Contemporary Practice Patterns in the Treatment of Cervical Stenosis and Central Cord Syndrome

A Survey of the Cervical Spine Research Society

Hannah A. Levy, MD, Zachariah W. Pinter, MD,* Erick R. Kazarian, MD,† Sonal Sodha, MD,‡ John M. Rhee, MD,§ Michael G. Fehlings, MD, PhD,‖ Brett A. Freedman, MD,* Ahmad N. Nassr, MD,* Brian A. Karamian, MD,¶ Arjun S. Sebastian, MD,* and Bradford Currier, MD**

Study Design: Cross-sectional study.

Objective: To evaluate for areas of consensus and divergence of opinion within the spine community regarding the management of cervical spondylotic conditions and acute traumatic central cord syndrome (ATCCS) and the influence of the patient's age, disease severity, and myelomalacia.

Summary of Background Data: There is ongoing disagreement regarding the indications for, and urgency of, operative intervention in patients with mild degenerative myelopathy, moderate to severe radiculopathy, isolated axial symptomatology with evidence of spinal cord compression, and ATCCS without myelomalacia.

Methods: A survey request was sent to 330 attendees of the Cervical Spine Research Society (CSRS) 2021 Annual Meeting to assess practice patterns regarding the treatment of cervical stenosis, myelopathy, radiculopathy, and ATCCS in 16 unique clinical vignettes with associated MRIs. Operative versus nonoperative treatment consensus was defined by a management option selected by $>80\%$ of survey participants.

Results: Overall, 116 meeting attendees completed the survey. Consensus supported nonoperative management for elderly patients with axial neck pain and adults with axial neck pain without myelomalacia. Operative management was indicated for adult patients with mild myelopathy and myelomalacia, adult patients with severe radiculopathy, elderly patients with severe radiculopathy and myelomalacia, and elderly ATCCS patients with pre-existing myelopathic symptoms. Treatment discrepancy in favor of nonoperative management was found for adult patients with isolated axial symptomatology and myelomalacia. Treatment discrepancy favored operative management for elderly patients with mild myelopathy, adult patients with mild myelopathy without myelomalacia, elderly patients with severe radiculopathy without myelomalacia, and elderly ATCCS patients without preceding symptoms.

Conclusions: Although there is uncertainty regarding the treatment of mild myelopathy, operative intervention was favored for nonelderly patients with evidence of myelomalacia or radiculopathy and for elderly patients with ATCCS, especially if preinjury myelopathic symptoms were present.

Level of Evidence: Level V.

Key Words: cervical stenosis, myelopathy, radiculopathy, central cord syndrome, myelomalacia

(*Clin Spine Surg* 2025;38:E61–E68)

Received for publication September 16, 2023; accepted June 28, 2024.

From the *Department of Orthopedic Surgery, Mayo Clinic, Rochester, MN; †Department of Orthopedic Surgery, Rothman Institute, New York City, NY; ‡Rasouli Spine Surgery, Beverly Hills, CA; §Department of Orthopedic Surgery, Emory University, Atlanta, GA; ‖Department of Surgery, Division of Neurosurgery, University of Toronto, Toronto, ON, Canada; and ¶Department of Orthopaedic Surgery, University of Utah, Salt Lake City, UT.

B.C.: DePuy, A Johnson & Johnson Company: IP royalties, SpinologyTenex: Stock or stock options, Surgalign: paid consultant, Wolters Kluwer Health-Lippincott Williams & Wilkins: publishing royalties, financial or material support, Zimmer: IP royalties. B.A.F.: Ankasa: research support, AO Spine: paid presenter or speaker, Clear Choice Therapeutics: stock or stock options, Kuros: paid consultant, Medtronic: paid consultant; research support, Neuroinnovations: stock or stock options, Synthes: paid consultant, Theradaptive: paid consultant. A.N.N.: American Orthopaedic Association: Board or committee member, AO Spine: research support, Cervical Spine Research Society: Board or committee member, Lumbar Spine Research Society: Board or committee member, Pfizer: research support, Premia Spine: research support, Scoliosis Research Society: Board or committee member, Techniques in Orthopedics: editorial or governing board. B.A.K.: Clinical Spine Surgery: editorial or governing board. A.S.S.: Cerapedics: paid consultant; paid presenter or speaker, CTL Amedica: IP royalties, DePuy, A Johnson & Johnson Company: paid consultant, Jaypee Publishers: IP royalties. J.M.R.: Alphatec Spine: paid consultant; paid presenter or speaker, Biomet: IP royalties, Cervical Spine Research Society: Board or committee member, Medtronic: paid presenter or speaker, Stryker: IP royalties; paid presenter or speaker, Wolters Kluwer Health-Lippincott Williams & Wilkins: publishing royalties, financial or material support, Zimmer: paid presenter or speaker. M.G.F.: Neuraxis: paid consultant. The remaining authors declare no conflict of interest.

Reprints: Hannah A. Levy, MD, Department of Orthopedic Surgery, Mayo Clinic, 200 1st St. SW, Rochester, MN 55905 (e-mail: levy.hannah@mayo.edu).

Supplemental Digital Content is available for this article. Direct URL citations are provided in the HTML and PDF versions of this article on the journal's website, www.jspinaldisorders.com.

