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# Diagnosis and treatment of hidden lesions in "mild" cervical spondylotic myelopathy patients with apparent symptoms

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**Abstract**

Patients with apparent symptoms of cervical spondylotic myelopathy (CSM) may only show a mild compressive lesion in ordinary magnetic resonance imaging (MRI). The aim of this study was to investigate the characteristics of CSM patients with "hidden" lesions on kinetic MRI and to determine an effective treatment.

Thirty-one patients with obvious spinal cord compression only on kinetic MRI were included in our study. A variety of parameters were calculated from MRI of the cervical spine at different postures. The anterior cervical decompression and fusion (ACDF) procedure were used for treatment of CSM. To evaluate the effect of surgery, a further 31 age- and gender-matched ordinary CSM patients that received ACDF procedures were enrolled as the control group.

The diameter of the cervical cord at the narrowest level in extension was significantly lower than that in the neutral posture ($P < .01$). The percentage of spinal cord compression was 34.6%. The diameter of the cervical canal at the narrowest level in the extension posture was significantly lower than that in the neutral posture ($P < .01$). The percentage of cervical canal stenosis was 43.6%. The anteroposterior diameter of the cervical canal in the case group was significantly lower than that in the control group ($P < .01$). However, the recovery rate of the Japanese Orthopaedic Association score at final follow-up was comparable between the case group and the control group ($P = .53$).

Kinetic MRI is useful for the diagnosis of CSM with hidden lesions. ACDF is an effective procedure for treatment of CSM.

**Abbreviations:** ACDF = anterior cervical decompression and fusion, AP = anteroposterior, CSM = cervical spondylotic myelopathy, ICC = intraclass correlation coefficient, JOA = Japanese Orthopaedic Association, MRI = magnetic resonance imaging.

**Keywords:** cervical spine, disc herniation, kinetic magnetic resonance imaging, ligamentum flavum, myelopathy

## 1. Introduction

Cervical spondylotic myelopathy (CSM) is a degenerative disease of the cervical spine and is frequently seen in elderly patients.[1,2] Symptoms of CSM are caused by compressive lesions on the spinal cord, the most common of which include osteophytes, a herniated vertebral disc, and hypertrophic ligamentum flava. A definite diagnosis of CSM is based on the combination of clinical symptoms and signs, as well as imaging tests.[3] However, some patients with apparent symptoms of CSM have no compression or only a mild compressive lesion no ordinary magnetic resonance imaging (MRI).

In healthy individuals, the space and cerebrospinal fluid in the spinal canal can protect the spinal cord from injury. However, in some cases, "hidden" herniation of the discs or ligamentum flava may occur during movement of the spine.[4] For example, the space around the cervical cord is reduced when the cervical spine undergoes hyperextension, and the spinal cord may suffer dynamic injury from this movement.[5] As imaging of the cervical spine is routinely performed in patients using a neutral posture, severe lesions may be frequently overlooked. As such, early diagnosis and treatment of cervical myelopathy is often difficult. Thus, it is important to provide further details on hidden lesions of the cervical spine, particularly for patients with apparent symptoms, but with no or a mild lesion on MRI.

MRI is a sensitive technique for showing the structure of soft tissue in the cervical spine, such as the intervertebral discs and the ligamentum flava.[6] Given that radiographic abnormalities may be absent in cases of CSM with hidden lesions, kinetic MRI evaluations of the cervical spine in flexion and extension postures may help provide further information on the etiology and cervical pathology in CSM.[7,8] However, there are limited studies examining the diagnosis and treatment of hidden lesions of CSM using kinetic MRI. Herein, we investigated the characteristics of CSM patients with hidden lesions observed by kinetic MRI, measured the changes in compressive lesions during positional changes of the cervical spine, and assessed the effects of surgical treatment.

