Global Spine Journal
2025, Vol. 0(0) 1–9
© The Author(s) 2025
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/21925682251331050
journals.sagepub.com/home/gsj

AO Spine Clinical Practice Recommendations for Diagnosis and Management of Degenerative Cervical Myelopathy: Evidence Based Decision Making - A Review of Cutting Edge Recent Literature Related to Degenerative Cervical Myelopathy

Michael G. Fehlings, MD, PhD[1], Nathan Evaniew, MD, PhD[2], Paula Valerie Ter Wengel, MD, PhD[3], Aditya Vedantam, MD[4], Daipayan Guha, MD, PhD[5], Konstantinos Margetis, MD, PhD[6], Aria Nouri, MD, MSc[7], Aminul I. Ahmed, MD, PhD[8], Chris J. Neal, MD[9], Benjamin M. Davies, MD, PhD[10], Mario Ganau, MD, PhD[11], Jefferson R. Wilson, MD, PhD[12], Allan R. Martin, MD, PhD[13], Lukas Grassner, MD, PhD[14], Lindsay Tetreault, MD, PhD[15], Vafa Rahimi-Movaghar, MD[16], Rex Marco, MD[17], James Harrop, MD[18], James Guest, MD, PhD[19], Mohammed Ali Alvi, MD[20], Karlo M. Pedro, MD[21], Brian K. Kwon, MD, PhD[22], Charles G. Fisher, MD[23], Shekar N. Kurpad, MD, PhD[4], and On behalf of the AO Spine Knowledge Forum Spinal Cord Injury

[1] Division of Neurosurgery and Spine Program, University of Toronto, Toronto, ON, Canada
[2] Foothills Medical Centre, University of Calgary, Calgary, AB, Canada
[3] Department of Neurosurgery, Haaglanden Medical Center, Hague, the Netherlands
[4] Department of Neurosurgery, Medical College of Wisconsin, Milwaukee, WI, USA
[5] Division of Neurosurgery, McMaster University, Hamilton, ON, Canada
[6] The Mount Sinai Hospital, New York, NY, USA
[7] Division of Neurosurgery, Geneva University Hospitals, Geneva, Switzerland
[8] Wolfson SPaRC, King's College London, London, UK
[9] Division of Neurosurgery, Maine Medical Center, Portland, ME, USA
[10] Division of Neurosurgery, Department of Clinical Neurosciences, Addenbrooke's Hospital, University of Cambridge, Cambridge, UK
[11] Nuffield Department of Clinical Neurosciences, University of Oxford, Oxford, UK
[12] Division of Neurosurgery, Department of Surgery, University of Toronto, Toronto, ON, Canada
[13] University of California Davis, Davis, CA, USA
[14] Department of Neurosurgery, Christian Doppler Clinic. Paracelsus Medical University, Salzburg, Austria
[15] NYU Langone Health, New York, USA
[16] Sina Trauma and Surgery Research Center, Tehran University of Medical Sciences, Tehran, Iran
[17] UT Health Houston McGovern Medical School, Houston, TX, USA
[18] Department of Neurological Surgery, Thomas Jefferson University, Philadelphia, PA, USA
[19] University of Miami, Miami, FL, USA
[20] Institute of Medical Science, University of Toronto, Toronto, Canada
[21] Institute of Medical Science, University of Toronto, Toronto, Canada
[22] The University of British Columbia, Vancouver, BC, Canada
[23] Division of Spine Surgery, University of British Columbia and Vancouver General Hospital, Vancouver, BC, Canada

Corresponding Author:
Michael G. Fehlings, 399 Bathurst Street, Suite 4WW-449, Toronto, ON, M5T 2S8, Canada.
Email: Michael.fehlings@uhn.ca

Creative Commons Non Commercial No Derivs CC BY-NC-ND: This article is distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs 4.0 License (https://creativecommons.org/licenses/by-nc-nd/4.0/) which permits non-commercial use, reproduction and distribution of the work as published without adaptation or alteration, without further permission provided the original work is attributed as specified on the SAGE and Open Access pages (https://us.sagepub.com/en-us/nam/open-access-at-sage).

Abstract

Study Design: Literature review of key topics related to degenerative cervical myelopathy (DCM) with critical appraisal and clinical recommendations.

Objective: This article summarizes several key current topics related to the management of DCM.

Methods: Recent literature related to the management of DCM was reviewed. Four articles were selected and critically appraised. Recommendations were graded as Strong or Conditional.

