Correlation of Magnetic Resonance Imaging Findings and Reported Symptoms in Patients with Chronic Cervical Dysfunction

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Evidence-based clinical decision-making for diagnosing cervical myelopathy is challenging. Within this decision-making process, it is believed that the information gathered during the patient history, physical examination, and advanced confirmation testing improves the post-test probability of mak-

ing a correct diagnosis¹⁻⁴. An assumption exists that the components of examination are interrelated and that each piece of information has value in the decision-making process. Unfortunately, key historical features and clinical tests for diagnosing cervical myelopathy have yet to be identified and seem to add little value

toward improving the post-test probability⁵⁻⁹. While most authors agree that cervical myelopathy remains a clinical diagnosis, magnetic resonance imaging (MRI) remains the reference standard for diagnosis^{5,6,8-12}.

Specifically, signal intensity changes found on MRI are routinely used as the strongest indicator of cervical myelopathy^{11,13-15}. Studies have also reported other imaging findings, such as anteroposterior (AP) diameter and cross-sectional area of spinal cord or canal, and obliteration of subarachnoid space, as indicators of cervical myelopathy¹⁶⁻¹⁸. Recent studies have sought to examine the relationship and diagnostic utility of commonly used special tests for diagnosing cervical myelopathy using MRI as a reference standard; these findings have shown limited clinical utility of these special tests when used alone or in clusters for identifying patients with this disorder^{5,7-9,19}.

The aim of this study was to examine the relationship between results tabulated from routine patient history questions and specific findings on MRI in a population of patients with chronic neck dysfunction. Patient history was specifically addressed, as this element of the examination has been recognized to offer the most value in examination processing

ABSTRACT: Information gathered from the patient history, physical examination, and advanced testing augments the decision-making process and is proposed to improve the probability of diagnostic and prognostic accuracy. However, these findings may provide inconsistent results and can lead to errors in decision-making. The purpose of this study was to examine the relationship between common clinical complaints and specific findings on magnetic resonance imaging (MRI) in patients with chronic neck dysfunction. Forty-five English-speaking participants (25 female), with mean age of 52 (SD = 13.4), were evaluated by a neurosurgeon for complaints of symptoms related to the cervical spine. All participants answered a subjective questionnaire and received an MRI of the cervical spine. Cramer's V nominal correlation was performed to explore the relationship between the targeted variables. The correlation matrix calculations captured three significant findings. Evidence of spinal cord compression was significantly correlated to 1) anteroposterior canal diameter of less than or equal to 9 mm ($r = .31$; $p < 0.05$) and 2) diminished subarachnoid fluid around the cord ($r = .48$; $p < 0.01$). Report of loss of dexterity was significantly correlated with 3) report of lower extremity clumsiness ($r = .33$; $p < 0.05$). In this study, no definitive relationships were found between the clinical complaints of neck pain, hand function, or clumsiness and specific MRI findings of spinal cord compression. Further research is needed to investigate the diagnostic utility of subjective complaints and their association with advanced testing.

KEYWORDS: Cervical Spine, Correlation, Magnetic Resonance Imaging, Myelopathy

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in a variety of patient presentations²⁰⁻²². In addition, patient history is typically first and most likely to be affected by the *Recency effect*^{23,24}, which involves any situation during an exploratory process where the very last piece of information is weighted higher in the decision-making than any previous finding. The initial hypothesis was that a strong correlation exists between patient history and confirmatory imaging, suggesting that these findings provide value when combined in the diagnosis of patients with chronic neck pain.

Methods

The study protocol was approved by the Institutional Review Board of the Duke University Health System. The study involved a cohort of patients seen for a neurosurgical consult for a primary complaint of neck discomfort. Subjects were recruited as part of a parallel trial on diagnostic accuracy⁵. For inclusion into the study, English-speaking patients needed to be older than 18 years of age, have undergone MR imaging, and consent to participate in the study. Final recorded physician diagnoses varied among the patients and included radiculopathy, myelopathy, and cervical strains, with radiculopathy and myelopathy accounting for over 75% of the diagnoses.