DOI: 10.1097/BSD.0000000000001663

Cervical spondylosis is estimated to affect over 90% of individuals over 60 years old and can lead to symptoms of radiculopathy and/or myelopathy, which represent major causes of axial and/or radicular neck pain, functional decline, and disability.[1–3] In patients with severe degenerative cervical myelopathy (DCM) and intramedullary T2-signal change on magnetic resonance imaging (MRI), operative intervention is performed to halt neurological decline and improve quality of life and disability.[4–7] Conversely, in patients with mild radiculopathy or isolated axial neck pain in the absence of central compression, nonoperative management and as-needed surveillance are most appropriate.[8] However, significant disagreement exists regarding the indications for, and urgency of, operative intervention in patients with mild DCM, moderate to severe radiculopathy, and isolated axial symptomatology with evidence of spinal cord compression.[9–12] Specifically, in the 2017 Cervical Spine Research Society (CSRS) and AO Spine clinical practice guidelines for both mild DCM and asymptomatic cord compression with electromyographic radiculopathy, the authors highlight that there is low-level evidence in the recommendation of either operative treatment or a trial of nonoperative care with structured rehabilitation, with surgical management considered with clinical progression or stagnation.[12] Furthermore, the importance of patient age and MRI intramedullary signal intensity on the decision for surgical decision-making remains incompletely characterized.[13]

Similarly, there is ongoing controversy regarding the optimal treatment of central cord syndrome.[14,15] Acute traumatic central cord syndrome (ATCCS), the most commonly encountered incomplete spinal cord injury, generally occurs after a hyperextension injury resulting in upper greater than lower extremity sensorimotor deficit and myelopathic symptoms.[16,17] ATCCS presents in a bimodal distribution secondary to high-energy trauma in younger patients and low-energy falls in the elderly population with or without pre-existing cervical stenosis.[18] Historically, nonoperative management was often prioritized in ATCCS due to significant operative morbidity and evidence of substantial neurological improvement with observation alone.[17] Subsequently, as operative techniques improved, numerous investigations have demonstrated greater functional recovery and quicker return of motor function in operative relative to nonoperative ATCCS groups with associated mechanical instability.[19–22] However, there remains uncertainty regarding the indications for, and urgency of, operative intervention in ATCCS without mechanical instability.[14,23] Moreover, the potential role of antecedent myelopathic symptoms and MRI intramedullary signal intensity in ATCCS surgical decision-making is yet to be determined.[24]

The present investigation surveyed spine surgeons regarding significant variations in the treatment of axial neck pain, radiculopathy, DCM, and ATCCS. Utilizing multiple clinical scenarios, this study aimed to determine the presence or absence of cervical spine community treatment consensus (operative vs. nonoperative) dependent on patient age, acute and chronic symptomatology, and intramedullary signal intensity.

MATERIALS AND METHODS

Study Participants

After approval from the Institutional Review Board, a survey request was sent to all 330 physician attendees of the CSRS 2021 Annual Meeting to recruit a diverse group of surgeons who routinely treat patients with cervical spondylotic conditions. The study was deemed exempt from requiring informed consent by the Institutional Review Board. The survey assessed practice patterns related to the management of cervical stenosis and central cord syndrome through theoretical clinical scenarios. Participation criteria included post-graduate practicing spine surgeons. As such, surgical trainees, medical students, and allied staff were excluded.

Survey Design

The survey included 26 multiple-choice questions administered virtually on SurveyMonkey. Participants were asked demographic questions regarding their CSRS membership status, surgical subspecialty, practice type, number of years in practice, and location of practice. Surgeons were asked how, if at all, magnetic resonance imaging (MRI) intramedullary signal intensity (ISI) corresponding to myelomalacia, electrophysiological cervical cord dysfunction on somatosensory and motor-evoked potentials, and modified Japanese Orthopaedic Association (mJOA) score influence operative decision-making in cervical spondylosis. Participants were also questioned regarding the frequency with which they obtain mJOA for the evaluation of a patient with DCM. The remainder of the survey evaluated surgeon treatment preferences in 16 clinical vignettes with selected sagittal and axial cuts of associated MRI imaging (Supplemental Table 1, Supplemental Digital Content 1, http://links.lww.com/CLINSPINE/A334). Myelopathy severity was determined from mJOA scores (Supplemental Table 2, Supplemental Digital Content 2, http://links.lww.com/CLINSPINE/A335). The clinical scenarios focused on degenerative cervical stenosis or central cord syndrome after traumatic injury. Patients were further defined by age (older adult = age 60 or elderly = age 85), absence or presence of myelopathy and radiculopathy symptoms (presented as separate variables), and absence or presence of myelomalacia on MRI (Fig. 1). In each degenerative case vignette, surgeon participants recommended operative versus nonoperative management according to the following: return to clinic as needed, scheduled clinic follow-up without new MRI, scheduled clinic follow-up with new scheduled MRI, or surgical intervention. In the central cord syndrome cases, operative versus nonoperative management treatment decisions were presented as admit for MAP control and serial exams with no urgent surgical intervention, admit for MAP control and serial exams with surgical intervention only if neurological deterioration, urgent surgical intervention (<24 h), nonurgent surgical intervention during admission (>24 h), scheduled elective surgery post-discharge, and scheduled clinical follow-up with new