Results: Article 1: The Relationship Between pre-operative MRI Signal Intensity and outcomes. **Conditional** recommendation to use diffusion-weighted imaging MR signal changes in the cervical cord to evaluate prognosis following surgical intervention for DCM. Article 2: Efficacy and Safety of Surgery for Mild DCM. **Conditional** recommendation that surgery is a valid option for mild DCM with favourable clinical outcomes. Article 3: Effect of Ventral vs Dorsal Spinal Surgery on Patient-Reported Physical Functioning in Patients With Cervical Spondylotic Myelopathy: A Randomized Clinical Trial. **Strong** recommendation that there is equipoise in the outcomes of anterior vs posterior surgical approaches in cases where either technique could be used. Article 4: Machine learning-based cluster analysis of DCM phenotypes. **Conditional** recommendation that clinicians consider pain, medical frailty, and the impact on health-related quality of life when counselling patients.

Conclusions: DCM requires a multidimensional assessment including neurological dysfunction, pain, impact on health-related quality of life, medical frailty and MR imaging changes in the cord. Surgical treatment is effective and is a valid option for mild DCM. In patients where either anterior or posterior surgical approaches can be used, both techniques afford similar clinical benefit albeit with different complication profiles.

Keywords

degenerative cervical myelopathy (DCM), management, clinical recommendations



"Scan QR code to take part in Knowledge Translation. Access is valid for 3 months from date of publication".

Introduction

Degenerative cervical myelopathy (DCM) is the commonest form of spinal cord impairment in adults worldwide. DCM is a heterogeneous clinical entity which encompasses benign degenerative and congenital conditions that cause progressive compression of the cervical spinal cord, including cervical spondylosis and ossification of the posterior longitudinal ligament.[1,2] Based on advances in imaging, diagnostic evaluation and surgical techniques, several large prospective studies have shown that operative intervention benefits many patients with DCM, and is largely safe and efficacious. The 2017 AO Spine/CSRS Guidelines provided a strong recommendation that surgery be undertaken for patients with severe and moderate DCM, using the modified Japanese Orthopedic Association (mJOA) instrument to classify the clinical severity.[3] Greater uncertainty exists in the optimal management of patients with mild DCM, with relative equipoise between nonoperative management with careful clinical observation and surgical intervention. The purpose of this review is to define this clinical entity and articulated key priorities for further clinical research.[1,4]

The clinical manifestations of DCM are remarkably heterogeneous, influenced by various factors including the degree of spinal cord compression, the specific cervical segments involved, and the individual's overall health status. This heterogeneity poses significant challenges for clinicians in terms of diagnosis, prognosis, and treatment planning, as patients with seemingly similar clinical presentations may sometimes have different underlying pathologies and responses to treatment.

The current article summarizes 4 key recent manuscripts which address the following important questions consistent with the knowledge gaps defined by the RECODE DCM efforts:

- the optimal assessment of the heterogeneous clinical presentation of patients with DCM;

- the role of magnetic resonance imaging (MRI) in assisting clinicians in defining the trajectory of recovery of patients with DCM undergoing surgical treatment;
- the role of surgery for mild DCM;
- the relative merits of anterior vs posterior surgical techniques to manage DCM when both approaches could be applied.

Methods

Recent literature related to current important topics relevant to the management of DCM was reviewed by a working group of the AO Spine Knowledge Forum Spinal Cord Injury. Four key articles, one for each of the 4 individual gaps of RECODE DCM above, were selected, summarized and critically appraised. These articles were selected based on their relevance to the knowledge gap, as well as the quality of the study. Additionally, we also summarized key findings extracted from systematic reviews published previously. Clinical recommendations were formulated and graded as Strong or Conditional using GRADE methodology.[5]

Results

The following 4 articles selected by the working group are summarized and critically appraised below.

Article 1

The Relationship Between pre-operative MRI Signal Intensity, Clinical, and Surgical Outcome in Degenerative Cervical Myelopathy. Nouri, et al. 2017 Dec 15;42(24):1851-1858. doi: 10.1097/BRS.0000000000002234.

Clinical Rationale

MRI is an important tool in the diagnosis of degenerative cervical myelopathy (DCM); in this study, the authors sought to determine whether the signal characteristics in the cervical spinal cord correlated clinically with (1) the degree of disability and (2) whether the signal abnormalities can be used as an outcome predictor.

Study Summary

Data was queried from 2 prospective DCM surgical cohorts, with 419 patients. Cervical MRI images were reviewed for changes in signal intensity in the spinal cord parenchyma and categorized into 3 groups. Those with no change in signal intensity, those with T2 hyperintensity only, and those with both T2 hyperintensity and T1 hypointensity. This categorization was then correlated with the patient's pre-operative clinical status and their 2-year post-operative outcome based on mJOA score. Baseline clinical severity was significantly increased with the presence of T2 hyperintensity and even more so with both T2 hyperintensity and T1 hypointensity. At 2-year follow-up post-operatively, those with both T2 hyperintensity and T1 hypointensity, compared to those with no signal change or with T2 hyperintensity only, were found to have significantly worse Hirabayashi recovery ratio ($r = -0.209$, $P < .001$). T1 hypointensity had the most significant correlation with the severity of disease. However, only one-fifth of patients had this MRI finding, and its inter-rater agreement was only 'fair,' thus limiting its utility.

