Clinical and Radiological Parameters Predict Functional Improvement following Surgical Intervention

Undergraduate Research Thesis

Presented in Partial Fulfillment of the Requirements for graduation "with Research Distinction"

in the undergraduate Colleges of Ohio State University

By

Erin Sheehan

The Ohio State University

April 24, 2020

Project Advisor: Dr. H. Francis Farhadi, MD, PhD, College of Medicine

Introduction

Cervical spondylotic myelopathy (CSM), defined as "compression of the spinal cord in the cervical area of the spine", which ranges widely in severity and mechanism. [1] In North America, the prevalence (the number of people currently living with cervical spinal myelopathy) is estimated at 605 per million. The annual incidence (the rate of cases per person-time) is estimated at 4.04 cases/ 100,000 people/ year, which equates to approximately 23,000 new cases each year. [2] These metrics do not uniformly affect the entire population with CSM found in 85% of the individuals over 60. [3] The most common modes of onset are due to the aging process which results in degenerative changes and in advanced cases, compression of the spinal cord. [4]

The region of the spine affected can result in instability of gait, loss of fine motor control of upper limbs, weakness, and neck pain with reduced range of motion.[5] Patients with CSM incur great cost for chronic treatments as well as surgery, with the average patient in 2012 spending $32,916 per quality-adjusted life year on surgery.[6] Severe cases of CSM can result in patients having severe pain, a loss of mobility, and increased social and economic ramifications. CSM can result in lower quality of life as demonstrated by consistent Short Form Survey- 36 (SF-36), specifically in the younger population. [7] Due to the severe social and economic consequences, our ability to prognosticate neurological and functional recovery is critical to patient counseling and resource distribution. Additionally, proper measurements to assess CSM progression could potentially improve outcomes and treatment plans.

The two available options clinicians offer patients are primarily surgical and in some cases non-surgical treatment. Surgical decompression is the most common procedure used to stabilize the spine in severe cases. It has been found that approximately two-thirds improve following surgery with 15-30% of cases being unsuccessful.[8] There is some debate as to which

approach is optimal for treatment of CSM. In the US, the three most common are anterior decompression and fusion, posterior decompression and fusion, and laminoplasty. [9] Each technique has its own benefits and drawbacks taking into consideration the number of levels each patient has compressed. However, the ultimate goal of these surgeries is the same through relieving pressure from the spinal cord and allowing the nerves to no longer be compressed. [10]

The current research involving CSM involves studying surgical outcomes and determining the most reliable outcome measurements including radiological variables. Previous to this study, a thoracic myelopathy study has found intermedullary lesion length (IML) to be a factor to predict postoperative recovery.[16] In this paper, I will investigate the relative ability for various radiological parameters to serve as measurements that can improve outcomes and treatment plans in CSM. Parameters we looked at include age, sex, weight, smoking history, diabetes, coronary artery disease, hypertension, COPD, chronic heart failure, symptom duration, and previous history in a retrospective analysis presenting to Dr. Farhadi in a consecutive case series.

The relevant admission magnetic resonance imaging (MRI) study parameters are defined on page 7 of this text. Torg- Pavlov, Lateral-Mass Canal, T1 Change, T2 Change, Compression levels with only anterior or posterior, Compression levels with both anterior and posterior, and Compression levels with both. An important component regarding patient recovery studied was the Modified Japanese Orthopedic Association (mJOA). This measurement is an investigator-administered tool that can evaluate neurological function in patients with CSM based on an 18 point scale. It specifically looks at upper extremity (5 points) and lower extremity (7 points) motor function, sensation (3 points) and micturition (3 points). A total score of 18 reflects no neurological deficits whereas a lower score indicates a greater degree of disability and functional

impairment. Severe cases are classified approximately from 0-11, moderate are 12-14, and mold are 15-17. [11] One limitation of this system is that is does not address the sensory function in the trunk or lower extremities. [12] Another investigator administered tool used to evaluate functional status in patients with degenerative cervical myelopathy was the Nurick grade. This tool is a 5 points scale looking at functional impairment in DCM. Sever cases are classified from 3-5 with moderate cases ranging from 1-2 and healthy patients with a score of 0.

