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Clinical Study

Comparison of outcomes after anterior versus posterior surgery for degenerative cervical myelopathy: a pooled analysis of individual patient data

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Abstract

BACKGROUND CONTEXT: Uncertainty exists regarding the optimal surgical approach to treat patients with degenerative cervical myelopathy (DCM). This uncertainty is particularly marked for patients with mild DCM who may be more sensitive to different management techniques.

PURPOSE: To determine the effect of surgical approach on one-year outcomes for DCM.

STUDY DESIGN/SETTING: Individual patient data meta-analysis of 3 independent, prospective, multicentre clinical trials (ie, CSM-North America, CSM-International, CSM-Protect) that enrolled patients between 2005 and 2018 in academic hospitals, with 1 yr follow up. Statistical analysis was performed from September 13, 2023 to April 2, 2024.

PATIENT SAMPLE: From a total of 1047 adult subjects with DCM, 980 met the eligibility criteria who were surgical candidates with symptomatic and radiologically-evidenced DCM with no prior cervical surgery.

OUTCOMES MEASURES: The primary endpoint was change in 36-Item Short Form Health Survey Physical Component Summary score (SF36-PCS; minimum clinically important difference [MCID]=4) at 1 yr compared to preoperatively. Secondary endpoints were change in modified Japanese Orthopedic Association (mJOA; MCID=2) score, Neck Disability Index (NDI; MCID=15) score, SF36 Mental Component Summary (SF36-MCS; MCID=4) score, and postoperative complications.

METHODS: Two comparison cohorts were created: i) anterior surgery and ii) posterior surgery. Mean differences (MD) of outcomes with 95% confidence intervals (CI) were estimated using one-stage covariate-adjusted hierarchical mixed-effects meta-analyses with study and treatment exposure as random effects. A *priori* subgroup analysis in mild DCM patients (mJOA=15-17) was conducted.

RESULTS: The mean patient age was 56.9 years (SD=11.4), with 38.7% that identified as female. 560 patients (57.1%) received anterior cervical decompressive surgery for DCM. Patients who had anterior decompressive surgery experienced greater improvements in quality of life and disability at 1 yr follow-up than those who underwent posterior decompressive surgery in SF36-PCS (MD=1.57 [95% CI 0.11−3.03], p=.0348) and NDI (MD=3.32 [95% CI 0.58−6.05], p=.017).

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Abbreviations: CSM-NA, Cervical Spondylotic Myelopathy-North America Study; CSM-I, Cervical Spondylotic Myelopathy-International Study; CSM-P, Cervical Spondylotic Myelopathy Protect Study; DCM, degenerative cervical myelopathy; MCID, minimum clinically important difference; MD, mean difference; mJOA, modified Japanese orthopedics association; NDI, neck disability index; OPLL, ossified posterior longitudinal ligament; SF36-PCS, 36-item short form health survey physical component summary score; SF36-MCS, 36-item short form health survey mental component summary score

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Dysphagia was more likely after anterior surgery. Pseudoarthrosis and wound infections were more likely after posterior surgery. In a subgroup of patients with mild DCM, patients who underwent anterior decompressive surgery experienced even greater improvements in SF36-PCS (MD=5.45 [95% CI 1.73−9.18], p=.0042), NDI (MD=10.37 [95%CI 3.43−17.31], p=.0035), and mJOA (MD=0.95 [95% CI 0.12−1.77], p=.0238; MCID=1) than posterior surgery patients.
CONCLUSION: Anterior surgical decompression for DCM is associated with greater improvements in 1 yr patient-reported quality of life and disability than posterior surgical decompression. These results may assist clinicians in driving complex management decisions.

Keywords: Comparative effectiveness; Clinical trial; Cervical spondylotic myelopathy; Degenerative cervical myelopathy; Functional outcomes; Patient-reported outcomes

Introduction

Degenerative cervical myelopathy (DCM) is the most common cause of spinal cord dysfunction in adults globally [1]. DCM is caused by progressive, degenerative, and non-traumatic compression of the spinal cord from age-related degeneration of the cervical vertebra, ligaments, and discs [2]. Consequently, myelopathy at the cervical spine often presents insidiously with signs such as hyperreflexia and weakness, as well as symptoms such as gait instability [3]. Based on the impact severity of the disease on function, DCM is often categorized into mild, moderate, and severe disease. Surgical decompression is considered standard of care for neurological dysfunction secondary to cord compression in moderate and severe DCM, which has been shown to effectively improve patient functional status and quality of life [4]. In mild symptomatic presentations, there remains equipoise in the guidelines on operative management with suggestions of either surgery or a supervised trial of structured rehabilitation for initial management [4]. The Institute of Medicine selected DCM as 1 of the top 100 national health priorities for comparative effectiveness research in 2009 [5].

Surgical treatment of DCM has become increasingly frequent, with anterior cervical fusion doubling and posterior fusions increasing threefold from 2001 to 2010 [6]. With over 70% of individuals over the age of 60 demonstrating radio-pathological evidence of cervical degeneration, and 25% of these patients reporting symptoms of compression [7,8], the popularity of cervical spine surgery for DCM is expected to rise. Although the effectiveness of operative interventions for DCM has repeatedly been exhibited, there remains significant controversy surrounding the optimal surgical approach. From clinical acumen, surgeons may opt for anterior cervical fusion for simple, nonmultilevel decompression and approach patients with multilevel ossified posterior longitudinal ligaments (OPLL) posteriorly. There are also geographic differences in surgical techniques. In the United States, posterior cervical decompression and fusion techniques dominate [9], while in Europe and Asia, posterior laminoplasties are widespread. Complications following surgery for DCM are common [10], with dysphagia rates reported to be as high as 71% after anterior surgeries [11].

