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# Management of mild degenerative cervical myelopathy and asymptomatic spinal cord compression: an international survey

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**STUDY DESIGN:** Cross-sectional survey.

**OBJECTIVE:** Currently there is limited evidence and guidance on the management of mild degenerative cervical myelopathy (DCM) and asymptomatic spinal cord compression (ASCC). Anecdotal evidence suggest variance in clinical practice. The objectives of this study were to assess current practice and to quantify the variability in clinical practice.

**METHODS:** Spinal surgeons and some additional health professionals completed a web-based survey distributed by email to members of AO Spine and the Cervical Spine Research Society (CSRS) North American Society. Questions captured experience with DCM, frequency of DCM patient encounters, and standard of practice in the assessment of DCM. Further questions assessed the definition and management of mild DCM, and the management of ASCC.

**RESULTS:** A total of 699 respondents, mostly surgeons, completed the survey. Every world region was represented in the responses. Half (50.1%,  $n = 359$ ) had greater than 10 years of professional experience with DCM. For mild DCM, standardised follow-up for non-operative patients was reported by 488 respondents (69.5%). Follow-up included a heterogeneous mix of investigations, most often at 6-month intervals (32.9%,  $n = 158$ ). There was some inconsistency regarding which clinical features would cause a surgeon to counsel a patient towards surgery. Practice for ASCC aligned closely with mild DCM. Finally, there were some contradictory definitions of mild DCM provided in the form of free text.

**CONCLUSIONS:** Professionals typically offer outpatient follow up for patients with mild DCM and/or asymptomatic ASCC. However, what this constitutes varies widely. Further research is needed to define best practice and support patient care.

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## INTRODUCTION

Degenerative cervical myelopathy (DCM) is an umbrella term for symptomatic spinal cord compression, secondary to degenerative changes of the cervical spine [1–3]. Symptoms are often debilitating and progressive, typically resulting in permanent disability and poor quality of life [4–8].

Disease severity is often quantified using the modified Japanese Orthopaedic Association (mJOA) score, an objective physician evaluation of neurological dysfunction [9]. Moderate and severe DCM are defined as cases where mJOA  $\leq 14$  [10] and surgery has been recommended for such patients, as outlined in the most recent clinical practice guidelines [11]. Prior to surgery, many

factors contribute to a delay in diagnosis [12, 13] in moderate/severe DCM. Nonetheless, there is a consensus amongst surgeons in support of operative management.

In contrast, there is weak evidence informing the management of mild DCM [11], most commonly defined in the literature as mJOA 15–17 [10]. Amongst mild DCM patients, there is a subpopulation that deteriorates and another which remains stable [14]. An absence of prognostic biomarkers and symptoms [15] means that there are no strong predictions to support decision making.

Guidelines therefore currently suggest surgical intervention or a trial of structured rehabilitation in mild DCM, with the latter escalating to the former in cases of deterioration [11]. This tentative

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guidance is reflected in variable practice, as has been anecdotally reported by surgeons. There is no specification on what structured rehabilitation or surveillance should entail [16].

Similar heterogeneity is believed to exist in the management of ASCC, a precursor to DCM [14]. In this case, the guidelines cite weak evidence supporting non-operative management, involving counselling and education [11]. Likewise, what this should constitute remains undefined.

Whilst widespread underdiagnosis [17, 18] so far limits the number of patients with mild or asymptomatic disease in spinal clinics, this is estimated to be vast (one meta-analysis estimates 1 in 5 adults could have ASCC) and rising with aging. Initiatives to accelerate diagnosis are on-going [15, 19], and anticipated to increase case ascertainment.

On this background of weak evidence and variable practice, and driven by projected demand, efforts to better inform care for mild DCM and ASCC are a critical priority. The objective of this study was to assess current practices in the assessment and management of mild DCM and ASCC. This work also aligns with two other research priorities of the AO Spine RECODE-DCM initiative [20]: *diagnostic criteria* [19] and *assessment and monitoring* [21]. We hypothesise that there is substantial variability in the definition, assessment, and management of mild DCM and ASCC.

## METHODS

The survey is reported following the Checklist for Reporting Results of Internet E-Surveys [22] (CHERRIES).

### Survey design

A cross-sectional observational study was conducted utilising a web-based survey targeted at surgeons who operate on the cervical spine, along with physicians and allied health professionals (AHPs) involved in the DCM patient journey.

The survey questions can be found in Supplementary Material 1. Questions captured experience with DCM, frequency of DCM patient encounters, and standard of practice in the assessment of DCM. Further questions assessed the definition and management of mild DCM, and the management of asymptomatic spinal cord compression.

Question format was a mostly of multiple-choice questions, the only exception being a question requiring a full-text answer.

### Ethical approval and consent

The survey was approved by AO Spine before dissemination amongst the surgeon community.

Participants completed the survey voluntarily and were informed before doing so that anonymised data would be shared with researchers associated with the AO Spine Knowledge Forum Spinal Cord Injury for the purposes of academic research.