## 2. Methods

### 2.1. Patient population

This study was approved by the ethics committee of the Third Hospital of Hebei Medical University. From January 2010 to

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September 2015, 31 patients were retrospectively reviewed and enrolled in our study. Inclusion criteria were objective clinical findings of CSM, such as abnormal sensory disturbances, increased deep tendon reflexes, and positive pathological reflexes; without or with only mild spinal cord compression on MRI when the spine was in neutral posture; and showing obvious spinal cord compression by the vertebral discs, the ligamentum flava, or both on kinetic MRI. Patients with ossification of the posterior longitudinal ligament, previous histories of spinal surgery, vertebral fractures, traumatic cervical myelopathy, motor neuron disease, multiple sclerosis, or congenital anomalies were excluded from our study.

### 2.2. Measurement method

Kinetic MRI was performed on an MRI scanner (Siemens Magnetom Symphony; Siemens, Berlin, Germany) with dynamic motion of the cervical spine in flexion, neutral, and extension postures (Fig. 1). MRI analysis software was used to performed data measurement on T2-weighted MRI images. Various parameters were calculated from MRI images taken with the cervical spine in different postures. The anteroposterior (AP) diameter of the cervical canal was measured at the mid-vertebra level on T2 sagittal MRI from C4 to C7 with the cervical spine in the neutral posture, and the mean value was calculated.[9] The diameter of the cervical cord at the narrowest part of the compression-affected levels was then measured. The diameter of the cervical canal was quantified as the distance between the posterior edge of the disc and the ligament flavum at the narrowest level. Data measurements were performed by 2 independent examiners (YS and KY) and the mean value was used for data analysis.

The percentage of spinal cord compression resulting from extension was calculated as (1 – [diameter of the cervical cord at the narrowest part in extension posture/diameter of the cervical cord in the neutral posture]) × 100%. The percentage of cervical canal stenosis resulting from extension was calculated as (1 – [diameter of the cervical canal at the narrowest part in the extension posture/diameter of the cervical canal in the neutral posture]) × 100% (Fig. 2).

### 2.3. Treatment and follow-up

The surgical procedure involved 1- or 2-level anterior cervical decompression and fusion (ACDF). After general anesthesia, the patient was placed in the supine position with slight cervical extension. A standard right-sided Smith-Robinson approach via a transverse incision was used to expose the targeted segment. All compressive materials were then removed, which include osteophytes, a herniated intervertebral disc, and the posterior longitudinal ligament, until the dura was exposed. Additional uncinated processes were partially resected when patients had a foraminal stenosis because of uncovertebral osteophytes. Next, a polyetheretherketone cage filled with excised osteophytes was inserted between the vertebral bodies, and the plate then fixed with screws inserted cranially and caudally to ensure firm fusion. All surgeries were performed by the same surgeon. A soft collar was used for 6-weeks postoperative recovery.

To compare the surgical outcomes, 31 age- and gender-matched ordinary CSM patients after ACDF procedures were also enrolled in the study as a control group. These patients only had anterior compression because of a herniated disc or osteophytes on MRI. Relevant clinical factors, including age, gender, and duration of disease, were collected from the records of these patients. The AP diameter of the cervical canal was also measured by MRI with the cervical spine in the neutral posture. Scheduled regular follow-up visits were recommended at 3, 6, and 12 months postoperatively, and then annually. All patients in the case group and the control group were followed-up for at least 1 year. The Japanese Orthopaedic Association (JOA) score

