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Association of Degenerative Cervical Spondylolisthesis with Clinical Presentation and Surgical Outcomes in Degenerative Cervical Myelopathy: A Single-Centre Retrospective Cohort Study

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Abbreviations: ACCF, anterior cervical corpectomy and fusion; ACDF, anterior cervical discectomy and fusion; ASA, American Society of Anesthesiologists; DCM, degenerative cervical myelopathy; DCS, degenerative cervical spondylolisthesis; IQR, interquartile range; mJOA, modified Japanese Orthopaedic Association; NDI, Neck Disability Index; NRS, Numeric Rating Scale; OPLL, ossification of the posterior longitudinal ligament; SCOR, Spinal Cord Occupation Ratio.

Abstract

Purpose: The clinical significance of degenerative cervical spondylolisthesis (DCS) in patients undergoing surgery for degenerative cervical myelopathy (DCM) remains unclear. We examined its association with clinical presentation, operative strategy, and postoperative outcomes.

Methods: We retrospectively analysed prospectively collected data from 102 surgically treated patients with DCM (2013–2024), stratified by the presence of DCS on preoperative MRI. Neurological and patient-reported outcomes were evaluated before surgery, at 3–4 months, and at 1 year. Between-group comparisons were exploratory and unadjusted.

Results: DCS was identified in 18 patients (17.6%). Patients with DCS were older (median 61.0 vs 56.5 years; p = 0.014) and had lower preoperative mJOA scores (13.0 vs 14.0; p = 0.006). Anterior surgery was less frequent (55.6% vs 85.7%; p = 0.007), whereas posterior surgery was more frequent (38.9% vs 13.1%; p = 0.016). Constructs included more levels (median 3 vs 2; p = 0.001). At 1 year, median mJOA remained lower in patients with DCS (14.5 vs 16.0; p = 0.040), but neither change in mJOA from baseline nor Hirabayashi recovery rate differed significantly between groups (p = 0.752 and p = 0.328, respectively).

Conclusion: DCS was associated with worse baseline neurological function and more extensive surgical treatment. Although absolute postoperative mJOA was lower, neurological improvement was observed in both groups. Larger adjusted studies are needed to establish whether DCS independently influences surgical outcomes.

Keywords: Degenerative cervical myelopathy; Degenerative cervical spondylolisthesis; Cervical spine surgery; Neurological recovery; Surgical outcomes

Introduction

Degenerative cervical myelopathy (DCM) is a common cause of spinal cord dysfunction in adults and a major indication for cervical spine surgery [15]. The pathogenesis of DCM is multifactorial, involving static and dynamic factors that progressively compromise the spinal cord.

Although intervertebral disc collapse, osteophyte formation, ligamentum flavum hypertrophy, and ossification of the posterior longitudinal ligament are well-recognised contributors to spinal cord compression, the role of degenerative cervical spondylolisthesis (DCS) remains less clearly defined [4, 7, 11]. DCS may reflect segmental instability, altered sagittal alignment, and abnormal spinal biomechanics, potentially contributing to spinal canal narrowing and repetitive mechanical stress on the spinal cord [8].

Several questions remain unresolved. It is unclear whether DCS contributes independently to clinical myelopathy or is primarily a marker of more advanced degeneration. Its association with postoperative outcomes is also debated [6, 12, 21]. In addition, relatively little evidence is available on how the presence of DCS relates to surgical decision-making in patients with DCM.

We therefore aimed to compare the clinical presentation, radiological features, surgical strategies, and postoperative outcomes of surgically treated patients with DCM according to the presence or absence of DCS.

Materials and methods

Study Design and Patient Population

We performed a retrospective, single-centre observational cohort analysis at Geneva University Hospitals (Geneva, Switzerland), using a prospectively maintained institutional database. Consecutive patients who underwent surgical treatment for DCM between 2013 and 2024 were screened. Inclusion criteria were (1) DCM diagnosed on clinical and radiological grounds, (2) available preoperative MRI, and (3) complete clinical outcome data at both early (3–4-month) and 1-year follow-up. Exclusion criteria were a non-degenerative aetiology (trauma, infection, or tumour), previous cervical spine surgery, or incomplete 1-year follow-up. Biological sex, recorded as male or female, was extracted from medical records.

This cohort has previously been described in an analysis comparing anterior and posterior surgical approaches [1]. The present secondary analysis instead evaluates associations with preoperative DCS status.

Definition of Degenerative Cervical Spondylolisthesis

DCS was defined as any anterior or posterior displacement of a cervical vertebral body relative to the adjacent caudal vertebra identified on static preoperative MRI in the neutral position. Diagnosis was established by the operating neurosurgeon based on review of sagittal T2-weighted sequences, without application of a minimum displacement threshold, consistent with the qualitative MRI-based approach adopted by Nouri et al.[13]

Radiological Assessment

All patients underwent preoperative cervical spine MRI. MRI evaluation included assessment of T1- and T2-weighted sagittal intramedullary signal changes and the level of maximal cord compression. Cord and canal compromise were quantified as dimensionless ratios using the following formulae: cord compromise = 1 − (sagittal cord diameter at the level of maximal compression / mean sagittal cord diameter at adjacent unaffected segments); canal compromise = 1 − (sagittal canal diameter at the level of maximal compression / mean sagittal canal diameter at adjacent unaffected segments). A ratio of 0 indicates no compromise, while a value approaching 1 indicates near-complete obliteration of the respective space. Compression morphology was classified as anterior, posterior, or circumferential. Associated pathologies were recorded, including ligamentum flavum hypertrophy, ossification of the posterior longitudinal ligament (OPLL), multilevel or isolated disc pathology, and congenital stenosis.