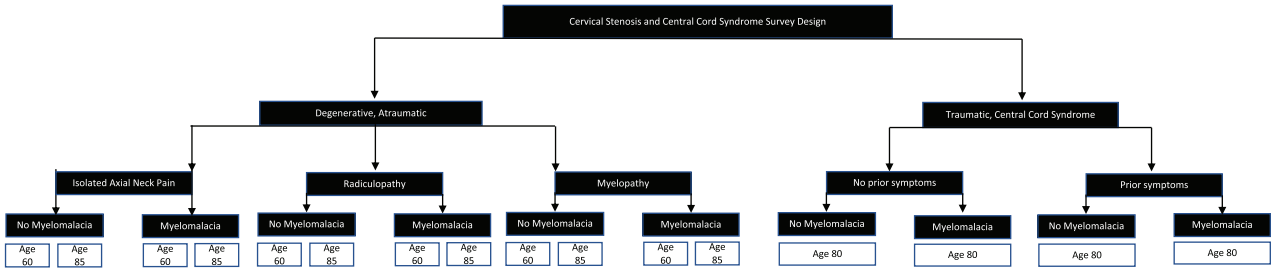

FIGURE 1. Summary of clinical vignette scenarios.

scheduled MRI. Participants were provided with the option to receive a report with aggregated survey results after survey completion.

Statistical Analysis

Survey responses were aggregated to evaluate the presence or absence of consensus regarding the management of cervical spondylosis and central cord syndrome in each clinical vignette. Operative versus nonoperative treatment consensus was defined by a single management option selected by $>80\%$ of survey participants per prior studies.[25,26] Within each presenting problem (axial neck pain, radiculopathy, DCM, and ATCCS), pairwise comparisons were utilized to directly evaluate management differences based on patient age and MRI ISI. Descriptive statistics were used to compare respondent demographics and survey responses in terms of mean and standard deviation or the number of occurrences and percent of the total. All statistical analysis was performed with the Statistical Packages for the Social Sciences (SPSS).

RESULTS

Study Participants

A total of 116 of the 330 (35.2%) CSRS 2021 meeting surgeon attendees completed the survey. Respondent demographic characteristics, including the surgical subspecialty, practice type, number of years in practice, location of practice, and CSRS membership status, are shown in Table 1. The majority of respondents were orthopedic surgeons (84.5%), practiced in an academic setting (48.3%), practiced in the United States (69.8%), and had been in practice for >10 years (70.4%) (Table 1).

Surgical Decision-Making Tools

The majority of respondents (58.7%) believed that mJOA should be utilized to direct the clinical management of patients with myelopathy. However, the frequency of obtaining mJOA in clinical practice was variable among surgeons: 23.3% always, 25.0% frequently (more than two-thirds of cases), 23.3% in select cases (less than one-third of cases), and 28.5% never. Similarly, 85.8% of respondents reported that ISI on MRI impacted their surgical decision-making. Specifically, surgeons noted that the likelihood of surgery increased with the greater longitudinal extent of myelomalacia on the T2-weighted image (52.2%), greater ISI on the T1-weighted image (48.7%), and more intense and sharply demarcated margin of ISI on the T2 (38.1%). A small minority of surgeons (9.73%) reported that the presence of myelomalacia increased the probability of anterior surgery to achieve direct decompression. Conversely, most survey respondents (79.8%) did not believe that the presence of electrophysiological cervical cord dysfunction on somatosensory and motor-evoked potentials was an indication for surgery in an asymptomatic patient.

Clinical Vignettes

Axial Neck Pain and Asymptomatic Stenosis

In patient cases with axial neck pain without myelopathy or radiculopathy symptoms, there was consensus that nonoperative management was indicated for both adult (98.3%) and elderly (99.1%) patients without myelomalacia and elderly patients with myelomalacia (82.8%) (Fig. 2). The majority of surgeons favored scheduling nonoperative clinical follow-up without a new scheduled MRI (Fig. 2). There was discrepancy favoring nonoperative (66.4%) versus operative (33.6%) management in adults with axial symptoms and myelomalacia.

Mild Myelopathy

Consensus opinion (85.3%) supported the operative management of adult patients with mild DCM (with reference to mJOA range) and myelomalacia on MRI. However, discrepancies in surgical decision-making existed for elderly patients with myelomalacia and both adult and elderly patients without myelomalacia (Fig. 3).

Radiculopathy in the Presence of Spinal Cord Compression

In patients presenting with severe radiculopathy and asymptomatic cord compression, surgeon consensus supported operative management for those with radiographic evidence of myelomalacia (adult: 96.6%, elderly: 86.2%), regardless of age, and adults without myelomalacia (87.0%). Of note, the decision to proceed with operative management was dependent on the severity of radiculopathy (Fig. 4). Adults with myelomalacia compromised the patient demographic with the greatest likelihood of surgical treatment independent of radicular symptom severity (Fig. 3). There was a discrepancy favoring operative intervention (77.6%) in elderly patients with radiculopathy without myelomalacia.

