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Review Article

Cervical Spondylotic Myelopathy: World Federation of Neurosurgical Societies (WFNS) to the Italian Neurosurgical Society (SINch) Recommendations

Corresponding Author
Carla Daniela Anania
https://orcid.org/0000-0002-5893-2201

Neurosurgical Department, IRCCS Humanitas Research Hospital, Rozzano, Italy
Email: carla.anania@humanitas.it

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Francesco Costa[1], Carla Daniela Anania[2], Umberto Agrillo[3], Assietti Roberto[4], Bernucci Claudio[5], Bistazzoni Simona[6], Bongetta Daniele[4], Brembilla Carlo[5], Cappelletto Barbara[7], Cocciaro Ardico[8], Costella Giovanni Battista[9], De Falco Raffaele[10], De Rosa Andrea[11], Del Vecchio Carlo[12], Dobran Mauro[13], Fiorenza Vito[14], Garbossa Diego[15], Guizzardi Giancarlo[16], Iaccarino Corrado[17], Irace Claudio[18], Incerti Michele[19], Gualtiero Innocenzi[20], Landi Alessandro[21], Lastrucci Giancarlo[22], Maida Giuseppe[23], Mastrantuoni Ciro[10], Maugeri Rosario[24], Meglio Vincenzo[11], Montemurro Nicola[8], Nina Pierpaolo[25], Parlangeli Andrea[19], Pinna Giovanni[26], Pretti Pier Federico[27], Rapanà Armando[28], Ricci Alessandro[29], Rispoli Rossella[7], Romoli Stefano[22], Per Filippo Sbaffi[30], Somma Teresa[11], Tessitore Enrico[31], Vitali Matteo[32], Alberto Zerbi[33], Zona Gianluigi[34,35], Andrea Barbanera[32]; and the SINch Spine Section Group

[1]Spine Surgery Unit, Department of Neurosurgery, Fondazione IRCCS Istituto Nazionale Neurologico C. Besta, Milan, Italy
[2]Neurosurgical Department, IRCCS Humanitas Research Hospital, Rozzano, Italy
[3]Clinica Quisisana, Roma, Italy
[4]Unit of Neurosurgery, Azienda Socio Sanitaria Territoriale Fatebenefratelli Sacco, Fatebenefratelli Hospital, Milan, Italy
[5]Department of Neurosurgery, ASST Papa Giovanni XXIII Hospital, Bergamo, Italy
[6]Department of Neurosurgery, Sant'Anna Hospital, Como, Italy
[7]Section of Spine and Spinal Cord Surgery, Department of Neurological Sciences, ASUFC University Hospital of Udine, Udine, Italy
[8]Department of Neurosurgery, Azienda Ospedaliera Universitaria Pisana (AUOP), University of Pisa, Pisa, Italy
[9]Unit of Neurosurgery, SS. Annunziata Hospital, Taranto, Italy
[10]Department of Neurosurgery, P.O. Santa Maria delle Grazie, Pozzuoli (NA), Italy
[11]Division of Neurosurgery, Department of Neurosciences, Reproductive and Odontostomatological Sciences, Università degli Studi di Napoli Federico II, Naples, Italy
[12]Neurosurgery Unit University Hospital of Bari, Bari, Italy
[13]Department of Neurosurgery, Università Politecnica delle Marche, Azienda Ospedali Riuniti, Ancona, Italy
[14]Department of Neurosurgery, A.R.N.A.S. "Civico Di Cristina Benfratelli" Hospital, Palermo, Italy
[15]Department of Neuroscience "Rita Levi Montalcini", Neurosurgery Unit, University of Turin, Turin, Italy
[16]Division of Neurosurgery, Department of Biomedical, Metabolic and Neural Sciences, University of Modena and Reggio Emilia, Modena University Hospital, Modena, Italy
[17]Neurosurgical Unit, Careggi University Hospital Florence, Italy
[18]Department of Neurosurgery, Hospital Igea, Milan, Italy
[19]Neurosurgery Unit Policlinico di Monza, Monza, Italy
[20]UOS Spinal Neurosurgery, San Carlo di Nancy Hospital, Rome, Italy
[21]Neurosurgical Department, IRCCS Neuromed, Pozzilli, Italy
[22]Unit of Spine Surgery, Careggi University Hospital, Florence, Italy
[23]Department of Spine Surgery, Multidisciplinary Spine Center, Santa Maria Maddalena Hospital, Occhiobello (RO), Italy
[24]Department of Experimental Biomedicine and Clinical Neurosciences, School of Medicine, Unit of Neurosurgery, AOUP "Paolo Giaccone", Palermo, Italy
[25]Neurosurgical Unit of San Giovanni Bosco Hospital, Naples, Italy
[26]Neurosurgical Unit, ARNAS G. Brotzu, Cagliari, Italy
[27]Ospedale San Giovanni Bosco, Torino, Italy
[28]Neurosurgery Unit, Lorenzo Bonomo Hospital, Andria, Italy
[29]Unit of Neurosurgery, Ospedale Civile San Salvatore, L'Aquila, Italy
[30]Humanitas Gradenigo, Torino, Italy
[31]Neurosurgical Unit, Faculty of Medicine, Geneva University Hospitals, Geneva, Switzerland
[32]Department of Neurosurgery, SS Antonio e Biagio e Cesare Arrigo Alessandria Hospital, Alessandria, Italy
[33]Fondazione Iseni Y Nervi, Istituti Clinici Iseni, Lonate Pozzolo, Italy
[34]Department of Neuroscience, Rehabilitation, Ophthalmology, Genetics and Maternal and Child Health (DINOGMI), University of Genoa, Genoa, Italy
[35]Department of Neurosurgery, IRCCS San Martino University Hospital, Genoa, Italy

