ACDF or ACCF are favored for one to two-level DCM due to direct decompression advantages and lower infection rates, while posterior approaches are preferred for three or more levels due to wider decompression capabilities (Xu et al., 2017). However, no significant difference in neurological recovery has been established between these methods, although anterior surgeries show higher complication and reoperation rates (Park et al., 2023).

In a prospective analysis of 10 degenerative cervical myelopathy cases, Papavero et al. validated a seven-letter coding system (7LC) that integrates seven imaging/clinical parameters and showed strong interrater reliability (κ = 0.85) among senior surgeons, as well as a clear learning curve for junior counterparts (Papavero et al., 2020). In contrast, our CSS encompasses a broader range of clinical (e.g., age, comorbidities) and radiological factors, assigning numerical values for each parameter. Specifically, the CSS represent an innovative tool with aim to address these complexities by integrating multiple epidemiological, clinical, and radiological factors, offering a comprehensive stratification of patients that can better capture patient complexity and optimize treatment recommendations, particularly in challenging DCM cases.

Specifically, our data showed that adherence to CSS indications resulted in significantly better outcomes in long term neurological recovery rates, Nurick scores and pain improvements included as VAS and NDI scores. Patients in the concordant cohort, who were treated according to CSS recommendations, demonstrated superior recovery rates compared to those in the discordant cohort. Furthermore, patients in the prospective cohort, who adhered to the protocol in 100 % of cases, had significantly better outcomes than patients in the retrospective cohort, who adhered to the protocol in just over 70 % of cases, thus suggesting that adopting the CSS as the standard of decision-making may lead to better patient outcome. Additionally, the one- and two-year improved neurological recovery rates and a higher NDI score among the CSS-concordant cohort suggest that CSS adherence not only aids in functional recovery but also enhances neurological outcomes.

Finally, although no clear correlation has been established between the burden of radiological myelopathy and clinical status, there was a statistically significant discrepancy in patients who had myelopathy reduction at MRI between concordant and discordant cohorts (78 % vs

Table 3
Summary of clinical demographical and surgical data in CSS concordant and CSS discordant cohorts.

	Concordant Cohort	Discordant Cohort	p-value
Number of patients	**190**	**29**	/
Age	59.76 ± 12.64	62.92 ± 11.44	0.13
Sex (M/F)	123/67	19/10	0.4
ASA Score	1.34 ± 0.74	1.34 ± 0.61	0.27
Charlson	2.57 ± 1.98	2.41 ± 1.3	0.41
Symptoms Duration (days)	621.79 ± 906.25	806.1 ± 587.6	0.32
Neck VAS	4.33 ± 2.64	4.66 ± 2.66	0.65
Arm VAS	3.99 ± 2.45	3.21 ± 3	0.15
NDI	26 % ± 16 %	31 % ± 19 %	0.4
Preop Nurick	3.02 ± 1.15	3.03 ± 1.35	0.29
Preoperative mJOA	12.79 ± 2.41	13.45 ± 1.8	0.24
mJOA Grade of Clinical Myelopathy			0.11
Mild	46	11	
Moderate	90	14	
Severe	54	4	
Symptoms Type			
Pain (D)	130	19	0.42
Paresthesias (P)	114	18	0.6
Motor Issues (M)	112	17	0.91
Sphincteric Issues (S)	33	5	0.83
Levels of Cervical Pathology			0.14
1 level	74	12	
2 level	45	11	
3 level	45	6	
4+ level	16	0	
Extent of Compression			0.72
Disk	96	16	
Disk + vertebral body	94	13	
Predominance of Compression			0.08
Anterior	131	7	
Both	36	18	
Posterior	23	4	
Cervical Alignment			0.15
Kyphosis	45	5	
Lordosis	93	8	
Neutral	51	16	
Type of Compression			0.7
Soft	65	11	
Hard	124	18	
Previous Cervical Surgery	13	0	0.11
CSS	12.73 ± 3.21	12.93 ± 2.3	0.8
Duration of Surgery (min)	91.85 ± 41.74	94.14 ± 39.04	0.12
Length of Stay (days)	3.39 ± 4.92	4.66 ± 2.92	0.09
Surgeon Expertise Level	L = 39; M = 28; H = 123	L = 20; M = 9; H = 0	**0.003**
Type of Approach			**0.004**
Anterior	148	3	
ACDF	135	2	
ACCF	11	1	
CDR	0	0	
Posterior	41	26	
LWOF	30	24	
LWF	7	0	
LP	2	0	
Combined	1	0	
Other approaches	0	2	
Complications	13	6	0.06