This acted as voluntary electronic consent, with completion of the survey questions taken as agreement to participate.

### Development and testing

The usability and technical functionality of the survey was piloted by a team of spinal surgeons from the AO Spine Natural History Incubator [23] before dissemination.

### Data protection

No patient identifiable information was stored. The minimum amount of data was securely stored and accessed by the minimum number of researchers for the minimum amount of time required to complete the research.

### Participants

All participants were practicing surgeons, physicians, AHPs or academics, based in centres around the world.

### Recruitment

An open survey type was utilised. Surgeons were recruited to a web-based questionnaire, administered by SurveyMonkey (Momentive, California, USA).

The survey was disseminated via email directly to the members of AO Spine. In addition, a request to submit the survey to the CSRS North American society was undertaken and accepted.

No contact was made with participants outside of the survey.

### Administration

AO Spine is a not-for-profit institution, comprising the world's largest community of spinal surgeons, researchers and allied spine professions. There was no sample pre-selection. The survey was administered via email. Completion of the survey was voluntary, and no incentives were offered. Respondents were able to review their answers by using a "Back" button. Responses were collected from 12th October 2021 to July 7th 2022.

### Response rates

In 2021, AO Spine consisted of approximately 6000 members. As 688 participants from AO Spine completed the survey, the theoretical minimum response rate was 11%. The completion rate was calculated by SurveyMonkey to be 78%. After the initial email drive via AO Spine, a low response rate from North America was observed, and therefore a formal request to survey the CSRS North America community was undertaken and accepted.

IP addresses were recorded as metadata with each survey response, allowing assessment for duplication and preventing multiple entries from the same individual.

### Data analysis

Survey data were extracted into an Excel spreadsheet (Microsoft, California, USA). Analysis and data visualisation were performed using R (v4.0.5; R Core Team, 2020) and RStudio (v1.4.1106; RStudio Team, 2021). Incomplete responses were excluded from the analysis, except in cases where incomplete questions were independent from those answered.

## RESULTS

A total of 699 responses were received, comprising mostly orthopaedic surgeons (64.0%,  $n = 458$ ) and neurosurgeons (33.2%,  $n = 238$ ), along with a few responses from neurologists/AHPs/academics (2.8%,  $n = 20$ ). The largest proportion of respondents worked in Asia (28.8%,  $n = 206$ ), followed by Latin/South America (24.2%,  $n = 173$ ), Europe (23.3%,  $n = 167$ ), North America (16.8%,  $n = 120$ ), Africa (2.7%,  $n = 19$ ), the Middle East (2.4%,  $n = 17$ ) and Oceania (2.0%,  $n = 14$ ). A majority of respondents (50.14%,  $n = 359$ ) had greater than 10 years of experience managing patients with DCM (Fig. 1).

Most respondents (58.0%,  $n = 415$ ) reported more than 6 encounters with DCM patients each month (Fig. 2).

The full dataset can be found in Supplementary Material 2.

### DCM investigations

In addition to MRI, respondents most often request lateral and AP cervical X-rays (70.3%, 503; Table 1). Only 30 respondents (4.2%) reported using no further investigations when working up a suspected DCM diagnosis.

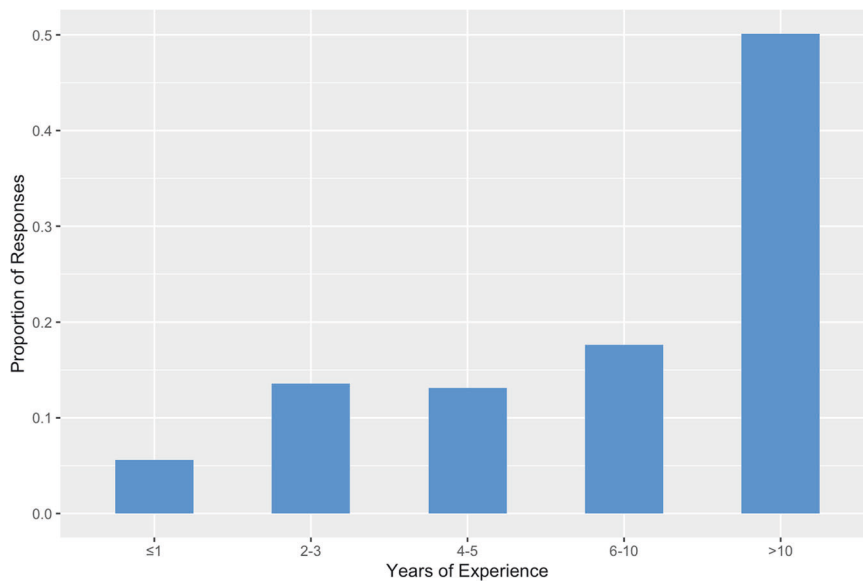
Electrophysiology was mostly reported to be used "rarely/specific cases" (54.5%,  $n = 390$ ) in the diagnosis of DCM (Supplementary Material 3).