Cervical spondylotic myelopathy (CSM) is a progressively growing pathology to afford by a spinal surgeon due to the aging of the population, associated with better treatment management and the best diagnosis and treatment solutions are greatly discussed. Nowadays that scientific literature is progressively increasing to identify the gold standard in diagnosis and treatment can be very challenging. This is particularly evident in spinal surgery with many different indications not only in different countries but also in the same local reality. In this scenario, many neurosurgical societies works to identify some guideline or recommendations to help spinal surgeons in daily practice. Furthermore, in an era in which legal issues are increasingly present in clinical practice to have some indications globally accepted can be very useful. World Federation of Neurosurgical Societies (WFNS) few years ago starts this process creating a list of recommendations originating from a worldwide steering committee to respect all the local reality. The spinal section of Italian Neurosurgical Society decides to adopt the WFNS recommendations with some revision basing on Italian scenario. The steering committee of the Spinal Section of Italian Neurosurgical Society identify 7 groups to review the literature of the last 10 years about different topics on CSM and to analyses the WFNS recommendations to adapt it to the Italian daily practice. The statements were discussed and voted in 2 sessions to obtain the final version. A list of recommendations on natural course and clinical presentation; diagnostic tests; conservative and surgical treatment; anterior, posterior and combined surgical treatment; role of neurophysiological monitoring and follow-up and outcome was created with only few new or revised statements respect the ones of WFNS. The Spine Section of Italian Neurosurgical Society create a list of recommendations that represent the more contemporary treatment concepts for CSM as presented in the highest quality clinical literature and best clinical practices available on this subject.

Keywords: Cervical spondylotic myelopathy, Recommendations, Guidelines, Evidence-based medicine

INTRODUCTION

Cervical spondylotic myelopathy (CSM) is a degenerative pathology, known to be the most common cause of spinal cord dysfunction. Due to an aging population and superior treatment management for elderly patients, both neurosurgeons and orthopedic surgeons have to manage this pathology more frequently. However, guidelines are advocated to better define clinical management due to the potentially high social impact of this condition, regarding daily activity as well as a medical-legal standpoint. The World Federation of Neurosurgical Societies (WFNS) start few years ago the definition of recommendations on different topics of spine surgery with the aim of standardize daily clinical practice. These recommendations are intended to reflect contemporary treatment concepts for CSM as presented in the highest quality clinical literature and best clinical practices available on this subject.

Aim of WFNS is to provide practical indication for the management of spine pathologies that can be applied by the different Neurosurgical Societies worldwide, including also middle and low-income countries. However, this process may not reflect exactly the standard of care of the different countries. For this reason, with the aim of standardizing the diagnosis and treatment of the spine pathologies as done before in the case of lumbar stenosis[1] (LS) as much as possible, the spinal section of the Italian Society of Neurosurgeon (SINch) analyzed and proposed their own recommendations for the management of CSM in accordance with the recommendations published by the spine committee of the WFNS.[2-7] In this paper, we present the standardized protocol of revision, the methodology and as well the results.

MATERIALS AND METHODS

Following the criteria and methodology adopted the by the spinal section for the recommendations of degenerative lumbar spine stenosis 1 the results of the WFNS consensus conference, were carefully and critically analyzed. All the statements of the WFNS were presented to the Spinal Section of the SINch. The literature review was presented by each group to all the members of the Spine Section and all the WFNS recommendations were voted for consensus with Delphy Method. After the first voting session, some recommendations were proposed for revision and each group proposed some new statements; after the

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Steering Committee validation all the revised and new statements were voted again. This process had the purpose to critically review the best literature indication on the topic according to the personal experience and the local daily practice specific for our country.

In detail, the committee of the Spine Section of the SINch was divided into 7 groups to perform this critical revision, and each group revisited a specific topic of the recommendation of CSM: (1) natural course and clinical presentation, (2) diagnostic tests, (3) conservative treatment versus surgical treatment, (4) anterior surgical treatment, (5) posterior and combined surgical treatment, (6) role of neurophysiological monitoring; (7) follow-up and outcome.

Each group was composed by at least 4–5 active members of the Spinal Section of the SINch and comprise 1 senior surgeon (>60 years-old), 2 experienced (>40, <60 years-old), and at least 1 young (<40 years-old).

A literature review was conducted using the Cochrane Database of systematic reviews and MEDLINE/PubMed, including papers from a 10-year span (2011–2021). A secondary search of the listed citations was performed on the identified articles, to ensure that all relevant publications were included.

The literature review and the analysis of the WFNS recommendations were discussed during regular Zoom meetings, while the final results were presented and voted (via an electronic survey among only the members of the spinal section of the SINch) during the Spine Section Congress of SINch (Mestre -September 17–18, 2021) (Fig. 1).