Non-surgical treatments of CSM are limited and may be treated with cervical immobilization, analgesics, anti-inflammatory and physiotherapy.[13] In cases associated with cervical radiculopathies, drugs such as tricyclic antidepressants, anticonvulsants or even antagonists of drugs N-methyl-D-aspartate receptors as riluzole may be used.[14] The new potential treatment of riluzole was found to reduce oxidative damage in animal models and improve long term function following decompression surgery. [15] Recent phase 3 clinical trials show a potential treatment for non-surgical options. However, no treatment except surgical decompression has been proven in humans to promote recovery due to the heterogeneity of the condition.

Previous studies have shown mJOA to be useful in assessing pre-surgical vs. post-surgical analysis. (Figure 2) Similar statistical testing will be employed here to assess the potential significance of these admission findings in the context of cervical spondylitic myelopathy. The use of various radiological parameters as measures compared to mJOA may also help further stratify patients in clinical trials to assess for potential therapeutic benefits.

Methods

Research Questions

- What is the ability of various admission imaging parameters in predicting neurologic recovery for patients with degenerative CSM following surgery?
- Can these various parameters be used for prognosticating recovery and improve mJOA following surgical decompression?

Study Population

A total of 368 patient medical records tagged for myelopathy were reviewed. From this population, a total of 50 patients fit the inclusion criteria, and were included in this analysis (Figure 1). Males and females were equally represented. However, of the sample group that had no ΔmJOA, more males were present with 72.2% being represented. The mean age of the cohort was 64.33 ± 10.79 for patients with no change in ΔmJOA and 63.53 ± 9.93 for patients with a change in ΔmJOA. There was a disproportionately represented of patients over the age of 55 due to the nature of myelopathy. BMI ranged significantly with patients with no change in ΔmJOA having a mean of 28.07 ± 7.84 and patients with a change in ΔmJOA having a mean of 32.66 ± 6.20. Smoking status was highly variable with patients with no change in ΔmJOA having 16.7% current smokers, 50% former smokers, 33.3% never. Patients with a ΔmJOA had 21.9% current smokers, 37.5% former smokers, and 40.6% never. Type II diabetes mellitus was relatively similar with patients with no ΔmJOA having a mean of 27.8% and patients with a ΔmJOA having a mean of 21.9%. Coronary Artery Disease was present in 16.7% of patients with no ΔmJOA and 21.9% of patients with a ΔmJOA. Hypertension was very common with a mean of 61.1% of patients without a ΔmJOA and 65.6% of patients with a ΔmJOA. COPD/ Pulmonary hypertension had a mean of 22.2% of pateitns without a ΔmJOA and 15.6% of patients with a ΔmJOA. Additionally, chronic heart failure was present in 5.6% of patients with no ΔmJOA and

9.4% of patients with a ΔmJOA. Duration of symptoms had a mean of 21.39 ± 27.27days for patients with no ΔmJOA and a mean of 37.13 ± 64.89days for patients with ΔmJOA. Finally, history of other neck surgery was also observed with a mean of 16.7% of patients without a ΔmJOA and 15.6% of patients with ΔmJOA.

Study Design

Institutional Review Board approval was obtained and followed throughout the duration of the study. This study was conducted using a single surgeon retrospective analysis following consecutive surgical patients. This study design allows for a good estimate of risk, and a clear temporal relationship between surgical decompression and outcomes (neurologic severity and mJOA change). This study design also allows investigators to investigate more than one outcome. However, retrospective studies are potentially hampered by loss-to-follow up as well as potential different modes of data collection across institutions. Data was drawn from the IHIS Electronic Medical Record System.

Data Collection

Patients were enrolled in a prospective fashion and the data was collected from 368 patient medical record numbers (MRNs) associated with myelopathy of lumbar, thoracic, and cervical regions from Information Warehouse at The Ohio State University. All patients were evaluated at The Ohio State Wexner Medical Center in a consecutive series from 2013-2018. The patients were analyzed with regard to the following inclusion and exclusion criteria (figure 1).

