The natural history of cervical spondylotic myelopathy

PAUL G. MATZ, M.D.,[1] PAUL A. ANDERSON, M.D.,[2] LANGSTON T. HOLLY, M.D.,[3]
MICHAEL W. GROFF, M.D.,[4] ROBERT F. HEARY, M.D.,[5] MICHAEL G. KAISER, M.D.,[6]
PRAVEEN V. MUMMANENI, M.D.,[7] TIMOTHY C. RYKEN, M.D.,[8] TANVIR F. CHOUDHRI, M.D.,[9]
EDWARD J. VRESILOVIC, M.D., PH.D.,[10] AND DANIEL K. RESNICK, M.D.[11]

[1]Division of Neurological Surgery, University of Alabama, Birmingham, Alabama; Departments of
[2]Orthopaedic Surgery and [11]Neurological Surgery, University of Wisconsin, Madison, Wisconsin;
[3]Division of Neurosurgery, David Geffen School of Medicine, University of California at Los Angeles,
California; [4]Department of Neurosurgery, Harvard Medical School and Beth Israel Deaconess Medical
Center, Boston, Massachusetts; [5]Department of Neurosurgery, University of Medicine and Dentistry of New
Jersey—New Jersey Medical School, Newark, New Jersey; [6]Department of Neurological Surgery,
Neurological Institute, Columbia University, New York, New York; [7]Department of Neurosurgery,
University of California at San Francisco, California; [8]Department of Neurosurgery, University of Iowa
Hospitals and Clinics, Iowa City, Iowa; [9]Department of Neurosurgery, Mount Sinai School of Medicine,
New York, New York; and [10]Department of Orthopaedic Surgery, Milton S. Hershey Medical Center,
Pennsylvania State College of Medicine, Hershey, Pennsylvania

Object. The objective of this systematic review was to use evidence-based medicine to delineate the natural history of cervical spondylotic myelopathy (CSM) and identify factors associated with clinical deterioration.

Methods. The National Library of Medicine and Cochrane Database were queried using MeSH headings and keywords relevant to the natural history of CSM. Abstracts were reviewed and studies meeting the inclusion criteria were selected. The guidelines group assembled an evidentiary table summarizing the quality of evidence (Classes I–III). Disagreements regarding the level of evidence were resolved through an expert consensus conference. The group formulated recommendations that contained the degree of strength based on the Scottish Intercollegiate Guidelines network. Validation was done through peer review by the Joint Guidelines Committee of the American Association of Neurological Surgeons and the Congress of Neurological Surgeons.

Results. The natural history of CSM is mixed: it may manifest as a slow, stepwise decline or there may be a long period of quiescence (Class III). Long periods of severe stenosis are associated with demyelination and may result in necrosis of both gray and white matter. With severe and/or long lasting CSM symptoms, the likelihood of improvement with nonoperative measures is low. Objectively measurable deterioration is rarely seen acutely in patients younger than 75 years of age with mild CSM (modified Japanese Orthopaedic Association scale score > 12; Class I). In patients with cervical stenosis without myelopathy, the presence of abnormal electromyography findings or the presence of clinical radiculopathy is associated with the development of symptomatic CSM in this patient population (Class I).

Conclusions. The natural history of CSM is variable, which may affect treatment decisions.
(DOI: 10.3171/2009.1.SPINE08716)

KEY WORDS • cervical spine • cervical spondylosis • myelopathy •
natural history • practice guidelines

Recommendations

In younger patients with mild CSM (age younger than 75 years and mJOA scale score > 12), it is recommended that both operative and nonoperative management options be offered, as objectively measurable deterioration in function is rarely seen acutely (quality of evidence: Class I; strength of recommendation, B).

It is recommended that both operative and nonoperative management options be offered to younger patients with mild CSM given that the evidence indicates that clinical gains after nonoperative treatment are often maintained over 3 years in 70% of cases (quality of evidence, Class III; strength of recommendation, D).

It is recommended that discussion of the natural his-

---

tory of CSM conveys that the course of CSM is mixed, with many patients experiencing a slow, stepwise decline. Discussion should address the fact that long periods of quiescence are not uncommon and that a subgroup of patients may have interim improvement (quality of evidence, Class III; strength of recommendation, D).

It is also recommended that discussion of the natural history of CSM convey that long periods of severe stenosis over many years are associated with demyelination of white matter and may result in necrosis of both gray and white matter leading to potentially irreversible deficit (quality of evidence Class III; strength of recommendation, D).

It is recommended that operative therapy be offered to patients with severe and/or long lasting symptoms, because the likelihood of improvement with nonoperative measures is low (quality of evidence Class III; strength of recommendation, D).