The Delphi method was applied to administer a questionnaire and obtain a consensus on the topics. To establish a consensus, the levels of agreement or disagreement for each item were voted independently in a blind-manner using a Likert-type scale from 1 to 5 (1, strongly disagree; 2, disagree; 3, somewhat agree; 4, agree; 5, strongly agree). Results were expressed as a percentage of respondents who scored each item as 1 or 2 (disagreement) or as 3, 4, or 5 (agreement). Consensus was achieved when the sum for disagreement or agreement was ≥66%. Each consensus point was clearly defined with evidence strength, recommendation grade, and consensus level provided.

To obtain the final version of the Italian Recommendations on CSM each group proposed a list of statements, the modified or the new ones were drafted by all the group and the senior member provide the final version to propose to the Steering Committee first (for revision) and finally to all the members (for the vote). We explain in detail in the authors contributions who provide the drafted version of statement and the final one (all the members write the original draft of the statements and the discussion of the literature review; the senior members write the final version of the statements). Furthermore, the authors provided the draft, the correction and the final version of the papers.

RESULTS

Following the literature review performed by each study group, the Spinal Section accepted 62 of the 68 recommendations (89.4%) proposed by the WFNS, while 6 statements were suggested for revision. Moreover, based on national clinical practice, the committee considered further indications appropriate and accordingly proposed 13 new statements. This led to a total of 19 statements (6 revisions and 13 new) being proposed for a vote and added to the recommendations. The results are presented in specifics for each group.

1. Group 1: Natural Course and Clinical Presentation

All the 8 statements of the WFNS were accepted without revision (Table 1) and 2 new statements were proposed to be added. The statement proposed for the vote and consequent re-

Fig. 1. Spine Section Congress of SINch (Mestre - September 17-18, 2021) organized by Franco Guida. SINch, Italian Neurosurgical Society.

Table 1. Recommendations for natural course and clinical presentation of cervical spondylotic myelopathy (CSM)

Recommendations for natural course and clinical presentation of CSM	WFNS	SINch
Myelopathic signs (hyperreflexia, inverted brachioradialis reflex, Hoffmann sign, Babinski and clonus) are an integral component of clinical diagnosis of cervical myelopathy. However, they are not very sensitive and may be absent in about 20% of myelopathic patients.	√	
Individual myelopathic signs taken alone cannot diagnose cervical myelopathy in all patients but at least one is present in severe myelopathy.	√	
Clinical diagnosis of CSM relies heavily on characteristic symptoms and signs elicited during history and physical exam which prompt further investigation with cervical spine imaging.	√	
In severe myelopathic patients, after laminoplasty, major recovery in myelopathic signs occurs during the first 6 months and there after it plateaus.	√	
In patients with myelopathic signs, if there are no alternative explanations, a combination of clinical symptoms and imaging studies must form the basis of our treatment decisions. The absence of myelopathic signs does not preclude the diagnosis of CSM nor its successful surgical treatment.	√	
Natural course of patients with cervical stenosis and signs of myelopathy greatly varies.	√	
Progression of the disease is possible, but prediction of those patients is not well known. Some patients may remain static for lengthy periods, and some patients with severe disability can improve without treatment.	√	
For patients with no symptoms but having significant stenosis (premyelopathic), risk of developing myelopathy with cervical stenosis is approximately 3% per year.	√	
Patients should be warned about the increased susceptibility to acute spinal cord injury and that they should avoid hazardous activities and environments.		New
Patients without clear sign of myelopathy but clinical and/or electrophysiological evidence of cervical radicular dysfunction should be counselled on the risk of developing myelopathy.		New

WFNS, World Federation of Neurosurgical Societies; SINch, Italian Neurosurgical Society.

sults are:

(1) Patients should be warned about the increased susceptibility to acute spinal cord injury and that they should avoid hazardous activities and environments. This statement reached a strong positive consensus with total of 96.1% of positive votes (the detail of the vote was: 1.32% grade 1 of Linkert scale, 2.63% grade 2, 25% grade 3, 18.42% grade 4, and 52.63% grade 5).

(2) Patients without clear sign of myelopathy but clinical and/or electrophysiological evidence of cervical radicular dysfunction should be counselled on the risk of developing myelopathy. This statement reached a strong positive vote with an agreement of 86.4% (2.67% grade 1, 10.67% grade 2, 33.33% grade 3, 20% grade 4, 33.33% grade 5).

2. Group 2: Diagnostic Tests

Twelve statements of the WFNS were accepted without revision and one was suggested for revision (Table 2), with one new statement proposed to be added. The statements suggested for the vote and consequent results are:

(3) Electrophysiological tests may have better outcome predictions than magnetic resonance (MR) changes. To date, one of the most important roles of neurophysiological assessment is to monitor the progression of cervical myelopathy, which can add to the surgical decision-making. This statement reached a strong positive consensus with an agreement of 84.0% (2.67% grade 1, 13.33% grade 2, 37.33% grade 3, 18.67% grade 4, 28% grade 5).

(4) Preoperative somatosensory evoked potential/motor evoked potential (SEP/MEP) may be useful to better analyze radiological CSM associated with normal/subclinical signs of myelopathy and can be added to the surgical decision-making tool. This statement reached a strong positive consensus with a total of 93,3% of positive votes (none voted grade 1, 6.67% grade 2, 29.33% grade 3, 24% grade 4, 40% grade 5).