TABLE 1. Summary of Respondent Demographics

Category	Characteristic	Respondent (%)
Geographic location, n = 116	United States	69.8
	North America—Outside of the United States	6.0
	Europe	12.9
	South America	1.7
	Asia	13.8
Number of years in practice, n = 115	< 1 year	2.6
	1–5 years	13.0
	5–10 years	13.9
	11–15 years	12.2
	16–25 years	23.5
	> 26 years	34.8
Surgical subspecialty, n = 116	Neurosurgeon	14.7
	Orthopedic spine	84.5
	Other	0.9
Practice type, n = 116	Private	25.9
	Academic	48.3
	Privademic	19.8
	Other	6.0

Central Cord Syndrome

In elderly patients with ATCCS who endorsed myelopathic symptoms preceding the trauma, surgeon consensus supported operative management (myelomalacia: 94.9%, no myelomalacia: 89.6%). Most surgeons favored performing surgery during the index hospitalization on an urgent (myelomalacia: 44.4%, no myelomalacia: 43.1%) or nonurgent (myelomalacia: 40.0%, no myelomalacia: 34.5%) basis. Conversely, in ATCCS patients without preceding symptoms, there was a discrepancy favoring operative (myelomalacia: 79.3%, no myelomalacia: 71.4) versus nonoperative (myelomalacia: 20.7%, no myelomalacia: 28.6%) treatment (Fig. 5).

DISCUSSION

In cervical spondylosis associated with radiculopathy or myelopathy and ATCCS, there is an ongoing controversy in the spinal literature regarding the indications for and relative urgency of operative intervention. The results of the present survey highlight the continued uncertainty in the management of mild DCM and cervical spinal cord compression with myelopathic symptoms. Clinical practice guidelines developed by CSRS and AO Spine in 2017 suggest surgical intervention in patients with moderate or severe myelopathy, surgical intervention or structured rehabilitation for patients with mild DCM, no surgical intervention for non-myelopathic patients with cervical spinal cord compression, and surgical intervention or nonoperative care with close surveillance for non-myelopathic patients with cervical spinal cord compression and clinical evidence of radiculopathy.[12] However, these treatment recommendations are not only limited to aggregation of evidence from small observational studies but also do not account for patient-specific demographic or diagnostic characteristics outside of myelopathy severity assessment.

In agreement with prior literature and clinical practice guidelines, the current investigation's results favor nonoperative management for the majority of patients with cervical stenosis with spinal cord compression not associated with myelopathy or radiculopathy.[10,13,27] Previous investigations have shown that the short-term risk of developing myelopathy in asymptomatic patients with cervical spondylosis is generally low.[13,27] In an observational cohort of patients with asymptomatic discogenic or osteoligamentous spinal cord compression, < 25% developed myelopathic symptoms by 2-year follow-up.[28] Furthermore, while it is possible that asymptomatic degenerative central stenosis increases the risk of neurological injury after trauma, there has been minimal evidence to

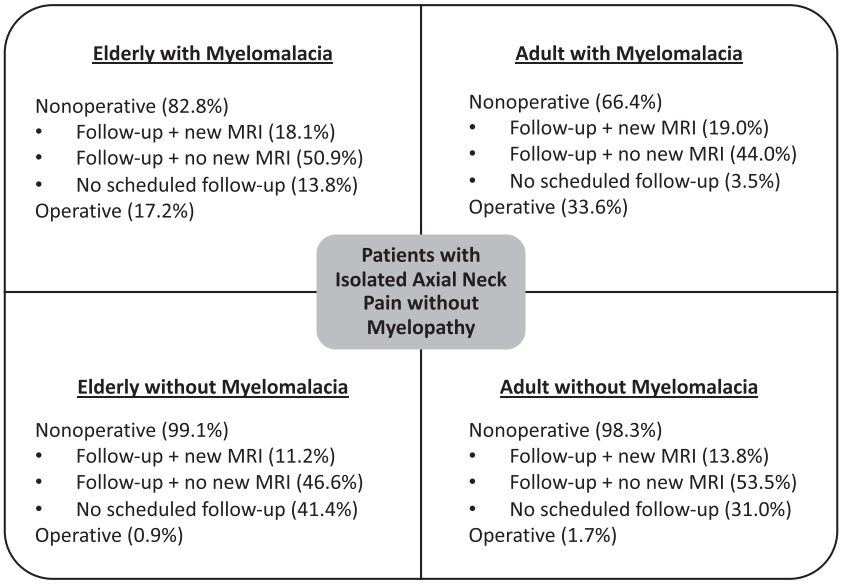

FIGURE 2. Summary of survey responses in axial neck pain case scenarios.

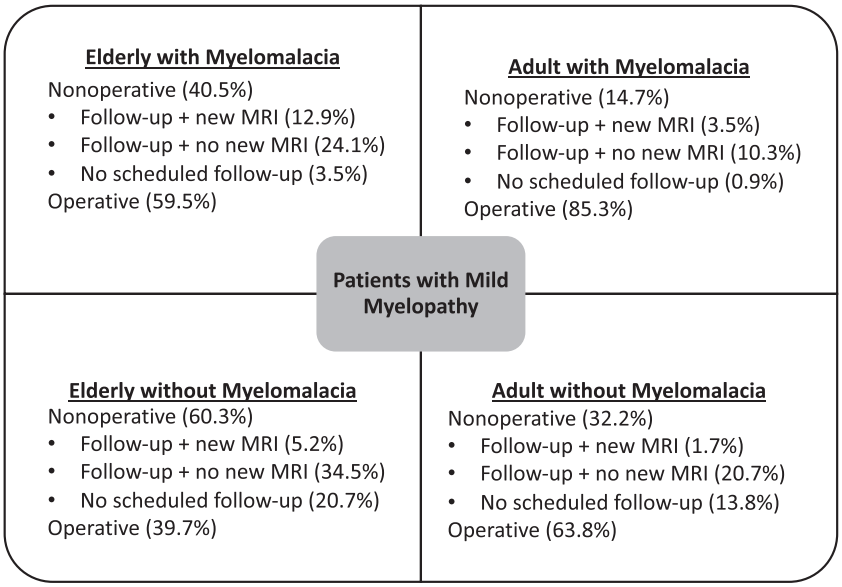

FIGURE 3. Summary of survey responses in mild myelopathy case scenarios.