Congenital cord–canal mismatch was assessed using the Spinal Cord Occupation Ratio (SCOR), defined as the ratio of the mean sagittal cord diameter to the mean sagittal canal diameter, both measured at segments adjacent to the level of maximal compression.[14] A prespecified cut-off of SCOR ≥0.70 was used to identify patients with anatomical predisposition to spinal cord injury, as previously validated.[14]

Sagittal cervical alignment was measured using the C2–C7 Cobb angle on standing lateral radiographs and classified as normal (10°–40°), hyperlordotic (≥40°), or kyphotic (≤10°).

Surgical Technique and Approach

The surgical approach was determined by the operating neurosurgeon based on the level and pattern of compression, sagittal alignment, number of affected levels, and individual patient factors. Anterior approaches included anterior cervical discectomy and fusion (ACDF) and anterior cervical corpectomy and fusion (ACCF). Posterior approaches included laminectomy with or without instrumented fixation. A combined anterior–posterior approach was used in selected cases. The number of levels included in the construct was recorded for each patient.

Clinical Outcome Measures

The primary outcome was the modified Japanese Orthopaedic Association (mJOA) score (17-point Keller scale [9], range 0–17), assessed preoperatively and at each follow-up. Neurological recovery was also expressed using the Hirabayashi recovery rate [5]: (postoperative mJOA − preoperative mJOA) / (17 − preoperative mJOA) × 100. This represents the proportion of the maximum possible neurological gain achieved after surgery. Patients with preoperative mJOA = 17 were excluded from this calculation to avoid division by zero.

Secondary outcome measures were the Neck Disability Index (NDI, 0–100%) and the Numeric Rating Scale for arm pain (NRS arm, 0–10). For both NDI and NRS, a reduction from baseline indicates clinical improvement. All outcomes were assessed at two time points: early postoperative follow-up at 3–4 months and one-year follow-up.

Complication Assessment

Perioperative and postoperative complications were systematically recorded, including: postoperative haematoma, surgical site infection, cerebrospinal fluid leak, C5 palsy, dysphagia, dysphonia, Horner syndrome, postoperative kyphosis, implant-related complications, and incomplete decompression. Dysphagia was considered as acute, persistent or chronic if still present at hospital discharge, at 3-months and 1-year follow-up, respectively. The 30-day reoperation rate was recorded. The overall complication burden is reported both as the number of patients experiencing at least one complication and as the total number of complication events, as a single patient may sustain more than one complication.

Statistical Analysis

Continuous variables were assessed for normality using the Shapiro–Wilk test. As most continuous or ordinal variables (mJOA, NDI, NRS, ASA score, operated levels, cord and canal compromise ratios, age, and symptom duration) were non-normally distributed, they are summarised as median (interquartile range [IQR]) and compared using the Mann–Whitney U test. BMI, the only normally distributed variable, is presented as mean ± standard deviation and compared with the

independent-samples t-test. Within-group changes from baseline were assessed using the Wilcoxon signed-rank test. Categorical data are reported as numbers (percentages) and compared using Fisher's exact test because of small expected cell counts in the DCS group. Two-sided p values < 0.05 were considered statistically significant; p values from 0.05 to < 0.10 were described as borderline and interpreted cautiously. Analyses were performed in jamovi (version 2.7.14; The jamovi Project, 2025). Owing to the exploratory design and small DCS subgroup, no multivariable adjustment or correction for multiple comparisons was performed.

Results

Patient Demographics and Baseline Characteristics

A total of 102 patients met the inclusion criteria: 18 (17.6%) with DCS and 84 (82.4%) without DCS (Table 1). Patients with DCS were older (median age 61.0 vs 56.5 years; p = 0.014). There were no statistically significant between-group differences in male sex (44.4% vs 52.4%; p = 0.609), BMI (25.0 ± 4.1 vs 27.1 ± 4.7 kg/m²; p = 0.086), ASA score (median 2.0 in both groups; p = 0.659), or symptom duration (median 11.0 vs 6.0 months; p = 0.121). The distribution of isolated myelopathy versus myeloradiculopathy was similar (p = 0.774), as were the assessed comorbidities (all p > 0.10).

Table 1. Baseline demographic and clinical characteristics by spondylolisthesis status.

Variable	Spondylolisthesis (n=18)	No Spondylolisthesis (n=84)	p-value
Demographics			
Age (years), median (IQR)	61.0 (55.8–74.8)	56.5 (47.8–64.0)	0.014*
Male sex, n (%)	8 (44.4%)	44 (52.4%)	0.609
BMI (kg/m²), mean ± SD	25.0 ± 4.1	27.1 ± 4.7	0.086
ASA score, median (IQR)	2.0 (2.0–3.0)	2.0 (2.0–3.0)	0.659
Duration of symptoms (months), median (IQR)	11.0 (5.2–13.0)	6.0 (3.0–13.0)	0.121
Clinical Presentation			
Myelopathy only, n (%)	14 (77.8%)	61 (72.6%)	0.774
Myeloradiculopathy, n (%)	4 (22.2%)	23 (27.4%)	0.774
Comorbidities			
Diabetes, n (%)	5 (27.8%)	15 (17.9%)	0.339
Cardiac comorbidities, n (%)	11 (61.1%)	39 (46.4%)	0.305
Respiratory comorbidities, n (%)	3 (16.7%)	23 (27.4%)	0.552
Osteoporosis, n (%)	3 (16.7%)	5 (6.0%)	0.146
Smoking, n (%)	7 (38.9%)	36 (42.9%)	0.799

*p < 0.05. Continuous variables compared with the Mann–Whitney U test (median, IQR), except BMI (independent t-test, mean ± SD); categorical variables with the Fisher exact test. IQR: interquartile range; BMI: body mass index; ASA: American Society of Anesthesiologists; SD: standard deviation.