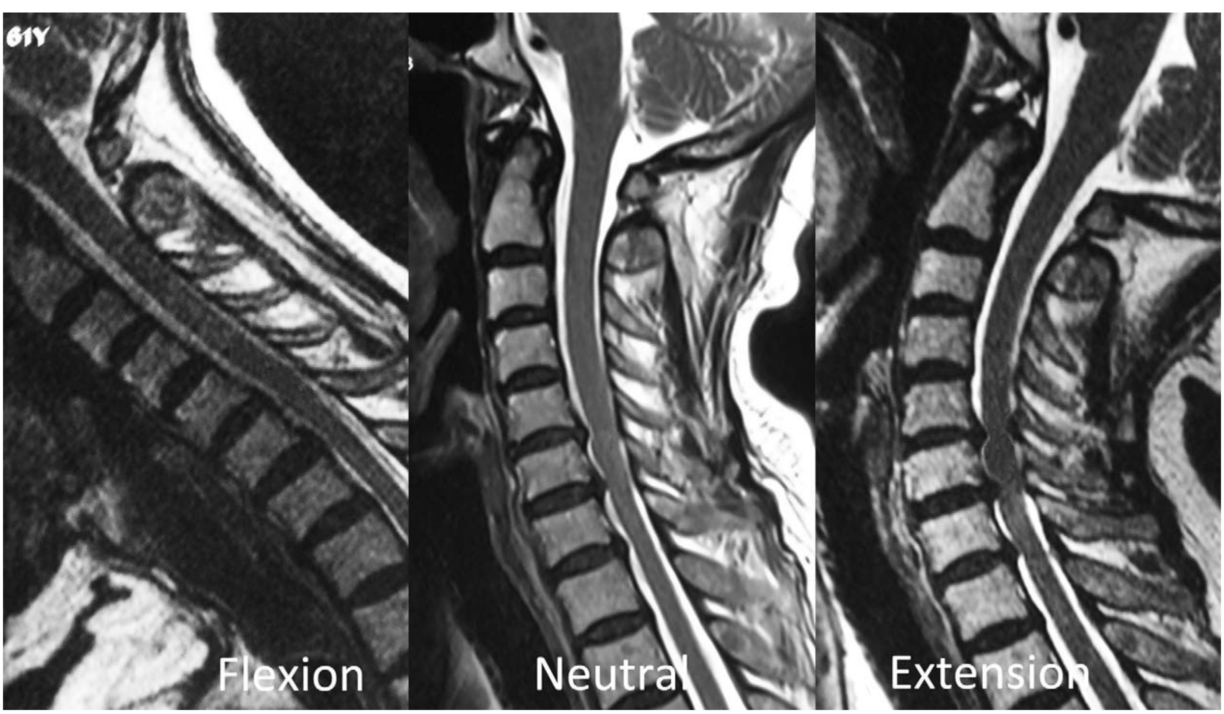


**Figure 1.** Kinetic magnetic resonance images of a patient with dynamic motion of the cervical spine in flexion, neutral, and extension postures.

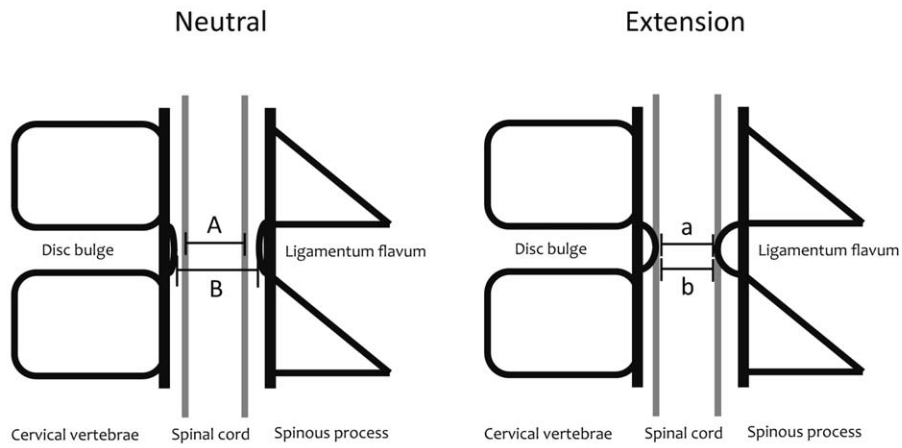


**Figure 2.** Abridged overview of the method used to measure the diameter of cervical cord and stenosis of cervical canal. A and a are diameter of cervical cord at the narrowest segment in neutral and extension postures, respectively; B and b are diameter of cervical canal at the narrowest segment in neutral and extension postures, respectively. The percentage of spinal cord compression = (1–a/A) × 100%; the percentage of cervical canal stenosis = (1–b/B) × 100%.

was used to assess preoperative and postoperative neurological function (Table 1). Besides, the recovery rate of the JOA score was assessed by Hirabayashi's method,[10] which was calculated according to the formula: recovery rate = (postoperative JOA score − preoperative JOA score) / (17 − preoperative JOA score) × 100%.