3. Group 3: Conservative Treatment Versus Surgical Treatment

Nine statements were accepted without revision while one was suggested for revision (Table 3) and 3 new statements were proposed. The statements suggested for the vote and consequent results are:

(5) When counselling patients with mild CSM, quality of life (QoL) assessment should be part of the examination and physical function in day-to-day activities as social functioning should be carefully investigated while taking in consideration the patient's reported performance status. This statement reached a

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Table 2. Recommendations for diagnostic tests for cervical spondylotic myelopathy (CSM)

Recommendations for diagnostic tests	WFNS	SINch
Value of electrophysiology		
Electrophysiological tests to be used in CSM patients are (in order of benefits): motor evoked potential (MEP), spinal cord evoked potential, somatosensory evoked potential (SEP), and electromyography.	√	
Routine electrophysiological tests are useful in differential diagnosis of CSM from other neurological conditions. However, especially during the early course of the disease differential diagnosis is very difficult, specific tests are necessary and mild forms of amiotrofic lateral sclerosis and polyneuropathy may not be differentiated easily.	√	
Although MEP and SEP have been found as valuable tests to predict outcomes of CSM surgery, there is no evidence that they are more valuable than clinical parameters.	√	
Electrophysiological tests may have better outcome predictions than magnetic resonance (MR) changes. To date, one of the most important roles of neurophysiological assessment is to monitor the progression of cervical myelopathy, which can add to the surgical decision-making.	×	Rev
Preoperative SEP/MEP may be useful to better analyze radiological CSM associated with normal/subclinical signs of myelopathy and can be added to the surgical decision-making tool.		New
Recommendations for value of canal diameters in CT and MRI		
In spite of conflicting evidence, MRI morphometric analysis of the spine has a significant role in evaluation and prognostication of CSM and it should be included in the preoperative workup.	√	
Among the many variables assessed using MRI – compression ratio, maximum canal compromise and transverse area are most importantly correlated with functional outcomes following surgery in patients with CSM. Each parameter has its own strength and limitation, therefore a combined assessment of MR parameters has a greater predictive yield.	√	
Intense spinal cord T2 hyperintensity on cervical MRI may be correlated with a worse outcome in CSM.	√	
Patients with lighter signal changes in T2 on cervical MRI should not be excluded from surgical treatment of CSM.	√	
More studies are needed to validate proposed grading systems, or to create new ones.	√	
T1 hyposignal should be considered as a sign of more advanced disease, with worse outcome.	√	
More studies are needed to assess the effect of sagittal and axial extension of T1 signal changes on outcome.	√	
Recommendations for new imaging techniques for CSM		
Diffusion MRI, MR spectroscopy and dynamic MRI may be a part of MR examinations for CSM protocol apart from conventional MRI. We suggest their usage for outcome studies. With data pooling of clinical and imaging findings, we will be able to prognosticate better and identify patients earlier before the changes and permanent damage sets in.	√	

WFNS, World Federation of Neurosurgical Societies; SINch, Italian Neurosurgical Society; CT, computed tomography; MRI, magnetic resonance imaging.

strong positive consensus with 92% of agreement (1.33% grade 1, 6.67% grade 2, 34.67% grade 3, 32% grade 4, 25.33% grade 5).

(6) We suggest to propose surgical intervention to patients with substantial reduction of QoL and greater neck pain and motor impairment at presentation or serious SEP abnormality. This statement reached a strong positive consensus with an agreement of 98.7% (none voted grade 1, 1.33% grade 2, 24% grade 3, 20% grade 4, 54.67% grade 5).

(7) A supervised trial of structured rehabilitation should be offered to patients with mild CSM with better QoL and less physical/mental dysfunction. This statement reached a positive consensus with 88.9% (1.39% grade 1, 9.72% grade 2, 41.67% grade 3, 23.61% grade 4, 23.61% grade 5).

(8) If initial nonoperative management is pursued, we recommend operative intervention if there is neurological deterioration or appearance of SEP abnormality and suggest operative intervention if the patient fails to improve. This statement reached a strong positive consensus with 100% of positive votes (none voted grade 1 or 2, 24.32% voted grade 3, 20.27% grade 4, 55.41% grade 5).

4. Group 4: Anterior Surgical Treatment

All 9 statements were accepted without revision, none was suggested for revision (Table 4) and no new statements were proposed.

5. Group 5: Posterior and Combined Surgical Treatment

All the 10 statements were accepted without revision (Table

Table 3. Recommendations for value of surgical and nonsurgical treatment for cervical spondylotic myelopathy (CSM)