Inclusion/ Exclusion Criteria

Patients with thoracic or lumbar myelopathy were excluded. Patients who had other diagnoses than CSM were excluded. Patients with cervical radiculopathy, abysses, infections or

trauma were excluded. Patients with less than one year follow up were excluded. Patients that had concomitant severe lumbar stenosis requiring surgery were excluded due to confounding symptoms resulting from their lumbar diagnosis. The inclusion criteria were as follows: (1) 18 years of age or older (2) Diagnosis of CSM (3) Underwent cervical surgical fusion decompression by Dr. Farhadi (4) Admitted directly to Ohio State University Wexner Medical Center, or transferred with full documentation of care; (5) presence of admission MRI; (6) availability of one-year follow-up data. The presence of admission imaging was of paramount importance, as 12 of the MRI parameters were used to prognosticate outcomes following surgical decompression.

Study Parameters

- Torg Pavlov was used to evaluate canal stenosis and cord compression. This measure is a continuous variable calculated by dividing the sagittal diameter of the spinal canal to the sagittal diameter of the corresponding vertebral body. This measurement is useful to describe developmental spinal canal stenosis and has been proven to be reliable for determining cervical spinal stenosis. Collected at levels C3-C6 of the spine and averaged.
- Lateral Mass to Canal diameter was also used to evaluate canal stenosis and cord compression. This measure is a continuous variable calculated by dividing the overlay of facet articulations on lateral cervical radiographs. These facet articulations share a roughly similar geographic location as the spinal canal. This measurement is useful to detect spinal canal narrowing and stenosis. One limitation of this method are patients with congenital spinal stenosis which is a condition in which this method would not account for the already narrow spine. Collected at levels C3-C6 of the spine and averaged.

- The number of compression levels with anterior and posterior CSF, number of levels with only anterior or posterior CSF, and the number of levels with both were used to assess cervical compression of the spinal cord on MRI.
- The T2 and T1 change on cervical MRI was used to evaluate edema, swelling, and myelomalacia. A T2 weighted signal appears bright and have hyperintensity on the MRI due to the length of time taken to decay. However, this is difficult to differentiate between edema and myelomalacia. The length and number of levels with the positive T2 signal was also measured. In a T1 weighted signal, the presence of a signal evaluates the density of tissue and more directly refers to myelomalacia or the irreversible death of cells.
- Cervical Kyphosis was used to evaluate abnormal curvature in the spine or neck. Creating a C-like curve in the cervical region of the spine, MRI's of patients were quantified using a binary system, with 0 indicating no kyphosis and 1 indicating kyphosis based on appearance of spine.
- MRI AP (Anteroposterior) Canal Diameter (most severe) was used to evaluate canal stenosis and cord compression. This was done by taking a sagittal measurement of the cervical spine on an MRI from
- Spinal Cord-most narrow/severe
- The Modern Japanese Orthopedic Association (mJOA) score is a validated, investigator-administered tool used to evaluate functional status in patients with degenerative cervical myelopathy (DCM). It specifically looks at upper extremity (5 points) and lower extremity (7 points) motor function, sensation (3 points) and micturition (3 points). A total score of 18 reflects no neurological deficits whereas a lower score indicates a greater

degree of disability and functional impairment. Severe cases are classified approximately from 0-11, moderate are 12-14, and mild are 15-17. [11] One limitation of this system is that is does not address the sensory function in the trunk or lower extremities (Figure 2).

- The Nurick grade is a validated, investigator-administered tool also used to evaluate functional status in patients with degenerative cervical myelopathy (DCM). It is a 5 points scale looking at functional impairment in DCM. Severe cases are classified from 3-5 with moderate cases ranging from 1-2 and healthy patients with a score of 0.

Statistical Methods

The statistical analyses for this study were conducted using SPSS with a reference significance value of ≤ 0.05 for univariate analysis and ≤ 0.15 for multivariate analysis. Categorical variables were analyzed with Chi-square tests, univariate and multivariate with help of Dr. Farhadi. (Tables 1and 2; Table 3 respectively). These categorical variables are presented as the number of subjects and relative frequencies. Continuous variables are presented as the mean and standard deviation or median, when appropriate.