Each patient provided the following information: age, race/ethnicity, and gender. In addition, each patient completed a yes/no questionnaire related to current neck pain, progressive loss of hand dexterity, hand numbness, and progressive upper or lower extremity clumsiness. MRI findings of AP diameter of the canal of less than or equal to 9 mm, evidence of compression on the spinal cord, diminished subarachnoid fluid around the spinal cord, and signal abnormalities on the cord were tabulated as yes/no for each patient. Signal abnormalities are commonly associated with myelomalacia (Figure 1 and Figure 2). All MR images were read by a radiologist with over 19 years of experience and a specialization in spinal cord-related orthopedic injuries. The radiologist was blinded to the clinical findings and diagnosis of the patients.

Data Analysis

All analyses were performed using SPSS 12.0.1. (233 S. Whacker Drive, Chicago, IL 60606-6307). Demographic characteristics of the sample were identified using means and standard deviations when appropriate. Frequency distributions were used to further describe the sample.

A Cramer's V nominal correlation was run to explore the relationships between the targeted variables in the study. Cramer's V is a chi-square-based measure of nominal association that is useful regardless of table size or if row marginals equal column marginals. Cramer's V is calculated as the square root of chi-square divided by the product of sample size, n , and m , which is the smaller of $(rows - 1)$ or $(columns - 1)$: $V = \sqrt{X^2/nm}$.

Results

Descriptive Data

Fifty-one patients who satisfied the inclusion criteria were identified from February through December 2007. High-quality MR images were obtained on 45 of the 51 individuals. In all situations, the MR images were within one year of the clinical examination for this study, with the majority of images dating between two weeks and three months of the clinical exam. Ages ranged from 33 to 82 with a mean age of 52 years ($SD=13.4$). Eight-two percent (82%) of patients identified themselves as White, 7% identified themselves as Black, and 10% checked "other." Of the 45 patients, 25 (55.6%) were women and 20 were men.

At the time of recruitment, patients were asked to complete a subjective inventory of their signs and symptoms. Thirty-three of 45 patients (73.3%) indicated the presence of neck pain during the clinical visit. Loss of hand dexterity was reported for 29 of 45 patients (64.4%). Report of medial numbness of both hands was present in 16 patients (35.6%). Clumsiness during walking was reported by 18 of the 45 patients (40.0%). Duration of symptoms was not recorded.

The correlation matrix calculations captured three significant findings (Table 1). An AP diameter of the canal of less than or equal to 9mm and evidence of compression on the spinal cord were significantly correlated ($r = .31$; $p < 0.05$), as was evidence of compression on the spinal cord and diminished subarachnoid fluid around the cord ($r = .48$; $p < 0.01$). Reported loss of dexterity and reported lower extremity clumsiness were also significantly related ($r = .33$; $p < 0.05$).

Discussion

Patient subjective history has been frequently cited as one of the most valuable tools in the clinical decision-making process²⁰⁻²² and knowledge of a patient's history has been shown to influence reliability and validity of the subsequent physical examination²⁵. Information from the patient history aids in formulating a diagnostic hypothesis that is either confirmed or refuted during physical examination and further work-up²⁶, but that assumes that the subjective history is informative enough to direct the remainder of the examination. This study sought to determine what relationship exists between common clinical complaints and MRI findings in patients with chronic neck disorders suggestive of cervical myelopathy.

The imaging relationships found in this study seem intuitive, as spinal cord compression, AP diameter, and diminished subarachnoid fluid are all indicators of decreased canal space. However, our results failed to find a significant correlation between these markers of spinal canal narrowing and pathologic changes of the spinal cord. Similarly, Kadanka et al¹² reported no significant relationship between the presence of signal hyper-intensity changes of the spinal cord and transverse spinal cord cross-sectional area found on MRI in patients with cervical myelopathy. These findings may highlight the resiliency of the spinal cord in accommodating compressive forces, but the exact relationship between cord compression and a subsequent development of pathological spinal cord changes remains unclear. Multiple studies have attempted to clar-

ify the relevance of these pathological changes of the spinal canal on diagnosis, prognosis, and outcome^{11-13,15,27-31}.