support this finding, and currently is not an indication for prophylactic fixation.[29] However, numerous patient anatomic factors including greater canal occupancy ratio, native cervical range of motion, and extent of posterior longitudinal ligament ossification and evidence of electrophysiological and ISI spinal cord changes may increase the risk or rate of myelopathy development.[8,13,27] As such, in the current study, approximately one-third of survey respondents supported surgical intervention for axial neck pain with central stenosis only in younger patients if myelomalacia was present. The survey results also underscore the importance of scheduled clinical follow-up in patients with a younger age of presentation or who are at elevated risk of developing myelopathy. However, the majority of surgeons did not recommend obtaining a new MRI at follow-up, which likely reflects that progression to operative management in known cervical central stenosis depends primarily on evolving myelopathic symptoms and exam findings.

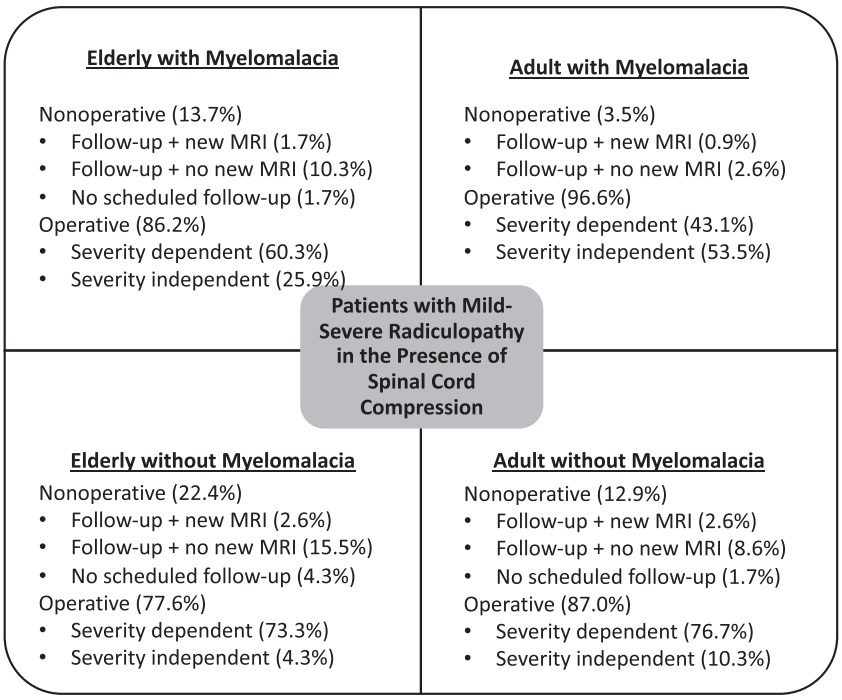

FIGURE 4. Summary of survey responses in radiculopathy case scenarios.

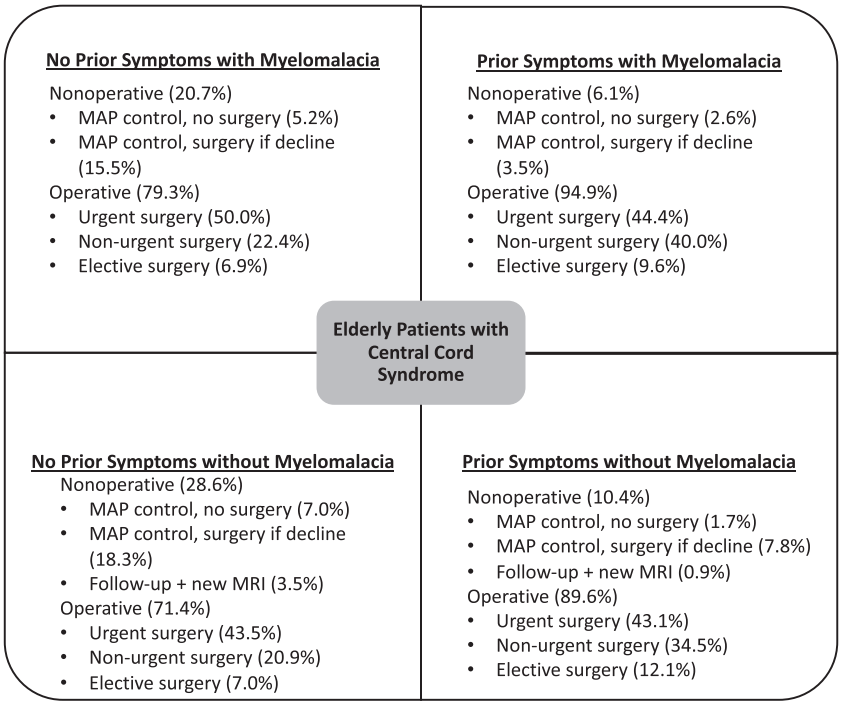

FIGURE 5. Summary of survey responses in ATCCS case scenarios.