Methodological Review

The authors conducted a retrospective analysis of 2 prospective, multicenter studies on surgical treatment of DCM, the AO Spine CSM-NA (Cervical Spondylotic Myelopathy-North America)[6] and the AO Spine CSM-I (Cervical Spondylotic Myelopathy-International)[7] studies. Pre-operative and post-operative cervical MRIs were evaluated for the presence of signal hyperintensity on sagittal T2WIs and for the presence of signal hypointensity on sagittal T1WIs at the site of the T2WI hyperintensity signal. Functional impairment was measured with the modified Japanese Orthopedic Association (mJOA) and Nurick scores. Surgical outcome at 2 years was assessed using the Hirabayashi recovery ratio and a qualified postoperative mJOA score.

Patients (n = 419) were categorized based on their MRI findings as having no signal change (28.9%), T2WI change only (51.8%), and T1WI + T2WI changes (19.3%). T2WI signal change at multiple levels was seen in 27% of the cohort. None of the signal changes were correlated with lesser myelopathic features while more severe clinical findings were associated with the presence of T2WI + T1WI findings. Baseline mJOA and Nurick scores showed a stepwise worsening trend when comparing those with no signal change, T2WI only changes, and T2WI + T1WI changes. In patients with myelopathic signs/symptoms, the number of T2WI hyperintense levels was significantly higher than in patients without myelopathic signs/symptoms.

Two-year outcome measures showed that patients with no signal change were the most likely to attain what the authors considered an optimal surgical outcome (mJOA > 16). Conversely, those patients with more T2WI hyperintense levels or T1WI + T2WI had the lowest probability of achieving an optimal surgical outcome. T2WI change alone was not significantly related to optimal surgical outcome. Using the Hirabayashi recovery ratio, T2WI + T1WI changes and the number of T2WI hyperintense levels were associated with less recovery.

Recommendation for Integrating Into Clinical Practice

MRI findings are important in evaluating patients with DCM and correlate with both the severity of symptoms and their post-surgical prognosis. T1WI hypo-intense signal change

may be an important finding, being associated with a higher frequency of myelopathic features and decreased recovery potential. Similarly, multi-level T2WI hyperintense signal changes are also associated with decreased recovery potential. Single-level T2WI hyperintense changes on MRI were found to be only weakly correlated with both preoperative clinical signs and symptoms as well as postoperative prognosis. Additionally, other metrics such as fractional anisotropy (FA), mean diffusivity, magnetization transfer (MT), and intracellular volume fraction have been shown to facilitate the diagnosis and management of DCM, respectively.[8] FA is a quantifiable measure of DTI which is decreased among patients with DCM, due to damaged axonal integrity.[9] Based on the above-mentioned findings, we provide a **conditional recommendation that understanding the correlation between MRI findings and outcomes allows the care team to better counsel their patients regarding their expected recovery.**

Article 2

Efficacy and Safety of Surgery for Mild Degenerative Cervical Myelopathy: Results of the AOSpine North America and International Prospective Multicenter Studies Spine Neurosurgery. Badhiwala, et al. 2019 April; 84(4):890-897. doi: 10.1093/neuros/nyy133.

Clinical Rationale

Treatment for mild DCM is controversial; either surgery or a trial of structured rehabilitation is recommended.[3] The categorization of DCM as 'mild', 'moderate' or 'severe' is based on the modified Japanese Orthopedic Association (mJOA) grading, which captures upper and lower extremity motor function as well as sensation and bladder control.[10] However, notably this classification does not account for quality of life measures. Surgery, the only evidence-based treatment for DCM, involves decompression of the stenotic spinal canal; however, it may be associated with complications.[11] Weighing the risks and benefits of surgery in mild DCM requires guidance from the best available evidence, particularly in the context of functional impairment and quality of life. The SF-36, a well-accepted health outcomes measure, is often used to evaluate changes in quality of life.

Study Summary

One hundred ninety-three patients with mild DCM (mJOA 15-17) were identified from the prospective, multicenter AO Spine CSM-NA and CSM-I trials. The mean age of the cohort was 52.4 years, with 34.7% being females. All patients underwent surgical decompression of the cervical spine using anterior, posterior, or combined approaches, with or without instrumented fusion. The choice of surgical approach was at the discretion of the treating surgeon.

All domains of the baseline quality of life Short Form-36 version 2 (SF-36v2) showed significant impairment compared to population norms and other common disease states, such as asthma and congestive heart failure. Impairments were particularly pronounced in social functioning, physical functioning and mental health.