In patients with cervical stenosis without myelopathy who either have abnormal EMG findings or clinical radiculopathy, decompression should be considered (if the patient does not otherwise require surgery for radiculopathy) because the presence of EMG abnormalities or clinical radiculopathy is associated with development of symptomatic CSM in this patient population (quality of evidence, Class I; strength of recommendation, B).

Rationale

As cervical disc degeneration progresses, posterior element osteophytes develop along with ligamentum flavum hypertrophy. The end result is acquired cervical canal stenosis that may be exacerbated by underlying congenital stenosis. This resultant canal narrowing is often asymptomatic. However, compression of the spinal cord and nerve roots may become clinically symptomatic as CSM.

The purpose of this study is to undertake a systematic review of the natural history and disease progression of CSM. Although CSM has been studied for several years, several questions remain regarding disease progression. Specifically, it is not well understood why myelopathy develops in certain patients but not in others, despite radiographic evidence of cervical stenosis. It is also poorly understood why certain patients have clinically severe myelopathy and others manifest only mild myelopathy. Finally, the time course of disease progression seems to differ between studies, with some authors reporting a precipitous decline and others showing static symptoms. Increased use of functional scales such as the JOA allows the severity of CSM to be quantified. The use of such scales has also permitted a more objective analysis of the natural history of the disease. For the purposes of this manuscript, "natural history" refers either to no treatment or nonoperative therapy because it has been impossible to verify compliance with most nonoperative therapies (including rest and cervical collar immobilization).

Search Criteria

We completed a computerized search of the National Library of Medicine database and the Cochrane database of the literature published from 1966 to 2007 using search terms and MeSH headings. A search using the subject heading "spondylosis and myelopathy" yielded 754 citations. We combined the following subject headings with "spondylosis and myelopathy": "disease progression" (18 citations), "outcome assessment" (113 citations), "signs and symptoms" (142 citations), "pathophysiology" (171 citations). Also searched were terms "cervical spine and natural history" (111 citations) and "cervical spine and myelopathy and natural history" (20 citations). Accounting for redundancy, we acquired 438 citations; we selected only English citations. We then reviewed the titles and abstracts of the articles and culled additional references from the bibliographies.

Among the articles reviewed, we included 32 studies and reviews that dealt with CSM and its progression and outcome without surgical intervention (Evidentiary Table 1). Seventeen of these studies examined outcomes over a period permitting longitudinal follow-up. Outcome measures used were primarily the JOA and the Nurick scale. Other parameters studied included abnormalities on MR imaging and changes on electrophysiological testing.

Scientific Foundation

Longitudinal Analysis Without Objective Outcomes

An assessment of the natural history of disease progression in CSM essentially involves prognosis in the absence of surgical intervention. A determination of prognosis involves evaluation of validity, results, and applicability.[3] Specifically, a reviewer must determine whether a sample of patients was representative and homogeneous. Also vital are a sufficient length of follow-up and objective outcome measures. Results must illustrate outcomes over time and the precision of said outcomes.

Most studies have examined CSM primarily in qualitative terms, often without the use of objective outcome measures. Quantitative outcome measures for cervical myelopathy are many; the most commonly used were the JOA score and the Nurick scale.[5,15] The JOA scale is a reliable, valid, and responsive measure. Although more traditional, the Nurick scale has not been studied in as great detail. Prior to utilization of these outcome measures, most authors assessed CSM qualitatively.

Clarke and Robinson[4] described a retrospective series of 120 patients with CSM over several years. In this study, CSM appeared to have a mixed progression. Of this cohort, 26 patients did not undergo surgery. The authors combined the natural history of these 26 with the progression of the disease in the remaining patients prior to surgery. The authors assessed outcomes based on clinical symptoms including motor symptoms in one or both legs, motor symptoms in one or both arms, and sensory symptoms in arms and legs. The authors found that the disease process consisted of episodes during which new symptoms and signs appeared in 75% of patients. During quiescent intervals, deterioration was seen in 2/3 of patients, while 1/3 of the patients had no deterioration. In 20% of patients, the authors observed a slow, steady progression of symptoms without stepwise decline; 5%

had a rapid onset of symptoms followed by a long plateau. In the 26 patients who did not undergo surgery, the study described improvement in 50%. Overall, this population was heterogeneous and was followed without objective outcome measures (Class III).[4]