Results

MRI Findings

Cervical spine MRI studies were performed on admission in 50 patients (Table 2). Cervical Kyphosis was found to be present in 33.3% of patient who had no significant change in ΔmJOA and found in 3.1% of patients who had significant change in ΔmJOA . The number of levels without CSF in both the anterior and posterior region had a mean of 1.72 ± 1.13 for patients with had no significant change in ΔmJOA and a mean of 0.91 ± 0.78 for patients with a significant change in ΔmJOA. The number of levels without CSF in both the anterior OR posterior region had a mean of 0.94 ± 0.80 for patients with had no significant change in ΔmJOA

and a mean of 1.09 ± 0.86 for patients with a significant change in ΔmJOA. Combining these two parameters to create the overall compressed levels led to a mean of 2.67 ± 1.19 for patients with had no significant change in ΔmJOA and a mean of 2.00 ± 1.11 for patients with a significant change in ΔmJOA. A positive T2 signal was assessed and found to have 83.3% of patients which had had no significant change in ΔmJOA and 34.4% of patients with a significant change in ΔmJOA. The number of levels of T2 change was found to have a mean of 1.28 ± 1.02 for patients that had no significant change in ΔmJOA and 0.34 ± 0.48 for patients that had significant change in ΔmJOA.

Intramedullary Lesion length (IML) was assessed along the sagittal plane of the T2 signal. The mean rostrocaudal length of IML was found to be 12.57 ± 9.84 mm in patients that had no significant change in ΔmJOA and 2.78 ± 4.43 mm in patients that had significant change in ΔmJOA. A positive T1 signal change was assessed and found to have 16.7% of patients which had had no significant change in ΔmJOA and 6.3% of patients with a significant change in ΔmJOA. The most severe MRI Anteroposterior Canal diameter had a mean of 5.18 ± 1.18 mm for patients who had no significant change in ΔmJOA and 6.69 ± 1.76 mm for patients who had significant change in ΔmJOA. Spinal cord length (most severe) was also taken and found to have a mean of 3.86 ± 1.06 mm for patients who had no significant change in ΔmJOA and 4.96 ± 1.11 mm for patients who had significant change in in ΔmJOA. Torg Pavlov Ratio average of the four levels (C3-C6) was found to have a mean of 0.65 ± 0.12 for patients with no significant change in ΔmJOA and 0.77 ± 0.14 for patients with significant change in ΔmJOA. Lateral Mass Canal Diameter Ratio Average of the four levels (C3-C6) was found to have a mean of 0.69 ± 0.06 for patients with no significant change in ΔmJOA and 0.71 ± 0.05 for patients with significant change in ΔmJOA.

Clinical Variables and Outcomes

Clinical variables were analyzed using univariate chi-square testing to assess clinical parameters between patients with no significant ΔmJOA and patients with significant ΔmJOA (Table 1). Neurological severity was quantified using the number of patients which improved mJOA (ΔmJOA) compared to those who remained the same. Follow up time was not significantly associated with ΔmJOA (p=0.571). This is important to confirm the clinical relevance of the study suggesting the length of time taken to follow up is not a confounding variable. Another important variable was that the pre-op mJOA was not significantly associated with ΔmJOA (p=0.939). This also confirms that patients had similar pre-mJOA before surgery.

Age was not significantly associated with ΔmJOA (p = 0.792). Sex was not significantly associated with ΔmJOA (p=0.264) BMI was found to be significantly associated with ΔmJOA (p=0.027). Smoking Status was not significantly associated with ΔmJOA (p=0.689). Type 2 Diabetes Mellitus was not significantly associated with ΔmJOA (p=0.0639). Coronary Artery Disease was not significantly associated with ΔmJOA (p=0.730). Hypertension was not significantly associated with ΔmJOA. (p=0.750). COPD and pulmonary hypertension were not significantly associated with ΔmJOA (p=0.705). Chronic heart failure was not significantly associated with ΔmJOA (p≥0.99). Duration of symptoms were not significantly associated with ΔmJOA (p=0.435). History of neck symptoms were not significantly associated with ΔmJOA (p≥0.99). Pre- op Nurick was significantly associated with ΔmJOA (p=0.014).

MRI Variables and Outcomes

MRI variables Cervical Kyphosis, no CSF Ant/Pst, No CSF Ant OR Pst, Compressed levels, T2 signal change, #levels with T2 signal change, IML, T1 signal change, MRI AP Canal

Diameter (most severe), Spinal Cord-most narrow/ severe, Torg Pavlov average, Lateral Mass Canal Dia. Avg were analyzed using univariate chi-square testing to assess radiologic severity between patients with no significant ΔmJOA and patients with significant ΔmJOA (Table 2).