### Non-operative patient follow-up

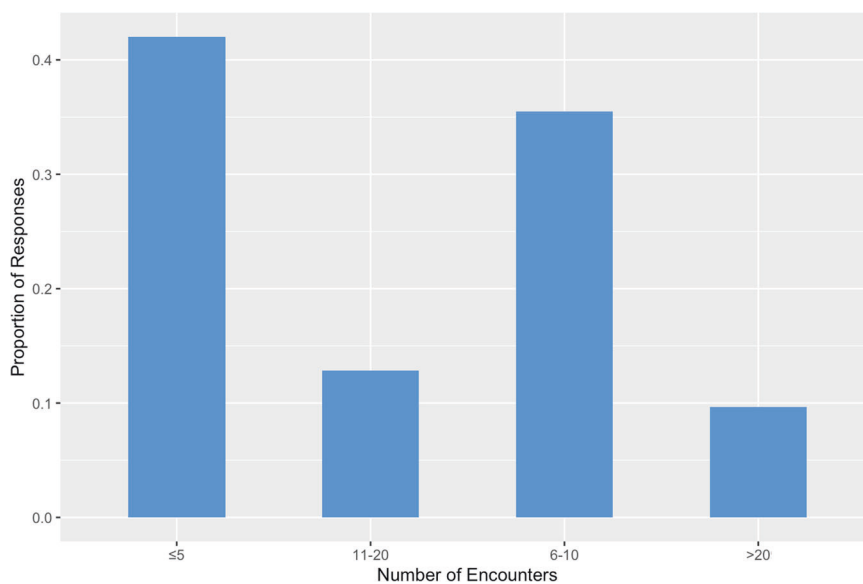
A process of standardised follow-up for non-operative patients was reported by 488 respondents (69.5%).

The period of follow-up, where reported, was most often 6 months (32.9%,  $n = 158$ ) or 3 months (28.3%,  $n = 136$ ), as shown in Fig. 3.

At follow-up, a clinical severity assessment (e.g., mJOA) was the most frequently reported assessment (64.6%,  $n = 310$ ), in addition to a physical exam (Fig. 4). Approximately half of the respondents reported some form of MRI imaging (49.7%,  $n = 239$ ). Nothing more than a physical exam was reported in 10.6% of cases ( $n = 51$ ).



**Fig. 1 Clinical Experience in Managing Patients with DCM.** Bar graph illustrating the proportion of respondents categorised by their years of experience in managing patients with DCM.



**Fig. 2 Monthly Clinical Encounters with DCM Patients.** Bar chart illustrating the monthly frequency at which respondents encounter patients with DCM.

### Mild DCM definition

When asked to define mild DCM, the free text responses were used to generate a word cloud (Supplementary Material 4).

Many respondents opted for a definition based upon the mJOA score. An mJOA score of 15–17 was most commonly cited as the definition of mild DCM, where a score was specified (46.2%,  $n = 49$ ). A variation of this answer, with no upper bound ( $mJOA \geq 15$ ), was provided as a definition by 25 respondents (23.6% of those using an mJOA-based definition). A geographical subgroup analysis of mild DCM definitions was performed (Fig. 5). Each value represents the proportion of mJOA-based score definitions, per region. The greatest proportion of mJOA score definitions aligned with the international guidelines were provided by respondents in Oceania (28.6%,  $n = 4$ ). Of the 17 respondents in the Middle East, no such mJOA definitions were provided.

Score ranges unrelated to the guidelines (e.g., mJOA >12, 14–15) were provided by 32 respondents.

The remaining responses used discrete clinical and imaging findings as a proposed definition.

### Mild DCM management

When asked what factors would influence a decision to recommend surgery to mild DCM patients, most responses included ‘presence of T2 hyperintensity of the spinal cord’ and/or ‘presence of dynamic spondylolisthesis/instability’ (Fig. 6).

If non-operative management was pursued in a case of mild DCM, there was variation in the changes that would prompt a recommendation of surgery (Table 2).

### ASCC assessment and management

Similar questions were posed in the context of ASCC.