Radiological Findings

Radiological findings are summarised in Table 2. T2 intramedullary signal change was present in the majority of both groups (88.9% vs. 83.3%; p = 0.731), while T1 signal change was absent in all spondylolisthesis patients (0% vs. 4.8%; p = 1.000). Ligamentum flavum hypertrophy showed a borderline trend toward greater frequency in the DCS group (55.6% vs. 31.0%; p = 0.060). Isolated disc pathology was less common in the DCS group (11.1% vs. 36.9%; p = 0.050), while multilevel disc pathology was numerically more prevalent (77.8% vs. 60.7%; p = 0.279), consistent with a more advanced and diffuse degenerative pattern. Congenital stenosis (SCOR ≥0.70) showed a borderline trend toward greater prevalence in the DCS group (22.2% vs. 7.1%; p = 0.073).

Sagittal alignment did not differ significantly between groups. The median C2–C7 Cobb angle was 11.1° versus 9.8° (p = 0.902). A kyphotic profile was observed in 8/17 patients with DCS (47.1%) and 40/80 without DCS (50.0%; p = 1.000). Normal lordotic alignment was seen in 9/17 (52.9%) and 38/80 (47.5%), respectively; only two control patients (2.5%) were classified as hyperlordotic. Cord and canal compromise ratios were also similar (p = 0.632 and p = 0.214, respectively).

Importantly, spondylolisthesis was never identified as an isolated radiological finding in this cohort: all 18 DCS patients presented with at least one concomitant degenerative pathology. The most frequent associated condition was multilevel disc pathology, present in 14/18 patients (77.8%), followed by ligamentum flavum hypertrophy in 10/18 (55.6%) and congenital stenosis in 4/18 (22.2%). Only 2 patients (11.1%) had isolated disc pathology as the sole additional finding, and no patient had OPLL. In terms of combination patterns, 7 patients (38.9%) had spondylolisthesis combined with both multilevel disc pathology and ligamentum flavum hypertrophy, 5 patients (27.8%) presented with multilevel disc pathology as the only additional finding, and 3 patients (16.7%) had spondylolisthesis coexisting with multilevel disc disease and congenital stenosis.

Table 2. Preoperative radiological characteristics by spondylolisthesis status.

Radiological Variable	Spondylolisthesis (n=18)	No Spondylolisthesis (n=84)	p-value
T2 signal change, n (%)	16 (88.9%)	70 (83.3%)	0.731
T1 signal change, n (%)	0 (0.0%)	4 (4.8%)	1.000
Ligamentum flavum hypertrophy, n (%)	10 (55.6%)	26 (31.0%)	0.060†
Multilevel disc pathology, n (%)	14 (77.8%)	51 (60.7%)	0.279
Isolated disc pathology, n (%)	2 (11.1%)	31 (36.9%)	0.050†
OPLL, n (%)	0 (0.0%)	2 (2.4%)	1.000
Congenital stenosis (SCOR ≥0.70), n (%)	4 (22.2%)	6 (7.1%)	0.073†
Kyphotic sagittal profile, n (%)[1]	8/17 (47.1%)	40/80 (50.0%)	1.000
Cord compromise ratio, median (IQR)	0.28 (0.16–0.34)	0.31 (0.19–0.41)	0.632
Canal compromise ratio, median (IQR)	0.46 (0.40–0.56)	0.54 (0.42–0.60)	0.214

†Borderline significance ($0.05 \le p < 0.10$). [1]Sagittal profile data available for 17/18 spondylolisthesis patients and 80/84 controls (missing lateral radiographs in 1 and 4 patients respectively). Categorical variables compared with the Fisher exact test; ratios with the Mann–Whitney U test. OPLL: ossification of the posterior longitudinal ligament. SCOR: Spinal Cord Occupation Ratio = mean sagittal cord diameter / mean sagittal canal diameter at segments adjacent to maximal compression; ≥0.70 indicates congenital cord–canal mismatch.

Surgical Approach and Extent of Surgery

Surgical approaches differed between groups (Table 3, Fig. 1). Anterior surgery was less frequent in patients with DCS (55.6% vs 85.7%; p = 0.007), whereas posterior surgery was more frequent (38.9% vs 13.1%; p = 0.016). Surgical constructs involved more levels in the DCS group (median 3.0 vs 2.0; p = 0.001).

Table 3. Surgical approach and extent of surgery by spondylolisthesis status.

Surgical Variable	Spondylolisthesis (n=18)	No Spondylolisthesis (n=84)	p-value
Anterior approach, n (%)	10 (55.6%)	72 (85.7%)	0.007**
Posterior approach, n (%)	7 (38.9%)	11 (13.1%)	0.016*
Combined approach, n (%)	1 (5.6%)	1 (1.2%)	0.323
Levels included, median (IQR)	3.0 (2.0–3.8)	2.0 (1.0–2.0)	0.001***

*$p < 0.05$; **$p < 0.01$; ***$p \le 0.001$. Categorical variables: Fisher's exact test; levels included: Mann–Whitney U test (median, IQR).