Cervical Kyphosis was significantly associated with ΔmJOA (p=0.006). Compression of both the anterior and posterior side of the spinal cord was significantly associated with ΔmJOA (p=0.010). Compression of only the anterior or posterior side of the spinal cord was not significant in ΔmJOA (p=0.490). The total number of compressed levels was significant in ΔmJOA (p= 0.038). T2 signal change was significantly associated with ΔmJOA (p=0.001). The number of levels with a T2 signal change was significantly associated with ΔmJOA (p<0.001). IML length was significantly associated with ΔmJOA (p<0.001). T1 signal change was not significantly associated with ΔmJOA (p=0.336). MRI AP Canal Diameter (most severe) was significantly associated with ΔmJOA (p=0.003). Spinal Cord-most narrow/severe was significantly associated with ΔmJOA (p=0.001). Torg Pavlov average was significantly associated with ΔmJOA (p=0.007). Lateral mass canal dia. Avg was not significantly associated with ΔmJOA (p=0.385).

A multivariate analysis was conducted to find prognosticating risk factors associated with ΔmJOA. The three factors found to be significant were BMI, Cervical Kyphosis, and IML. By reducing codependence and covariance to determine what remains statistically significant, this analysis found new p-values compared to previously. BMI was found to be significantly associated with ΔmJOA (p=0.048). Cervical Kyphosis was found to be significantly associated with ΔmJOA (p=0.091). Finally, IML was found to be significantly associated with ΔmJOA (p=0.006).

Discussion

All current intervention for cervical spondylotic myelopathy is surgical decompression and aimed at improving recovery following surgery. Several factors contribute to the lack of prognostic factors in human CSM patients. The preoperative mJOA score is one factor contributing to the lack due to a lack of proper prediction of outcomes (as found in Table 2). The scale has too much inter and intra variability resulting in an improper stratification. The heterogeneity of the condition confounds the analysis of potential prognostic factors and novel prognosticating indexes. Additionally, because of the nature of cervical spondylotic myelopathy, other diagnoses can confound symptoms and neurologic evaluation in patients. With the cervical region being the most superior region, it also affects many other areas of the spinal cord. If stenosis is severe enough, patients can lose feeling below the arm. With the greater percentage of patients being in the age group over 60, age is a confounding variable which may further cloud the neurologic evaluation. Improved prognostication would help clinicians better counsel patients with regard to their expected recovery. This counseling is especially important in CSM because of the lifelong associated social and economic burdens and the increased aging population. In the realm of clinical research, improved prognostication would also allow for more rational clinical trial design with improved patient stratification. Researchers could then better assess the efficacy of surgical interventions in CSM patients.

Cervical Spondylotic Myelopathy represent a particularly heterogenous cohort, and stenosis can be variable. Since the rate and degree of neurologic deterioration is variable and optimal management strategies are complex, it is difficult to quantify similar damage to the spinal cords. The cause of CSM is relatively unknown with changes in the cervical spine producing narrowing of the canal itself. This can lead to the thickening of ligaments and bone spur (osteophyte) formation causing compression. The chronic compression of the spinal cord

and nerve roots leads to impaired blood flow and neurological deficits. The aforementioned variables help to explain why distinct anatomical regions within the cervical spine show differential rates of neurologic recovery.

This study has allowed for novel insight into potential prognosticating factors to assess outcomes following surgical intervention. We identified associations between clinical factors such as BMI and radiologic factors such as Cervical Kyphosis and IML with respect to patients with no significant ΔmJOA and patients with significant ΔmJOA (Table 3). The potential role of obesity in neural recovery is not well understood. A larger sample of cervical spondylotic myelopathy patients is needed to allow for more definitive conclusions regarding the role of obesity in neurologic recovery.

This study found that IML length and Cervical Kyphosis were excellent radiological predictors of ΔmJOA in patients on admission. These results are similar to a study on thoracic myelopathy which found IML to be a predictor of postoperative outcomes.[16] However kyphosis was not a parameter studied in this paper. This may suggest IML may be a better prognosticating factor for postoperative recovery. A potential counseling and research assessment tool is described in Tables 4 and 5. Through entering the patient's BMI, Cervical Kyphosis extent, and IML, the scale will have the potential to prognosticate recovery following surgical decompression in patients with CSM. Therefore, further research with larger patient samples will be needed to more reliably assess the potential differences in predictive ability between prognosticating factors in order to generate an accurate prognosticating index.