At the two-year follow-up, surgically treated patients demonstrated significant improvements across all major outcome measures. Specifically, there were statistically significant improvements in the mean scores for mJOA (0.87), Nurick grade (−1.13), NDI (−12.97), as well as SF-36v2 Physical Component Summary (5.75) and Mental Component Summary (6.93). The rate of postoperative complications within 30 days of surgery was 30%, with the most common complications being the progression of myelopathy (6.74%), worsening of axial neck pain (6.22%), and dysphagia (5.70%).

Methodological Review

This study was a post-hoc analysis of 2 non-randomized prospective, multi-center cohort studies that aimed to evaluate the efficacy of surgical decompression in patients with DCM. These studies used a classification scheme of mild (mJOA 15-17), moderate (mJOA 12-14), and severe (mJOA < 12) disease categories. This classification was developed and adopted a priori with the aim to test the hypothesis that the outcomes of DCM surgery vary with disease severity.[12] The studies recruited adult patients with at least one clinical sign of myelopathy, had cervical cord compression on imaging, and had no prior cervical spine surgery.

The abstract clearly outlined the primary outcomes and key results. The methods were clearly laid out with well described and reported primary and secondary outcomes. The study performed appropriate statistical analyses for the data, including a power calculation, although it was unclear if this was developed prior to study's initiation. For the SF-36v2, the authors used a normative Canadian population for comparison. Follow-up data were available for 93.3% of patients at 24 months. Ethics approval was obtained.

The data reporting included comprehensive tables detailing baseline characteristics, symptoms, outcomes, types of surgeries, and complications. The outcomes were reported with means and 95% confidence intervals for each time point. A graph with the difference in the domains of quality of life in the mild DCM patients compared to population norms would have been informative.

The discussion was well balanced, accurately representing the findings and providing explanations for the lack of observed improvement in the 30-meter walking test. The authors adequately addressed the study limitations, especially the potential for selection bias. An interesting finding is the complication rate of 30.6%, which appears high compared to contemporary practices. However, the study cohort underwent predominantly anterior surgery for which dysphagia was a complication. The high prevalence of mild and transient

dysphagia in anterior surgical approaches likely contributes to this rate.

Overall, this study was well conducted and transparent, though it had inherent limitations due to its non-randomized design, lack of non-surgical control group, and the potential for selection bias from recruiting surgeons and variability in surgical technique. Also, categorization of severity by mJOA score may add to selection bias, as this tool has limited inter-observer reliability, with disagreement between mild and moderate severity in over 10% of patients.[13] The quality of evidence is moderate by GRADE reporting criteria.

Recommendation for Integrating Into Your Clinical Practice

The authors conducted a well-designed, retrospective cohort study using high-quality prospective data addressing an important question in spine surgery practice. As awareness of DCM in primary care increases, mild DCM is becoming a more common presentation in spinal surgical clinics, necessitating management guidance.

Given the findings of this rationally-designed and executed study, the potential improvement in function and quality of life following surgery likely outweighs associated complications, with moderate quality of evidence. Moreover, there is now evidence that surgery for mild DCM is associated with an incremental lifetime increase of 1.26 quality-adjusted life years (QALY) compared to observation.[14]

We therefore provide **a conditional recommendation, that surgery should be offered as an option in cases of mild DCM**. However, due to the lack of comparative evidence to non-surgical management, we are unable to make a strong recommendation in favour of surgery. Structured follow-up remains a viable option in the clinically-stable patient.

Article 3

Effect of Ventral vs Dorsal Spinal Surgery on Patient-Reported Physical Functioning in Patients With Cervical Spondylotic Myelopathy: A Randomized Clinical Trial. Ghogawala, Z. et al. JAMA 2021 Mar 9;325(10): 942-951. doi: 10.1001/jama.2021.1233.

Clinical Rationale

Spinal cord decompression is the primary surgical treatment for degenerative cervical myelopathy (DCM). Once a decision to intervene surgically has been made, the next clinical questions are whether surgery should be performed anteriorly (ventral) or posteriorly (dorsal), and whether it should be motion restricting or preserving.[15,16] Although objective clinical factors (comorbidities such as enthesopathies), and radiological findings (like the presence of ossification of posterior longitudinal ligament, kyphosis, instability) can influence decision making,[17,18] the surgical strategy is often heavily influenced by surgeons preferences. Previous comparative studies[19,20] have attempted to address the need for clarity in decision making, particularly whether there is equipoise for ventral and dorsal decompression. However, most of these studies have been observational in nature with no pre-defined sample size or statistical rigor, and therefore cannot exclude selection bias.[21] Randomization removes this risk, enabling the outcomes to be causally linked to a decision, and hence remain the gold standard.[22] To address this knowledge gap, Ghogawala et al[23] conducted this multi-center randomized controlled trial comparing patient-reported functional outcomes for ventral vs dorsal surgery in DCM.