Lees and Turner[11] detailed a cohort of 44 patients with CSM assembled over several years and diagnosed on the basis of repeated examination and myelography. It appeared from their study that the natural history of CSM may be prolonged with long periods of quiescence. They classified symptom severity as nil, mild (similar to Nurick Grade II), moderate (similar to Nurick Grade III), or severe (similar to Nurick Grades IV and V). The authors divided patients into those whose symptoms were < 10 years (3–10 years) and those who had symptoms longer than 10 years (10–40 years). As an aggregate group, initial CSM symptoms were nil in 0, mild in 4, moderate in 15, and severe in 25 patients. At follow-up, symptoms were nil in 2, mild in 3, moderate in 21, and severe in 18 patients. Most notable was that 15 patients with symptoms of longer than 10-years' duration had severe CSM that improved to moderate. In this cohort, several patients were treated with a cervical collar. Ultimately, 8 patients underwent surgery, 4 of whom had deteriorated during the observation period. In the 28 patients who were managed entirely in nonoperative fashion, 60% improved. Furthermore, improvement may occur with conservative management even in the presence of a long duration. This study population was a heterogeneous group evaluated without objective outcome measures and assessed at differing time points (Class III).[11]

Roberts[18] reviewed a retrospective series of 24 patients with CSM (average age 54.2 years) diagnosed by examination and myelography. The author concluded that a long duration and severity of symptoms seems to preclude recovery. This study detailed the 2-year period prior to any therapy. The mean follow-up period was 3.1 years, and patients were treated with bed rest and immobilization. The author graded motor disability in the patients (1–4 roughly equivalent to Nurick Grades II–V). During the study period, 7 patients (29%) improved, 9 were unchanged, and 8 worsened. Of those who improved, all recovered within 5 months. In contrast, poor outcome was associated with symptom duration > 18 months. The population in this study was heterogeneous, and objective outcome measures were lacking (Class III).[18]

Sadasivan et al.[19] corroborated the negative association between symptom duration and outcome. These authors described 22 patients (average age 50.8 years) with symptom durations averaging 6.3 years prior to diagnosis of CSM. Based on their medical histories, all patients were assessed as having Nurick Grade II myelopathy at diagnosis. One patient's myelopathy progressed to Nurick Grade III, in 17 it progresesd to Nurick Grade IV, and in 4 to Nurick Grade V. Gait was involved in 100%, dexterity in 72%, and weakness in 45% of patients. Although this sample was heterogeneous and was assessed without truly objective outcome measures (Class III), the results did suggest deterioration over time. However, the Nurick classifications were determined based on history and not on clinical records.[19]

Barnes and Saunders[1] found that increased ROM and female sex portended a worse outcome. These authors examined 45 patients with CSM (average age 65 years) with an average follow-up period of 8.2 years. The mean time between symptoms and treatment was 1.2 years. Myelopathy in the patients in Group I improved 1 Nurick grade, in Group III it deteriorated by 1 Nurick grade, and in Group II it remained stable. Nine patients were in Group I, 30 in Group II, and 6 in Group III. These authors found that, over several years, the majority of patients with CSM remain stable, with deterioration more prevalent with female sex and increased ROM. This population was heterogeneous and assessed without truly objective outcome measures (Class III).

Pathology

Ogino et al.,[16] Ono et al.,[17] and Ito and colleagues[6] all described pathological series of CSM at autopsy. In essence, all 3 studies indicated pathological progression that appears to worsen with duration and AP compression. Ogino et al.[16] detailed 9 patients (average age 76.4 years) from diagnosis to death (average duration of symptoms was 18.2 years). In their similar study, Ono et al.[17] reported on 5 patients with an average age of 74.2 years. Ito et al.[6] reported on 7 patients (average age 67.9 years) with a symptom duration of 4.7 years. Ito and colleagues noted that, over time, marked atrophy and neuronal loss developed in gray matter with severe degeneration in the white matter columns. These authors described this as a pattern similar to what is seen in a transient hypoperfusion syndrome. Ono et al.[16] noted similar findings to that of Ito and associates. Specifically, infarction and cavitation of the gray matter developed with white matter demyelination. In most instances, the AP compression ratio was below normal. Ogino et al.[16] noted that when the AP compression ratio was 40–44% of normal, flattening of the gray matter was present with mild demyelination. At 22–39% of normal, small cavitation developed in the gray matter with diffuse demyelination. Finally, at 12–19%, extensive gray matter necrosis with white matter gliosis occurred. However, these were small, heterogeneous series (Class III).

Longitudinal Analysis With Outcome Measures

Kadanka and colleagues[9,10] used the mJOA scale, a timed 10-m walk, and evaluation of video-recorded ADLs to assess 33 patients with CSM (average age 54 years). These authors concluded that the symptoms of mild CSM (mJOA score > 12) in patients younger than 75 years of age do not worsen in the majority of patients (80%), and may occasionally improve. The average duration of symptoms was 1 year, and entry criteria mandated diagnosis on MR imaging with an mJOA scale score > 12 (mild symptoms). Patients had an average of 2 stenotic levels.[9] The authors stratified outcomes into nonresponders, responders, and very good responders. Responders improved in the 10-m walk or added a point on the mJOA scale. Those in the very good responder group demonstrated +2 on the mJOA scale. At 6 months, 9 patients were nonresponders, 24 were responders, and 6 were very good responders, At 36

months, 8 were nonresponders, 22 were responders, and 7 were very good responders.[10] The average mJOA scale score improved from 14.6 to 14.7 (95% CI 14.0–15.3). The 10-m walk times stayed similar at 7.4–7.5 seconds (95% CI 6.7–8.4).[9] Patients who responded better seemed to be on the older side and had increased Pavlov ratios.