**Table 1**

**Japanese Orthopaedic Association (JOA) scores for assessment of cervical myelopathy.**

| Category | Score (points) |
|---|---|
| I. Motor function of the upper extremity | |
| Unable to eat with either chopsticks or a spoon | 0 |
| Able to eat with a spoon, but not with chopsticks | 1 |
| Able to eat with chopsticks, but inadequately | 2 |
| Able to eat with chopsticks, but awkwardly | 3 |
| Normal | 4 |
| II. Motor function of the lower extremity | |
| Unable to walk | 0 |
| Needs a cane or other walking aid on flat ground | 1 |
| Needs walking aid only on stairs | 2 |
| Able to walk unaided, but slowly | 3 |
| Normal | 4 |
| III. Sensory function | |
| a. Upper extremity | |
| Apparent sensory disturbance | 0 |
| Minimal sensory disturbance | 1 |
| Normal | 2 |
| b. Lower extremity | |
| Apparent sensory disturbance | 0 |
| Minimal sensory disturbance | 1 |
| Normal | 2 |
| c. Trunk | |
| Apparent sensory disturbance | 0 |
| Minimal sensory disturbance | 1 |
| Normal | 2 |
| IV. Bladder function | |
| Urinary retention or incontinence | 0 |
| Severe dysuria (sense of retention) | 1 |
| Slight dysuria (pollakiuria, retardation) | 2 |
| Normal | 3 |

The score in a normal subject is the total of the best scores: (I + II + III + IV) = 17 points.
JOA = Japanese Orthopedic Association.

### *2.4. Statistical analysis*

Descriptive data for the patient population are presented as mean ± standard deviations for continuous variables, and as frequencies and percentages for categorical variables. The Fisher exact tests or paired *t*-test were used to determine differences between the groups. Intra- and inter-rater reproducibility of measurement for the cervical cord and cervical canal were tested and quantified by the intraclass correlation coefficient (ICC). ICC values were categorized as: poor (<0.4), fair to good (0.4–0.7), and excellent (>0.7). Statistical analyses were performed with statistical software (SPSS v18.0 for Windows; SPSS, Inc., Chicago, IL). A *P*-value of < .05 was considered to indicate a statistically significant difference.

## 3. Results

Of the 31 patients in the case group, there were 18 men and 13 women. The mean age at the time of surgery was 61.8 ± 9.2 years (range, 43–71 years). The mean duration of disease was 1.2 ± 0.8 years (range, 3 months to 3 years). There were 21 patients with 1 affected level, and the other 10 patients with involvement of 2 levels. The main compressive tissues were disc bulge in the front and a hypertrophic ligamentum flavum on the back. The most commonly involved segment was at the C5/C6 (43.9%), followed by the C6/C7 (34.1%) and the C4/C5 (22.0%) levels.

The intra-rater ICCs for measurement of the cervical cord and the cervical canal were 0.91 (0.87–0.94) and 0.84 (0.76–0.89), respectively. The inter-rater ICC for measurement of the cervical cord and the cervical canal were 0.92 (0.88–0.95) and 0.87 (0.81–0.90), respectively. Both intra-rater and inter-rater ICC showed perfect agreement. The diameter of the cervical cord at the narrowest level was 5.1 ± 1.3 mm with the cervical spine in the extension posture, and 7.8 ± 0.8 in the neutral posture. The diameter of cervical cord in extension was significantly lower than that in the neutral posture (*P* < .01). The percentage of spinal cord compression was 34.6%. The diameter of the cervical canal at the narrowest level was 5.3 ± 1.5 mm with the cervical spine in the extension posture, and 9.4 ± 2.2 in the neutral posture. Stenosis of the cervical canal in the extension posture was significantly lower than that in the neutral posture (*P* < .01). The percentage of cervical canal stenosis was 43.6%. An extension posture of the cervical spine was the main factor that increased