Conclusions

This study showed that clinical and radiological parameters can be measured to assess improvement following surgical decompression using ΔmJOA within a consecutive single

surgeon CSM patient sample. Further, BMI, Cervical Kyphosis, and IML can predict improved postoperative outcomes (ΔmJOA) assessed more than one year later. Interestingly, intermedullary lesion length (IML) may be a better prognosticating factor. Further studies should ideally apply a larger sample size to better assess prognosticating factors to derive a more accurate prognosticating index. The predictive ability of these measures can be applied to better counsel patients and improve stratification in interventional studies.

References:

[1] Cervical Myelopathy. Retrieved from https://www.hopkinsmedicine.org/health/conditions-and-diseases/cervical-myelopathy

[2] Nouri A, Tetreault L, Singh A, Karadimas SK, Fehlings MG. Degenerative cervical myelopathy: epidemiology, genetics, and pathogenesis. Spine (Phila Pa 1976), 2015, 40: E675–E693 doi: 10.1097/BRS.0000000000000913

[3] Matsumoto M, Fujimura Y, Suzuki N, et al. MRI of cervical intervertebral discs in asymptomatic subjects. *The Journal of Bone and Joint Surgery B*. 1998;80(1):19–24. Doi: 10.1302/0301-620x.80b1.7929

[4] Young WF. Cervical spondylotic myelopathy: a common cause of spinal cord dysfunction in older persons. Am Fam Physician. 2000;62(5):1064-1070. doi: 10997531

[5] de Oliveira Vilaça C, Orsini M, Leite MA, et al. Cervical Spondylotic Myelopathy: What the Neurologist Should Know. *Neurol Int*. 2016;8(4):6330. Published 2016 Nov 23. doi:10.4081/ni.2016.6330

[6] Fehlings MG, Jha NK, Hewson SM, et al. Is surgery for cervical spondylotic myelopathy cost-effective? A cost-utility analysis based on data from the AOSpine North America prospective CSM study. J Neurosurg Spine. 2012;17(1 Suppl):89–93 doi: 10.3171/2012.6.AOSPINE111069

[7] Oh T, Lafage R, Lafage V, Protopsaltis T, Challier 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. doi: 10.1016/j.wneu.2016.12.124. doi: 0.1016/j.wneu.2016.12.124

[8] Rowland LP. Surgical treatment of cervical spondylotic myelopathy: time for a controlled trial. Neurology. 1992 Jan;42(1):5–13 doi: 10.1212/wnl.42.1.5

[9] Ghogawala Z, Benzel EC, Heary RF, et al. Cervical spondylotic myelopathy surgical trial: randomized, controlled trial design and rationale. *Neurosurgery*. 2014;75(4):334–346. doi:10.1227/NEU.0000000000000479

[10] Rhee JM, Basra S. Posterior surgery for cervical myelopathy: laminectomy, laminectomy with fusion, and laminoplasty. *Asian Spine J*. 2008;2(2):114–126. doi:10.4184/asj.2008.2.2.114

[11] Tetreault L, Kopjar B, Nouri A 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(1):78-84. Doi: 10.1007/s00586-016-4660-8

[12] Kato S, Oshima Y, Oka H, et al. Comparison of the Japanese Orthopaedic Association (JOA) score and modified JOA (mJOA) score for the assessment of cervical myelopathy: a multicenter observational study [published correction appears in PLoS One. 2015;10(5):e0128392]. *PLoS One*. 2015;10(4):e0123022. Published 2015 Apr 2. doi:10.1371/journal.pone.0123022

[13] Lavelle WF, Bell GR. Cervical myelopathy: history and physical examination. Spine Surg 2007;19:6-11 doi: 10.1053/j.semss.2007.01.004

[14] Spillane JD, Lloyd GH. The diagnosis of lesions of the spinal cord in association with "osteoarthritic" disease of the cervical spine. Age 1952;68:57. Doi: 10.1093/brain/75.2.177