The current survey results highlight the dearth of evidence to support operative or nonoperative intervention for patients with mild DCM, demonstrating discrepancy in the management of elderly patients with mild DCM and adult patients with mild DCM without myelomalacia.[10,30,31] Prior literature has demonstrated that preoperative cervical spinal cord T1 hypo-intensity, but not T2 hyperintensity, is associated with lower mJOA score after decompression and fusion for myelopathy.[32,33] However, there is conflicting evidence to support T1 hypo-intensity as an independent predictor of postoperative neurological recovery.[32,34] Furthermore, these investigations do not attempt to stratify patients with mild versus moderate-severe myelopathy and are focused on postoperative outcomes rather than operative indications. Similarly, the impact of patient age on DCM operative decision-making and postoperative outcomes remains controversial.[9,35–37] In a small cohort study of patients with mild myelopathic symptoms and spinal cord compression with T2 hyperintensity, patient age at presentation was not found to predict the need for surgical intervention over the 3-year study period.[9] Conversely, in a matched cohort analysis of DCM patients $<$ age 70 versus $\geq$ age 70, the postoperative improvement in mJOA, neck disability index, and physical and mental component scores were significantly greater in the younger group.[36] In the present investigation's mild DCM case scenarios, when patient age and MRI ISI were altered independently, there was no consensus on operative versus nonoperative management. However, the mild DCM case scenario with both a younger patient and myelomalacia present was generally found to warrant operative intervention.

In the current study, there was consensus that operative treatment is warranted for patients with severe cervical radiculopathy, with the exception of elderly patients without myelomalacia. Cervical radiculopathy randomized controlled studies comparing anterior cervical discectomy and fusion with physical therapy to physical therapy alone demonstrate excellent recovery of both groups but significantly greater improvement in neck disability index and VAS pain directly after surgery that is generally sustained at long-term follow-up.[38,39] In contrast to severe DCM, an initial trial of medical management, physical therapy, and corticosteroid injections is generally indicated in radiculopathy regardless of presenting symptom severity due to good long-term improvement potential. It is possible that surgery for radiculopathy was severity-dependent in this study because patients with severe presentation were more likely recalcitrant to conservative management. Furthermore, clinical practice guidelines have identified that cervical radiculopathy in the presence of central stenosis increases the risk of developing symptomatic myelopathy.[10,12,28] In a recent systematic review, electromyographic signs of anterior horn cell lesions (relative risk = 2.4) and symptomatic radiculopathy (relative risk = 3.0) were identified as risk factors for the development of myelopathy defined as the development of myelopathic symptoms and a concurrent decrease in mJOA $\geq$1.[27] As such, in adult patients with radiculopathy and myelomalacia without myelopathy, over half of the survey respondents supported operative intervention independent of the radiculopathy severity, likely reflecting the likelihood of myelopathy development in this subgroup.

The survey results support operative management in >70% of elderly individuals with ATCCS, regardless of MRI ISI or prior symptomology, which reflects the general shift from historically nonoperative management to early surgical decompression to maximize the rate and extent of neurological and functional recovery.[14,15,23] Numerous patient and injury-specific factors have been associated with poor prognosis in ATCSS and should be considered to guide operative decision-making, including older age, greater medical comorbidities, unstable injury patterns, and greater severity of spinal cord injury assessed through ASIA grade, spasticity, hand function, and cord compression on MRI T1 and T2 sequences.[15,24,40] In addition, underlying cervical spondylosis with central stenosis may increase the risk of neurological compromise associated with traumatic injury proximity to a rigid segment.[24] In this study, both myelomalacia and pre-injury myelopathic symptoms increased the likelihood of ATCCS operative intervention; however, >80% consensus supporting operative management was only present in cases of pre-injury symptoms. To the author's knowledge, the present investigation is the first to directly study the impact of pre-existing myelopathic symptoms on ATCCS management, likely due to inherent limitations in medical charting and retrospective data collection. These novel survey findings suggest that provider assessment of pre-injury motor, sensory, hand dexterity, and bowel and bladder function should be prioritized for ATCCS patients, especially in individuals with underlying central stenosis.

The survey results highlight the ongoing controversy regarding the optimal timing of surgical decompression in ATCCS. Survey respondents generally agreed that operative decompression should be performed during the index hospitalization, but there was a lack of agreement as to whether surgery should be performed on an urgent (<24 h) or nonurgent basis. In the Surgical Timing in Acute Spinal Cord Injury Trial, which evaluated operative intervention less than versus greater than or equal to 24 hours after cervical spinal cord injury, patients in the early decompression group were more likely to experience a 2-grade improvement in ASIA grade at 6 months follow-up.[41] However, this study included all patients with incomplete cervical spinal cord injury and was not specific to ATCCS. A 2015 systematic review on ATCCS surgical timing found that while urgent surgical intervention after ATCCS was safe and effective, there was only low-level evidence that urgent versus nonurgent intervention led to significantly greater ASIA and mJOA improvement at 1-year follow-up.[23]