**Table 2**

**Basic characteristics of patients.**

| Variable | Value |
|---|---|
| Number of patients | 31 |
| Age, years | 61.8±9.2 |
| Gender, male/female | 18:13 |
| Duration of disease, years | 1.2±0.8 |
| Number of patients involving 1 level | 21 |
| Number of patients involving 2 levels | 10 |
| Levels involved | |
| C4/C5 | 9 |
| C5/C6 | 18 |
| C6/C7 | 14 |
| Anteroposterior diameter of cervical canal, mm | 12.6±1.4 |
| Diameter of cervical cord in extension, mm | 5.1±1.3 |
| Diameter of cervical cord in neutral, mm | 7.8±0.8 |
| Percentage of spinal cord compression,* % | 34.6 |
| Diameter of cervical canal in extension, mm | 5.3±1.5 |
| Diameter of cervical canal in neutral, mm | 9.4±2.2 |
| Percentage of cervical canal stenosis,† % | 43.6 |
| JOA score before surgery | 11.0±2.3 |
| JOA score at final follow-up | 14.0±1.1 |

JOA=Japanese Orthopaedic Association scores.

* Percentage of spinal cord compression because of extension (%)=(1 − [diameter of the cervical cord at the narrowest part in extension posture/diameter of the cervical cord in the neutral posture]) × 100%.

† Percentage of cervical canal stenosis because of extension (%)=(1 − [diameter of the cervical canal at the narrowest part in the extension posture/diameter of the cervical canal in the neutral posture]) × 100%.

the severity of cervical canal stenosis and spinal cord compression. The characteristics of the patients in the case group are shown in Table 2.

The AP diameter of the cervical canal in the case group (12.6±1.4 mm) was significantly lower than that in the control group (14.8±1.7 mm; $P<.01$). All patients were followed up for more than 1 year, and the mean lengths of follow-up were 3.9±1.6 years and 4.2±2.0 years, respectively ($P=.52$). The mean JOA scores between the groups before surgery and at the final follow-up are shown in Fig. 3. There was no difference in the mean JOA scores between the case group (11.0±2.3) and the control group (10.6±1.8l; $P=.45$) before surgery, or between the case group (14.0±1.1) and the control group (13.7±1.7; $P=.58$) after surgery at the end of follow-up. However, both groups showed a significant increase in JOA scores after surgery compared with preoperative values ($P<.01$). The recovery rate of the JOA score at final follow-up was similar between the case group (50.0±10.3%) and the control group (48.4±9.6%, $P=.53$).

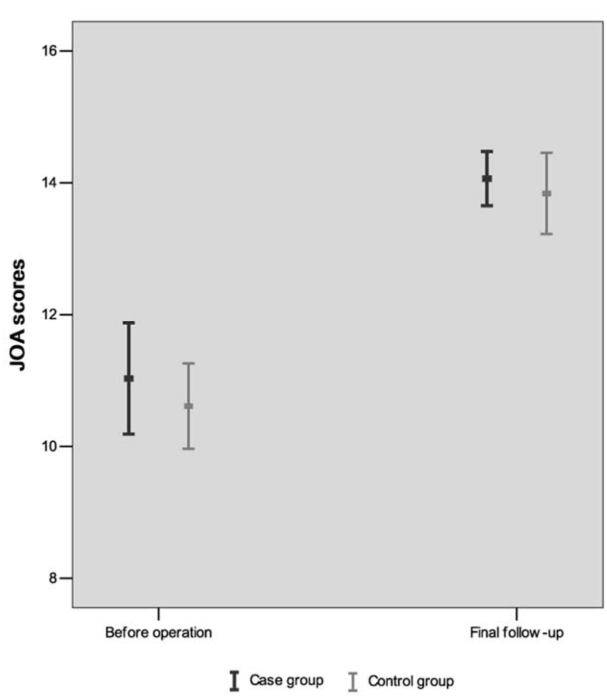


**Figure 3.** Error bar showing pre- and postoperative Japanese Orthopedic Association (JOA) scores. JOA = Japanese Orthopedic Association.

## 4. Discussion

In the present study, we found that kinetic MRI could clearly show the structure of soft tissue in the cervical spine, such as the intervertebral discs and ligamentum flava, and allow detailed analyses of the source of cervical pathology in patients with hidden lesions.[7,8] In patients with a hidden lesion, the C5/C6 segment was most commonly involved, followed by the C6/C7 and the C4/C5 levels. Stenosis of the cervical canal was also more severe in the extension posture than that in the neutral posture. Meanwhile, the extension posture increased the severity of spinal cord compression. Except for intervertebral disc and ligamentum flavum, the AP diameter of cervical canal may also play an important role that lay patients in a susceptible situation. Finally, we found that the ACDF procedure was effective for treatment of CSM with hidden lesions.