The objective of this pooled individual patient data meta-analysis study was to assess whether an anterior surgical approach compared to a posterior surgical approach improved patient functional outcomes at 1 year for treatment of mild and symptomatic DCM.

Methods

Data sources and participant eligibility

Adult DCM patients that underwent anterior or posterior surgical decompression between 2005 and 2018 were identified using a pooled dataset comprised of the AO Spine Cervical Spondylotic Myelopathy North America (CSM-NA, ClinicalTrials.gov Identifier: NCT00285337) [12], AO Spine CSM International (CSM-I, ClinicalTrials.gov Identifier: NCT00565734) [13], and AO Spine CSM-Protect (CSM-P, ClinicalTrials.gov Identifier: NCT01257828) studies [14]. Ethics approval was obtained from each site's internal review board. Patients were enrolled into these studies if they provided written informed consent and: i) were 18 years or older; ii) had symptomatic DCM as defined by a criterion of a minimum of 1 symptom and at least 1 clinical sign of myelopathy; iii) had radiological evidence of cervical spinal cord compression; and iv) had no prior cervical spine surgery. Patients were excluded from the studies if they had asymptomatic DCM, active infection, rheumatoid arthritis, trauma, ankylosing spondylitis, concomitant lumbar stenosis, or neoplastic disease. All patients underwent cervical surgery with or without instrumentation, including anteriorly by discectomy and/or corpectomy; or posteriorly with laminectomy and fusion or laminoplasty.

Outcome measures

The primary outcome of the study was change at 1 yr in patient-reported physical functioning as measured by the 36-Item Short Form Health Survey Physical Component Summary (SF36-PCS). The SF36-PCS score cumulates patient-reported perceived physical, general health, as well as limitations in work and activities due to pain. The SF36-PCS score is graded between 0 and 100 and is calculated as population-adjusted normalized scores with a mean of 50 and standard deviation (SD) of 10. From previous literature, the meaningful clinically important difference (MCID) for SF36-PCS is 4 [15].

Secondary outcomes included change at 1 yr for modified Japanese Orthopedic Association (mJOA) scale scores, neck disability index (NDI) scores, SF36 Mental Component Summary (SF36-MCS) scores, and postoperative complications. The mJOA scale is a commonly used clinician-administrated tool to assess functional status with scores ranging from 0 (worst) to 18 (no myelopathy). The established MCID for the mJOA is 1 for mild disease, while a MCID of 2 is commonly used for moderate-severe DCM [16]. The NDI is a validated 10-item patient-reported measurement, scored from 0 to 100, created specifically to categorize the degree of disability caused by neck pain, with an MCID of 15 [17]. The SF36-MCS is graded from 0 to 100 and calculated as a population-adjusted normalized score with a mean of 50 and SD of 10, with a MCID of 4 [15]. Complications data were prospectively collected for dysphagia, hardware failure, reoperation, incidental durotomy, pseudoarthrosis, progression of myelopathy, and wound infection.

Statistical analysis

A large-scale study with pooling of individual patient data from 3 high-quality, prospective, multicenter DCM datasets was conducted. Using 1 of the largest prospective datasets on DCM, we created comparison cohorts of patients that received anterior surgical decompression (ie, cervical discectomy and fusion, corpectomy with fusion) or posterior surgical decompression (ie, laminectomy with fusion, laminoplasty). Descriptive statistics were estimated with means and SD for continuous variables and counts with percentages for categorical variables. Baseline continuous variables were compared between groups using analysis of variance and categorical variables were compared using the chi-square test. Missing outcome data at 1 yr was imputed using a within-study multiple imputation model with 40 iterations based on Markov chain Monte Carlo methods. We applied Rubin's rules at the study level prior to the pooling of study-specific estimates, which is the suggested method for random-effects individual participant data meta-analyses [18]. The missing-at-random assumption was deemed plausible based on previous studies showing patients lost to follow up after cervical spine surgery did not bias outcome assessments [19].

The primary outcome analysis compared 1 yr changes in SF-36 PCS scores between anterior and posterior surgery cohorts with a 1-stage individual patient data meta-analysis using a hierarchical mixed-effects linear regression model with study and treatment exposure as a random intercept and inverse-variance weighting [20]. The 1-stage approach was used to analyze all individual patient data in a single step, using a model that accounts for the clustering of patients within studies, which was then used to estimate mean differences (MD) with 95% confidence intervals (CI). Baseline covariates that were significantly different between groups were included as fixed effect variables in the mixed-effects model to estimate adjusted mean differences (aMD) with 95% CIs. One-stage meta-analysis methodology was used to compare secondary endpoints of 1 yr change in mJOA scores, NDI scores, and SF36-MCS scores. The secondary analysis consisted of estimation of the odds ratios (OR) for the proportion of patients that reached the MCID by surgical approach for each outcome using multilevel mixed-effects logistic regression with study as a random effect. Odds ratios were adjusted by including the same covariates as the primary analysis. Furthermore, a *priori* subgroup analysis in mild DCM patients (preoperative mJOA 15-17) was conducted.