Recommendations for value of surgical and nonsurgical treatment for CSM	WFNS	SINch
For patients with moderate and severe CSM surgical intervention is recommended. We recommend using modified Japanese Orthopedic Association scale or its regional modifications to classify CSM as severe, moderate or mild.	√	
When counselling patients with mild CSM, QoL assessment should be part of the examination and physical function in day-to-day activities as social functioning should be carefully investigated while taking in consideration the patient's reported performance status.		New
We suggest offering surgical intervention to patients with substantial reduction of QoL and greater neck pain and motors impairment at presentation or serious SEP abnormality.	×	Rev
Nonmyelopathic patients with radiologic evidence of cord compression but without signs and symptoms of radiculopathy should not be offered a prophylactic surgery. These patients should be counselled about the potential risk of worsening, educated about the signs and symptoms of progression and followed up clinically regularly. An informed consent should be obtained about neurological deficits that may follow trivial injury. More studies are needed to validate proposed grading systems, or to create new ones	√	
Nonmyelopathic patients with radiologic evidence of cord compression and with clinical evidence of radiculopathy are potential candidates who may deteriorate thus carrying high risk and hence need to be counselled about it. These patients are recommended to undergo surgery or close observation with rehabilitation if the patient refuse to undergo surgery. In the event of developing myelopathic signs they are advised to go for surgery at the earliest. An informed consent should be obtained about neurological deficits that may follow trivial injury.	√	
There is a consistent lack of evidence regarding the value of nonoperative treatment of cervical myelopathy in the literature. Hence nonoperative treatment may not be the final decision in most cases.	√	
A supervised trial of structured rehabilitation should be offered to patients with mild CSM with better QoL and less physical/mental disfunction.		New
If initial nonoperative management is pursued, we recommend operative intervention if there is neurological deterioration or appearance of SEP abnormality and suggest operative intervention if the patient fails to improve.		New
Predicting factors that indicate a possible deterioration during nonoperative management are: circumferential cord compression in axial MRI, reduced diameter of CSF space, hypermobility of spinal segment, angular edged deformity, instability, greater angle of vertebral slip, lower segmental lordotic angle, and presence of OPLL.	√	
Important predictors of myelopathy development include the presence of symptomatic radiculopathy, prolonged MEPs and SEPs and electromyography signs of anterior horn cell lesions (low evidence).	√	
Duration of symptoms has a greater impact on outcomes. Substantial delay in surgical management leads to suboptimal outcome. In other words, patients are likely to achieve a better result after surgery if they have a shorter duration of symptoms (low evidence).	√	
As there is still clinical equipoise between surgery and conservative treatment in mild CSM, the WFNS Spine Committee strongly encourages randomized controlled trials comparing surgical versus nonsurgical interventions in mild CSM. There is also a need to analyze the cost effectiveness, standardized methodology and costs of long-term follow-up in mild CSM.	√	
In patients with CSM, the indications for surgery include persistent or recurrent radiculopathy nonresponsive to conservative treatment (3 years); progressive neurological deficit; static neurological deficit with severe radicular pain when associated with confirmatory imaging (CT, MRI) and clinical-radiological correlation.	√	
The indications of anterior surgery for patients with CSM include straightened spine or kyphotic spine with a compression level below three.	√	

WFNS, World Federation of Neurosurgical Societies; SINch, Italian Neurosurgical Society; QoL, quality of life; SEP, somatosensory evoked potential; MRI, magnetic resonance imaging; CSF, cerebral spinal fluid; OPLL, ossification of the posterior longitudinal ligament; MEP, motor evoked potential; CT, computed tomography.

5) and 2 new statements were proposed. The statements suggested for the vote and consequent results are:

(9) Stand-alone laminectomy, in absence of superiority/inferiority study respect to the different posterior techniques, may be considered a valuable surgical option. This statement reached a positive consensus with an agreement of 79.5% (more than 40% voted grade 3 of Linkert Scale).

(10) Stand-alone laminectomy is advisable in cases with preserved cervical lordosis and in patients with low risk to develop late instability. This statement reached a positive consensus with 84.61% of positive votes (5.13% voted grade 1, 15.38% voted grade 2, 41.03% grade 3, 17.96% grade 4, 20.51% grade 5).

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Table 4. Recommendations for anterior surgical approach for cervical spondylotic myelopathy (CSM)

	WFNS	SINch
Recommendations for anterior surgical approach		
There are many options for anterior decompression such as anterior cervical discectomy and fusion (ACDF), anterior cervical corpectomy and fusion (ACCF), oblique corpectomy, skip corpectomy and hybrid surgery.	√	
A corpectomy is a good option for a ventral compression of less than 3 vertebral segments where a single level disc and osteophyte excision are inadequate to decompress the cord in patients with CSM. In cases with a kyphotic deformity of the cervical spine, corpectomy can restore the normal lordotic curvature alignment.	√	
In cases of a multisegment disease with contiguous multisegment compression, alternate segment discectomy/osteophyte removal while keeping the body of the intervening vertebra intact is biomechanically more stable than a complete corpectomy with contiguous segment discectomy.	√	
An oblique partial corpectomy can improve the sagittal canal diameter substantially. However, this procedure may be difficult to perform in cases with bilateral radiculopathy. If there is significant instability, oblique corpectomy should not be chosen.	√	
The incidence of the Horner syndrome due to unilateral disruption of the sympathetic chain has been decreased to less than 5% by some modifications in surgical technique.	√	
In the elderly age groups with bony ankylosis due to osteophytes at C5-6-7, CSM may manifest at higher levels where motion segments are preserved, especially the C3-4 level and also at lower levels such as the C7-T1 level.	√	
Improvement after anterior surgery for CSM has been reported in 70% to 80% of patients. Japanese Orthopedic Association recovery rates are around 60% to 70%.	√	
There is no significant difference of success rates with ACDF, ACCF, and oblique corpectomy.	√	
Reported complications resulting from anterior surgeries for CSM are quite variable.		
Approach-related complications (dysphagia, dysphonia, esophageal injury, respiratory distress etc.) are more often than neurologic, and implant-related complications. With appropriate choice of implants and meticulous surgical technique, the surgical complications should be seen only rarely.	√	
Selection of surgical approach		
There are several factors that should be considered for selection of surgical approach in patients with CSM: sagittal curvature, locations of the compressive pathology, number of levels involved, and patient comorbidities.	√	

WFNS, World Federation of Neurosurgical Societies; SINch, Italian Neurosurgical Society.

