FEATURE

Using Dynamic MRI to Diagnose Neck Pain: The Importance of Positional Cervical Cord Compression (PC3)

Andrew J. Holman, MD
Associate Clinical Professor of Medicine
Division of Rheumatology
University of Washington
Rheumatologist
Pacific Rheumatology Associates, Inc. PS
Pacific Rheumatology Research, Inc.
Seattle, Washington

It has become axiomatic that cervical pain and regional imaging often correlate poorly. Both degenerative disc disease and cervical pain are common among our patients. Yet, many have one apparently without the other. One diagnostic response is to discount the informative value of cervical imaging and rely more on history, symptoms, and physical signs. Another is to consider how to better image this area of complex anatomy, without discounting the primary importance of clinical findings.

As a dynamic structure, the cervical spine anatomy may be suspected of varying in conformation, depending on its orientation in flexion, extension, rotation, and lateral bending. However, accepted diagnostic imaging, especially by magnetic resonance imaging (MRI), most often has been static and limited to neutral positioning. Such convention ultimately may prove deceptive and fraught with bias.

Neck Pain and the Spinal Cord

General medical reviews describing "neck pain" often omit mention of any role attributable to the cervical spinal cord. Abnormalities of discs, facet joints, ligaments, nerve roots, and muscles are considered, but abnormalities of the cord itself generally are not.

Such abnormalities are discussed in reviews on cervical spondylotic myelopathy (CSM). Malcolm eloquently reviewed five different CSM syndromes: "the transverse lesion syndrome, the motor system syndrome, the central cord syndrome, the Brown Sequard syndrome, and the brachalgia and cord syndrome."[1] Each is associated with a different set of clinical signs and symptoms. Figure 1 (page 52) provides an excellent example of cord compression using a traditional, static, neutral C-spine MRI protocol. In Dr. Malcolm's review, he describes a case where the cervical spinal cord was compressed at 2 disc levels; after decompression, the cord was freed and there was evidence

Figure 1. Sagittal MRI shows disc space collapse at C5-C6, C6-C7, and C7-T1.

of cerebral spinal fluid flowing unimpeded within a widened cervical canal. If we accept these images as indicative of—or at least consistent with—CSM followed by resolution of its symptoms, then one may argue that we are compelled to similarly judge identical images obtained through dynamic imaging.

Over 50 years ago, Olsson reported how position influenced cervical spinal canal diameter in the canine model.[2] Penning expanded this evaluation to human spondylitic myelopathy in 1966.[3] Much later, after the discovery of MRI, Muhle et al examined a cohort of 46 patients to assess the effect of conformational changes to the cervical canal in extension (30°) and flexion (50°).[4] Cervical spinal stenosis was more commonly found at extension (48%) compared to flexion (24%, $P<0.05$). Further, 11% of the 46 patients had cord compression in flexion compared to 20% in extension. "Concerning the number of patients with cervical cord compression at flexion and extension, significant differences [$P<0.05$] were found in patients with degenerative changes at 4 segments compared with patients with 1 segment involvement," noted the authors.

Classifying CSM

In an enlarged subsequent analysis (n=81), many of these authors collaborated with esteemed radiologist Donald Resnick to develop a classification system correlating the kinematic (positional) MRI with the degree of CSM.[5] In patients with progressive degenerative disease of the cervical spine (stage I-IV spinal stenosis varied between a score of 0 [normal diameter canal and anatomy] to 3 [anterior and posterior impingement they call a "pincer effect"]). In neutral, advancing degenerative stage (I-IV) correlated with a 3 score of spinal cord compression: stage I (46%), stage II (26%), stage III (54%), stage IV (87%). This pincer appearance was accentuated in extension and reduced in flexion. Further, they remarked: "On the assumption that a reliable diagnostic indicator of the genesis of CSM is the demonstration of cord compression at the site of the cord lesion, kinematic MRI showed functional cord impingement in 4 of 6 patients [with stage IV disease], whereas no cervical cord compression was seen at the neutral position." The authors suggest that the usefulness of obtaining additional flexion and extension MRI sagittal views reveals greater functional cervical cord impingement in extension, as well as better recognition of unsuspected cord compromise, which becomes more likely with advancing degenerative spondylitic stage.