The robustness of the findings was assessed with several sensitivity analyses. First, we conducted 2-stage meta-analyses on the outcome variables. The 2-stage sensitivity analysis involved generating study-effect estimates and variances by fitting the desired model to the data from each study, separately [21]. These effect estimates were then combined using a hierarchical mixed-effects model with hospital site as a random intercept, which was used to estimate pooled adjusted mean differences with 95% CIs [21]. I^2 heterogeneity statistic was estimated to measure the relative magnitude of the between-study and within-study variances using the DerSimonian-Laird estimator. A second sensitivity analysis was conducted using a 1-stage hierarchical mixed-effects regression model on a nonimputed dataset. All statistical analyses were conducted using R, version 4.1.1 (R Foundation for Statistical Computing, Vienna, Austria) and Stata 17 (Stata Corp, College Station, TX) at a significance level of 95% (p=.05; 2-tailed). The study methodology and results were reported following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

Results

A total of 1047 patients were identified from the 3 datasets. After following the inclusion and exclusion criteria, 980 patients were included for analysis. The mean patient age was 56.9 years (SD 11.4), with 38.7% that identified as female. 560 patients (57.1%) had anterior cervical decompressive surgery for DCM, whereas 420 patients (42.9%) underwent posterior cervical decompressive surgery (Table 1).

Upon comparing raw change in outcomes at 1 yr from baseline, patients who had anterior decompressive surgery experienced greater improvements in disability and quality of life at 1 yr follow-up than those who underwent posterior decompressive surgery in NDI score (adjusted MD 3.32 [95% CI 0.58 to 6.05], p=.017) and SF36-PCS score

Table 1
Comparison of baseline demographics, comorbidities, disease characteristics, operative characteristics, and functional scores between surgical approach cohorts

	All DCM			Mild DCM		
	Anterior (*N*=560)	Posterior (*N*=420)	p value	Anterior (*N*=139)	Posterior (*N*=43)	p value
Mean age in years (SD)	53.71 (11.05)	61.04 (10.56)	<.001	50.65 (9.48)	58.33 (10.27)	<.001
Male sex (%)	318 (56.8)	282 (67.1)	.001	84 (60.4)	35 (81.4)	.019
Race (%)			<.001			.027
White	442 (78.9)	293 (69.8)		98 (70.5)	32 (74.4)	
Black or African American	20 (3.6)	52 (12.4)		3 (2.2)	5 (11.6)	
Asian	71 (12.7)	55 (13.1)		32 (23.0)	5 (11.6)	
Other	27 (4.8)	20 (4.8)		6 (4.3)	1 (2.3)	
Comorbidities						
Diabetes (%)	43 (7.7)	43 (10.2)	.198	7 (5.0)	2 (4.7)	1.000
Hypertension (%)	123 (22.0)	126 (30.0)	.005	19 (13.7)	10 (23.3)	.207
Congestive heart failure (%)	3 (0.5)	5 (1.2)	.442	0 (0.0)	0 (0.0)	NaN
Myocardial infarction (%)	12 (2.1)	8 (1.9)	.974	1 (0.7)	0 (0.0)	1.000
Coronary artery disease (%)	23 (4.1)	18 (4.3)	1.000	2 (1.4)	1 (2.3)	1.000
Chronic obstructive pulmonary disease (%)	58 (10.4)	55 (13.1)	.220	4 (2.9)	6 (14.0)	.016
Psychiatric illness (%)	84 (15.0)	58 (13.8)	.666	15 (10.8)	5 (11.6)	1.000
Current or former smoker (%)	317 (56.6)	232 (55.2)	.717	61 (43.9)	29 (67.4)	.012
Disease characteristics						
Mean duration of symptoms in months (SD)	28.18 (43.54)	31.16 (40.37)	.273	27.26 (38.23)	29.77 (31.10)	.696
OPLL (%)	109 (19.5)	87 (20.7)	.687	28 (20.1)	11 (25.6)	.585
Operated levels (%)			<.001			<.001
One level	1 (0.2)	0 (0.0)		1 (0.7)	0 (0.0)	
Two levels	169 (30.2)	5 (1.2)		47 (33.8)	0 (0.0)	
3 or more levels	390 (69.6)	415 (98.8)		91 (65.5)	43 (100.0)	
Procedure (%)			-			-
Anterior cervical discectomy and fusion	440 (78.6)	-		113 (81.3)	-	
Anterior cervical corpectomy and fusion	120 (21.4)	-		26 (18.7)	-	
Laminectomy and fusion	-	268 (63.8)		-	30 (69.8)	
Laminectomy	-	20 (4.8)		-	0 (0.0)	
Laminoplasty	-	101 (24.0)		-	11 (25.6)	
Combined laminectomy and laminoplasty	-	31 (7.4)			2 (4.7)	
Mean preoperative mJOA score (SD)	12.87 (2.51)	11.81 (2.48)	<.001	15.76 (0.77)	15.84 (0.81)	.583
Mean preoperative SF36-PCS score (SD)	34.37 (8.89)	33.62 (9.52)	.207	39.28 (8.70)	40.93 (9.54)	.289
Mean preoperative SF36-MCS score (SD)	39.97 (13.34)	41.58 (13.58)	.065	42.59 (13.14)	43.52 (13.69)	.688
Mean preoperative NDI score (SD)	40.18 (20.14)	38.93 (20.32)	.337	31.98 (17.28)	28.19 (16.53)	.206

OPLL, ossification of the posterior longitudinal ligament; SF36, 36-item short form health survey version 2; PCS, physical component summary; MCS, mental component summary; mJOA, modified Japanese Orthopedic Association.