In a similar series, Kadanka et al.[7,8] detailed their experience in 27 patients (average age 55.6 years, all younger than 75 years) with mJOA scale scores > 12. The authors noted that mild-to-moderate CSM stabilizes over 24 months. They assessed outcome over 24 months using a timed 10-m walk, evaluation of video-recorded ADLs, and mJOA scale scores. In the conservatively managed group, the 10-m walk times reduced from 8.3 to 8.0 seconds at 24 months. Activities of daily living were unchanged in 70.4%, worsened in 18.5% (–1), and improved in 11.1% (+1). The mJOA scale scores improved from average of 14.3 to 14.5 over 24 months.[7,8] These 4 studies were Class I, because they contained homogenous groups and stratified prognostic factors with objective outcome measures detailed over time.

Nakamura and colleagues[14] reviewed 64 patients with CSM (average age 52 years) with a minimum sagittal diameter of 12.0 mm (average 13.5 mm). The authors observed a level of normalcy (no disability) in 27% in the upper and 26% in the lower extremity. The duration of symptoms in the study patients was 2 years. The authors measured outcome using the extremity subscale from the JOA. Follow-up was a minimum of 1 year and averaged 6. Conservative therapy varied and included Crutchfield tongs, plaster casts, traction, and bracing. In this series, 55% of patients improved in the upper extremity and 57% improved in the lower extremity. Only 3% showed deterioration in the lower extremity and all others remained the same. Younger patients and those with a mild disability more frequently achieved no disability status. Maintenance was 70% over several years with only 3% of patients experiencing worsening. This study was graded Class III because the cohort did not stratify for prognostic factors, and the authors did not include all patients in the time periods studied.[14]

Matsumoto and colleagues[12] reviewed soft cervical disc displacement in 27 patients (average age 44.4 years, JOA scale score > 10) with myelopathy. The JOA scale scores ranged 11–16 (average 13.6). Treatment was with a cervical collar 8 hours daily for 3 months. Patients were symptomatic an average of 4–5 months prior to enrollment and the average follow-up was 3.9 years. Of these 27 patients, 10 experienced clinical deterioration and required surgery, whereas 17 did not require further intervention. Among those who underwent surgery, the average JOA scale score was 14.1 initially, falling to 12.9 at 3 months and 12.1 at 6 months. After surgery, these patients improved to 16.0. In those who did not clinically worsen, JOA was 13.6 initially and improved to 14.9 at 3 months, and 15.6 at 6 months with a final JOA of 16.2. This study was Class III because a large group underwent surgical intervention over the final time course and that the patients were not truly representative of the overall CSM population.[12]

Predictors of Development and Worsening of CSM

Traditionally, clinicians have used electrophysiological techniques to study peripheral nerve abnormalities. Kadanka et al.[7] and Bednarik et al.[2] examined the development of CSM as it related to electrophysiological abnormalities. Kadanka and colleagues[7] described a series of 30 patients without clinical CSM all of whom had radiographic cervical stenosis. The study evaluated patients using SEPs and motor-evoked potentials in the upper and lower extremities. The authors found abnormal electrophysiological results in 15 of 30 patients. Of those in the group with abnormalities, clinical CSM ulimately developed in 5 patients over a 2-year follow-up period, whereas none of the 15 patients in the electrophysiologically normal group developed CSM (likelihood ratio positive 2.5, likelihood ratio negative 0, positive predictive value 30%, and negative predictive value 100%). This study was graded Class III. Although it represented a homogenous sample followed over time with objective outcome measures of EP, the clinical outcome measures were not documented quantitatively.[7]

Bednarik et al.[2] described 66 patients with spondylotic compression of the spinal cord, all of whom had mJOA scale scores of 18 (normal). These authors concluded that development of CSM in the presence of spondylotic compression is associated with clinical radiculopathy and premorbid abnormalities on EMG and SEP testing.[2] The authors longitudinally studied EMG of the anterior horn cells, SEPs, radiographic compression ratios on MR images, and clinical examination results. They defined development of myelopathy by clinical examination and loss of 1 point on the mJOA scale. In this series, 19.7% developed CSM (~ 5%/year). Clinical radiculopathy was present in 92% of the patients with CSM and in 24% of those in whom CSM did not develop (p < 0.0001). Somatosensory evoked potentials were abnormal in 38.5% of patients with CSM and 9.4% of patients without (p < 0.02). Electromyography abnormalities were present in 61% of those who developed CSM and 11.3% of those who did not (p < 0.01). This study was graded Class I because a representative, homogeneous sample was followed over a reasonable time period with objective outcome measures. The limitation of this study is that the mJOA scale is typically not responsive to a one point difference.[20]