It is notable, but not surprising, that reports of neck pain or other clinical symptoms were not significantly correlated with any imaging findings. MRI is the tool that often serves as the reference standard for depicting musculoskeletal anatomy of the cervical spine and is frequently used to confirm a suspected diagnosis. A challenge for most MRI studies of the cervical spine is that there is often no agreed-upon "gold standard" finding, which can result in disparate interpretations by skilled clinicians. The lack of correlation between clinical complaints and MRI findings found in this study is consistent with multiple previous studies, which demonstrated that pathological changes of the cervical spine evident on MRI were not consistent with pain reports³²⁻³⁶. Boden et al³⁵

investigated the prevalence of abnormal MRI findings in asymptomatic subjects. Abnormalities, such as presence of herniated disc, foraminal stenosis, and disc degeneration, were found in a number of these subjects, especially in those over 40 years. Siivola et al³⁴ found cervical abnormalities on MRI were equally present in younger adults, aged 24 to 27, with neck pain and without.

Okada et al³⁶ followed a population over 10 years and noted progression of signs of cervical degeneration on MRI in close to 90% of the subjects. Clinical symptoms of neck pain, shoulder stiffness, and upper extremity numbness were reported in less than half of their study population. All but one subject in their study had a normal neurological evaluation on physical examination. In addition, consistent with this study, no significant difference in the proportion of MRI findings was found between sub-

jects who reported upper extremity numbness and those who didn't.

In regards to cervical myelopathy, Rhee et al⁷ sought to examine the prevalence and clinical utility of commonly tested myelopathic signs in patients who had a satisfactory outcome following surgery for this disorder. These signs included the presence of hyper-reflexia and positive provocative tests, such as Babinski, clonus, Hoffmann's, and inverted brachioradialis reflex. Over 20% of patients who had historical features and correlated MRI findings of myelopathy did not have positive clinical tests. Patients with signal intensity changes on MRI were more likely to exhibit a positive sign in some tests thought to be indicative of myelopathy, but not in all. The association of traditional complaints of myelopathy (i.e., upper extremity clumsiness, gait difficulty, and numbness or tingling) with

FIGURE 1. (LEFT) Sagittal view of Cervical Spine Demonstrating Myelomalacia using Magnetic Resonance Imaging.

FIGURE 2. (RIGHT) Cross Sectional Image of Cervical Spine Demonstrating Myelomalacia using Magnetic Resonance Imaging.

TABLE 1. Correlation matrix of MRI findings and report of clinical findings in patients with chronic neck pain.

Cramer's V	AP diameter of canal of less than or equal to 9 mm	Evidence of compression on the spinal cord	Diminished subarachnoid fluid around the cord at targeted level	MR signal intensity abnormality	Report of neck pain	Report of loss of dexterity	Report of numbness or tingling	Report of lower extremity clumsiness
AP diameter of canal of less than or equal to 9 mm	1.00							
Evidence of compression on the spinal cord	.308*	1.00						
Diminished subarachnoid fluid around the cord			1.00					
MR signal intensity abnormality	-.035	.481**	.135	1.00				
Report of neck pain	.194	.281	-.066	.165	1.00			
Report of loss of dexterity	-.066	-.094	-.101	.007	-.088	1.00		
Report of numbness or tingling	-.101	-.145	-.198	.236	-.060	.163	1.00	
Report of lower extremity clumsiness	-.198	-.284						1.00
	.169	.000	.169	.056	.122	.328*	.050	

* Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

the diagnosis of myelopathy and MRI findings of cord compression was not reported. Rhee et al⁷ concluded that in the absence of clinical myelopathic signs, a careful history correlated with MRI is needed for diagnosing CM. In contrast, our study does not support the relationship between the same historical features and the findings on MRI. The apparent lack of sensitivity of these commonly applied clinical tests has been reported in other studies as well^{5,8,19}.