In 2003, Chen et al reported similar findings.[6] For 62 patients with cervical degenerative disease, 31% demonstrated functional cord compression in extension compared to 3% in flexion. Degenerative stage ($P<0.001$) and a neutral canal diameter of ≤10 mm ($P<0.037$) were predictive of cord compression.

Upright MRI also demonstrated similar findings,[7] with more readily apparent cord compression in extension, along with recognition of reduced angular mobility, particularly at C4/5 and C5/6, in a study of 459 patients with cervical degenerative disc disease.[8]

Analogously, Muhle and Resnick also reported in 1998 how position affected neuroforaminal patency in patients with cervical radiculopathy.[9] Dynamic MRI demonstrated that ipsilateral rotation and lateral bending increased nerve root compression consistent with what clinicians might expect with a positive Spurling test.

Use in Rheumatoid Arthritis

Another application of dynamic MRI is in very advanced rheumatoid arthritis (RA), which can lead to a potentially fatal atlantoaxial dislocation or subluxation from progressive destruction/laxity of the transverse ligament. In flexion, the odontoid process may compress the upper cervical cord, which is clinically expressed as Lhermitte's sign, and if sufficiently forceful, can cause death. Traditionally, radiographs (x-rays) have been employed to identify this condition, but flexion-extension MRI views also have been studied. Dedicated MRI positioning devices have been engineered for patients with RA,[10] as they have for patients with degenerative diseases,[11,12] and some authors suggest that this imaging technique should be the diagnostic "study of choice for the upper rheumatoid C-spine" for presurgical staging.[13]

Positional Spinal Cord Compression Linked With FM

In 2002, Heffez also advocated viewing the cervical cord more dynamically with MRI. His suggestion was presented in the context of sorting out

Figure 2. Sagittal neutral, flexion, and extension MR cervical spine images of the same patient demonstrating cervical cord abutment at C4-C5 only in extension. Note obliteration of the CSF space around the cord by positional distortion of the C4-C5 disc and ligamentum flavum.
Reprinted from *The Journal of Pain*, 2008;9(7):613-622, Holman AJ, Positional cervical spinal cord compression and fibromyalgia: a novel comorbidity with important diagnostic and treatment implications. Copyright (2012), with permission from Elsevier.

another complex presentation, fibromyalgia (FM), at a small meeting of the National Fibromyalgia Research Association, in Portland, Oregon. His analysis found that symptoms of FM and cervical myelopathy overlapped for many patients with FM. Further, he noted that when he surgically decompressed severe, comorbid myelopathy, FM symptoms (allodynia, fatigue, central sensitization, pain, dyscognition, sleep disturbance) often abated.[14] Similar observations were made for FM combined with Chiari malformation.[15]

To say that Heffez's message was received with mixed responses would be overly generous. A furor built quickly to relegate it to near oblivion. Nary a clinician wanted to consider the specter of surgical intervention for 6 to 10 million American patients with FM.

In light of the above findings, beginning in 2003, radiologists working with the Pacific Rheumatology Associates began obtaining flexion-extension cervical spine MRI routinely for patients without additional charge. Positional cervical cord compression (PC3) was defined as clear, visually-confirmed abutment of the cervical cord, with a canal diameter measured at 10 mm or less (Figure 2). (Of note, the typical cervical spinal canal can average 14 to 16 mm in men and 13 to 15 mm in women, depending on disc level and patient size.) Compression or abutment of the cord was often intermittent, and consistent with prior studies, with PC3 much more evident in extension rather than in flexion.