**Table 1.** Further investigations for suspected DCM.

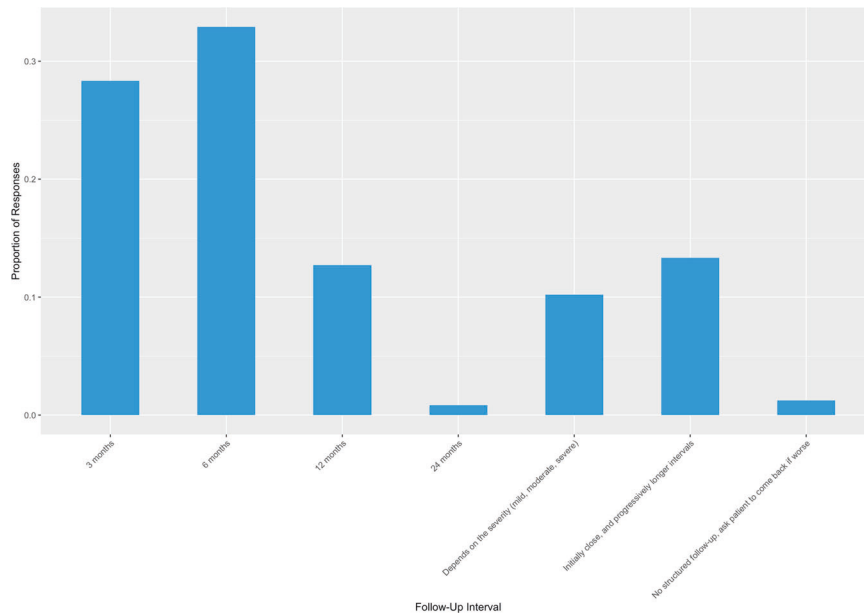
Investigation	Responses
Lateral and AP cervical X-ray	70.3% (n = 503)
Flexion and extension X-ray	64.5% (n = 462)
Standing and whole-body X-ray	9.4% (n = 67)
Cervical CT scan	48.3% (n = 346)
Electrophysiology examination	26.7% (n = 191)
Flexion and extension MRI	9.9% (n = 71)
Other	7.1% (n = 51)
None of the above	4.2% (n = 30)

The most common descriptive term used clinically for ASCC was reported as ‘cervical stenosis without myelopathy’ (58.17%, n = 331), followed by ‘asymptomatic cervical spinal cord compression’ (49.56%, n = 282; Fig. 7).

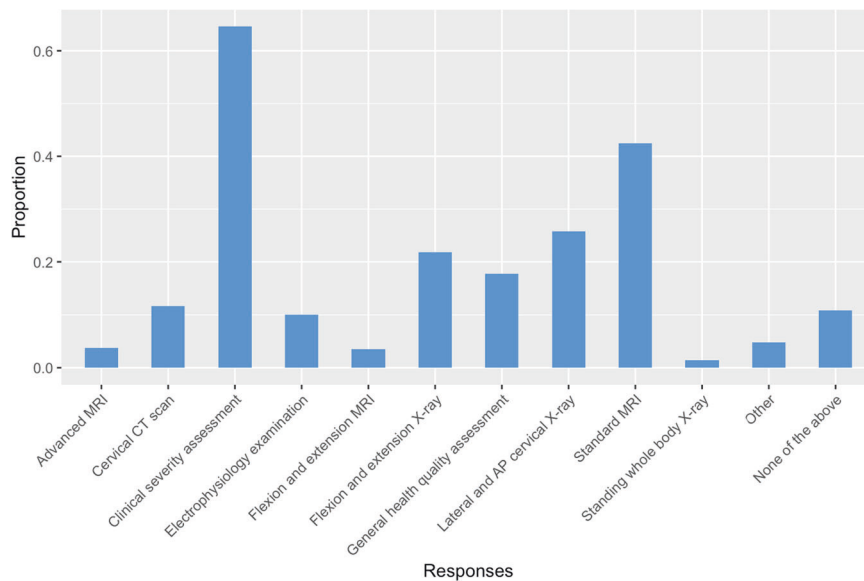
A standardised follow-up schedule was employed by 588 respondents (75.17%). The interval of follow-up (Fig. 8) and additional assessments (Supplementary Material 5) mapped closely to responses in the context of mild DCM.

**DISCUSSION**

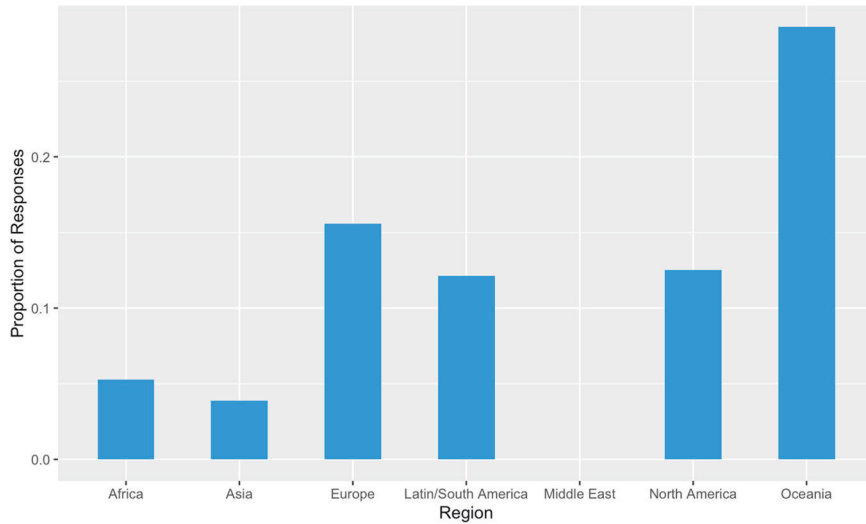
Our results suggest that there is no consensus on the management of either mild DCM or ASCC. Moreover, responses indicate that the definition of mild DCM is uncertain and that follow-up assessment