52 %, p-value< 0.001). This significant difference aligns with the overall trend of better clinical outcomes and underscores the potential superior efficacy of CSS-guided approaches in reducing myelopathy.

A critical observation from our study is the significant disparity in surgical expertise between the concordant and discordant cohorts. High-expertise surgeons were more likely to concord with CSS recommendations, whereas low-expertise surgeons deviated more frequently. This expertise gap was statistically significant and demonstrates the hypothesis by which the CSS optimally reflects the surgical decision-making of highly experienced surgeons with high caseloads.

Based on the abovementioned analysis we could therefore specify CSS utility among the three categories of surgeon expertise.

1) Low-Experienced Surgeons: in this subgroup, the surgeon was mainly discordant with CSS, while concordant patients showed significantly better outcomes across all outcome measures, suggesting that CSS adherence is particularly beneficial for less experienced surgeons aiding their relative lack of experience.
2) Medium-Experienced Surgeons: while some outcomes remained significantly better for concordant patients, the difference was less significative compared to the low-expertise subgroup. For example, the discrepancy in the two-year neurological recovery rate did not reach statistical significance. Nonetheless, the large statistically significant discrepancy in two-year Nurick score and other measures like NDI Improvement and Arm VAS improvement suggest that CSS adherence could still offer significant benefits. This indicates that medium-expertise could enhance their results by adhering to CSS indications.
3) High-Experienced Surgeons: no comparative analysis was possible within this group due to the lack of high-expertise surgeons in the discordant cohort. However, outcomes for concordant patients treated by high-expertise surgeons were consistently high, underscoring the combined benefit of CSS adherence and surgical expertise.

Our study highlights that CSS not only aids in selecting the more appropriate surgical approach but also potentially enhances the overall standard of care supporting decision-making process in DCM. Indeed, the significant improvements in patient outcomes associated with CSS adherence suggest that its use should be encourage in low-medium experienced spinal surgeons.

Finally, while our study provides robust findings, it also presents some limitations. Firstly, the partial retrospective design introduces inherent biases such as selection bias and information bias. Secondly, the relatively small size of the medium-level surgeons in the discordant cohort may have affected the statistical significance of certain findings. Thirdly, the reliance on institutional data and the single-center nature of our study may constrain the generalizability of our results. Furthermore, while the CSS offers a structured framework for surgical decision-making, it is important to recognize that the decision-making process in DCM surgery remains inherently patient-specific. Therefore, while the CSS serves as a valuable tool for guiding discussions, particularly in complex cases, it should not supersede the indication of experienced surgeons. Instead, it should be utilized as a supplementary aid in the decision-making process.

5. Conclusion and future direction

In conclusion, the Cervical Surgical Score is an easy feasible tool that helps the decision-making process in DCM. Our results suggest that its use could improves patient outcomes particularly for surgeons with lower levels of experience. CSS allows a better pre-operative assessment of the etio-pathological features providing an overall evaluation that is essential to offer a patient specific treatment. Future directions will include a prospective multicenter international evaluation of the application of the CSS as a tool to guide the surgical management of DCM.

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Declaration of competing interest

The authors declare that they have no known competing financial

Table 4
Comparison between CSS concordant vs CSS discordant cohort.