Recently, dynamic changes in disc bulging were reported to be a major factor in cervical spinal stenosis.[11] Apart from cases with herniated vertebral discs (commonly observed in elderly patients), the ligamentum flava occupy a significant part in the cervical spinal canal, and can lead to significant narrowing of the canal and cause subsequent clinical symptoms of myelopathy.[5] The ligamentum flava are important posterior structures of the spinal canal that connect the adjacent laminae from C2 to S1.[12] In comparison with the thoracic and lumbar spine, the ligamentum flava in the cervical region are longer and broader, but also thinner, making them more likely to protrude into the spinal canal when the neck moves. The volume and the diameter of the cervical spinal canal are not constant, rather the shape of the spinal canal changes markedly between extension to flexion.[13–15] The vertebral discs and ligamentum flava can also herniate during movement of the cervical spine, thus narrowing the diameter of the osseous canal during extension, and widening during flexion. Movement from flexion to extension can cause the “clamp mechanism,” whereby compression from both the anterior and posterior tissues causes narrowing of the spinal canal and compression of neural elements, leading to clinical symptoms of myelopathy.[13] However, these herniated tissues can recover and are not observed when the cervical spine is in neutral posture. Thus, this disorder is commonly overlooked by surgeons. Our data suggest that additional kinetic MRI in extension and flexion views can provide important information for a correct diagnosis.

Movement of the cervical spine has different effects on different levels of the spinal cord, which may predispose these levels to cord compression syndromes and associated neuropathies. For example, Zeng et al[5] reported that hidden hypertrophy of ligamentum flava was significant at C4/C5 and C5/C6, whereas Sayit et al[16] found that the ligamentum flava were thickest at C6/C7 and C7/T1 in the extension posture. In the present study, C5/C6 was the most frequently involved segment, followed by the

C6/C7 and C4/C5 levels. Thus, the C4/C5, C5/C6, and C6/C7 segments may be most vulnerable to cervical canal stenosis during movement of the cervical spine. The small AP diameter of the cervical canal is also an important cause of injury in these patients. Thus, clinicians should pay particular attention to specific spinal cord levels, particularly in patients with congenital canal stenosis.[17]

The optimal surgical procedure for CSM patients with hidden lesions remains unclear. Both ACDF and laminoplasty have been reported to eliminate the lesions.[18–20] ACDF is typically performed in cases with spondylolisthesis or cervical cord compression by a vertebral disc, whereas laminoplasty is recommended when the cervical cord is compressed mainly by the ligamentum flava. In the present study, patients only received the ACDF procedure, which allows surgeons to directly remove the compressive object in front of the cervical cord. After fusion and fixation of the vertebral bodies, the movement of local segments is impossible. Further, the ligamentum flava cannot protrude into the canal and compress the spinal cord during cervical spine extension, even though the ligamentum flava are not removed. We found that a single ACDF procedure was able to eliminate the "clamp damage," and effectively reduced the symptoms of patients during follow-up.

There are several limitations of our study. First, as patients only received ACDF, we were unable to assess the efficacy of ACDF versus laminoplasty. Second, although we tried to collect all eligible patients, the number of patients with hidden lesions was relatively small, which may have limited our ability to assess clinical outcomes. A multicenter study involving a large population and long-term follow-up is required to confirm our results. Finally, we only used T2-weighted MRI for data measurement. Diffusion tensor imaging can be used to characterize microstructural changes within neural tissues, and analysis of the spinal cord using diffusion tensor imaging in our patients may provide more detailed information.

In conclusion, kinetic MRI can show the hidden hypertrophy of the ligamentum flava and herniated vertebral discs during cervical movement. The spinal canal stenosis was obvious when the spine was in extension posture, and this posture can lead to severe spinal cord compression. Except for the intervertebral discs and ligamentum flava, the AP diameter of the cervical canal may also play an important role in injury in CSM patients. Finally, the ACDF procedure was effective for treatment of CSM with hidden lesions.

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