[15] Karadimas SK, Laliberte AM, Tetreault L, et al. Riluzole blocks perioperative ischemia-reperfusion injury and enhances postdecompression outcomes in cervical spondylotic

myelopathy. Sci Transl Med. 2015;7:316ra194 10.1126/scitranslmed.aac6524 doi: 10.1126/scitranslmed.aac6524

[16] Sanghvi AV, Chhabra HS, Mascarenhas AA, Mittal VK, Sangondimath GM. Thoracic myelopathy due to ossification of ligamentum flavum: a retrospective analysis of predictors of surgical outcome and factors affecting preoperative neurological status. *Eur Spine J.* 2011;20(2):205–215. doi:10.1007/s00586-010-1423-9

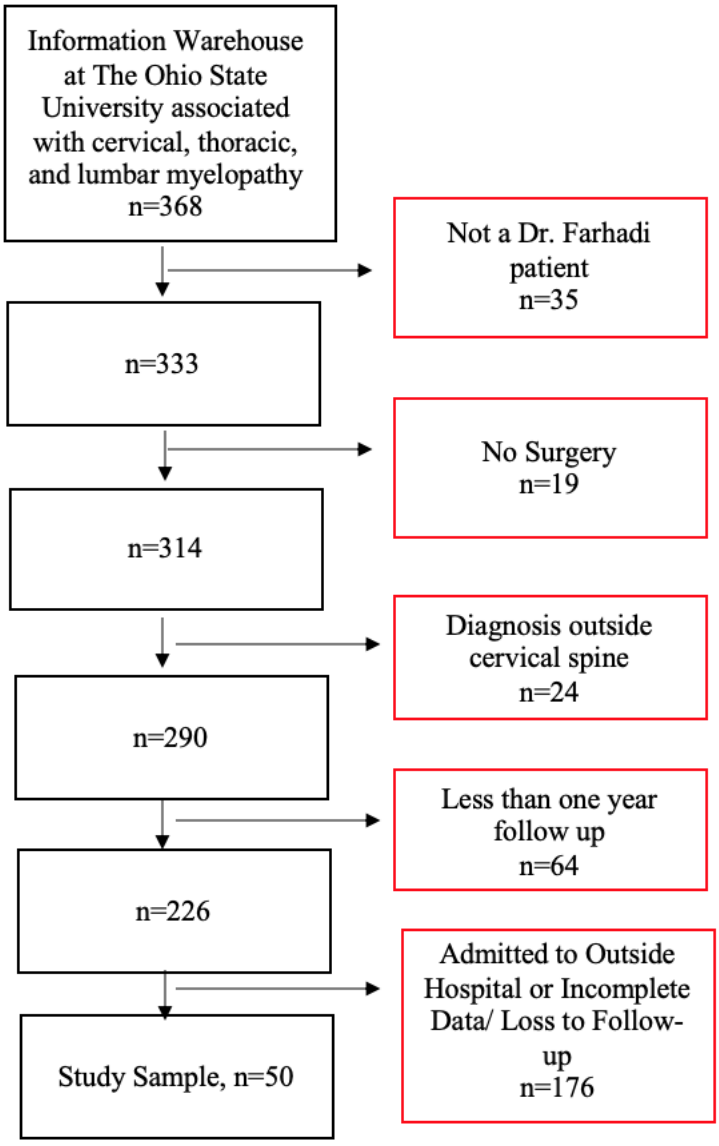

FIGURE 1: APPLICATION OF EXCLUSION CRITERIA

FIGURE 2: mJOA GRADE

Neurological Status	Score
Motor dysfunction of the upper extremities	
Inability to move hands	0
Inability to eat with a spoon but able to move hands	1
Inability to button shirt but able to eat with a spoon	2
Able to button shirt with great difficulty	3
Able to button shirt with slight difficulty	4
No dysfunction	5
Motor dysfunction of lower extremities	
Complete loss of motor and sensory function	0
Sensory preservation without ability to move legs	1
Able to move legs but unable to walk	2
Able to walk on flat floor with a walking aid (such as a can or crutch)	3
Able to walk up and/or down stairs with hand rail	4
Moderate to significant lack of stability but able to walk Up and/or down stairs without hand rail	5
Mild lack of stability but walks unaided with smooth reciprocation	6
No dysfunction	7
Sensation	
Complete loss of hand sensation	0
Severe sensory loss or pain	1
Mild sensory loss	2
No sensory loss	3
Sphincter dysfunction	
Inability to micturate voluntarily	0
Marked difficulty with micturition	1
Mild to moderate difficulty with micturition	2
Normal micturition	3