The relationship between loss of dexterity and gait clumsiness is less clear but may be related to the clinical presentation of cervical myelopathy. It has been stated that mild to severe cord compression may be related to physical signs, such as gait disturbances, upper extremity numbness/parasthesias, fine motor loss, and upper and lower extremity weakness^{6,10,31,37}. Alafifi et al³¹ found the most common symptoms associated with cervical myelopathy to be deteriorating hand function, upper extremity sensory disturbance, and difficulty with gait. In the current study, complaints related to these symptoms did not correlate with MRI findings suggestive of spinal cord compression or spinal cord changes.

The components of patient history used in this study are commonly cited in the literature, especially in screening for the presence of cervical myelopathy^{38,39}. Several authors have described a progression of symptoms over time, including gradual loss of hand function^{31,37,40} or progression of difficulty with walking^{31,37,41}, both of which may be attributed by the patient to aging or arthritis. Although the traditional grouping of these symptoms has been regarded as representative of cervical myelopathy, this relationship has not been previously investigated. This study is the first to specifically address the connection between these patient history questions and MRI findings. Despite the frequent use of these questions as a screen for cervical spine pathology, this study failed to confirm a significant relationship between the results of the patient history questions and the imaging findings. In essence, our failure to find a relationship between selected patient history find-

ings and standard parameters of MR findings draws attention to the following two potential problems with our current decision-making model. First, these questions routinely associated with myelopathy may actually have limited relationship and offer little value in decision-making. Second, we may assign higher credibility to imaging methods than these tools actually provide, resulting in over-reliance and misdiagnosis based on imaging findings.

Limitations

There are a number of limitations to this study. The first involves the use of a questionnaire to obtain the involved patient history. Bertilson et al⁴² used a pain diagram to indicate location and intensity of symptoms in patients with neck and shoulder pain. When additional questioning was performed, it was found that many patients under-reported their symptoms. It is possible that with a more focused follow-up subjective examination, a more reliable and relevant history could have been obtained from our subjects. This may have changed the response rate to the questions, perhaps resulting in more significant correlation between the queried symptoms and the expected findings.

Conclusion

Relevant information gathered during a patient history and during clinical examination, confirmed by the presence of specific findings with advanced testing, is crucial in the probabilistic decision-making process. This study sheds some light on the weaknesses of our current clinical decision-making process in patients with chronic neck disorders. For the specific diagnosis of myelopathy, clinicians are reminded that symptoms can be highly variable and progressive⁴³, and simple questioning of common complaints does not appear to increase diagnostic accuracy. One of the most important tools in making this diagnosis is recognition that a high index of suspicion is often necessary to make the diagnosis⁴⁰. Further research is needed to identify whether relevant questions and imaging findings can improve diagnostic accuracy.