In their Class I study described above, Bednarik et al.[2] also studied compression ratios—defined as the quotient of AP/width—including the standard Pavlov ratio. These authors found that the severity of the compression ratios did not correlate with the rate of development of CSM. Congenital stenosis was defined as a Pavlov ratio < 0.8 and spondylotic compression was defined as an AP/width ratio < 0.4.

Matsumoto et al.[13] focused on ISI in the cervical spinal cord on the T2-weighted MR imaging sequence. They described a series of 52 patients (29 with CSM, 12 with cervical disc displacement, and 11 with ossification of the posterior longitudinal ligament) with myelopathy (JOA scale score > 10, average age 55 years). The morbidity period before treatment ranged between 1 month and 2 years (mean 7 months). Treatment included cervical immobilization 8 hours daily for 3 months. Increased signal

TABLE 1: Summary of studies regarding CSM and natural history*

Authors & Year	Description	Results	Class	Conclusions
Lees & Turner, 1963	44 CSM patients (age 31–80 yrs) longitudinal FU for min 3 yrs. Categorized into nil, mild, moderate, & severe (similar to Nurick 0, 2, 3, 4–5).	A heterogeneous group was assembled at differing time points w/o objective FU. 2 categories of patients (those w/ CSM <10-yr duration & >10 yrs). Initially, CSM symptoms categorized as nil 0, mild 4, moderate 15, & severe 25. At FU, nil 2, mild 3, moderate 21, severe 18. Age & duration did not appear to be prognostic factors.	III	Natural history of CSM may be prolonged & long periods of nonprogressive disability are often seen.
Clarke & Robinson, 1956	120 CSM patients, mean age 53 yrs (range 35–80 yrs) w/ 26 patients untreated. Diagnosis by myelography or autopsy. Avg disease duration 3 yrs (0.25–15 yrs).	In 75%, the disease process appeared to consist of a series of episodes during which new symptoms & signs appeared. Deterioration in 2/3 between episodes, & no deterioration in 1/3. In 20%, slow, steady progression of symptoms. In 5%, rapid onset of signs & symptoms followed by a long period of plateau. A heterogeneous group was assembled at differing time points w/o objective FU.	III	Untreated CSM has an unpredictable rate of progression.
Roberts, 1966	24 CSM patients (avg 54.2 yrs old) w/ 2-yr duration before Tx. Mean FU 3.1 yrs. Patients treated w/ bedrest, immobilization.	Overall, 7 patients improved, 9 unchanged, & 8 worse. Of those who improved, all improved w/in 5 mos. Poor outcome associated w/ symptom duration >18 mos & severity of presentation. Heterogeneous group that did not exclude prognostic factors. No objective outcome measures.	III	Long duration & severe symptoms predict poor outcome from nonoperative therapy.
Barnes & Saunders, 1984	45 CSM patients (mean 65 yrs old) w/ 8.2-yr FU. Mean time between symptoms & Tx was 1.2 yrs. Nurick scale used for outcome assessment. Group I improved 1 grade, Group II was the same, Group III deteriorated 1 level.	Group I (n = 9), Group II (n = 30), Group III (n = 6). Group III had a higher proportion of patients w/ increased ROM & female sex. Heterogeneous group w/o truly objective outcome measures.	III	Deterioration w/ CSM is associated w/ female sex & increased ROM.
Sadasivan et al., 1993	22 patients (age 50.8 yrs) retrospectively followed. Duration averaged 6.3 yrs between symptoms & diagnosis of CSM.	All patients were Nurick Grade II at initial diagnosis by history. At time of surgical treatment, 1 was Nurick III, 17 Nurick IV, 4 Nurick V. Gait involved in 100%, dexterity in 72%, & weakness in 45%. Nonhomogeneous sample w/o objective FU over variable duration.	III	CSM may progress over yrs w/ profound gait abnormality. Gait eventually involved in 100%.
Ogino et al., 1983	9 patients w/ CSM (age 76.4 yrs) followed from diagnosis to expiration. Postmortem examination.	Duration from symptoms to death was 18.2 yrs. When AP compression ratio 40–44%, flattening of gray matter & mild demyelination; at 22–39%, small cavitation of gray & diffuse demyelination; at 12–19%, extensive gray necrosis & extensive gliosis.	III	Worsening AP canal compression ratio is associated w/ more extensive destruction of gray & white matter. Symptoms may be present for yrs prior to death.
Ono et al., 1977	5 patients w/ CSM (age 74.2 yrs) followed from diagnosis to expiration. Postmortem examination.	Most cases, the AP compression ratio was below normal. Gray matter developed infarction & cavitation while white matter developed extensive demyelination.	III	Chronic CSM is associated w/ neuronal death & demyelination.
Ito et al., 1996	7 CSM patients (67.9 yrs) w/ symptom duration 4.7 yrs. Tissue examined at autopsy.	Over time, marked atrophy & neuronal loss develop in gray matter w/ severe degeneration in lateral funiculus.	III	CSM produces significant degeneration in a pattern similar to transient hypoperfusion.
Kadanka et al., 2005	33 patients w/ CSM (age 54 yrs, duration of symptoms 1 yr, MRI & mJOA >12). Outcome over 36 mos (10-m walk, video ADLs, mJOA). Outcome stratified to nonresponder (NR), responder (R), & very good responder (VGR).	At 6 mos, NR 9, R 24, VGR 6; at 36 mos, NR 8, R 22, VGR 7. R = improved 10-m walk &/or +1 on mJOA, VGR = +2 on mJOA.	I	Over 3-yr period, symptoms of mild-to-moderate CSM may improve in many patients. Improved outcome seemed to be associated w/ older age & an increased Pavlov ratio.