	CSS concordant cohort				CSS discordant cohort				
	Pre-op	1-year FU	2-years FU	Improvement at last FU	Pre-op	1-year FU	2-year FU	Improvement at last FU	p-value
Patients	190	188	176	190	29	27	26	29	
mJOA	12.79 ± 2.41	15.25 ± 2.26	16.09 ± 2.01	3.3 ± 2.15	13.45 ± 1.8	14.78 ± 1.65	15.59 ± 1.97	2.14 ± 1.75	**0.0006**
Nurick	3.02 ± 1.15	1.72 ± 1.24	1.3 ± 1.35	1.72 ± 1.22	3.03 ± 1.35	2.79 ± 1.45	2.57 ± 1.68	0.46 ± 1.2	0.06
Neck VAS	4.33 ± 2.64	/	1.82 ± 1.61	2.48 ± 2.31	4.6 ± 2.66	/	3.34 ± 2.52	1.44 ± 2.26	**0.035**
Arm VAS	3.99 ± 2.45	/	1.74 ± 1.89	2.26 ± 2.4	3.21 ± 3	/	2.76 ± 2.3	0.38 ± 2.01	**0.006**
NDI	26 % ± 16 %	/	10.4 % ± 9.2 %	15.5 % ± 14.4 %	31 % ± 19 %	/	22.6 % ± 15.7 %	2.14 ± 1.75	**0.04**
Return To Work	/	/	84 % ± 34 %	/	/	/	75 % ± 43 %	/	0.2
Return To Activity	/	/	76 % ± 36 %	/	/	/	57 % ± 42 %	/	**0.015**
MRI Myelopathy Reduction	/	/	78 %	/	/	/	52 %	/	**0.04**

Table 5
Comparison between CSS concordant vs CSS discordant group subcategorized based on surgeon expertise level.

	Low-experience surgeon			Medium-experience surgeon			High-experience surgeon
Outcome	Mean in Concordant	Mean in Discordant	p-value	Mean in Concordant	Mean in Discordant	p-value	Mean in Concordant
1-year Nurick Recovery Rate	1.16	0.22	**0.003**	1.21	0.11	**0.005**	1.36
1-year Neurological Recovery Rate (%)	46.6 %	20.6 %	**0.012**	49 %	35.3 %	0.226	49.9 %
2-year Neurological Recovery Rate (%)	56.2 %	29.9 %	**0.001**	56 %	40.7 %	0.277	68.1 %
2-year Nurick Recovery Rate	1.27	0.14	**0.009**	1.35	0	**0.003**	1.89
Neck VAS Improvement	2.29	1.14	**0.003**	1.87	2.06	0.845	2.68
Arm VAS Improvement	1.83	−0.029	**0.004**	2.05	1.25	**0.04**	2.44
NDI Improvement	20 %	8.1 %	**0.011**	12 %	12 %	0.969	16.6 %
Return to Work	81.5 %	80 %	**0.026**	84.6 %	64.3 %	**0.008**	84.5 %
Return to activity	75 %	46 %	**0.003**	80.8 %	78.6 %	0.5	78.2 %

Table 6
Summarization of significant outcome discrepancies between the concordant and discordant cohorts for the low and medium expertise sub-groups.

	Low-experience surgeon			Medium-experience surgeon		
Outcome	T-test	p-value	Preserved significance	T-test	p-value	Preserved significance
1-year Nurick Recovery Rate	3.12	**0.003**	Yes	2.93	**0.005**	Yes
1-year Neurological Recovery Rate (%)	2.61	**0.012**	Yes	1.23	0.226	No
2-year Neurological Recovery Rate (%)	3.43	**0.001**	Yes	1.1	0.277	No
2-year Nurick Recovery Rate	2.73	**0.009**	Yes	3.1	**0.003**	Yes
Neck VAS Improvement	3.02	**0.003**	Yes	−0.19	0.845	No
Arm VAS Improvement	2.98	**0.004**	Yes	1.82	**0.04**	Yes
NDI Improvement	2.61	**0.011**	Yes	−0.03	0.969	No
Return to Work	2.28	**0.026**	Yes	1.44	0.5	No
Return to activity	3.12	**0.003**	Yes	2.93	**0.005**	Yes

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References

Cha, A.S., Law, E.H., Shaw, J.W., Pickard, A.S., 2019. A comparison of self-rated health using EQ-5D VAS in the United States in 2002 and 2017. Qual. Life Res. 28, 3065–3069. https://doi.org/10.1007/S11136-019-02249-Y.