REFERENCES

1. Elstein AS, Schwartz A. Clinical problem solving and diagnostic decision making: Selective review of the cognitive literature. *BMJ* 2002;324:729-732.
2. Hunink MGM. *Decision Making in Health and Medicine: Integrating Evidence and Values*. Cambridge, UK: Cambridge University Press, 2001.
3. Sackett DL. *Clinical Epidemiology: A Basic Science for Clinical Medicine*. 2nd ed. Boston: Little, Brown, 1991.
4. Soltani A, Moayeri A. Deterministic versus evidence-based attitude towards clinical diagnosis. *J Eval Clin Pract* 2007;13:533-537.
5. Cook C, Roman M, Stewart KM, Leithe LG, Isaacs R. Reliability and diagnostic accuracy of clinical special tests for myelopathy in patients seen for cervical dysfunction. *J Orthop Sports Phys Ther* 2009;39:172-178.
6. Cook CE, Hegedus E, Pietrobon R, Goode A. A pragmatic neurological screen for patients with suspected cord compressive myelopathy. *Phys Ther* 2007;87:1233-1242.
7. Rhee JM, Heflin JA, Hamasaki T, Freedman B. Prevalence of physical signs in cervical myelopathy: A prospective, controlled study. *Spine* 2009;34:890-895.
8. Houten JK, Noce LA. Clinical correlations of cervical myelopathy and the Hoffmann sign. *J Neurosurg Spine*. 2008;9:237-242.
9. Seichi A, Takeshita K, Kawaguchi H, et al. Neurologic level diagnosis of cervical stenotic myelopathy. *Spine* 2006;31:1338-1343.
10. McCormick WE, Steinmetz MP, Benz EC. Cervical spondylotic myelopathy: Make the difficult diagnosis, then refer for surgery. *Cleve Clin J Med* 2003;70:899-904.
11. Yukawa Y, Kato F, Yoshihara H, Yanase M, Ito K. MR T2 image classification in cervical compression myelopathy: Predictor of surgical outcomes. *Spine* 2007;32:1675-1678; discussion 1679.
12. Kadanka Z, Kerkovsky M, Bednarik J, Jarkovsky J. Cross-sectional transverse area and hyper-intensities on magnetic resonance imaging in relation to the clinical picture in cervical spondylotic myelopathy. *Spine* 2007;32:2573-2577.
13. Matsumoto M, Toyama Y, Ishikawa M, Chiba K, Suzuki N, Fujimura Y. Increased signal intensity of the spinal cord on magnetic resonance images in cervical com-