6. Group 6: Role of Neurophysiological Monitoring

One out of 3 statements was accepted without revision with 2 being modified (Table 6), 4 new statements were proposed. The statements suggested for the vote and consequent results are:

(11) The value of monitoring during anterior cervical discectomy and fusion surgery is questionable due to high rate of false positive. This statement reached a positive consensus with 79.5% of positive votes (4.11% grade 1, 16.44% grade 2, 38.36% grade 3, 15.07% grade 4, 26% grade 5).

(12) It is preferable to use both intraoperative MEP/SEP during posterior approaches for CSM surgery, as they may be useful to change some surgical choices. This statement reached a positive consensus, although with a percentage of 67.13%, at the limit with nonconsensus (4.11% grade 1, 28.77% grade 2, 38.36% grade 3, 12.33% grade 4, 16.44% grade 5).

(13) Intraoperative MEP/SEP worsening is specific, but it does not show clinical worsening in every incidence. This statement reached a strong positive consensus with 93.25% of positive votes (none voted grade 1, 6.76% grade 2, 45.95% grade 3, 20.27% grade 4, 27.03% grade 5).

(14) Preoperative MEP have a significant and linear correlation with clinical presentation (modified Japanese Orthopedic Association scale, mJOA) and are particular helpful for early diagnosis in "silent" or subclinical CSM form. This statement reached a positive consensus with an agreement of 82.1% (2.56% grade 1, 15.39% grade 2, 43.59% grade 3, 17.96% grade 4, 20.51% grade 5).

(15) Preoperative SEP seems useful to predict development of CSM in case of cervical stenosis, and has a good correlation with the prognosis of the disease. This statement reached a positive consensus with an agreement of 71.8% (5.13% grade 1, 23.08% grade 2, 38.46% grade 3, 10.26% grade 4, 23.08% grade 5).

(16) MEP/SEP may be performed at 6 months follow-up after surgery in case of absence of clinical changes or in persistent compression at magnetic resonance imaging (MRI). This statement reached a positive consensus with 71.8% of positive votes

Table 5. Recommendations for posterior and combined surgical approached

	WFNS	SINch
Recommendations for posterior and combined surgical approached		
Posterior surgical decompression is an effective technique in improving the neurological function of patients with CSM.	√	
Posterior surgical techniques for CSM consist of laminectomy alone, laminectomy with fusion, and laminoplasty. These techniques are often used if there are 3 or more levels anterior compressions. But, in cases with significant posterior compression at 1 or 2 levels, posterior decompressive surgeries are mandatory.	√	
The relative merit of different posterior decompression techniques has not been well determined. In kyphotic cases, especially if it is a flexible kyphosis, laminectomy and posterior fixation with fusion should be chosen. However, in rigid kyphosis, an anterior surgery combined with a posterior decompression should be preferred. In cases with preserved lordosis, laminoplasty is a good option. Cases with severe axial neck pain should not be a candidate for laminoplasty. However, there are always gray zone cases such as straightened cervical spine that we do not know for sure which approach is better.	√	
Combined approach should be chosen in patients with significant ventral and dorsal osteophytic compression which cannot be handled holistically with a single anterior or posterior surgery.	√	
Multiple factors must be taken into account when deciding on the appropriate operation for a particular patient. Surgeons need to tailor their preoperative discussion to alert patients about these facts.	√	
Complications resulting from posterior surgeries for CSM include injury to spinal cord and nerve roots, implant-related complications, C5 palsy, spring-back closure of lamina after laminoplasty, post-laminectomy kyphosis.	√	
In comparing laminectomy to laminoplasty, there is a trend towards laminoplasty being better than traditional laminectomy but relatively equivalent to newer techniques of minimally invasive skip laminectomies.	√	
Future directions about surgical approaches		
Current knowledge is deficient, especially considering the cost to benefit analysis of various surgical approaches, comparative efficacy of surgical approaches using various techniques, and long-term follow-up to determine outcomes. Therefore, continued research into outcomes of cervical spine surgery is essential.	√	
Since randomized controlled studies are very difficult to conduct in spine surgery, prospective registries with long-term follow-up will be important for our future decisions.	√	
Stand-alone laminectomy, in absence of superiority/inferiority study respect the different posterior techniques, may be considered a valuable surgical option.		New
Stand-alone laminectomy is advisable in cases with preserved cervical lordosis and in patients with low risk to develop late instability.		New

WFNS, World Federation of Neurosurgical Societies; SINch, Italian Neurosurgical Society; CSM, cervical spondylotic myelopathy.

Table 6. Recommendations for value of electrophysiology for cervical spondylotic myelopathy (CSM)

Recommendations for value of electrophysiology during surgery	WFNS	SINch
The value of monitoring during ACDF surgery is questionable due to high rate of false positive.	×	Rev
EMG and MEP monitoring have been found to be useful to decrease C5 root palsy during CSM surgery.	√	
Intraoperative MEP/SEP worsening is specific, but it does not show clinical worsening in every incidence.	×	Rev
Is preferable to use both intraoperative MEP/SEP during posterior approaches for CSM surgery, as they may be useful to change some surgical choice.		New
Preoperative MEP have a significant and linear correlation with clinical presentation (mJOA) and are particular helpful for early diagnosis in "silent" or subclinical CSM form.		New
Preoperative SEP seems useful to predict development of CSM in case of cervical stenosis, and have a good correlation with the prognosis of the disease.		New
MEP/SEP may be performed at 6 months follow-up after surgery in case of absence of clinical changes or in persistent compression at MRI.		New

WFNS, World Federation of Neurosurgical Societies; SINch, Italian Neurosurgical Society; ACDF, anterior cervical discectomy and fusion; EMG, electromyography; MEP, motor evoked potential; SEP, somatosensory evoked potential; mJOA, modified Japanese Orthopedic Association; MRI, magnetic resonance imaging.