(adjusted MD 1.57 [95% CI 0.11 to 3.03], p=.0348). The mJOA score (adjusted MD 0.24 [95% CI −0.09 to 0.57], p=.154); and SF36-MCS score (adjusted MD −0.27 [95% CI −2.13 to 1.60], p=.789) were not significantly different (Table 2). In analyzing the proportion of patients achieving a MCID in patient-reported outcomes at 1 yr, patients undergoing anterior surgery were more likely to achieve a MCID for their NDI (OR 1.49 [95% CI 1.15 to 1.93], p=.002; aOR 1.46 [95% CI 1.08 to 1.96], p=.013) and SF36-PCS scores (OR 1.45 [95% CI 1.12 to 1.88], p=.004, aOR 1.34 [95% CI 1.00 to 1.80], p=.052) (Table 3). The rate of achieving the MCID for mJOA and SF36-MCS was

Table 2
Outcomes at 1 year follow-up by surgical approach in degenerative cervical myelopathy (one-stage meta-analyses)

Mean change (SD)	Posterior surgery (*N*=420)	Anterior surgery (*N*=560)	Unadjusted analysis		Adjusted analysis[a]	
			Mean difference (95% CI)	p value	Mean difference (95% CI)	p value
SF36-PCS score	5.24 (10.31)	7.25 (9.98)	2.01 (0.79−3.36)	.0025	1.57 (0.11−3.03)	.0348
mJOA score	2.65 (2.75)	2.46 (2.63)	−0.20 (−0.54−0.15)	.2588	0.24 (−0.09−0.57)	.1545
Neck disability Index	−10.45 (18.78)	−14.18 (19.32)	3.73 (1.30−6.13)	.0025	3.32 (0.58−6.05)	.0172
SF36-MCS score	5.77 (12.92)	6.27 (13.00)	0.50 (−1.16−2.13)	.5628	−0.27 (−2.13−1.60)	.7890

SF36, 36-item short form health survey version 2; PCS, physical component summary; MCS, mental component summary; mJOA, modified Japanese Orthopedic Association.

[a] Regression models have been adjusted for age, sex, race, hypertension, preoperative mJOA score, and number of operated spinal levels.

Table 3
Minimum clinically important difference outcomes at 1 year follow-up by surgical approach in degenerative cervical myelopathy

Count (%)	Posterior surgery (*N*=420)	Anterior surgery (*N*=560)	Unadjusted analysis		Adjusted analysis[a]	
			OR (95% CI)	p value	aOR (95% CI)	p value
Change of ≥4 in SF36-PCS score	222 (52.9)	347 (62.0)	1.45 (1.12−1.88)	.004	1.34 (1.00−1.80)	.052
Change of ≥2 in mJOA score	276 (65.7)	359 (64.1)	0.93 (0.71−1.22)	.600	1.19 (0.86−1.66)	.292
Change of ≤−15 change in NDI score	155 (36.9)	261 (46.6)	1.49 (1.15−1.93)	.002	1.46 (1.08−1.96)	.013
Change in ≥4 in SF36-MCS score	217 (51.7)	295 (52.7)	1.04 (0.81−1.35)	.737	1.04 (0.78−1.40)	.782

SF36, 36-item short form health survey version 2; PCS, physical component summary; MCS, mental component summary; mJOA, modified Japanese Orthopedic Association; OR, odds ratio; aOR, adjusted odds ratio.

[a] Regression models have been adjusted for age, sex, race, hypertension, preoperative mJOA score, and number of operated spinal levels with study as a random effect.

Table 4
Complications at 1 yr follow-up by surgical approach in degenerative cervical myelopathy

Complication	Posterior surgery (*N*=420)	Anterior surgery (*N*=560)	Adjusted Analysis[†]	
			Odds ratio (95% CI)	p value
Dysphagia	5 (1.2)	45 (8.0)	0.07 (0.03−0.18)	<.001
Hardware failure	5 (1.2)	5 (0.9)	0.95 (0.24−3.78)	.940
Reoperation	1 (0.2)	3 (0.5)	0.20 (0.02−2.18)	.188
Incidental durotomy	5 (1.2)	7 (1.3)	0.93 (0.26−3.30)	.916
Pseudoarthrosis	27 (6.4)	13 (2.3)	2.16 (1.01−4.58)	.046
Progression of myelopathy	5 (1.2)	14 (2.5)	0.41 (0.13−1.25)	.116
Wound infection	21 (5.0)	7 (1.3)	5.46 (1.87−15.94)	.002

[†] Regression models have been adjusted for age, sex, race, hypertension, preoperative modified Japanese Orthopedics Association score, and number of operated spinal levels. Odds ratios greater than 1 favor posterior surgery; less than 1 favor anterior surgery.

Table 5
Outcomes at 1 year follow-up by surgical approach in mild degenerative cervical myelopathy (one-stage meta-analyses)

Mean change (SD)	Posterior surgery (*N*=43)	Anterior surgery (*N*=139)	Unadjusted analysis		Adjusted analysis[a]	
			Mean difference (95% CI)	p value	Mean difference (95% CI)	p value
SF36-PCS score	1.06 (11.10)	7.87 (9.56)	6.80 (3.42−10.18)	.0001	5.45 (1.73−9.18)	.0042
mJOA score	−0.05 (2.54)	1.11 (1.60)	1.17 (0.49−1.85)	.0008	0.95 (0.12−1.77)	.0238
Neck disability index	−6.19 (19.13)	−13.88 (18.32)	7.70 (1.40−14.00)	.0165	10.37 (3.43−17.31)	.0035
SF36-MCS score	5.92 (11.12)	6.26 (12.83)	0.34 (−3.90−4.58)	.8843	−0.10 (−4.80−4.60)	.9698

SF36, 36-item short form health survey version 2; PCS, physical component summary; MCS, mental component summary; mJOA, modified Japanese Orthopedic Association.