Preoperative Clinical Outcomes

Patients with DCS presented with significantly worse preoperative neurological function, reflected by a lower median mJOA score (13.0 vs. 14.0; p = 0.006). NDI showed a borderline trend toward greater disability in the DCS group (median 41.1% vs. 27.4%; p = 0.056), indicating higher functional impairment at baseline. Preoperative NRS arm pain was similarly low in both groups (both median 0.0; p = 0.639), consistent with the predominance of myelopathic rather than radicular symptoms.

Early follow-up (3–4 months)

At early follow-up, patients with spondylolisthesis continued to show a significantly lower median mJOA score compared with those without (14.0 vs. 15.0; p = 0.040), and their median NDI remained significantly higher (34.2% vs. 20.0%; p = 0.037), indicating greater residual disability. However, the magnitude of neurological improvement from baseline was similar between groups (delta mJOA: median 1.0 in both; p = 0.368), and the Hirabayashi recovery rate was also comparable (35.4% vs. 40.0%; p = 0.611). NRS arm pain did not differ significantly between groups (p = 0.450).

One-year follow-up

At 1 year, patients with DCS had lower absolute mJOA scores than patients without DCS (median 14.5 vs 16.0; p = 0.040; Table 4, Figs. 2–4). However, the observed median improvement from baseline (ΔmJOA) was 1.0 point in both groups (p = 0.752), and the Hirabayashi recovery rate was 41.7% versus 53.6% (p = 0.328). Thus, no statistically significant between-group difference in the measured recovery indices was detected; these results do not establish equivalence. One-year NDI and NRS arm pain were also not significantly different (p = 0.241 and p = 0.297, respectively).

Within-group analysis confirmed statistically significant mJOA improvement at 1-year in both the spondylolisthesis group (p = 0.004) and the DCS-negative group (p < 0.001). In the DCS-negative group, NDI and NRS arm pain also improved significantly (p = 0.004 and p < 0.001, respectively). In the spondylolisthesis group, neither reached significance (NDI p = 0.256; NRS p = 0.066).

Table 4. Clinical outcomes at preoperative, 3–4 month, and 1-year follow-up by spondylolisthesis status.

Outcome	Spondylolisthesis (n=18)	No Spondylolisthesis (n=84)	p (between)	p (within)
Preoperative — median (IQR)				
mJOA	13.0 (11.0–14.0)	14.0 (12.0–16.0)	0.006**	—
NDI (%)	41.1 (23.0–57.2)	27.4 (16.0–45.0)	0.056†	—
NRS arm	0.0 (0.0–0.0)	0.0 (0.0–3.0)	0.639	—

Outcome	Spondylolisthesis (n=18)	No Spondylolisthesis (n=84)	p (between)	p (within)
3–4 Month Follow-up — median (IQR)				
mJOA	14.0 (12.0–15.0)	15.0 (14.0–16.0)	0.040*	—
NDI (%)	34.2 (22.5–48.0)	20.0 (7.5–44.0)	0.037*	—
NRS arm	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.450	—
Delta mJOA vs. preop	1.0 (0.0–3.0)	1.0 (0.0–2.0)	0.368	—
Hirabayashi RR (%)[2]	35.4 (0.0–50.0)	40.0 (0.0–61.7)	0.611	—
1-Year Follow-up — median (IQR)				
mJOA	14.5 (12.2–16.0)	16.0 (14.8–17.0)	0.040*	0.004 / <0.001
NDI (%)	24.0 (12.8–42.4)	19.0 (6.5–40.5)	0.241	0.256 / 0.004
NRS arm	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.297	0.066 / <0.001
ΔmJOA vs. preop	1.0 (1.0–3.0)	1.0 (0.0–3.0)	0.752	—
Hirabayashi RR (%)[2]	41.7 (13.8–62.5)	53.6 (0.0–100.0)	0.328	—

*p < 0.05; **p < 0.01; †p < 0.10 (borderline). Between-group comparisons: Mann–Whitney U test. Within-group comparisons (Wilcoxon signed-rank test) reported for the 1-year time point only, expressed as spondylolisthesis / no spondylolisthesis. For NDI and NRS, higher values indicate greater disability/pain; a reduction from baseline indicates improvement. [2]Hirabayashi recovery rate calculated on all 18 spondylolisthesis patients and on 80/84 DCS-negative patients (4 excluded for preoperative mJOA = 17). mJOA: modified Japanese Orthopaedic Association score; NDI: Neck Disability Index; NRS: Numeric Rating Scale; RR: recovery rate; IQR: interquartile range.

Complications and Reoperations

Complication data are detailed in Table 5. A total of 5 of 18 patients (27.8%) in the spondylolisthesis group experienced at least one complication, accounting for 6 complication events in total; one patient sustained two concurrent complications (dysphagia and incomplete decompression). In the DCS-negative group, 12 of 84 patients (14.3%) experienced a complication, each involving a single event. The overall difference between groups did not reach statistical significance (p = 0.175).

Dysphagia was the only individual complication to differ significantly between groups, occurring in 2 of 18 DCS patients (11.1%) versus none of the 84 controls (p = 0.030). Both cases arose in patients who underwent an anterior cervical approach (ACDF at C4–C6) and both resolved within three months of surgery.

The 30-day reoperation rate showed a clinically relevant but statistically non-significant trend toward higher frequency in the spondylolisthesis group (3/18, 16.7% vs. 3/84, 3.6%; p = 0.066). No cases of C5 palsy were recorded in either group. There was no 30-day mortality in the entire cohort.