Costa, F., Restelli, F., Mazzapicchi, E., et al., 2024. Proposal of a new score system (Cervical Surgical Score) for management of degenerative cervical myelopathy. J. Neurosurg. Sci. https://doi.org/10.23736/S0390-5616.23.06165-9.

Croci, D.M., Sherrod, B., Ali, Alvi M., et al., 2022. Differences in postoperative quality of life in young, early elderly, and late elderly patients undergoing surgical treatment for degenerative cervical myelopathy. J. Neurosurg. Spine 37, 339–349. https://doi.org/10.3171/2022.1.SPINE211157.

Davies, B.M., Stubbs, D., Gillespie, C.S., et al., 2023. Life expectancy in patients with degenerative cervical myelopathy is currently reduced but can be restored with timely treatment. Acta Neurochir. 165, 1133. https://doi.org/10.1007/S00701-023-05515-8.

Fehlings, M.G., Wilson, J.R., Kopjar, B., et al., 2013. 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. 95, 1651–1658. https://doi.org/10.2106/JBJS.L.00589.

Fehlings, M.G., Tetreault, L.A., Riew, K.D., et al., 2017. A clinical practice guideline for the management of patients with degenerative cervical myelopathy: recommendations for patients with mild, moderate, and severe disease and nonmyelopathic patients with evidence of cord compression. Glob. spine J. 7, 70S–83S. https://doi.org/10.1177/2192568217701914.

Hartmann, S., Tschugg, A., Obernauer, J., et al., 2016. Cervical corpectomies: results of a survey and review of the literature on diagnosis, indications, and surgical technique. Acta Neurochir. 158, 1859–1867. https://doi.org/10.1007/S00701-016-2908-Z.

Hejrati, N., Moghaddamjou, A., Marathe, N., Fehlings, M.G., 2022. Degenerative cervical myelopathy: towards a personalized approach. Can. J. Neurol. Sci. 49, 729–740. https://doi.org/10.1017/CJN.2021.214.

Hirabayashi, K., Miyakawa, J., Satomi, K., et al., 1981. Operative results and postoperative progression of ossification among patients with ossification of cervical posterior longitudinal ligament. Spine 6, 354–364. https://doi.org/10.1097/00007632-198107000-00005.

Hirayama, Y., Mowforth, O.D., Davies, B.M., Kotter, M.R.N., 2023. Determinants of quality of life in degenerative cervical myelopathy: a systematic review. Br. J. Neurosurg. 37, 71–81. https://doi.org/10.1080/02688697.2021.1999390.

Ibaez, F.A.L., Hem, S., Ajler, P., et al., 2011. A new classification of complications in neurosurgery. World Neurosurg. 75, 709–715. https://doi.org/10.1016/J.WNEU.2010.11.010.

Kato, S., Ganau, M., Fehlings, M.G., 2018. Surgical decision-making in degenerative cervical myelopathy - anterior versus posterior approach. J. Clin. Neurosci. 58, 7–12. https://doi.org/10.1016/J.JOCN.2018.08.046.

Mayo, B.C., Massel, D.H., Bohl, D.D., et al., 2016. Anterior cervical discectomy and fusion: the surgical learning curve. Spine 41, 1580–1585. https://doi.org/10.1097/BRS.0000000000001588.

Moghaddamjou, A., Wilson, J.R.F., Martin, A.R., et al., 2020. Multidisciplinary approach to degenerative cervical myelopathy. Expert Rev. Neurother. 20. https://doi.org/10.1080/14737175.2020.1798231.