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Table 7. Recommendations for follow-up and outcome for cervical spondylotic myelopathy (CSM)

Recommendations for follow-up and outcome for CSM	WFNS	SINch
Outcome measures		
There is a variety of outcome measures used for CSM. As functional measures we recommend modified Japanese Orthopedic Association scale (mJOA), Nurick grade and myelopathy disability index.	√	
Walking tests can be used for quantitative measurements although is not a standardize tool. 36-item Short Form health survey is a good functional quality life measure.	×	Rev
Clinical variables affecting outcome		
Three clinical variables that are most commonly related with CSM are age, duration of symptoms and severity of the myelopathy at presentation. Greater the age, the longer the duration of symptoms and the more severe symptoms at presentation, the more adverse outcomes can be expected after surgery.	√	
However, examination findings require more detailed study to validate their effect on the outcomes of surgery. The predictive variables which were studied and seemed to affect the outcomes in CSM are hand atrophy, leg spasticity, clonus and Babinski sign.	√	
Radiological variables affecting outcome		
Cervical alignment parameters are correlated with general health scores and myelopathy severity. The curvature of the cervical spine seems as one of the most important variables.	×	Rev
Cervical spine kyphosis predicts worse outcomes. Neurological improvement is significant in patients with normal cervical lordosis.	√	
Instability of the cervical spine is predictive for outcomes. In patients with single segmental CSM with instability, longer duration of symptoms, lower preoperative JOA score, and more preoperative physical signs are highly predictive of a poor surgical outcome.	√	
Spinal cord compression ratio is a critical factor for prognosis of CSM. However, anteroposterior diameter of the spinal canal has no clinical significance.	√	
Spinal cord atrophy cannot predict outcomes.	√	
High signal intensity on T2-weighted magnetic resonance (MR) images is a negative predictor for prognosis.	√	
Surgical variables affecting outcomes		
Surgery should be done from anterior or posterior if the disease is focal (1 or 2 levels).	√	
If the anterior compression is more than 2 levels or if it is a diffuse narrowing, posterior decompression should better be chosen.	√	
The most important factor on decision-making in cases with multilevel (more than 2) CSM is cervical sagittal vertical axis.	√	
Diffusion tensor imaging sequences on MR images have good capacity to predict outcome in CSM.		New

WFNS, World Federation of Neurosurgical Societies; SINch, Italian Neurosurgical Society.

(10.26% grade 1, 17.95% grade 2. 38.46% grade 3, 17.95% grade 4, 15.38% grade 5).

7. Group 7: Follow-up and Outcome

Eleven statements were accepted without revision, 2 were suggested for revision (Table 7) and 1 new statement was proposed. The statements suggested for the vote and consequent results are:

(17) Walking tests can be used for quantitative measurements although are not a standardize tool. 36-Item Short Form Survey (SF-36) is a good functional quality life measure. This statement reached a positive consensus with an agreement of 86.5% (none voted grade 1, 13.51% grade 2, 50% grade 3, 24.32% grade 4, 12.16% grade 5).

(18) Cervical alignment parameters are correlated with general health scores and myelopathy severity. The curvature of the cervical spine seems one of the most important variables. This statement reached a positive consensus with 79.7% of positive votes (2.7% grade 1, 17.57% grade 2, 48.66% grade 3, 13.51% grade 4, 17.57% grade 5).

(19) Diffusion tensor imaging (DTI) sequences on MR images have good capacity to predict outcome in CSM. This statement reached a positive consensus with an agreement of 80.8% 1.37% grade 1, 17.81% grade 2, 45.21% grade 3, 17.81% grade 4, 17.81% grade 5).

DISCUSSION

Although the recommendations of WFNS are useful and provide well balanced indications for the management of spine pathologies in some points may not reflect the current national necessity.

Following we disc use critically the single revision works of each group.

1. Group 1: Natural Course and Clinical Presentation

The literature prior to 2019 seems to be consistent with the statements regarding the natural history of CSM and there are no relevant articles after that year.

However, little is known about the spontaneous course and prognosis of clinically "silent" presymptomatic spondylotic cervical cord compression. In this scenario, patients should be counselled on the risk of developing myelopathy and the option of surgery; if nonoperative management is chosen, frequent reassessment is warranted.[8,9]

Similar considerations are advised in the clinical guidelines for the management of CSM proposed by Badhiwala et al.[10] Also in the Italian reality the warning for future neurological deficits development is considered important in relationship to the good QoL and life expectancy and may be considered as part of a preventive attitude of our Health Care System.

2. Group 2: Diagnostic Tests

The analysis of the literature did not result in substantial innovations with respect to almost all the statements of this section except for one. The statement "Electrophysiological tests may have better outcome predictions than MR changes." appears limited in this form.

In our country the use of electrophysiology in all the phases of study for this pathology (preop-, intraop-, and postoperation) is important. On one side for its predictive value, especially in preoperative evaluation for subclinical myelopathy presence/evolution, and on the other hands as prediction of postoperative outcome.