From a database that now exceeds 3,000 patients, a random two-month experience was reported in *The Journal of Pain* in 2008.[16] Of 107 referrals to a suburban rheumatology office, 53 had FM by 2001 American College of Rheumatology (ACR) classification criteria,[17] 32 had an autoimmune or connective tissue disease, and 22 had chronic widespread pain (CWP) without sufficient allodynia (tender points) to confirm FM. PC3 was identified by flexion-extension C-spine MRI in 71% of the FM group and in 85% of the CWP group. Also, in only 15 of 52 patients identified with PC3 (21%) could the cord compression be visualized on the traditional, neutral sagittal MRI view. Thus, 80% of patients in this study with PC3 would not have been diagnosed using the MRI protocol available to most practicing clinicians.

A variety of symptoms suggestive of a myelopathic process were described by Heffez and were later seen in Seattle, WA, and in Portland, at Oregon Health and Sciences University. In addition to pain in an extended cervical position, patients reported having poor balance, variable dysesthesias, weakness, muscular cramping, headaches, widespread and migratory regional pains, fatigue, and poor sleep in both studies. Examination findings often revealed motor and sensory deficits (Table 1, page 54). Patients also characteristically reported dysautonomic features, including thermoregulatory, cardiovascular, gastrointestinal, and urological issues as well as mood disturbances (Table 2, page 54).

At least for the FM cohort, these findings have been supported independently. Hryciw found that 54% of her clinic patients with FM had PC3 by flexion-extension MRI.[18] She also reported that 50% of those with PC3 had obstructive sleep apnea (OSA), a linkage of the cervical myelopathy with OSA also suggested by others. Parenthetically, 7 months after surgical decompression for Chiari malformation

Table 1. Neurologic Deficits Commonly Found With PC3[a]

- Decreased memory, poor concentration, disorientation
- Blurred vision, photophobia
- Weakness (ie, decreased, asymmetric grip strength)
- Gait instability, clumsiness
- Limb numbness, paresthesias

[a] Adapted from references 14 and 16.
PC3, positional cervical cord compression

(without FM), the apnea hypopnea index was reduced significantly (80%) in 16 patients with a comorbid mixture of central and obstructive sleep apnea.[19]

Neurologic deficits also have been reported in a controlled FM study, and PC3 was proposed as a reasonable explanation.[20] In fact, these authors later suggested that in patients with FM, only a flexion-extension C-spine MRI protocol is acceptable, especially when a patient is being evaluated for a Chiari malformation.[21]

Such observations raise the prospect that while it is visually and, in many ways, clinically similar to CSM, PC3 may offer a twist. The intermittent component of compression documented by a flexion-extension MRI may add a dimension worth studying and discriminate PC3 from CSM. Certainly, there are many important clinical and therapeutic features that distinguish intermittent from chronic peripheral nerve compression/entrapment. The same may very well be true for the cervical spinal cord. Unfortunately, available data are insufficient to be conclusive. Yet, in animal models, intermittent abutment of the cervical cord (without injury or ischemia) is a potent trigger of autonomic arousal.[22] And of note, similar abutment to thoracic and lumbar levels are not. Hence, there appears to be a curious connection between autonomic arousal and cervical cord irritation, and this observation may provide a rationale as to why FM—a potent dysautonomic, hyperexcitatory state—often is temporally related to cervical spine trauma.[23,24]

Summary

Regardless of whether there is a true connection between autonomic arousal and cervical cord irritation, dynamic imaging of structures confers more information and may assist in elucidating why there seem to be so many discrepancies between anatomy (as we see it so far) and symptoms. Application of enhanced imaging has had profound implications for many other areas of medicine. Those first steps were taken just as gingerly and sometimes as skeptically received. Yet, with further independent evaluation, the flexion-extension C-spine MRI may help ferret out a bit more of the mystical conundrum that is the cervical spine.

To learn about how to do a flexion-extension C-spine MRI, call Pacific Rheumatology Associates for video instruction. MRI technical settings are given in reference 16, Table 1.