(continued)

TABLE 1: Summary of studies regarding CSM and natural history* *(continued)*

Authors & Year	Description	Results	Class	Conclusions
Kadanka et al., 2002	33 CSM (age <75 yrs, mJOA >12) patients in conservative arm of trial. Avg age 54 yrs w/ 1-yr disease duration. Avg of 2 stenotic levels. Min 3-yr FU. Criteria were mJOA & 10-m walk. Tx was NSAIDs, rest, immobilization.	mJOA improved from 14.6 to 14.7 (CI 14.0–15.3) w/ 10-m walk times improving from 7.4 to 7.5 sec (CI 6.7–8.4).	I	Mild CSM in younger patients does not frequently progress over 3 yrs.
Kadanka et al., 2000	27 patients w/ mild-moderate CSM (age 55.6 yrs, age <75 yrs, mJOA >12) treated conservatively. Outcome over 24 mos (10-m walk, video ADLs, mJOA scale scores).	In conservative group, 10-m walk went from 8.3 to 8.0 sec at 24 mos. JOA score 14.3 at 0 mos & 14.5 at 24 mos.	II	Patients w/ mild-moderate CSM may stabilize over 2-yr period. Representative group but no analysis of prognostic factors to stratify group. The 2-yr FU is short.
Kadanka et al., 2000	27 patients w/ mild-moderate CSM (age 55.6 yrs, age <75 yrs, mJOA >12) treated conservatively. Outcome over 24 mos (10-m walk, video ADLs, mJOA). Also, MEP/SEP completed in 30 patients w/ no symptoms.	ADLs 70.4% unchanged, 18.5% −1, & 11.1% +1. JOA 14.3 at 0 mos to 14.5 at 24 mos. In asymptomatic patients, MEP/SEP abnormal in 15, 5/15 developed CSM while 0/15 patients w/ normal EPs had CSM.	II	MEP/SEP abnormalities correlated w/ development of CSM in asymptomatic patients.
Nakamura et al., 1998	64 CSM patients (52 yrs old) w/ sagittal diameter 13.5 mm & min 12.0 mm. Duration of symptoms 2 yrs. JOA extremity scale used for outcome. FU > 1 yr & averaged 6. Potpourri of therapy (Crutchfield, plaster cast, traction, & brace).	55% improved in UE JOA score & 57% improved in LE JOA. 45% in UE & 39% in LE remained the same. 3% deteriorated in LE. No disability achieved in 27% in UE & 26% in LE. Younger patients achieved no disability more frequently & milder disability was associated w/ a higher rate of no disability. UE: maintenance was 70%, improvement in 27%, & worsening in 3%. LE: 73, 20, & 7, respectively.	III	Nonoperative therapy resulted in improvement to no disability in ~30% w/ maintenance of improvement. Failure of conservative therapy requiring surgery was seen in ~30%.
Matsumoto et al., 2001	27 patients w/ cervical disc displacement & myelopathy (age 44.4 yrs, JOA scale score > 10). Avg JOA was 13.8 (11–16). Tx was cervical collar q8h for 3 mos. Preop symptoms lasted ~4–5 mos. FU was 3.9 yrs.	Out of 27, 10 deteriorated & required surgery, & 17 remained stable. In those who had surgery, JOA was 14.1 initially & deteriorated to 12.9 at 3 mos, & 12.1 at 6 mos. After surgery, it improved to 16.0. In those w/o clinical deterioration, JOA was 13.6 initially & improved to 14.9 at 3 mos, 15.6 at 6 mos, & 16.2 at final FU.	III	Patients w/ CDH may deteriorate w/ conservative Tx. Those who did not clinically worsen fare well over several yrs. Designated Class III because of focus on CDH & loss of cohort to surgery (10 patients).
Bednarik et al., 2004	66 CSM patients (age 50 yrs) w/ MRI spondylotic compression. mJOA scores = 18; FU was 2-yr min (4-yr avg). Studied were EMG (anterior horn cell), SEPs, Pavlov ratio, & clinical exam.	19.7% developed CSM (5%/yr). Radiculopathy present premorbid in 92% w/ CSM & 24% w/o (p <0.0001), SEPs were abnormal in 38.5% w/ CSM & 9.4% w/o (p <0.02); Anterior horn cell EMG abnormal in 61% CSM & 11.3% w/o (p <0.01). No imaging correlates.	I	Development of CSM in a pathological cervical spine occurs in those w/ radiculopathy, abnormal SEP, or anterior horn cell disease on EMG. The rate is 5%/yr.
Matsumoto et al., 2000	52 patients (CSM 29, CDH 12, OPLL 11) w/ myelopathy (age 55 yrs, JOA score >10). Pre-Tx symptoms 7 mos. Tx of cervical immobilization q8h x 3 mos. ISI in 34/52 (focal or multisegmental). Satisfactory (JOA >15 or improved function). FU 3 yrs (range 1–6 yrs).	Focal ISI (JOA 14.0–14.4), multisegmental (JOA 13.8 to 14.0), no ISI (JOA Scores 14.3–14.6); satisfactory 63% (focal ISI), 70% (multisegmental ISI), 78% (no ISI).	III	In conservatively managed patients w/ compressive myelopathy, ISI does not play a role. In mild myelopathy, stability is the norm.