Table 5. Perioperative and postoperative complications by spondylolisthesis status (adjacent segment disease excluded).

Complication	Spondylolisthesis (n=18)	No Spondylolisthesis (n=84)	p-value
Postoperative haematoma, n (%)	1 (5.6%)	2 (2.4%)	0.445
Surgical site infection, n (%)	1 (5.6%)	1 (1.2%)	0.323
CSF leak, n (%)	0 (0.0%)	1 (1.2%)	1.000
C5 palsy, n (%)	0 (0.0%)	0 (0.0%)	1.000
Dysphagia, n (%)	2 (11.1%)	0 (0.0%)	0.030*
Dysphonia, n (%)	0 (0.0%)	2 (2.4%)	1.000
Horner syndrome, n (%)	0 (0.0%)	1 (1.2%)	1.000
Postoperative kyphosis, n (%)	0 (0.0%)	1 (1.2%)	1.000
Implant-related complication, n (%)	0 (0.0%)	1 (1.2%)	1.000
Incomplete decompression, n (%)	2 (11.1%)	3 (3.6%)	0.212
30-day reoperation, n (%)	3 (16.7%)	3 (3.6%)	0.066†
Patients with ≥1 complication, n (%)	5 (27.8%)	12 (14.3%)	0.175
30-day mortality, n (%)	0 (0.0%)	0 (0.0%)	—

*p < 0.05; †Borderline significance (p = 0.066). Fisher's exact test used throughout. Percentages refer to the proportion of patients within each group. In the spondylolisthesis group, 5 patients experienced at least one complication (6 total events); both dysphagia cases followed anterior cervical procedures (ACDF C4–C6) and resolved within 3 months. CSF: cerebrospinal fluid.

Discussion

Current research on DCM seeks to identify outcome predictors that may improve diagnosis, treatment selection, and counselling. Age, symptom duration, baseline myelopathy severity, spinal cord signal changes on MRI, and electrophysiological abnormalities are among the factors commonly assessed [7]. Despite its detection on routine imaging, the relationship between DCS and DCM remains incompletely described. To our knowledge, our group has published one systematic review on this topic, including three primary studies [4]. DCS may reflect more advanced degeneration and could be associated with more complex clinical and surgical presentations. In this retrospective analysis of prospectively collected data from 102 patients, we compared patients with and without DCS to examine these associations.

Patients with DCS were older than those without DCS (median 61.0 vs 56.5 years; p = 0.014), consistent with previous studies reporting age differences of approximately 6.7–8.8 years [4]. Age may be relevant both to degenerative disease

burden and to postoperative recovery [6, 7, 12, 21], and it may confound unadjusted associations between DCS and outcomes.

Radiologically, DCS was always accompanied by other degenerative cervical abnormalities in this cohort, including multilevel disc pathology, ligamentum flavum hypertrophy, or congenital stenosis. This pattern is consistent with the facet arthropathy, joint changes, osteophytosis, and altered biomechanical loading described in DCS [8]. Nouri and colleagues have discussed static and dynamic mechanisms of injury in DCM, including potential effects on cord tension and vascular supply [15]. DCS may therefore reflect, and potentially contribute to, these mechanisms; causality cannot be inferred from our observational analysis.

Patients with DCS also had worse preoperative neurological function (median mJOA 13.0 vs 14.0; $p = 0.006$) and a borderline higher NDI (41.1% vs 27.4%; $p = 0.056$). Nouri and colleagues reported lower mJOA and Nurick scores and worse SF-36 physical component scores among 458 patients with DCM and DCS [13]. Similar observations have been reported in laminoplasty series [17, 19]. Together, these findings suggest that DCS may be a clinically relevant marker of more severe baseline disease. Whether this reflects segmental instability or a greater overall degenerative burden remains uncertain.

Posterior approaches were more frequent in the DCS group (38.9% vs 13.1%; $p = 0.016$), and surgical constructs involved more levels (median 3.0 vs 2.0; $p = 0.001$). This is consistent with reports of frequent posterior surgery in patients with DCM and DCS [4] and may reflect more extensive or multifocal pathology. Multilevel anterior reconstruction entails broader exposure and risks such as dysphagia, pseudarthrosis, and construct-related complications, especially in older patients [20], whereas posterior decompression is commonly considered for multilevel or predominantly posterior compression [1, 2]. All posterior decompressions in our series were accompanied by fusion to address stability and reduce the risk of post-laminectomy kyphosis. Laminoplasty has also yielded favourable outcomes in selected patients with DCS [17, 19].

Absolute mJOA scores remained lower in the DCS group at both follow-up visits, whereas the observed changes from baseline and Hirabayashi recovery rates did not differ significantly between groups. Older age and worse baseline neurological function, as well as more extensive cervical degeneration, may partly explain the lower absolute postoperative scores [3, 10, 12, 23, 24]. Both groups demonstrated statistically significant within-group improvement in mJOA at 1 year. These findings support the possibility of neurological benefit after decompression in patients with DCS, but do not demonstrate that the magnitude of benefit is equivalent across groups. Whether a more extensive or different surgical strategy improves outcomes in this population remains unknown [4].

Dysphagia was the only individual complication with a statistically significant between-group difference (2/18 [11.1%] with DCS vs 0/84 without DCS; $p = 0.030$). Both cases followed multilevel anterior surgery and resolved within 3 months. The small event count, potential differences in operative exposure [16, 18, 22], and multiple unadjusted comparisons warrant caution in interpreting this finding.