- pressive myelopathy: Does it predict the outcome of conservative treatment? *Spine* 2000;25:677-682.
14. Takahashi M, Sakamoto Y, Miyawaki M, Bussaka H. Increased MR signal intensity secondary to chronic cervical cord compression. *Neuroradiology* 1987;29:550-556.
 15. Wada E, Yonenobu K, Suzuki S, Kanazawa A, Ochi T. Can intramedullary signal change on magnetic resonance imaging predict surgical outcome in cervical spondylotic myelopathy? *Spine* 1999;24:455-461; discussion 462.
 16. Fukushima T, Ikata T, Taoka Y, Takata S. Magnetic resonance imaging study on spinal cord plasticity in patients with cervical compression myelopathy. *Spine* 1991;16:S534-S538.
 17. Golash A, Birchall D, Laitt RD, Jackson A. Significance of CSF area measurements in cervical spondylitic myelopathy. *Br J Neurosurg* 2001;15:17-21.
 18. Penning L, Wilmink JT, van Woerden HH, Knol E. CT myelographic findings in degenerative disorders of the cervical spine: Clinical significance. *Am J Roentgenol* 1986;146:793-801.
 19. Wong TM, Leung HB, Wong WC. Correlation between magnetic resonance imaging and radiographic measurement of cervical spine in cervical myelopathic patients. *J Orthop Surg* 2004;12:239-242.
 20. Cook C, Brismee JM, Fleming R, Sizer PS, Jr. Identifiers suggestive of clinical cervical spine instability: A Delphi study of physical therapists. *Phys Ther* 2005;85:895-906.
 21. Cook C, Brismee JM, Sizer PS, Jr. Subjective and objective descriptors of clinical lumbar spine instability: A Delphi study. *Man Ther* 2006;11:11-21.
 22. May S, Greasley A, Reeve S, Withers S. Expert therapists use specific clinical reasoning processes in the assessment and management of patients with shoulder pain: A qualitative study. *Aust J Physiother* 2008;54:261-266.
 23. Hogarth R, Einhorn H. Order effects in belief updating: The belief adjustment model. *Cogn Psych* 1992;24:1-55.
 24. Summerton N. The medical history as a diagnostic technology. *Br J Gen Pract* 2008;58:273-276.
 25. Bertilson BC, Grunnesjo M, Strender LE. Reliability of clinical tests in the assessment of patients with neck/shoulder problems: Impact of history. *Spine* 2003;28:2222-2231.
 26. Jones MA. Clinical reasoning in manual therapy. *Phys Ther* 1992;72:875-884.
 27. Fernandez de Rota JJ, Meschian S, Fernandez de Rota A, Urbano V, Baron M. Cervical spondylotic myelopathy due to chronic compression: The role of signal intensity changes in magnetic resonance images. *J Neurosurg Spine* 2007;6:17-22.
 28. Matsuda Y, Miyazaki K, Tada K, et al. Increased MR signal intensity due to cervical myelopathy: Analysis of 29 surgical cases. *J Neurosurg* 1991;74:887-892.
 29. Morio Y, Yamamoto K, Kuranobu K, Murata M, Tuda K. Does increased signal intensity of the spinal cord on MR images due to cervical myelopathy predict prognosis? *Arch Orthop Trauma Surg* 1994;113:254-259.
 30. Yone K, Sakou T, Yanase M, Ijiri K. Preoperative and postoperative magnetic resonance image evaluations of the spinal cord in cervical myelopathy. *Spine* 1992;17:S388-S392.
 31. Alafifi T, Kern R, Fehlings M. Clinical and MRI predictors of outcome after surgical intervention for cervical spondylotic myelopathy. *J Neuroimaging* 2007;17:315-322.
 32. Castinel BH, Adam P, Milburn PD, et al. Epidemiology of cervical spine abnormalities in asymptomatic adult professional Rugby Union players using static and dynamic MRI protocols—2002 to 2006. *Br J Sports Med*. Apr 2 2008 (Epub ahead of print).
 33. Crandall PH, Batzdorf U. Cervical spondylotic myelopathy. *J Neurosurg* 1966;25:57-66.
 34. Siivola SM, Levoska S, Tervonen O, Ilkko E, Vanharanta H, Keinänen-Kiukaanniemi S. MRI changes of cervical spine in asymptomatic and symptomatic young adults. *Eur Spine J* 2002;11:358-363.
 35. Boden SD, McCowin PR, Davis DO, Dina TS, Mark AS, Wiesel S. Abnormal magnetic-resonance scans of the cervical spine in asymptomatic subjects: A prospective investigation. *J Bone Joint Surg Am* 1990;72:1178-1184.
 36. Okada E, Matsumoto M, Ichihara D, et al. Aging of the cervical spine in healthy volunteers: A 10-year longitudinal magnetic resonance imaging study. *Spine* 2009;34:706-712.
 37. Emery SE. Cervical spondylotic myelopathy: Diagnosis and treatment. *J Am Acad Orthop Surg* 2001;9:376-388.
 38. Cleland J. *Orthopaedic Clinical Examination: An Evidence-Based Approach for Physical Therapists*. 1st ed. New Jersey: Elsevier Health Sciences, 2005.
 39. Magee DJ. *Orthopedic Physical Assessment*. 4th ed. Philadelphia, PA: Saunders, 2002.
 40. Rao R. Neck pain, cervical radiculopathy, and cervical myelopathy: Pathophysiology, natural history, and clinical evaluation. *J Bone Joint Surg Am* 2002;84-A:1872-1881.
 41. Nurick S. The pathogenesis of the spinal cord disorder associated with cervical spondylosis. *Brain* 1972;95:87-100.
 42. Bertilson B, Grunnesjo M, Johansson SE, Strender LE. Pain drawing in the assessment of neurogenic pain and dysfunction in the neck/shoulder region: Inter-examiner reliability and concordance with clinical examination. *Pain Med* 2007;8:134-146.
 43. Yonenobu K. Cervical radiculopathy and myelopathy: When and what can surgery contribute to treatment? *Eur Spine J* 2000;9:1-7.