[a] Regression models have been adjusted for age, sex, race, smoking status, chronic obstructive pulmonary disease, and number of operated spinal levels.

not significantly different between surgical approaches (Table 3). Upon comparing complications between surgical approaches at 1 yr, overall rates of complications were low. Patients who underwent posterior decompressive surgery were more likely to experience pseudoarthrosis (adjusted OR 2.16 [95% CI 1.01-4.58], p=.046) and wound infection (adjusted OR 5.46 [95% CI 1.87-15.94], p=.002) and less likely to experience dysphagia (adjusted OR 0.07 [95% CI 0.03-0.18], p<.001) compared to anterior surgery (Table 4).

In 182 patients with mild DCM, patients who underwent anterior decompressive surgery experienced greater clinically important improvements in SF36-PCS scores at 1 yr follow-up (adjusted MD 5.45 [95% CI 1.73 to 9.18], p=.0042) compared to those that had posterior surgical decompression (Table 4). At 1 yr after anterior surgery, patients with mild DCM also experienced greater improvements in mJOA score (adjusted MD 0.95 [95% CI 0.12 to 1.77], p=.0238) as well as NDI score (adjusted MD 10.37 [95% CI 3.43 to 17.31], p=.0035) as compared to posterior surgery patients (Table 4). SF36-MCS score (adjusted MD −0.10 [95% CI −4.80 to 4.60], p=.9698) was not found to be significantly different (Table 5).

In the sensitivity analysis, 2-stage meta-analyses showed consistent findings of improved functional status and patient-reported physical function in mild DCM patients that were surgically approached anteriorly compared to posteriorly, with similar effect sizes to the 1-stage meta-analyses (Fig. 1). For all primary analyses, there was no heterogeneity detected in the treatment effect (I^2=0). Moreover, results were consistent when multiple imputation was omitted for missing outcome data at 1 yr.