Table 1. Univariate analysis of demographic and clinical factors

	No sig ΔmJOA	Sig ΔmJOA	P Value
N	18	32	
Age (mean, yrs.)	64.33 ± 10.79	63.53 ± 9.93	0.792
Sex			0.264
Male	13 (72.2%)	18 (56.3%)	
Female	5 (27.8%)	14 (43.8%)	
BMI	28.07 ± 7.84	32.66 ± 6.20	**0.027**
Smoking status			0.689
Never Smoker	6 (33.3%)	13 (40.6%)	
Former Smoker	9 (50.0%)	12 (37.5%)	
Current Smoker	3 (16.7%)	7 (21.9%)	
Type II DM	5 (27.8%)	7 (21.9%)	0.639
CAD	3 (16.7%)	7 (21.9%)	0.730
HTN	11 (61.1%)	21 (65.6%)	0.750
COPD/PulmHTN	4 (22.2%)	5 (15.6%)	0.705
CHF	1 (5.6%)	3 (9.4%)	≥0.99
Duration of symptoms	21.39 ± 27.27	37.13 ± 64.89	0.435
Hx Neck Surgery	3 (16.7%)	5 (15.6%)	≥ 0.99

Data presented as mean ± SD or n (%).

Table 2. Univariate analysis of radiographic factors

	No sig ΔmJOA	Sig ΔmJOA	P Value
Cervical Kyphosis	6 (33.3%)	1 (3.1%)	**0.006**
No CSF Ant and Pst	1.72 ± 1.13	0.91 ± 0.78	**0.010**
No CSF Ant or Pst	0.94 ± 0.80	1.09 ± 0.86	0.490
Overall Compressed Levels	2.67 ± 1.19	2.00 ± 1.11	**0.038**
T2 Signal Change (y/n)	15 (83.3%)	11 (34.4%)	**0.001**
Number of Levels with T2 Signal Change	1.28 ± 1.02	0.34 ± 0.48	**<0.001**
Intramedullary Lesion Length (mm)	12.57 ± 9.84	2.78 ± 4.43	**<0.001**
T1 Signal Change	3 (16.7%)	2 (6.3%)	0.336
MRI AP Canal Diameter (most severe; mm)	5.18 ± 1.18	6.69 ± 1.76	**0.003**
Spinal Cord (most severe; mm)	3.86 ± 1.06	4.96 ± 1.11	**0.001**
Torg Pavlov Ratio Average	0.65 ± 0.12	0.77 ± 0.14	**0.007**
Lateral Mass Canal Diameter Ratio Average	0.69 ± 0.06	0.71 ± 0.05	0.385
Pre-op mJOA	12.39 ± 1.82	12.34 ± 2.10	0.939
Pre-op Nurick	3.28 ± 0.90	2.59 ± 0.98	**0.014**
Follow-up	1420.9 ± 791.77	1345.4 ± 698.6	0.571

Data presented as mean ± SD or n (%).

Table 3. Multivariate Analysis of risk factors associated with ΔmJOA.

Variable	Coefficient (B)	Odds Ratio	95% CI	p Value
BMI	0.129	1.138	1.001-1.293	**0.048**
Cervical Kyphosis	-2.164	0.115	0.009-1.412	0.091
IML	0.195	0.823	0.715-0.946	**0.006**
Constant	-1.778	0.169		0.351

Variables included in model at step one:

Table 4 Point system for the prediction of ΔmJOA

Risk Factor	Categories	Points
#1		
		0
		1
		3
		4
		6
		7
#2		
		0
		5
#3		
		0
		6
#4		
		0
		7
#5		
		0
		1
		2
		3
		4
		7

Table 5 Predicted likelihood of mJOA improvement

Point Total	Risk	Point Total	Risk	Point Total	Risk
0		**11**		**22**	
1		**12**		**23**	
2		**13**		**24**	
3		**14**		**25**	
4		**15**		**26**	
5		**16**		**27**	
6		**17**		**28**	
7		**18**		**29**	
8		**19**		**30**	
9		**20**		**31**	
10		**21**		**32**	