Limitations

This study has several limitations. The small DCS subgroup ($n = 18$) and unequal group sizes reduced statistical power, especially for uncommon complications. This was an exploratory analysis involving multiple unadjusted comparisons; baseline age, disease severity, and surgical approach differed between groups, and residual confounding cannot be excluded. The requirement for complete 1-year follow-up may introduce selection bias. Follow-up was limited to 1 year, potentially missing later complications such as adjacent segment disease, pseudarthrosis, and progressive kyphosis. DCS was defined qualitatively on neutral-position MRI without a minimum translation threshold or dynamic imaging, so subtle or motion-dependent slips may have been misclassified or missed. We also did not distinguish anterolisthesis from retrolisthesis. Finally, the cohort came from a single centre, limiting generalisability. Larger studies with quantitative imaging, adjusted analyses, and longer follow-up are needed.

Conclusion

In this retrospective cohort analysis, patients with DCM and DCS were older, had worse baseline neurological function, and underwent more extensive surgery, with posterior approaches used more frequently than in patients without DCS. Absolute mJOA scores were lower at 1 year, but no statistically significant between-group difference in neurological improvement from baseline was detected. DCS may therefore identify a subgroup with more complex cervical degenerative disease that can nevertheless experience postoperative neurological improvement. These associations require confirmation in larger, adjusted studies before a preferred surgical strategy can be established.

Figures

Fig. 1 Distribution of surgical approaches according to the presence of degenerative cervical spondylolisthesis (DCS). Anterior surgery was less frequent and posterior surgery more frequent in patients with DCS (Fisher exact test, p = 0.007 and p = 0.016, respectively). Percentages are calculated within each group

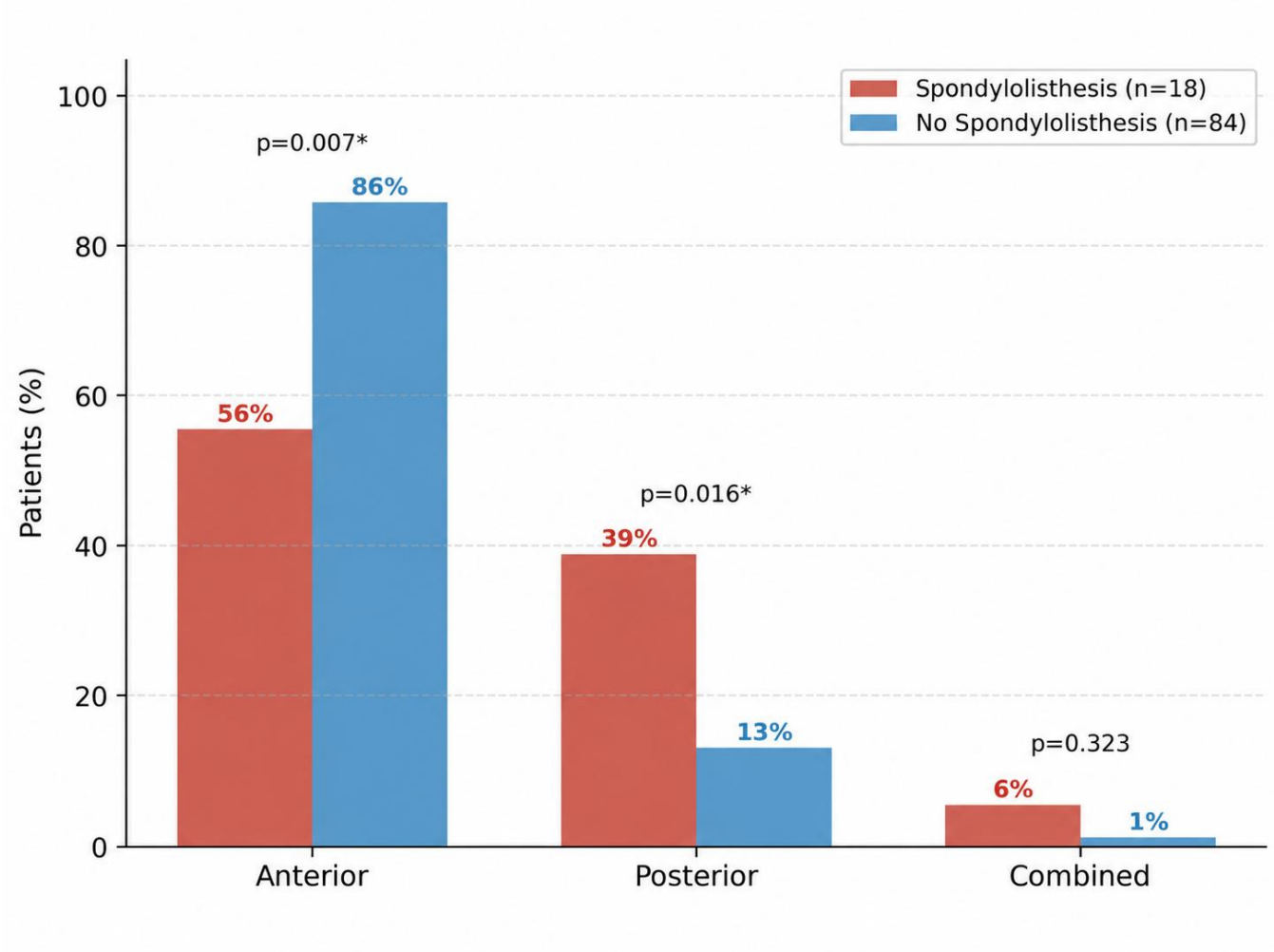


Fig. 2 Median mJOA, Neck Disability Index (NDI), and Numeric Rating Scale (NRS) arm-pain scores with interquartile ranges before surgery and at 3–4 months and 1 year. Asterisks indicate between-group differences (Mann–Whitney U test; $p < 0.05$)