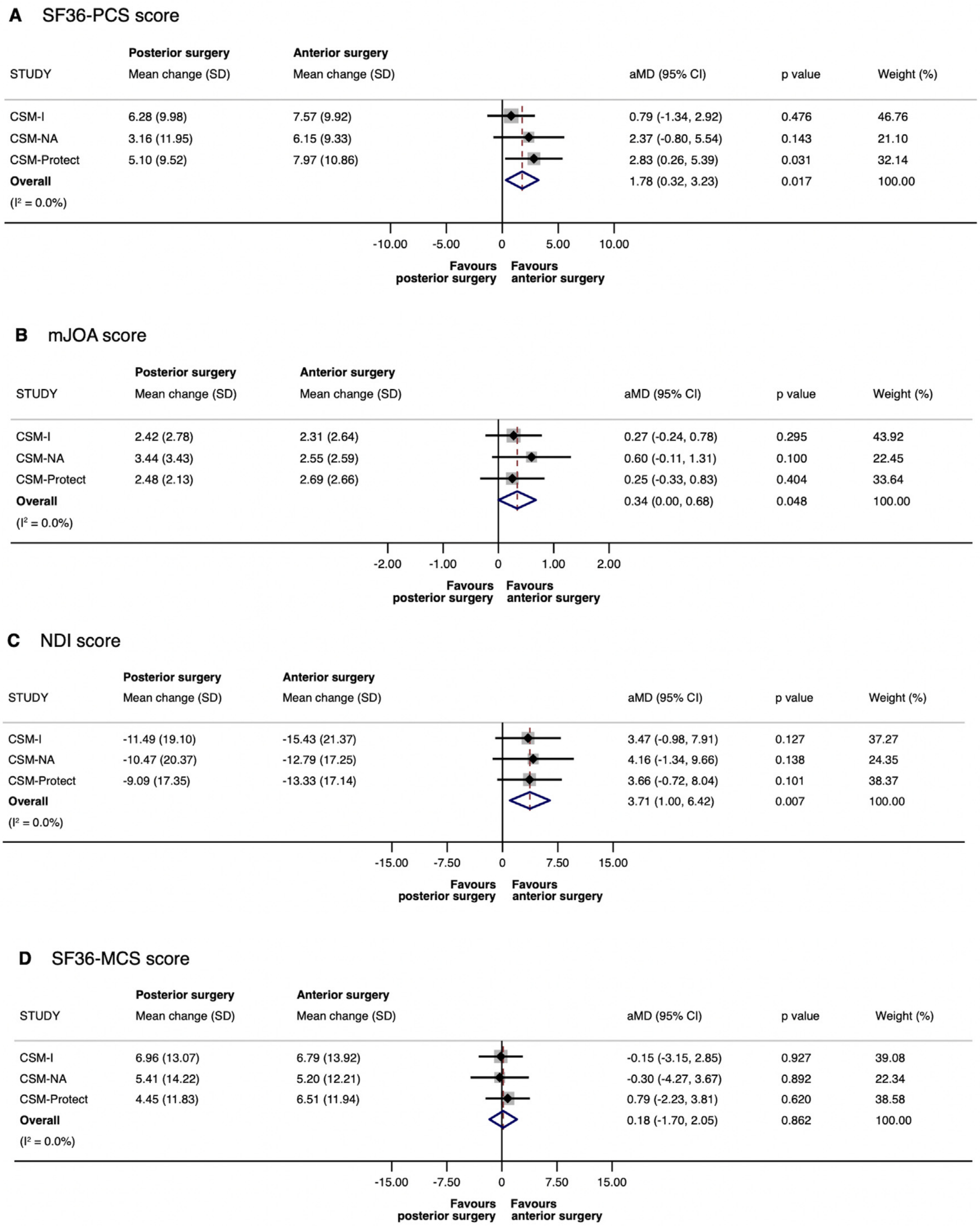

Fig. 1. Two-stage hierarchical mixed-effects meta-analysis of surgical approach in degenerative cervical myelopathy. (A) Pooled estimates of SF36-PCS score; (B) Pooled estimates of mJOA score; (C) Pooled estimates of NDI score; (D) Pooled estimates of SF36-MCS score. SF36, short form health survey, version 2; PCS, physical component summary; MCS, mental component summary; SD, standard deviation; aMD, adjusted mean difference; CI, confidence interval; CSM-*I*, Cervical Spondylotic Myelopathy-International clinical study; CSM-NA, Cervical Spondylotic Myelopathy-North America clinical study; CSM-Protect, Cervical Spondylotic Myelopathy-Protect randomized clinical trial.

We further analyzed components of NDI and SF-36 PCS to investigate the potential factors behind the difference in these outcomes between the 2 groups. We found that for NDI, the 2 components of NDI that differed significantly between anterior and posterior were "pain intensity" (NDI question 1) and "recreational activities" (NDI question 10) (Fig. 2). At baseline, 31% of patients undergoing posterior surgery and 34% of patients undergoing anterior surgery had fairly severe, very severe or worst imaginable pain. After 1 year, these numbers decreased to 12% and 11% for

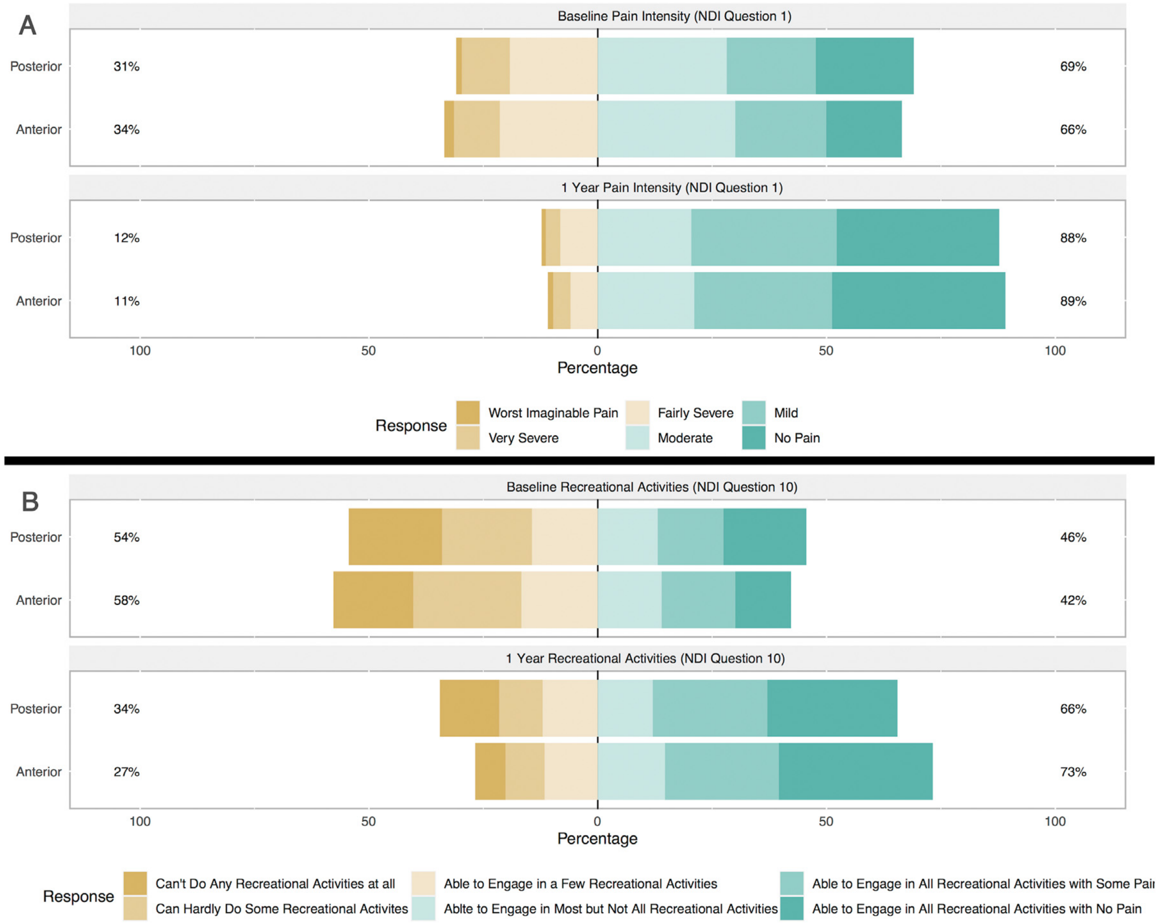

Fig. 2. Bar charts of Neck Disability Index (NDI) questions 1 and 10 for anterior versus posterior surgical cohorts for degenerative cervical myelopathy.

posterior and anterior, respectively (p=.020). Moreover, at baseline, 54% of patients undergoing posterior surgery and 58% of patients undergoing anterior surgery reported that due to their neck pain, they were either able to engage in few recreational activities, could hardly engage in any recreational activities or could not engage in any recreational activities at all. These numbers decreased to 34% and 27% for posterior and anterior surgery, respectively, after 1 year (p<.001).