Nagashima, H., Dokai, T., Hashiguchi, H., et al., 2011. Clinical features and surgical outcomes of cervical spondylotic myelopathy in patients aged 80 years or older: a multi-center retrospective study. Eur. Spine J. 20, 240. https://doi.org/10.1007/S00586-010-1672-7.

Papavero, L., Schmeiser, G., Kothe, R., et al., 2020. Degenerative cervical myelopathy: a 7-letter coding system that supports decision-making for the surgical approach. Neurospine 17, 164–171. https://doi.org/10.14245/NS.1938010.005.

Park, C., Shaffrey, C.I., Than, K.D., et al., 2023. What factors influence surgical decision-making in anterior versus posterior surgery for cervical myelopathy? A QOD analysis. J. Neurosurg. Spine 40, 206–215. https://doi.org/10.3171/2023.8.SPINE23194.

Parthiban, J., Alves, O.L., Chandrachari, K.P., et al., 2019. Value of surgery and nonsurgical approaches for cervical spondylotic myelopathy: WFNS spine committee recommendations. Neurospine 16, 403–407. https://doi.org/10.14245/NS.1938238.119.

Pedro, K.M., Alvi, M.A., Hejrati, N., et al., 2024. Machine learning-based cluster analysis identifies four unique phenotypes of patients with degenerative cervical myelopathy with distinct clinical profiles and long-term functional and neurological outcomes. EBioMedicine 106. https://doi.org/10.1016/J.EBIOM.2024.105226.

Rodrigues-Pinto, R., Montenegro, T.S., Davies, B.M., et al., 2022. Optimizing the application of surgery for degenerative cervical myelopathy [AO spine RECODE-DCM research priority number 10]. Glob. spine J. 12, 147S–158S. https://doi.org/10.1177/21925682211062494.

Tetreault, L., Kopjar, B., Nouri, A., et al., 2017. The modified Japanese Orthopaedic Association scale: establishing criteria for mild, moderate and severe impairment in patients with degenerative cervical myelopathy. Eur. Spine J. 26, 78–84. https://doi.org/10.1007/S00586-016-4660-8.

Vernon, H., 2008. The neck disability Index: state-of-the-art, 1991-2008. J. Manip. Physiol. Ther. 31, 491–502. https://doi.org/10.1016/J.JMPT.2008.08.006.

Wilson, J.R., Tetreault, L.A., Kim, J., et al., 2017. State of the art in degenerative cervical myelopathy: an update on current clinical evidence. Clin. Neurosurg. 80, S33–S45. https://doi.org/10.1093/NEUROS/NYW083.

Wilson, J.R.F., Badhiwala, J.H., Moghaddamjou, A., et al., 2023. Adverse effects of frailty on the outcomes of surgery for degenerative cervical myelopathy: results from a prospective multicenter international data set of 757 patients. J. Neurosurg. Spine 39, 815–821. https://doi.org/10.3171/2023.6.SPINE23461.

Witiw, C.D., Tetreault, L.A., Smieliauskas, F., et al., 2017. Surgery for degenerative cervical myelopathy: a patient-centered quality of life and health economic evaluation. Spine J. 17, 15–25. https://doi.org/10.1016/J.SPINEE.2016.10.015.

Xu, L., Sun, H., Li, Z., et al., 2017. Anterior cervical discectomy and fusion versus posterior laminoplasty for multilevel cervical myelopathy: a meta-analysis. Int. J. Surg. 48, 247–253. https://doi.org/10.1016/J.IJSU.2017.06.030.

Yoshimatsu, H., Nagata, K., Goto, H., et al., 2001. Conservative treatment for cervical spondylotic myelopathy: prediction of treatment effects by multivariate analysis. Spine J. 1, 269–273. https://doi.org/10.1016/S1529-9430(01)00082-1.

Yoshimoto, H., Sato, S., Hyakumachi, T., et al., 2009. Clinical accuracy of cervical pedicle screw insertion using lateral fluoroscopy: a radiographic analysis of the learning curve. Eur. Spine J. 18, 1326–1334. https://doi.org/10.1007/S00586-009-1109-3.