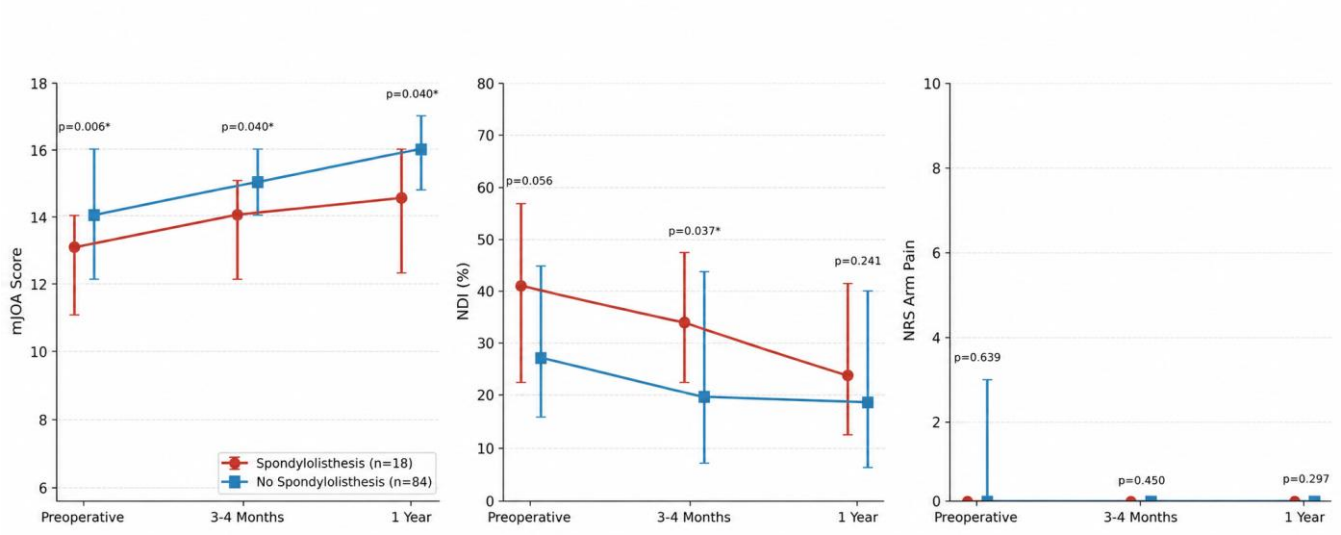


Fig. 3 Distribution of modified Japanese Orthopaedic Association (mJOA) scores before surgery, at 3–4 months, and at 1 year in patients with and without DCS. The central line represents the median, boxes the interquartile range, and whiskers the plotted non-outlier range; individual outliers are marked by circles