Study Summary

Patients with DCM scheduled for their first surgery and requiring decompression of at least 2 cervical levels were eligible. Their imaging (MRI, CT and Dynamic X-Rays) was reviewed by a panel of investigators to confirm equipoise, and their suitability for participation. One hundred and sixty-three DCM patients were randomized to ventral (n = 63) and dorsal (n = 100) surgery. Ventral surgery included anterior cervical discectomy (or corpectomy) and fusion with anterior plating. For the dorsal approach, surgeons could choose between a laminectomy and fusion (using lateral mass screws) or an open-door laminoplasty. This allowed for a secondary analysis comparing laminoplasty with ventral and dorsal fusion surgery. The primary outcome measure was the 1-year change in the Short Form 36 Physical Component Summary (SF36 PCS). Secondary outcome measures included the modified Japanese Orthopedic Association (mJOA) scale, Neck Disability Index (NDI) and EuroQol 5 Dimensions score.

The mean change in SF-36 PCS scores did not differ significantly between the ventral and dorsal group at 1 year (5.9 vs 6.2 $P = .86$) and this effect remained at 2 years after surgery. There were no significant differences in secondary outcome measures including NDI between the 2 groups. Ventral surgery was associated with a greater risk of all complications (48% vs 24%). Most ventral complications were dysphagia (41%), with half still affected at 6 months. Both ventral and dorsal treatment arms had 4 reoperations in each group. Dorsal surgery had no reports of dysphagia, but reported higher incidence of impaired wound healing/infection, systemic complications and new radiculopathy.

The non-randomized secondary analysis showed that dorsal laminoplasty was superior to both dorsal and ventral fusion at 2 years for the primary outcome. Additionally, laminoplasty was associated with significantly lower complication rate, post-surgical health care utilization of physical therapy and opioid treatment.

Methodological Review

This trial was the first multi-center randomized trial comparing ventral and dorsal surgery for DCM. Given the challenge of

determining cases where clinical equipoise existed, Ghogawala et al used an innovative enrollment strategy that leveraged technology to create a virtual review panel of surgeons to establish the equipoise needed for eligibility to be randomized. This novel approach boosted enrollment in this study, and enabled randomization (a potential lesson for more surgical RCTs). However, the decision of the review panel may not match an individual surgeon's determination of clinical equipoise- potentially transferring the study's findings to an ineligible case. Interestingly, the primary outcome measure was the SF36 PCS quality of life scale, which is not specific to DCM.[24] However, the results also did not show a significant difference for the secondary outcomes which included a myelopathy-specific symptom score - the mJOA. All outcome measures were subjective and patient-reported. Importantly, there were no objective measures of hand dysfunction or balance and these would have reduced bias in outcome reporting.

The planned secondary analysis, of laminoplasty vs laminectomy plus fusion, was not randomized. Only 8 of the 24 participating surgeons performed laminoplasty, highlighting a potential selection bias. Whilst the data suggests that laminoplasty may be more favorable (improved outcome, and fewer adverse events), this requires further validation as the patients selected for laminoplasty may have had unique characteristics that biased them towards a better outcome than the patients who had a laminectomy and fusion (at the choice of the surgeon).

Adverse events in trials, as here, require careful scrutiny. Trials are asked to report frequency, but not all events are of equal significance to patients. Severity systems do exist for trials,[25,26] and here the number of 'major' or 'minor' events was equivalent. However, the predominant adverse event for the patients treated with ventral surgery was dysphagia, which had an incidence that was much higher than previously reported.[27] This may relate to a very sensitive screening algorithm, from which 50% of cases persisted at 6 months. While long-term follow-up is planned, it is as yet unclear if the dysphagia in this cohort eventually resolved, as one might expect. The potential need for re-operation / risks of adjacent segment disease are a priority to patient groups, and an understanding of their equivalence or relative frequency will be important for decision making.[28]

Overall, this was a well conducted randomized clinical trial that addressed a common clinical problem using an innovative strategy to determine study eligibility. The outcomes were prespecified, well-defined and cross-over was limited. Overall, based on our evaluation of the study methodology, the quality of evidence is high.

Recommendation for Integrating Into Your Clinical Practice

This multi-center randomized trial showed that there was no significant difference in outcomes between ventral and dorsal approaches for DCM in patients where there is clinical equipoise. We believe this study supports a **strong recommendation for surgeons that a ventral or dorsal approach for patients with DCM in whom there is clinical equipoise is equivalent in terms of functional recovery, pain and quality of life. The differing adverse event profile should be considered as part of a shared decision-making process with the patient.**

Article 4

Machine learning-based cluster analysis identifies 4 unique phenotypes of patients with degenerative cervical myelopathy with distinct clinical profiles and long-term functional and neurological outcomes.