For SF36-PCS, the most pronounced changes were found to be for vigorous activities, moderate activities and ability to walk more than a mile and half a mile (Fig. 3). Among patients undergoing posterior surgery, at baseline, 79%, 17% and 4% reported that their vigorous activities were significantly limited, limited a little while and not limited at all, respectively. These numbers changed to 66%, 26% and 8% 1 yr after surgery. In contrast, for patients undergoing anterior surgery, at baseline 82%, 14% and 4% reported that their vigorous activities were significantly limited, limited a little and not limited at all, respectively. These numbers changed to 55%, 36% and 9% 1 yr after surgery (p=.016). Similarly, at baseline, 79%, 17% and 4% of patients undergoing posterior surgery reported that they were significantly limited, limited a little and not limited at all in their moderate activities which changed to 66% 26% and 8% 1 yr after surgery. On the other hand, for those undergoing anterior surgery, at baseline 82%, 14% and 4% reported that their moderate activities were significantly limited, limited a little and not limited at all, respectively; these numbers changed to 55%, 36% and 9% 1 yr after surgery (p=.018). Furthermore, when asked about their ability to walk more than a mile, for patients undergoing posterior surgery, at baseline, 61%, 20% and 19% reported that it was significantly limited, limited a little and not limited at all, respectively. These numbers changed to 45%, 29% and 26% 1 yr after surgery. In contrast, for patients undergoing anterior surgery, at baseline 54%, 29% and 16% reported that their ability to walk a mile was significantly limited, limited a little and not limited at all, before surgery which changed to 33%, 31% and 37% 1 yr after surgery (p=.009).

Discussion

We describe 1 of the largest prospective analyses to date, using data from 3 high-quality prospective studies, investigating the influence of surgical approach on patient outcomes in DCM. We found that anterior approach was associated with superior recovery of disability and quality

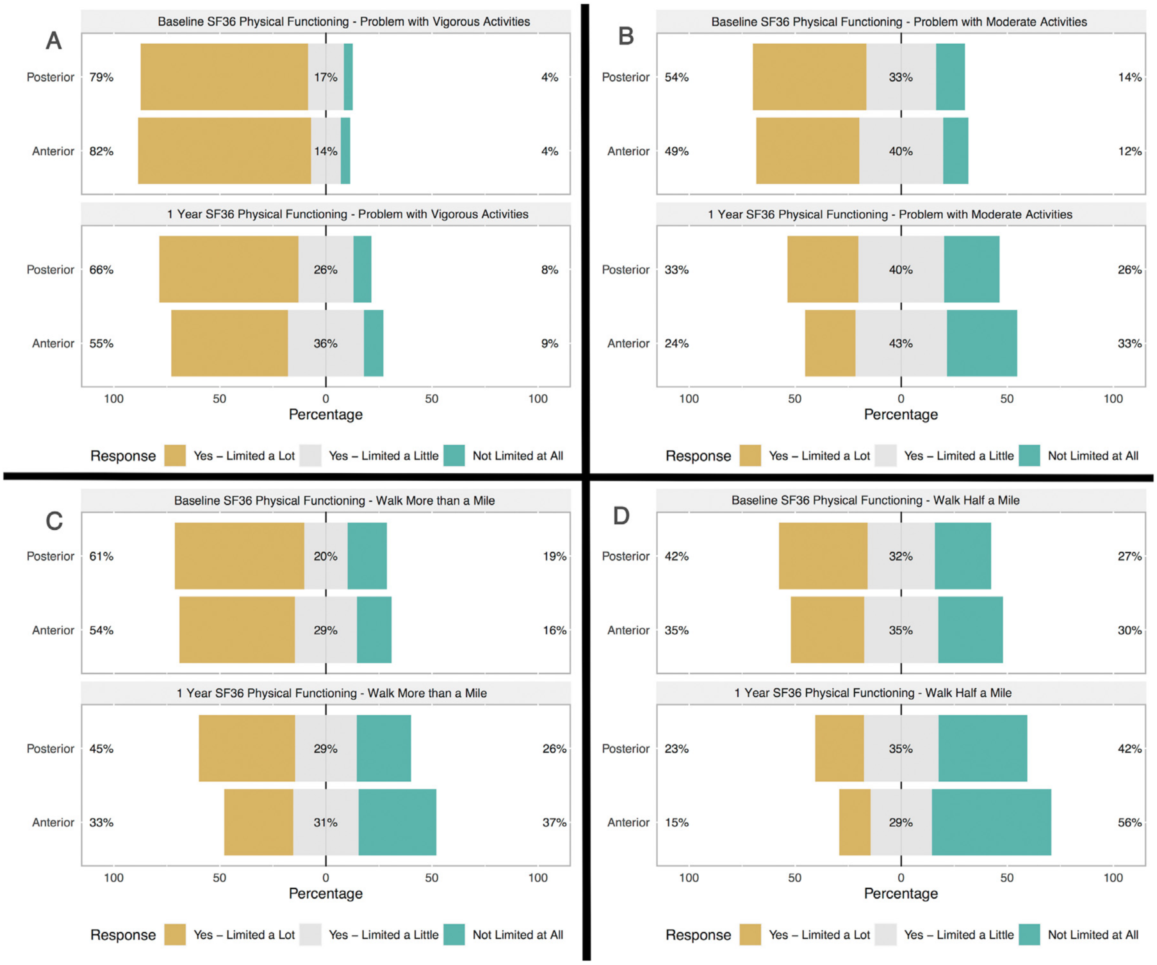

Fig. 3. Bar charts of Short Form Health Survey Physical Component Summary (SF36-PCS) components for anterior versus posterior surgical cohorts for degenerative cervical myelopathy.