Table 2. Dysautonomic Features Commonly Found With PC3

Thermoregulatory	Diaphoresis, perception of temperature fluctuation, peripheral edema
Cardiovascular	Palpitations, unexplained chest pain, orthostasis, POTS, Raynaud's
Gastrointestinal	GERD, irritable bowel syndrome, bloating
Urological	Increased urgency, frequency
Psychiatric	Increased panic, anxiety, bipolar disorder
Other	Insomnia, restless legs syndrome, bruxism (TMJD), fatigue

GERD, gastroesophageal reflux disease; PC3, positional cervical cord compression; POTS, postural orthostatic tachycardia syndrome; TMJD, temporomandibular joint disorder

Author's Bio: *Andrew J. Holman, MD, is associate clinical professor of medicine at the University of Washington and practices rheumatology at Valley Medical Center in a Seattle suburb. He completed his undergraduate studies at Bowdoin College in 1981 and received his medical degree from the University of Missouri-Columbia in 1987. His internal medicine residency training was completed at Denver Presbyterian Medical Center in 1990. After his rheumatology fellowship at the University of Washington, he has practiced clinical rheumatology, exploring new options for fibromyalgia and autoimmune connective tissue diseases. His research focuses on PC3, autonomic dysregulation, hypermobility syndrome, and how the autonomic nervous system interacts with the immune system.*

Dr. Holman has no financial information to disclose pertinent to this topic.

References

1. Maclolm GP. Surgical disorders of the cervical spine: presentation and management of common disorders. *J Neurol Neurosurg Psychiatry.* 2002;73(suppl 1):i34-i43.
2. Olsson SE. The dynamic factor in spinal cord compression: a study on dogs with special reference to cervical disc protrusion. *J Neurosurg.* 1958;15(3):308-321.
3. Penning L, Van der Zwaag P. Biomechanical aspects of spondylitic myelopathy. *Acta Radiol Diagn.* 1966;5:1090-1103.
4. Muhle C, Weinert D, Falliner A, et al. Dynamic changes of the spinal canal in patients with cervical spondylosis at flexion and extension using magnetic resonance imaging. *Invest Radiol.* 1998;33(8):444-449.
5. Muhle C, Metzner J, Weinhart D, et al. Classification system based on kinematic MR imaging in cervical spondylitis myelopathy. *Am J Neuroradiol. 1998;19(9):1763-1771.*
6. Chen CJ, Hsu HL, Niu CC, et al. Cervical degenerative disease at flexion-extension MR imaging: prediction criteria. *Radiology.* 2003;227(1):136-142.
7. Jinkins JR, Dworkin J. Proceedings of the State-of-the-Art Symposium on Diagnostic and Interventional Radiology of the Spine, Antwerp, September 7, 2002 (Part 2). Upright, weight-bearing, dynamic-kinetic MRI of the spine: pMRI/kMRI. *JBR-BTR.* 2003;86(5):286-293.
8. Morishita Y, Hymanson H, Miyazaki M, et al. Review article: kinematic evaluation of the spine: a kinetic magnetic resonance imaging study. *J Orthop Surg.* 2008;16(3):348-350.
9. Muhle C, Bischoff L, Weinert D, et al. Exacerbated pain in cervical radiculopathy at axial rotation, flexion, extension, and coupled motions of the cervical spine: evaluation by kinematic magnetic resonance imaging. *Invest Radiol.* 1998;33(5):279-288.
10. Karhu JO, Parkkola RK, Koskinen SK. Evaluation of flexion/extension of the upper cervical spine in patients with rheumatoid arthritis: an MRI study with dedicated positioning device compared to conventional radiographs. *Acta Radiol.* 2005;46(1):55-66.
11. Schlamann M, Reischke L, Klassen D, et al. Dynamic magnetic resonance imaging of the cervical spine using the NeuroSwing system. *Spine.* 2007;32(21):2398-2401.
12. Gerigk L, Bostel T, Hegewald A, et al. Dynamic magnetic resonance imaging of the cervical spine with high-resolution 3-dimensional T2-imaging. *Clin Neuroradiol.* 2012;22(1):93-99.
13. Bell GR, Stearns KL. Flexion-extension MRI of the upper rheumatoid cervical spine. *Orthopedics.* 1991;14(9):969-973.
14. Heffez DS, Ross RE, Shade-Zeldow Y, et al. Treatment of cervical myelopathy in patients with fibromyalgia syndrome: outcomes and implications. *Eur Spine* J. 2007;16(9):1423-1433.
15. Heffez DS, Ross RE, Shade-Zeldow Y, et al. Clinical evidence for cervical myelopathy due to Chiari malformation and spinal stenosis in a non-randomized group of patients with the diagnosis of fibromyalgia. *Eur Spine J.* 2004;13(6):516-523.
16. Holman AJ. Positional cervical spinal cord compression and fibromyalgia: a novel comorbidity with important diagnostic and treatment implications. *J Pai*n. 2008;9(7):613-622.
17. Wolfe F, Smythe HA, Yunus MB, et al. The American College of Rheumatology 1990 criteria for the classification of fibromyalgia: report of the multicenter criteria committee. *Arthritis Rheum.* 1990;33(2):160-172.
18. Hryciw CA, Holman AJ. Positional cervical cord compression (PC3) as a comorbidity in patients with fibromyalgia (FM): findings from a one-year retrospective study at an FM referral university [abstract]. Presented at: MYOPAIN 2010, Toledo, Spain.
19. Gagnadoux F, Meslier N, Svab I, Menei P, Racineux JL. Sleep-disordered breathing in patients with Chiari malformation: improvement after surgery. *Neurology.* 2006;66(1):136-138.
20. Watson NF, Buchwald D, Goldberg J, Noonan C, Ellenbogen RG. Neurologic signs and symptoms of fibromyalgia. *Arthritis Rheum.* 2009;60(9):2839-2844.
21. Watson NF, Buchwald D, Goldberg J, et al. Is Chiari I malformation associated with fibromyalgia? *Neurosurgery.* 2011;68(2):443-448.
22. Mayorov DN, Adams MA, Krassioukov AV. Telemetric blood pressure monitoring in conscious rats before and after compression injury of spinal cord. *J Neurotrauma.* 2001;18(7):727-736.
23. Buskila D, Neuman L, Vaisberg G, Alkalay D, Wolfe F. Increased rates of fibromyalgia following cervical spine injury: a controlled study of 161 cases of traumatic injury. *Arthritis Rheum.* 1997;40(3):446-452.
24. Jones GT, Nicholl BI, McBeth J, et al. Role of road traffic accidents and other traumatic events in the onset of chronic widespread pain: results from a population-based prospective study. *Arthritis Care Res.* 2011;63(5):696-701.