Pedro KM, et. EBioMedicine. 2024 Jul 4;106:105226. doi: 10.1016/j.ebiom.2024.105226.

Clinical Rationale

It is becoming increasingly evident through DCM research and clinical care that there is considerable heterogeneity of presentations among individual patients. This variability is well-documented even in the earliest description of the disease, highlighting the diverse symptoms and signs observed among patients.[29] Recent studies on recovery trajectories further support this conceptual framework, underscoring the significant prognostic and therapeutic implications of this heterogeneity.[30] Current guidelines emphasize classification of DCM severity according to mJOA scores, but this approach has significant limitations.[3] Machine learning-based cluster analysis has evolved as a precise method to categorize subpopulations of disorders. It is a novel analytical technique that can integrate multiple data sources to classify patients into clinically relevant disease phenotypes according to their patterns of symptoms.

Study Summary

The purpose of this study was to use a machine learning clustering technique to identify unique phenotypes among patients with DCM based solely on symptom presentation. Data from 1047 DCM patients enrolled in three, large, prospective, multicenter surgical studies were analyzed to determine whether patients could be more optimally classified into distinct phenotypes using machine-learning techniques. Demographic, clinical, and surgical characteristics were combined with ratings of functional impairment, disability, and pain. This approach identified 4 novel DCM phenotypes, each with unique symptom profiles and distinct functional recovery trajectories: (1) "severe multimodal impairment", (2) "minimal impairment", (3) "motor dominant", and (4) "pain dominant". The analysis identified neck pain and frailty as important factors, but

neither of which are measured by the mJOA. Management strategies that might be optimized among phenotypes are discussed, which illustrates how patient-centered classification could inform personalized treatment.

Methodological Review

The authors conducted a retrospective analysis of combined data from three large-scale, prospective, multicenter studies on DCM. These multicenter studies were the AO-Spine CSM-NA (Cervical Spondylotic Myelopathy-North America), AO Spine CSM-I (Cervical Spondylotic Myelopathy-International), and CSM-PROTECT (Efficacy of Riluzole in the Surgical Treatment of Cervical Spondylotic Myelopathy). Patient and treatment-specific data were collected, including symptom duration, frailty, surgical approach, and disease severity. Disease severity was evaluated using the Neck Disability Index (NDI) to assess disability status, the Nurick grade to assess gait impairment, combined upper and lower extremity motor and sensory subscores from the modified Japanese Orthopaedic Association (mJOA) to assess physical disability, and neck pain scores from the NDI to assess somatic pain. These disease severity measurements were used to identify distinct patient subgroups. One year after surgery, the outcome was assessed using the change in mJOA (ΔmJOA) and physical and mental quality of life (SF-36 MCS, PCS).

An unsupervised machine learning algorithm was used (k-means using Euclidean distance) to categorize baseline disease severity into clusters. The study identified 4 optimal groups, leading to the discovery of 4 distinct DCM phenotypes. The baseline and one-year outcome for each phenotype were described as follows:

1. *Severe multimodal impairment:* Patients exhibited dysfunction across all symptom domains, with the highest neck pain scores, NDI, and frailty levels. Despite significant baseline disability, they showed the most substantial improvement in mJOA scores after 1 year, but had the worst quality of life outcomes.
2. *Minimal impairment:* Patients had low level of impairment across all symptom domains and the lowest score for neck pain. They achieved the highest physical quality of life scores after 1 year, but had the lowest mental quality of life scores.
3. *Motor dominant impairment:* Patients experienced significant motor and sensory dysfunction with minimal/no pain. They showed modest improvement in both physical and mental quality of life 1 year post-surgery
4. *Pain dominant impairment:* Patients had high neck pain scores but relatively better motor and sensory function than those with severe multimodal impairment. They achieved the highest mental quality of life scores 1 year after surgery.

Recommendation for Integrating Into Clinical Practice

The identification of various baseline phenotypes in DCM through a patient-centered cluster analysis may enable more accurate classification than the conventional mJOA framework. This is promising new research that may lead to individualized treatment plans. From a clinical perspective, we offer a **conditional recommendation that clinicians consider neck and arm pain, medical frailty, and the impact of DCM on health-related quality of life when counseling patients.**

Discussion

Based on the 4 articles, selected for summary and critical appraisal, the following clinical insights can be drawn. DCM is the commonest form of spinal cord impairment in adults and requires a multidimensional assessment, which includes consideration of neurological dysfunction, pain, impact on health-related quality of life, medical frailty and MR imaging changes in the cord. Surgical treatment is effective and is a valid option for mild DCM. In patients where either anterior or posterior surgical approaches can be used, both techniques afford similar clinical benefit albeit with different complication profiles.