of life at 1 year after surgery. The magnitude of the difference in recovery was greater in mild DCM. Furthermore, we were able to determine that recovery of disability was driven by improvement in pain and ability to engage in recreational activities, while recovery in quality of life was driven by engagement in vigorous and moderate activities as well as ability to walk.

Previous studies comparing outcomes of anterior vs posterior surgical approach for patients with cervical myelopathy have been equivocal. The only randomized trial on this topic to date was reported by Ghogawala et al in 2021. Their study found no difference in SF36, mJOA, EQ5D and NDI at 2 years between the 2 groups [22]. Sattari et al [23] recently published a systematic review and meta-analysis of 19 studies investigating the difference in outcomes between ACDF and posterior decompression procedures. Notably, they excluded studies that included patients with OPLL and those that included patients undergoing corpectomy. The overall meta-analysis, similar to Ghogawala et al's trial, found no difference in any of the PROs including mJOA, NDI, SF36, VAS and EQ5D. However, in a subgroup analysis of 6 studies comparing only ACDF and posterior fusion, the authors found that ACDF was associated with higher change in NDI. In a recent real-world study by Wilkerson et al using the Quality Outcomes Database, the authors noted superior change in NDI for patients undergoing anterior surgery at 3 and 12 months, and superior change in quality of life (using EQ5D) at 3 months [24]. The latter 2 results are consistent with our results indicating that anterior surgery may be associated with higher long term improvement in disability measures as well as quality of life.

We found that the smaller recovery of NDI scores for the posterior surgery cohort was driven largely by pain and engagement with activities. Postoperative neck pain has long been recognized as an expected outcome for posterior cervical surgery, particularly in the immediate postoperative period [25]. This is also why posterior surgery has been found to result in longer length of stay in the hospital [23]. However, some studies have noted longer term neck pain, particularly for patients undergoing laminoplasty, where 1 study reported long term neck pain in up to 70% of patients

[26]. In a recent study by Kholinne et al [27], of 862 patients undergoing cervical spine surgery, a posterior approach was found to be an independent risk factor for postoperative shoulder pain. Duetzmann et al [25] opined that this may be due to the fact that posterior cervical surgery requires exposure and dissection of 2 fascial layers, namely the trapezius muscle fascia and the deep cervical fascia. Since these fasciae are typically stitched together, stress on 1 fascia postoperatively affects the other fascia. Thus, neck pain following surgery may result from either fascia.

Our finding that patients with posterior surgery were less likely to be engaged in activities and were less likely to be able to walk is also interesting. In a prospective observational study by Ghogawala et al, [28] anterior surgery was found to be associated with superior improvement in health-related quality of life and superior reduction in neck pain. Hence, it is reasonable to suggest that lower improvement in pain among patients undergoing posterior surgery may be associated with lower scores in terms of engagement in activities and their ability to walk.

Our analysis of complication rates after anterior or posterior surgery fit the trends reported in prior literature. Dysphagia is commonly associated with anterior surgery [29]. Our findings suggest that the posterior approach had a greater odds of wound infection and pseudoarthrosis compared to the anterior approach. Elevated wound infection complications with posterior surgery are well-reported, which may be attributed to increased length of stay, pressure on wound, and a more elaborate multilayer closure with tension [29,30]. The finding of pseudoarthrosis may be explained partly by its association with surgical site and wound infections, and sometimes occult infection [30−32].

Overall, while our analyses suggest greater improvement in pain and quality of life for anterior surgery compared to posterior surgery, the objective of the study is not to strictly advocate for 1 approach over the other. The decision to favor 1 approach over the other may be influenced by several other factors that were not controlled for or reported in this study, including radiographic factors. However, these results may nevertheless help set postoperative expectations for patients.

Limitations

Our study has some limitations. One limitation is that patients were not randomly assigned to anterior and posterior decompressive surgery groups. However, the data were collected in a thorough prospective fashion and a rigorous approach to match patients to deal with potential confounders was undertaken. An additional limitation is that we were unable to report numeric rating score (NRS) for neck and arm pain, which were only captured in the CSM-P trial and not the CSM-NA and CSM-I trials. However, other techniques to assess pain outcomes, specifically by examining subscores of the NDI, were available for analysis. Furthermore, future studies may benefit from collecting granular details of the complication severity, such as of dysphagia and whether reoperation was revision or nonrevision surgery in nature. Our study is limited by the outcomes measured. Future studies are needed to explore the effects of approach on other relevant findings such as spinal cord signal changes.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Alex B. Bak: Writing − review & editing, Writing − original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Mohammed Ali Alvi:** Writing − review & editing, Writing − original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ali Moghaddamjou:** Writing − review & editing, Writing − original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Michael G. Fehlings:** Writing − review & editing, Writing − original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

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