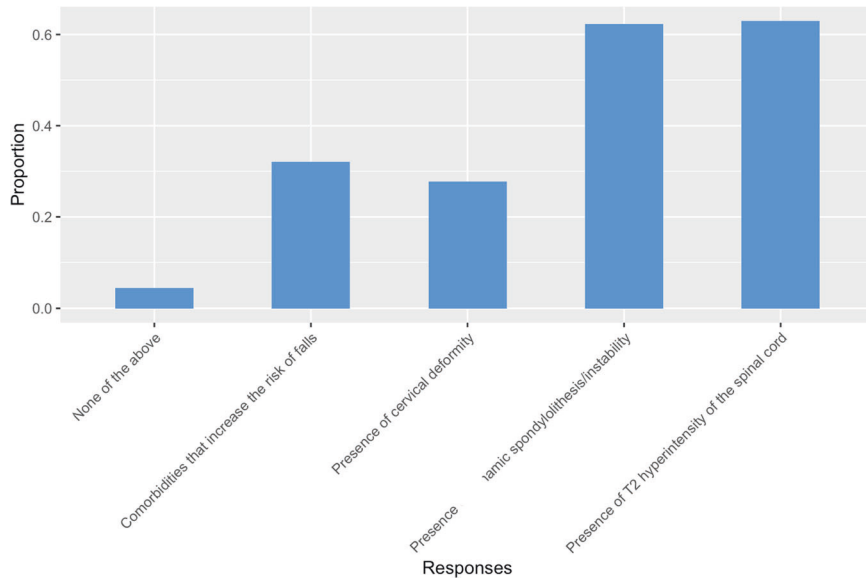
**Fig. 3 Follow-Up Intervals in Non-Operative DCM Management.** Bar chart presenting the proportion of respondents according to their reported intervals of standardised follow-up in the non-operative management of DCM.



**Fig. 4 Assessments in Non-Operative DCM Follow-Up.** Bar chart illustrating the proportion of respondents employing various assessments during follow-up visits in the non-operative management of DCM.



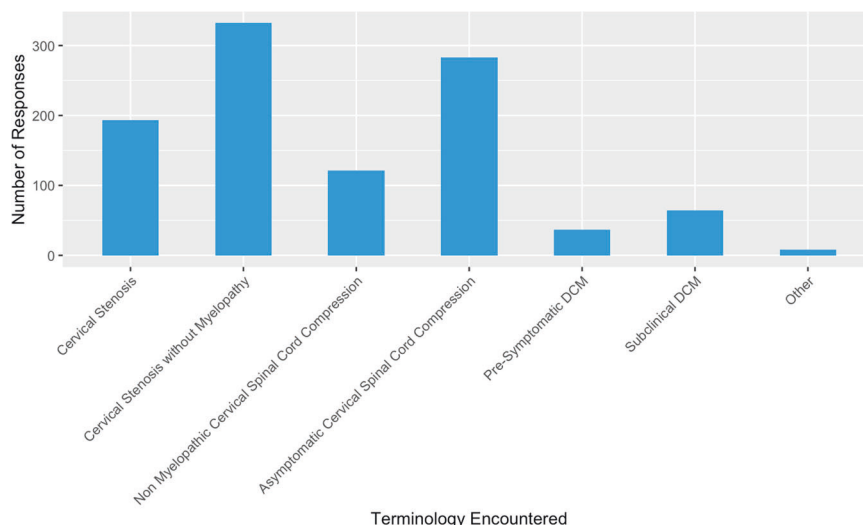
**Fig. 5 Regional Alignment of mJOA-based mild DCM definitions with recent guidelines (15–17).** Bar chart displaying the proportion of mJOA-based mild DCM definitions in alignment with recent guidelines across different world regions.



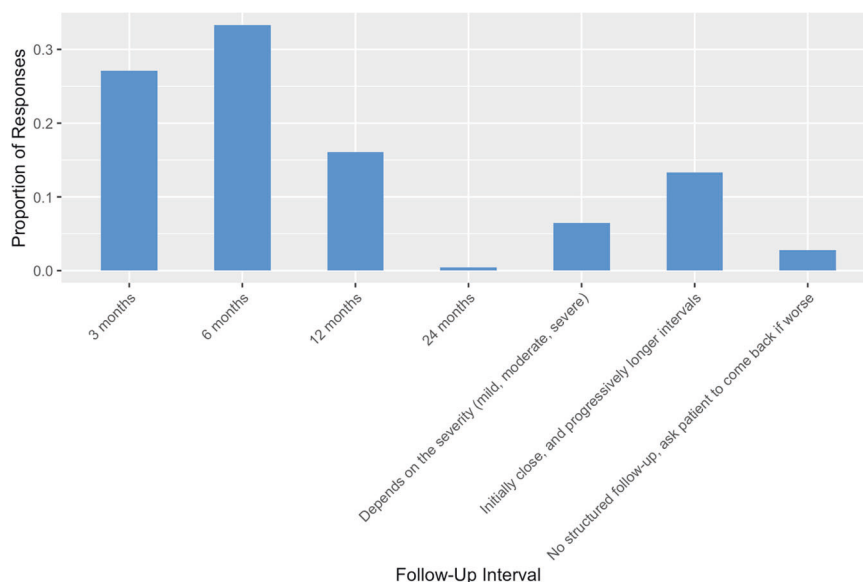
**Fig. 6 Factors Influencing Surgical Recommendation in Mild DCM.** Bar chart illustrating the proportion of respondents' opinions on various factors that would influence their decision to recommend surgery for patients with mild DCM.