Given the shifting demographics of our society with an aging population, it is anticipated that the incidence and prevalence of DCM will continue to rise. As defined by the RECODE DCM working group, ten key research priorities exist related to DCM which include raising the awareness of this condition, developing a greater understanding of the pathobiology of DCM, advancing regenerative and reparative options for the injured cord in DCM, defining the optimal techniques to assess clinical presentation and heterogeneity, optimizing nonoperative techniques to enhance clinical outcomes and personalizing the management of patients with DCM.[4]

The articles summarized in this review advance the field related to DCM and provide clinical insights to spine surgeons worldwide with current recommendations to assist with management. However, the articles also define key knowledge gaps that will require further research efforts. The multidimensional nature of clinical presentation of patients with DCM will require improved outcome measures, an understanding of the impact of genetics and advances in microstructural MRI. With greater awareness and improved imaging protocols, more patients with mild DCM will be identified. Hence, a greater understanding of the clinical trajectory of patients with mild DCM will be required to enhance the management of these patients. Advances in surgical technique continue to occur and will require further prospective evaluation to define the optimal personalized application in patients with DCM. The field of DCM presents exciting opportunities for further research and clinical advances.

Acknowledgments

AO Spine is a clinical division of the AO Foundation, which is an independent medically-guided not-for-profit organization. Study support was provided directly through AO Network Clinical Research. MG Fehlings wishes to acknowledge support from the Robert Campeau Family Foundation/Dr CH Tator Chair in Brain and Spinal Cord Research.

Declaration of Conflicting Interest

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: MG Fehlings is a past chair and current advisory board member of the AO Spine Knowledge Forum Spinal Cord Injury.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This study was organized and funded by AO Spine through the AO Spine Knowledge Forum Spinal Cord Injury, a focused group of international experts. SN Kurpad wishes to acknowledge support from the Bryon Riesch Paralysis Foundation.

ORCID iDs

Michael G. Fehlings https://orcid.org/0000-0002-5722-6364
Paula Valerie Ter Wengel https://orcid.org/0000-0003-1073-8239
Aditya Vedantam https://orcid.org/0000-0002-5212-0640
Daipayan Guha https://orcid.org/0000-0002-2052-4819
Konstantinos Margetis https://orcid.org/0000-0002-3715-8093
Aria Nouri https://orcid.org/0000-0002-4965-3059
Chris J. Neal https://orcid.org/0000-0002-5072-6454
Benjamin M. Davies https://orcid.org/0000-0003-0591-5069
Jefferson R. Wilson https://orcid.org/0000-0001-5965-0305
Vafa Rahimi-Movaghar https://orcid.org/0000-0001-7347-8767
Rex Marco https://orcid.org/0000-0003-3393-1672

References

1. Davies BM, Khan DZ, Barzangi K, 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*. 2024;14(2):503-512.
2. Badhiwala JH, Ahuja CS, Akbar MA, et al. Degenerative cervical myelopathy - update and future directions. *Nat Rev Neurol*. 2020;16:108-124.
3. Fehlings MG, Tetreault LA, Riew KD, 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. *Global Spine J*. 2017;7:70S-83S.
4. Davies BM, Khan DZ, Mowforth OD, et al. RE-CODE 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. *Global Spine J*. 2019;9:65S-76S.
5. Guyatt GH, Oxman AD, Vist GE, et al. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ*. 2008;336:924-926.
6. Fehlings MG, Barry S, Kopjar B, et al. Anterior versus posterior surgical approaches to treat cervical spondylotic myelopathy: outcomes of the prospective multicenter AOSpine North America CSM study in 264 patients. *Spine*. 2013;38:2247-2252.
7. Fehlings MG, Ibrahim A, Tetreault L, et al. A global perspective on the outcomes of surgical decompression in patients with cervical spondylotic myelopathy: results from the prospective multicenter AOSpine international study on 479 patients. *Spine*. 2015;40:1322-1328.
8. Khan AF, Mohammadi E, Haynes G, et al. Evaluating tissue injury in cervical spondylotic myelopathy with spinal cord MRI: a systematic review. *Eur Spine J*. 2024;33:133-154.
9. Mohammadi M, Roohollahi F, Mahmoudi MM, et al. Correlation between pre-operative diffusion tensor imaging indices and post-operative outcome in degenerative cervical myelopathy: a systematic review and meta-analysis. *Global Spine J*. 2024;14:1800-1817.
10. Tetreault L, Goldstein CL, Arnold P, et al. Degenerative cervical myelopathy: a spectrum of related disorders affecting the aging spine. *Neurosurgery*. 2015;77(Suppl 4):S51-67.
11. Tetreault L, Palubiski LM, Kryshtalskyj M, et al. Significant predictors of outcome following surgery for the treatment of degenerative cervical myelopathy: a systematic review of the literature. *Neurosurg Clin N Am*. 2018;29:115-127.e35.
12. Tetreault LA, Kopjar B, Vaccaro A, et al. A clinical prediction model to determine outcomes in patients with cervical spondylotic myelopathy undergoing surgical treatment: data from the prospective, multi-center AOSpine North America study. *J Bone Joint Surg Am*. 2013;95:1659-1666.
13. Martin AR, Jentzsch T, Wilson JRF, et al. Inter-rater reliability of the modified Japanese orthopedic association score in degenerative cervical myelopathy: a cross-sectional study. *Spine*. 2021;46:1063-1069.
14. Malhotra AK, Shakil H, Harrington EM, Fehlings MG, Wilson JR, Witiw CD. Early surgery compared to nonoperative management for mild degenerative cervical myelopathy: a cost-utility analysis. *Spine J*. 2023;24:21-31. doi:10.1016/j.spinee.2023.06.003
15. Ganau M, Holly LT, Mizuno J, Fehlings MG. Future directions and new technologies for the management of degenerative cervical myelopathy. *Neurosurg Clin N Am*. 2018;29:185-193.
16. Kotter MRN, Tetreault L, Badhiwala JH, et al. Surgical outcomes following laminectomy with fusion versus laminectomy alone in patients with degenerative cervical myelopathy. *Spine*. 2020;45:1696-1703.
17. Kwok SSS, Cheung JPY. Surgical decision-making for ossification of the posterior longitudinal ligament versus other types of degenerative cervical myelopathy: anterior versus posterior approaches. *BMC Musculoskelet Disord*. 2020;21:823.
18. Buell TJ, Buchholz AL, Quinn JC, Shaffrey CI, Smith JS. Importance of sagittal alignment of the cervical spine in the