This study is not without limitations, including those inherent in the application of survey-based studies into clinical practice. Though the case scenarios provided patient demographics, clinical symptoms, and MRI studies, they are unable to reflect the nuances of actual patient presentations with respect to operative decision-making and are incompletely generalizable. Furthermore, while the survey was delivered to a large group of experienced spine surgeons at a prominent cervical spine research meeting, the conference attendees likely imparted a selection bias favoring American spine surgeons (69.8%) who practice in an academic environment (48.3%). In addition, with an approximately one-third survey response rate, there is a significant response bias with unclear effects on survey results. Regarding survey design, this study focused primarily on the effects of age and MRI ISI in cervical stenosis and mild myelopathy, and as such, incompletely evaluated operative decision-making in isolated radiculopathy or severe myelopathy and the potential effects of additional clinical or imaging findings on myelopathy management. Lastly, future survey studies may aim to stratify degenerative and traumatic myelopathy surgical indications based on respondent demographics, training, and practice environments; however, this was not currently performed to increase clarity and simplicity of data presentation. In this investigation, stratification by multiple respondent demographics could not be performed while maintaining the deidentified nature of survey responses.

Though there is a general lack of consensus regarding the treatment of mild DCM, the survey results suggest that operative intervention may be considered in younger patient populations and those with evidence of myelomalacia or clinical findings of radiculopathy. In contrast, the majority of surgeons preferred operative management of elderly patients with ATCCS, especially if pre-injury myelopathic symptoms were present. There was a strong consensus against operative treatment in patients, regardless of age, with MRI evidence of cord compression but without clinical myelopathy. The management of mild DCM is an important area of controversy that requires attention and this knowledge gap represents an opportunity for translational research. In addition, management standards for ATCCS likely require revision in view of mounting evidence favoring an important role of surgical intervention. It is also recognized that the management of elderly patients and those with medical frailty remain challenges that require further research and discussion.

REFERENCES

1. Tracy JA, Bartleson JD. Cervical spondylotic myelopathy. *Neurologist*. 2010;16:176–187.
2. Iyer S, Kim HJ. Cervical radiculopathy. *Curr Rev Musculoskelet Medicine*. 2016;9:272–280.
3. Fakhoury J, Dowling TJ. *Cervical Degenerative Disc Disease*. In: StatPearls, ed. StatPearls Publishing LLC; 2020.
4. Nouri A, Tetreault L, Singh A, et al. Degenerative cervical myelopathy. *Spine*. 2015;40:E675–E693.
5. Tetreault LA, Kopjar B, Vaccaro A, et al. A clinical prediction model to determine outcomes in patients with cervical spondylotic myelopathy undergoing surgical treatment. *J Bone Jt Surg*. 2013;95:1659–1666.
6. Levy HA, Karamian BA, Adams AJ, et al. The impact of preoperative symptom duration on patient outcomes after posterior cervical decompression and fusion. *Glob Spine J*. 2022;13:219256822210877.
7. Badhiwala JH, Ahuja CS, Akbar MA, et al. Degenerative cervical myelopathy— update and future directions. *Nat Rev Neurol*. 2020;16:108–124.
8. Naito K, Yamagata T, Ohata K, et al. Management of the patient with cervical cord compression but no evidence of myelopathy what should we do? *Neurosurg Clin N Am*. 2018;29:145–152.