**Table 2.** Changes that would prompt a recommendation of surgery.

Findings	Responses
Deterioration following recent trauma	75.83% (n = 436)
The presence of instability/spondylolisthesis evident on dynamic imaging	64.2% (n = 369)
Minor worsening of neurological exam (e.g., loss of 1 point on mJOA/JOA)	60.2% (n = 346)
Progression of cervical kyphosis/deformity	57.9% (n = 333)
Worsening identified by relatives/carers	53.0% (n = 315)
No change in neurological exam but the patient subjectively feels worse	47.3% (n = 272)
No change in neurological status but patient indicates accidental falls since the last consultation	39.5% (n = 227)
The patient does not wish to have lifestyle restrictions (e.g., participation in contact sports)	29.7% (n = 171)
Other comorbidities that increase the risk of falls (e.g., Parkinson's disease)	26.8% (n = 154)
The patient remains impaired but has improved since the last follow-up	4.5% (n = 26)
No change in neurological exam and the patient remains subjectively stable	1.9% (n = 11)
None of the above	1.0% (n = 6)



**Fig. 7 Clinical Terminology for Asymptomatic Spinal Cord Compression.** Bar chart showing the frequency of terms encountered in clinical practice that refer to asymptomatic spinal cord compression.



**Fig. 8 Follow-Up Intervals for Asymptomatic Spinal Cord Compression Management.** Bar chart displaying the standard follow-up intervals as reported by respondents for managing asymptomatic spinal cord compression.

practices may be deficient. Moreover, the terminology used in the context of ASCC is mixed. Regarding international comparisons, heterogeneity was identified within each region surveyed, suggesting that the variation observed exists at a local level.

#### Variability in practice reflects weak evidence informing guidelines

Current international guidelines [11] are tentative and derived from a sparse evidence base. In mild DCM, the guidelines advise surgical intervention or a trial of structured rehabilitation. In ASCC, the guidelines recommend non-operative management, involving counselling and education.

The existence of tentative guidelines was reflected in decisions at several points along the management pathway. At follow-up, no single assessment was performed by more than 67% clinicians, yet 7 different assessments were reported by more than 10% (Fig. 4; Supplementary Material 5). When considering surgery in mild DCM, no decisive clinical feature was reported by more than 75%, however all possible features were reported by more than 30% (Fig. 6).

A more fundamental finding was the varied understanding of the terminology used in the questionnaire. Surprisingly, there was substantial variation in the definition of mild DCM (Supplementary Material 4). It is noteworthy that many reported definitions did not overlap with the objective score-based definition proposed by Tetreault and colleagues [10], and adopted in recent guidelines.

These variations were identified in every region surveyed. For example, standardised follow-up was not provided by between 20%–40% of respondents when divided by region. This suggests that response variation was not due to international cultural factors, and instead more likely due to local factors, such as trust policy and individual decision making.

Together, these findings demonstrate uncertainty amongst clinicians in both diagnosis, definition, and management.

#### Inconsistent terminology and practice can delay progress

An inconsistent use of diagnostic terms can give rise to ambiguity when exploring diagnosis, interventions, and outcomes. Further

consequences of inconsistency can arise when clinicians are performing literature searches on research databases, or when patients are seeking information related to their condition.

We identified considerable inconsistency in terminology referring to asymptomatic compression of the cervical cord. Every term suggested in our survey had been encountered by respondents (Fig. 7), the most frequent of which were 'cervical stenosis without myelopathy' and 'asymptomatic cervical spinal cord compression'. Whilst not sufficient, consistent disease terminology is a necessary to increase awareness and direct research efforts to better understand asymptomatic compression.

Efforts to establish consensus terminology in DCM provide a template to follow [2, 3] This preceded both an increase in research activity [24] and the publication of international evidence-based clinical practice guidelines [11].

Similarly, over 30% of respondents reported no process for standardised follow-up of non-operative DCM patients, despite best practice recommendations. [11] Equally, at standardised follow-up, over 30% of clinicians reported no use of clinical severity assessments, such as the mJOA score [9]. This implies that non-standardised and/or subjective measures were used by clinicians at follow-up.

Failure by clinicians to use valid, reliable, and responsive outcome measures for DCM limits their capacity to capture the severity of a patient's condition now, but also over time [25]. Not using valid outcome measures such as the mJOA also provides no interpretable measure of severity for other clinicians. The importance of valid outcome measures is becoming increasingly known, with a series of initiatives such as the Core Outcome Measures in Effectiveness Trials (COMET) increasing in use. The existing lack of priority of outcome measures amongst clinicians may reflect current medical education [26, 27], which is an important component of the number one research priority of the AO Spine RECODE-DCM initiative: *improving awareness* [28].