TOPICAL FINDINGS

Race and Gender Found Key Risk Factors For Osteoarthritis of Knee

African American women appear to be at increased risk of developing osteoarthritis (OA) of the knee, according to a study presented at the 2012 annual meeting of the American College of Rheumatology.[1] The study, which looked at the lifetime risk of knee OA for different segments of society, also found that Hispanic women have higher rates than Caucasian women, and all women had higher rates than men of all races.

Using a computer simulation model, Elena Losina, PhD, co-director of the Orthopedic and Arthritis Center for Outcomes Research at Brigham and Women's Hospital in Boston, and colleagues found that among people age 40 without existing arthritis, the highest lifetime risk of developing painful knee OA is in African American women (17%) and the lowest was in Caucasian men (10%). By age 65, 11.3% of African American women, 10.5% of Hispanic women, and 10% of Caucasian women are expected to develop painful knee OA. The need for a total knee replacement is expected in 6.8% of African American women, but in only 3.8% of Hispanic men.

The higher risk factors seen among African American and Hispanic women are due to higher rates of being overweight or obese, noted Dr. Losina. "We know that obesity increases the risk of osteoarthritis, and weight loss is likely to lower the risk of osteoarthritis and the need for total knee replacement surgery," she said.

Reference

1. Losina E, Daigle ME, Burbine SA, Katz JN. Race- and sex-specific estimates of 10-, 20-, 30-year, and lifetime risk of diagnosed symptomatic knee osteoarthritis and the need for total knee replacement in the US. Presented at the American College of Rheumatology Annual Meeting. Washington, DC; November 9-14, 2012; Presentation: 911.