* The criteria for scoring each manuscript into a class are described in *Introduction and Methodology: Guidelines for the Surgical Management of Cervical Degenerative Disease*, which appears in this issue of the *Journal of Neurosurgery: Spine*. Abbreviations: ADL = activity of daily living; CDH = cervical disc herniation; EP = evoked potential; FU = follow-up; mJOA = modified JOA; LE = lower extremity; NSAID = non-steroidal anti-inflammatory; OPLL = ossification of the posterior longitudinal ligament; UE = upper extremity; q8h = 8 hours/day.

intensity was present in 34/52 and was described as focal or multisegmental. A satisfactory outcome was defined as JOA > 15 or improved function. Follow-up averaged 3 years.

In patients with focal ISI, the average JOA scale score improved from 14.0 to 14.4. In patients with multisegmental ISI, JOA scores improved from 13.8 to 14.0. In those with no ISI, the average JOA scale score improved from 14.3 to 14.6. The authors reported satisfactory results in 63% of patients with focal ISI, 70% with multisegmental ISI, and 78% of those without ISI. These authors concluded that ISI does not play a role in outcome in patients with conservatively managed cervical myelopathy.[13] This study was graded Class III because the sample combined similar, but different, pathological entities. In addition, 20% of patients underwent surgery, and it was not clear whether they were included in the outcome analysis. However, the authors conducted follow-up in their patients over a period of time, used objective outcome measures, and also attempted to stratify imaging abnormalities.

Summary

Clinical studies have not been strong in defining the natural history of CSM. There is Class III evidence that the natural history of CSM may be mixed with many patients experiencing a slow, stepwise decline. Long periods of quiescence are not uncommon, however, and a subgroup of patients may improve. There is Class III evidence from 3 pathological studies associating CSM of several years' duration with demyelination of white matter. Severe stenosis may ultimately result in necrosis of both gray and white matter (Class III).

In patients younger than 75 years of age with mild CSM (mJOA scale score > 12), there is Class I evidence that associates nonoperative management with a stable clinical course over a 36-month period. In these patients, Class I evidence indicates that the mJOA scale score, 10-m walk times, and ADL assessments typically do not worsen over this time frame. Class III evidence indicates that clinical gains associated with nonoperative treatment are often maintained over 3 years in 70%.

With regard to predictive factors, Class I evidence demonstrates that EMG abnormalities in the anterior horn cells or the presence of clinical radiculopathy are associated with development of CSM in patients with asymptomatic stenosis. The importance of these findings in an asymptomatic individual is debatable.