### Limitations and future work

The survey was principally disseminated by two global spinal organisations; AO Spine and CSRS and it is noted that some groups may have been underrepresented. For example, Asia contributed 29% of responses, and Africa only 3%. Further the survey used a clinician's recollection of practice, making it vulnerable to recall bias. The overall large sample size, and the broad heterogeneity, with absence of trends event amongst subgroups, suggest this has not limited the findings.

The most pressing future work is to generate robust guidelines for non-operative patients.

This would benefit from a more detailed characterisation of DCM natural history, including the identification of any predictors of deterioration. Standardised patient follow-up is necessary to perform this analysis. A combination of clinician education and practical decision support tools may form first steps to ensure that this is conducted, using expert opinion to bridge known evidence gaps.

### CONCLUSIONS

There is a lack of consensus internationally on the management of mild DCM and ASCC. Weak guidelines are informed by a limited understanding of disease natural history. Developing a framework for this is needed both to support patient care, but also enable the evidence to be generated to advance our understanding for the future.

### DATA AVAILABILITY

Anonymised survey responses can be found in Supplementary Material 2.

### REFERENCES

- Davies BM, Mowforth OD, Smith EK, Kotter MR. Degenerative cervical myelopathy. *BMJ*. Published online February 22, 2018;k186. <https://doi.org/10.1136/bmj.k186>.
- Nouri A, Tetreault L, Singh A, Karadimas SK, Fehlings MG. Degenerative cervical myelopathy: epidemiology, genetics, and pathogenesis. *Spine*. 2015;40:E675.
- Davies BM, Khan DZ, Barzangi K, Ali A, Mowforth OD, Nouri A, et al. We choose to call it "degenerative cervical myelopathy": findings of ao spine recode-dcm, an international and multi-stakeholder partnership to agree a standard unifying term and definition for a disease. *Global Spine J*. Published online June 29, 2022;21925682221111780. <https://doi.org/10.1177/21925682221111780>.
- Davies BM, Munro C, Khan DZ, Fitzpatrick SM, Hilton B, Mowforth OD, et al. Outcomes of degenerative cervical myelopathy from the perspective of persons living with the condition: findings of a semistructured interview process with partnered internet survey. *Global Spine J*. Published online November 18, 2020;2192568220953811. <https://doi.org/10.1177/2192568220953811>.
- Oh T, Lafage R, Lafage V, Protosaltis T, Chailier V, Shaffrey C, et al. Comparing quality of life in cervical spondylotic myelopathy with other chronic debilitating diseases using the short form survey 36-health survey. *World Neurosurg*. 2017;106:699–706.
- Hirayama Y, Mowforth OD, Davies BM, Kotter MRN. Determinants of quality of life in degenerative cervical myelopathy: a systematic review. *Br J Neurosurg*. Published online November 18, 2021;1–11. <https://doi.org/10.1080/02688697.2021.1999390>.
- Mowforth OD, Davies BM, Kotter MR. Quality of life among informal caregivers of patients with degenerative cervical myelopathy: cross-sectional questionnaire Study. *Interact J Med Res*. 2019;8:e12381.
- Davies BM, Mowforth OD, Khan DZ, Yang X, Stacpoole SRL, Hazenbiller O, et al. The development of lived experience-centered word clouds to support research uncertainty gathering in degenerative cervical myelopathy: results from an engagement process and protocol for their evaluation, via a nested randomized controlled trial. *Trials*. 2021;22:415.
- Japanese Orthopaedic Association. Scoring system for cervical myelopathy. *Nippon Seikeigeka Gakkai Zasshi*. 1994;68:490–503.
- Tetreault L, Kopjar B, Nouri A, Arnold P, Barbagallo G, Bartels R, et al. The modified Japanese Orthopaedic Association scale: establishing criteria for mild, moderate and severe impairment in patients with degenerative cervical myelopathy. *Eur Spine J*. 2017;26:78–84.
- Fehlings MG, Tetreault LA, Riew KD, Middleton JW, Aarabi B, Arnold PM, et al. 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*. 2017;7:705–835.
- Hilton B, Tempest-Mitchell J, Davies B, Kotter M. Assessment of degenerative cervical myelopathy differs between specialists and may influence time to diagnosis and clinical outcomes. *PLoS One*. 2018;13:e0207709.
- Pope DH, Mowforth OD, Davies BM, Kotter MRN. Diagnostic delays lead to greater disability in degenerative cervical myelopathy and represent a health inequality. *Spine (Philos Pa 1976)*. 2020;45:368–77.
- Martin AR, De Leener B, Cohen-Adad J, Kalsi-Ryan S, Cadotte DW, Wilson JR, et al. Monitoring for myelopathic progression with multiparametric quantitative MRI. *PLoS One*. 2018;13:e0195733.
- Nouri A, Molliqaj G, Gondar R, Lavé A, Jannelli G, Davies B, et al. Can screening for degenerative cervical myelopathy (SCREEN-DCM) be effectively undertaken based on signs, symptoms and known risk factors? Rationale and research protocol for a prospective, multicentre, observational study. *BMJ Open*. 2022;12:e060689.
- Butler MB, Mowforth OD, Badran A, Starkey M, Boerger T, Sadler I, et al. Provision and perception of physiotherapy in the nonoperative management of degenerative cervical myelopathy (DCM): a cross-sectional questionnaire of people living with DCM. *Glob Spine J*. 2022;12:638–45.
- Grodzinski B, Stubbs DJ, Davies BM. Most degenerative cervical myelopathy remains undiagnosed, particularly amongst the elderly: modelling the prevalence of degenerative cervical myelopathy in the United Kingdom. *J Neurol*. Published online September 2, 2022. <https://doi.org/10.1007/s00415-022-11349-8>.
- Smith SS, Stewart ME, Davies BM, Kotter MRN. The prevalence of asymptomatic and symptomatic spinal cord compression on magnetic resonance imaging: a systematic review and meta-analysis. *Glob Spine J*. 2021;11:597–607.
- Hilton B, Gardner EL, Jiang Z, Tetreault L, Wilson JRF, Zipser CM, et al. Establishing diagnostic criteria for degenerative cervical myelopathy [AO Spine RECODE-DCM Research Priority Number 3]. *Global Spine J*. 2022;12:555–635.
- Davies BM, Khan DZ, Mowforth OD, McNair AGK, Gronlund T, Koliass AG, et al. RECODE DCM (REsearch Objectives and Common Data Elements for Degenerative Cervical Myelopathy): A Consensus Process to Improve Research Efficiency in