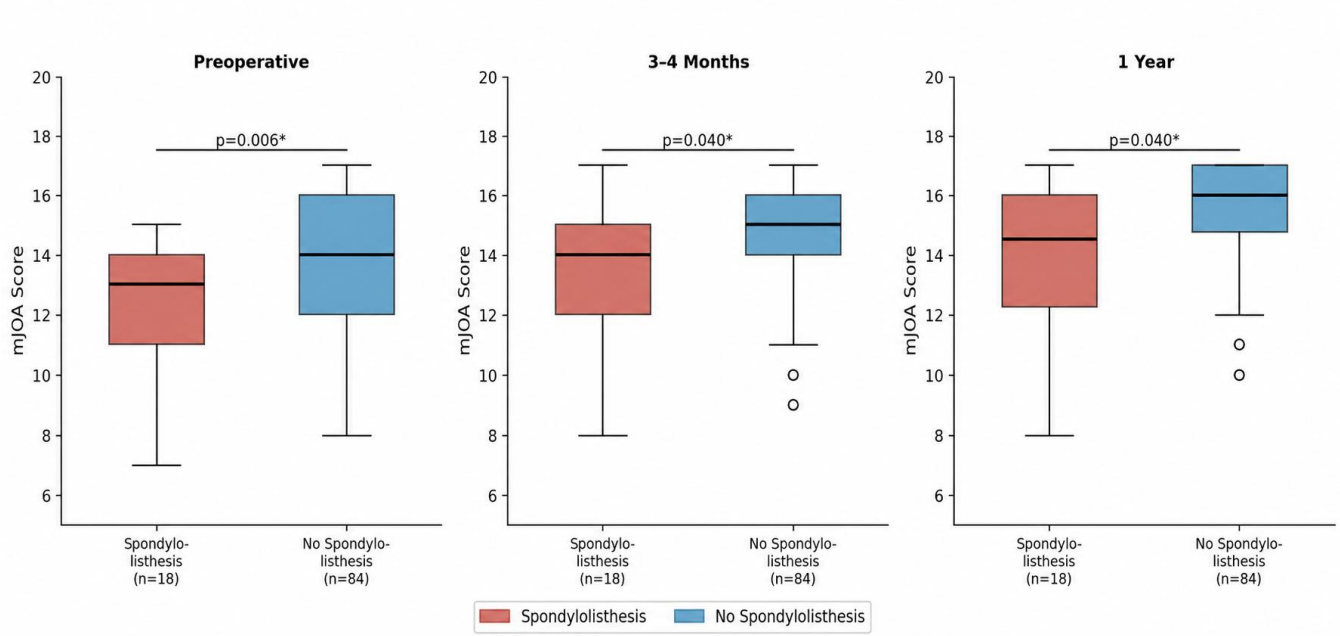
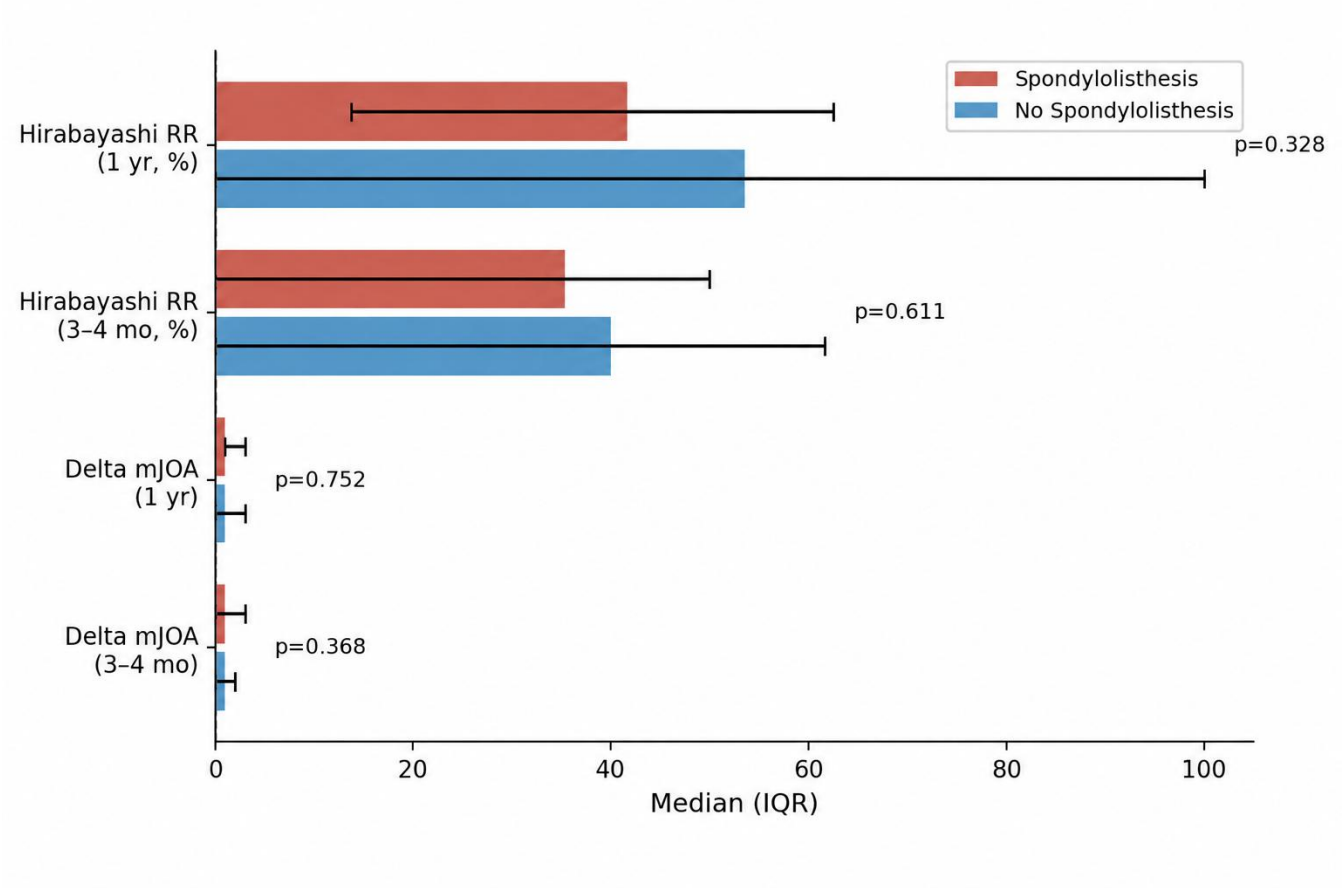


Fig. 4 Median changes in mJOA score from baseline and Hirabayashi recovery rates, shown with interquartile ranges, at 3–4 months and 1 year. No statistically significant between-group difference was detected at either follow-up (Mann–Whitney U test)



Statements and Declarations

Ethics approval: This study was approved by the Ethics Committee of Geneva University Hospitals, Geneva, Switzerland (protocol 11-194; NAC 11-067; 7 May 2012), and was conducted in accordance with the Declaration of Helsinki.

Consent to participate: Informed consent was obtained from all participants included in this study.

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Competing interests: Enrico Tessitore reports training fees from DePuy Synthes, Medtronic, and Spineart; consultancy fees from Brainlab, Medability, and Spine Vision; administrative roles as Chair of the EANS Spine Section and Board Member of Medical AI; and educational activities as faculty for AO Spine, EANS, and Eurospine. All other authors declare no financial or non-financial competing interests related to this work.

Author contributions: GJ: conceptualisation, methodology, formal analysis, writing – original draft; LA: conceptualisation, methodology, data curation, writing – original draft; MDB: data curation, writing – review and editing; NB: data curation, writing – review and editing; AN: supervision, writing – review and editing; ET: supervision, writing – review and editing. All authors reviewed and approved the final manuscript.

Data availability: Data supporting the findings are not publicly available because they include patient-level clinical information. De-identified data may be available from the corresponding author upon reasonable request, subject to institutional and ethical approval.

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