management of degenerative cervical myelopathy. *Neurosurg Clin N Am*. 2018;29:69-82.

19. El-Ghandour NMF, Soliman MAR, Ezzat AAM, Mohsen A, Zein-Elabedin M. The safety and efficacy of anterior versus posterior decompression surgery in degenerative cervical myelopathy: a prospective randomized trial. *J Neurosurg Spine*. 2020;33:288-296.
20. Badhiwala JH, Ellenbogen Y, Khan O, et al. Comparison of the inpatient complications and health care costs of anterior versus posterior cervical decompression and fusion in patients with multilevel degenerative cervical myelopathy: a retrospective propensity score-matched analysis. *World Neurosurg*. 2020;134: e112-e119.
21. Sattari SA, Ghanavatian M, Feghali J, et al. Anterior cervical discectomy and fusion versus posterior decompression in patients with degenerative cervical myelopathy: a systematic review and meta-analysis. *J Neurosurg Spine*. 2023;1-13.
22. Collins R, Bowman L, Landray M, Peto R. The magic of randomization versus the myth of real-world evidence. *N Engl J Med*. 2020;382:674-678.
23. Ghogawala Z, Terrin N, Dunbar MR, et al. Effect of ventral vs dorsal spinal surgery on patient-reported physical functioning in patients with cervical spondylotic myelopathy: a randomized clinical trial. *JAMA*. 2021;325:942-951.
24. Yanez Touzet A, Bhatti A, Dohle E, et al. Clinical outcome measures and their evidence base in degenerative cervical myelopathy: a systematic review to inform a core measurement set (AO Spine RECODE-DCM). *BMJ Open*. 2022;12:e057650.
25. Rampersaud YR, Neary MA, White K. Spine adverse events severity system: content validation and interobserver reliability assessment. *Spine*. 2010;35:790-795.
26. Schroll JB, Maund E, Gøtzsche PC. Challenges in coding adverse events in clinical trials: a systematic review. *PLoS One*. 2012;7:e41174.
27. Wang T, Tian XM, Liu SK, Wang H, Zhang YZ, Ding WY. Prevalence of complications after surgery in treatment for cervical compressive myelopathy: a meta-analysis for last decade. *Medicine*. 2017;96:e6421.
28. Rodrigues-Pinto R, Montenegro TS, Davies BM, et al. Optimizing the application of surgery for degenerative cervical myelopathy [AO spine RECODE-DCM research priority number 10]. *Global Spine J*. 2022;12:147S-158S.
29. Clarke E, Robinson PK. Cervical myelopathy: a complication of cervical spondylosis. *Brain*. 1956;79:483-510.
30. Jaja BNR, Witiw CD, Harrington EM, et al. Analysis of recovery trajectories in degenerative cervical myelopathy to facilitate improved patient counseling and individualized treatment recommendations. *J Neurosurg Spine*. 2023;1–9.