A common theme in all studies of natural course was possible selection bias. Many studies analyzed patients with CSM after completion of conservative or surgical treatment. It was not clear which selection criteria were used to determine who should receive conservative therapy. It is very likely that patients with more severe symptoms were excluded from the studies. In most analyses, ~ 20% of patients who initially underwent conservative treatment ultimately received surgery. What is unclear is the number of patients with CSM who were initially stratified to surgical therapy.

Key Issues

It is evident that there is a need for a randomized clinical trial examining patients with mild CSM and comparing operative and nonoperative treatment. There is sufficient evidence indicating that patients with severe symptoms and a long duration of symptoms will generally not improve, and attempts at randomizing these patients to different treatment groups may not be ethically feasible.

References

1. Barnes MP, Saunders M: The effect of cervical mobility on the natural history of cervical spondylotic myelopathy. **J Neurol Neurosurg Psychiatry 47:**17–20, 1984
2. Bednarik J, Kadanka Z, Dusek L, Novotny O, Surelova D, Urbanek I, et al: Presymptomatic spondylotic cervical cord compression. **Spine 29:**2260–2269, 2004
3. Cardarelli R, Oberdorfer JR: Evidence-based medicine, part 5. An introduction to critical appraisal of articles on prognosis. **J Am Osteopath Assoc 107:**315–319, 2007
4. Clarke E, Robinson PK: Cervical myelopathy: a complication of cervical spondylosis. **Brain 79:**483–510, 1956
5. Fujiwara A, Kobayashi N, Saiki K, Kitagawa T, Tamai K, Saotome K: Association of the Japanese Orthopaedic Association score with the Oswestry Disability Index, Roland-Morris Disability Questionnaire, and short-form 36. **Spine 28:** 1601–1607, 2003
6. Ito T, Oyanagi K, Takahashi H, Takahashi HE, Ikuta F: Cervical spondylotic myelopathy. Clinicopathologic study on the progression pattern and thin myelinated fibers of the lesions of seven patients examined during complete autopsy. **Spine 21:**827–833, 1996
7. Kadanka Z, Bednarik J, Vohanka S, Stejskal L, Smrcka V, Vlach O: Spondylotic cervical myelopathy: three aspects of the problem. **Suppl Clin Neurophysiol 53:**409–418, 2000
8. Kadanka Z, Bednarik J, Vohanka S, Vlach O, Stejskal L, Chaloupka R, et al: Conservative treatment versus surgery in spondylotic cervical myelopathy: a prospective randomised study. **Eur Spine J 9:**538–544, 2000
9. Kadanka Z, Mares M, Bednaník J, Smrcka V, Krbec M, Stejskal L, et al: Approaches to spondylotic cervical myelopathy: conservative versus surgical results in a 3-year follow-up study. **Spine 27:**2205–2211, 2002
10. Kadanka Z, Mares M, Bednarík J, Smrcka V, Krbec M, Chaloupka R, et al: Predictive factors for mild forms of spondy-

lotic cervical myelopathy treated conservatively or surgically. **Eur J Neurol 12:**16–24, 2005

11. Lees F, Turner JW: Natural history and prognosis of cervical spondylosis. **BMJ 2:**1607–1610, 1963

12. Matsumoto M, Chiba K, Ishikawa M, Maruiwa H, Fujimura Y, Toyama Y: Relationships between outcomes of conservative treatment and magnetic resonance imaging findings in patients with mild cervical myelopathy caused by soft disc herniations. **Spine 26:**1592–1598, 2001

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 compressive myelopathy. Does it predict the outcome of conservative treatment? **Spine 25:**677–682, 2000

14. Nakamura K, Kurokawa T, Hoshino Y, Saita K, Takeshita K, Kawaguchi H: Conservative treatment for cervical spondylotic myelopathy: achievement and sustainability of a level of "no disability." **J Spinal Disord 11:**175–179, 1998

15. Nurick S: The pathogenesis of the spinal cord disorder associated with cervical spondylosis. **Brain 95:**87–100, 1972

16. Ogino H, Tada K, Okada K, Yonenobu K, Yamamoto T, Ono K, et al: Canal diameter, anteroposterior compression ratio, and spondylotic myelopathy of the cervical spine. **Spine 8:**1–15, 1983

17. Ono K, Ota H, Tada K, Yamamoto T: Cervical myelopathy secondary to multiple spondylotic protrusions. A clinicopathologic study. **Spine 2:**109–125, 1977

18. Roberts AH: Myelopathy due to cervical spondylosis treated by collar immobilization. **Neurology 16:**951–954, 1966

19. Sadasivan KK, Reddy RP, Albright JA: The natural history of cervical spondylotic myelopathy. **Yale J Biol Med 66:**235–242, 1993

20. Singh A, Crockard HA: Comparison of seven different scales used to quantify severity of cervical spondylotic myelopathy and post-operative improvement. **J Outcome Meas 5:**798–818, 2001