- DCM, Through Establishment of a Standardized Dataset for Clinical Research and the Definition of the Research Priorities. *Glob Spine J.* 2019;9:655–765.
21. Tetreault L, Garwood P, Gharooni AA, Touzet AY, Nanna-Lohkamp L, Martin A, et al. Improving assessment of disease severity and strategies for monitoring progression indenerative cervical myelopathy [AO Spine RECODE-DCM Research Priority Number4]. *Global Spine J.* 2022;12:645–775.
  22. Eysenbach G. Improving the quality of web surveys: the checklist for reporting results of internet E-surveys (CHERRIES). *J Med Internet Res.* 2004;6:e34.
  23. Khan DZ, Hazenbiller O, Gronlund T, Sadler I, Sarewitz EB, Mowforth O, et al. The AO spine RECODE-DCM International Collaborative—Establishing the Foundations for Accelerated and Patient-Centered Innovation. *Glob Spine J.* 2022;12:1595–1715.
  24. Badhiwala JH, Ahuja CS, Akbar MA, Witiw CD, Nassiri F, Furlan JC, et al. Degenerative cervical myelopathy—update and future directions. *Nat Rev Neurol.* 2020;16:108–24.
  25. Choy WJ, Chen L, Quel De Oliveira C, Verhagen AP, Damodaran O, Anderson DB. Gait assessment tools for degenerative cervical myelopathy: a systematic review. *J Spine Surg.* 2022;8:149–62.
  26. Brannigan JFM, Davies BM, Stewart M, Smith S, Willison A, Ahmed S, et al. Degenerative cervical myelopathy education in UK medical schools: a national cross-sectional survey of medical students. *Br J Neurosurg.* Published online August 11, 2022:1–9. <https://doi.org/10.1080/02688697.2022.2106355>.
  27. Mowforth O, Davies B, Stewart M, Smith S, Willison A, Ahmed S, et al. Current provision of myelopathy education in medical schools in the UK: protocol for a national medical student survey. *BMJ Open.* 2020;10:e035563.
  28. Davies BM, Mowforth O, Wood H, et al. Improving Awareness Could Transform Outcomes in Degenerative Cervical Myelopathy [AO Spine RECODE-DCM Research Priority Number 1]. *Global Spine J.* 2022;12(1\_suppl):285–385. <https://doi.org/10.1177/21925682211050927>.

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This research aligns with the AO Spine RECODE-DCM top research priority *Natural History* selected by people living and working with DCM. For further information on how this process was conducted, why this question was prioritised, and global updates on currently aligned research, please visit [aospine.org/recode/natural-history](http://aospine.org/recode/natural-history).

## AUTHOR CONTRIBUTIONS

JFMB was responsible for designing the survey questionnaire, analysing data, writing and reviewing the manuscript. BMD, ODM, RY, VK, JD, JJZ, RKJM, MT, DBA, JH, GM, GWJ, JJFA, SK, MI, JW, RR, ND, DG, ET, ARM, and AN were involved in survey design, results interpretation, and review of the manuscript.

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## COMPETING INTERESTS

There were no conflicts of interest relating to this study. ND reports consulting fees from Stryker, Cerapedics, Medtronic, and Baxter. RKJM reports consulting fees from Stryker, Nuvasive, and Icotec. JFMB reports consulting fees from Synchron. BMD reports stock in MoveMed Ltd.

## ADDITIONAL INFORMATION

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