9. Oshima Y, Seichi A, Takeshita K, et al. Natural course and prognostic factors in patients with mild cervical spondylotic myelopathy with increased signal intensity on T2-weighted magnetic resonance imaging. *Spine*. 2012;37:1909–1913.
10. Fehlings MG, Wilson JR, Yoon ST, et al. Symptomatic progression of cervical myelopathy and the role of nonsurgical management. *Spine*. 2013;38(22S):S19–S20.
11. Woods BI, Hilibrand AS. Cervical radiculopathy. *J Spinal Disord Tech*. 2015;28:E251–E259.
12. 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. *Glob Spine J*. 2017;7(3_suppl):70S–83S.
13. Witiw CD, Mathieu F, Nouri A, et al. Clinico-radiographic discordance: an evidence-based commentary on the management of degenerative cervical spinal cord compression in the absence of symptoms or with only mild symptoms of myelopathy. *Glob Spine J*. 2018;8:527–534.
14. Divi SN, Schroeder GD, Mangan JJ, et al. Management of acute traumatic central cord syndrome: a narrative review. *Glob Spine J*. 2019;9(1_suppl):89S–97S.
15. Bulloch LR, Spector L, Patel A. Acute traumatic myelopathy: rethinking central cord syndrome. *J Am Acad Orthop Sur*. 2022;30: 1099–1107.
16. Hayes, Hsieh JTC KC, Wolfe DL, et al. Classifying incomplete spinal cord injury syndromes: algorithms based on the International Standards for Neurological and Functional Classification of spinal cord injury patients. *Arch Phys Med Rehabilitation*. 2000;81:644–652.
17. Schneider RC, Cherry G, Pantek H. The syndrome of acute central cervical spinal cord injury: with special reference to the mechanisms involved in hyperextension injuries of cervical spine. *J Neurosurg*. 1954;11:546–577.
18. Molliqaj G, Payer M, Schaller K, et al. Acute traumatic central cord syndrome: a comprehensive review. *Neurochirurgie*. 2014;60(1–2):5–11.
19. Jug M, Kejžar N, Vesel M, et al. Neurological recovery after traumatic cervical spinal cord injury is superior if surgical decompression and instrumented fusion are performed within 8 hours versus 8 to 24 hours after injury: a single center experience. *J Neurotrauma*. 2015;32:1385–1392.
20. Chen T-Y, Lee S-T, Lui T-N, et al. Efficacy of surgical treatment in traumatic central cord syndrome. *Surg Neurol*. 1997;48:435–441.
21. Brodkey JS, Miller CF, Harmody RM. The syndrome of acute central cervical spinal cord injury revisited. *Surg Neurol*. 1980;14:251–257.
22. Badhiwala JH, Wilson JR, Harrop JS, et al. Early vs late surgical decompression for central cord syndrome. *JAMA Surg*. 2022;157: 1024–1032.
23. Anderson KK, Tetreault L, Shamji MF, et al. Optimal timing of surgical decompression for acute traumatic central cord syndrome: a systematic review of the literature. *Neurosurgery*. 2015;77(suppl_1): S15–S32.
24. Song J, Mizuno J, Inoue T, et al. Clinical evaluation of traumatic central cord syndrome: emphasis on clinical significance of prevertebral hyperintensity, cord compression, and intramedullary high-signal intensity on magnetic resonance imaging. *Surg Neurol*. 2006;65:117–123.
25. Mallack EJ, Turk BR, Yan H, et al. MRI surveillance of boys with X-linked adrenoleukodystrophy identified by newborn screening: meta-analysis and consensus guidelines. *J Inherit Metab Dis*. 2021; 44:728–739.
26. Olszewska E, Rutkowska J, Ozgirgin N. Consensus-based recommendations on the definition and classification of cholesteatoma. *J Int Adv Otol*. 2015;11:81–87.
27. Wilson JR, Barry S, Fischer DJ, et al. Frequency, timing, and predictors of neurological dysfunction in the nonmyelopathic patient with cervical spinal cord compression, canal stenosis, and/or ossification of the posterior longitudinal ligament. *Spine*. 2013;38 (22S):S37–S54.
28. Bednarik J, Kadanka Z, Dusek L, et al. Presymptomatic spondylotic cervical myelopathy: an updated predictive model. *Eur Spine J*. 2008; 17:421–431.
29. Chang V, Ellingson BM, Salamon N, et al. The risk of acute spinal cord injury after minor trauma in patients with preexisting cervical stenosis. *Neurosurgery*. 2015;77:561–565.
30. Rhee JM, Shamji MF, Erwin WM, et al. Nonoperative management of cervical myelopathy. *Spine*. 2013;38(22S):S55–S67.
31. Matz PG. Does nonoperative management play a role in the treatment of cervical spondylotic myelopathy? *Spine J*. 2006;6: S175–S181.
32. Nouri A, Tetreault L, Zamorano JJ, et al. Role of magnetic resonance imaging in predicting surgical outcome in patients with cervical spondylotic myelopathy. *Spine*. 2015;40:171–178.
33. Uchida K, Nakajima H, Takeura N, et al. Prognostic value of changes in spinal cord signal intensity on magnetic resonance imaging in patients with cervical compressive myelopathy. *Spine J*. 2014;14:1601–1610.
34. Nouri A, Tetreault L, Côté P, et al. Does magnetic resonance imaging improve the predictive performance of a validated clinical prediction rule developed to evaluate surgical outcome in patients with degenerative cervical myelopathy&quest. *Spine*. 2015;40: 1092–1100.
35. Nakashima H, Tetreault LA, Nagoshi N, et al. Does age affect surgical outcomes in patients with degenerative cervical myelopathy? Results from the prospective multicenter AOSpine International study on 479 patients. *J Neurol, Neurosurg Psychiatry*. 2016; 87:734.
36. Wilson JRF, Badhiwala JH, Jiang F, et al. The impact of older age on functional recovery and quality of life outcomes after surgical decompression for degenerative cervical myelopathy: results from an ambispective, propensity-matched analysis from the CSM-NA and CSM-I international, multi-center studies. *J Clin Med*. 2019;8: 1708.
37. Bond M, McIntosh G, Fisher C, et al. Treatment of mild cervical myelopathy: factors associated with decision for surgical intervention. *Spine*. 2019;44:1606–1612.
38. Engquist M, Löfgren H, Öberg B, et al. A 5- to 8-year randomized study on the treatment of cervical radiculopathy: anterior cervical decompression and fusion plus physiotherapy versus physiotherapy alone. *J Neurosurg: Spine*. 2017;26:19–27.
39. Peolsson A, Söderlund A, Engquist M, et al. Physical function outcome in cervical radiculopathy patients after physiotherapy alone compared with anterior surgery followed by physiotherapy. *Spine*. 2013;38:300–307.
40. Ehara S, Shimamura T. Cervical spine injury in the elderly: imaging features. *Skelet Radiol*. 2001;30:1–7.
41. Fehlings MG, Vaccaro A, Wilson JR, et al. Early versus delayed decompression for traumatic cervical spinal cord injury: results of the Surgical Timing in Acute Spinal Cord Injury Study (STASCIS). *PLoS One*. 2012;7:e32037.