In particular preoperative SEP/MEP may be useful to better analyze radiological CSM associated with normal/subclinical signs of myelopathy and can be added to the surgical decision-making tools. In fact, electromyography, sensory-evoked potential abnormalities and clinical radiculopathy, when present in patients with subclinical cord compression, predicted the development of CSM.[11] Patients with significant cervical cord compression on MRI, but having presymptomatic spondylotic cervical stenosis (i.e., with no clinical myelopathy signs), risk of early progression into symptomatic CMS (< 1 year) was predicted by the presence of symptomatic radiculopathy and abnormal SEPs and MEPs.[11,12]

3. Group 3: Conservative Treatment Versus Surgical Treatment

The analysis of the literature, especially after 2019 did not bring substantial innovations with respect to all of the statements in this section, except for one.

The statement "We suggest offering surgical intervention or rehabilitation for patients with mild CSM (mJOA score 15–17). If at the beginning nonoperative management was followed, we recommend operative intervention when rapid progression of symptoms appear. Nonoperative management may be considered for slowly progressive disease" required revision. In fact, in 2018, shortly before the publication of the WFNS guidelines, Koyanagi[13] defined "mild myelopathy" with a score of 11 or greater on the neurosurgical cervical spine scale and did not use mJOA. In their series of 84 surgically treated patients, 9 met these criteria and the indication for surgical treatment depended on various factors; in fact, they concluded by stating that patients with mild myelopathy often show preserved QoL. Similar considerations appeared in a work published in 2020[14]: the authors stated that mild CSM represents a heterogeneous population with some patients who would benefit from surgical intervention.

Furthermore, in the same year, a Canadian group published a work,[15] in which they analyzed the characteristics and the clinical outcome in 122 patients with mild myelopathy according to the mJOA criteria, and found that patients selected for nonoperative management had higher QoL and less physical/mental function at baseline than those treated surgically, while they noticed that the cord signal intensity does not appear to correlate with severity of clinical symptoms or progression. Again, the Fehlings group in 2019[11] raised the problem of the sensitivity of the various scales, in particular the mJOA, in correctly differentiating between patients with "mild" forms those most disabled by their morbid condition. Finally, Feng et al.[16] proposed the predictive role SEP classification in identifying progressive myelopathy in patients with mild CSM.

Therefore, in consideration of the above, the group proposed to reformulated the statement as follows: "When counselling patients with mild CSM, QoL assessment should be part of the examination and physical function in day-to-day activities as social functioning should be carefully investigated while taking

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in consideration the patient's reported performance status. We suggest offering surgical intervention to patients with substantial reduction of QoL and greater neck pain and motor impairment at presentation or serious SEP abnormality. A supervised trial of structured rehabilitation should be offered to patients with mild CSM with better QoL and less physical/mental disfunction. If initial nonoperative management is pursued, we recommend operative intervention if there is neurological deterioration or appearance of SEP abnormality and suggest operative intervention if the patient fails to improve." For an easier clinical application this statement was divided and proposed in 4 different recommendations.

In general, we can conclude that in our country, basing on literature review and expert opinion, there is a more interventional behavior also in aged patients if the QoL and functional status are good or in case of progressive worsening. Also, in this case a fundamental role is played by the QoL guarantee and life expectancy.

The surgical treatment by anterior or posterior approach is nowadays worldwide well stated and this is reflected by the fact that any of the statement proposed by WFNS was revised. The Italian committee added 2 statements in favor of decompressive surgery without fusion in absence of present or delayed instability.

4. Group 4: Anterior Surgical Treatment

The analysis of the literature, especially after 2019 did not bring substantial innovations with respect to all the statements of this section.

5. Group 5: Posterior and Combined Surgical Treatment

The analysis of the literature did not underline substantial new data with respect to the statement of this section. Regarding the role of cervical laminectomy with or without posterior fusion, literature remains uncertain regarding the better choice. Kim and Dhillon[15] in a comparative study published in 2019 concluded that in carefully selected patients with normal preoperative cervical sagittal alignment stand-alone laminectomy may offer acceptable results. And although the risk to develop postoperative kyphosis is higher this is partially compensated by the higher risk correlated with posterior instrumentation itself. Kotter et al.[17] stated that globally cervical laminectomy with instrumented fusion is more effective, with a similar rate of preoperative complications. However, the authors stress the limitation of the study due to the bias of patient selection more unbalanced in favor of laminectomy and fixation. A similar conclusion was also presented by McAllister et al.[18]: In particular, they found short-term results similar, with better results in the long-term period in favor of laminectomy and fixation. For these reasons and based on expert opinion, the group proposed 2 further statements: "Stand-alone laminectomy, in absence of superiority/inferiority study respect to the different posterior techniques, may be considered a valuable surgical option" and "Stand-alone laminectomy is advisable in cases with preserved cervical lordosis and in patients with low risk to develop late instability."

At the end of the literature revision process for the different surgical approach the group underlined that in literature analysis the recommendations are mainly based on patients without Parkinson Disease (PD). We acknowledge the lack of available evidence on surgical indications and outcomes of cervical approaches in these patients. The group think that this pathological condition cannot be ignored related to progressively aging of the population with CSM that is eligible for surgery especially in our local reality. Thus, clinical and surgical recommendations have to rely on the biomechanical and physio pathological features of PD and on anterior approaches indications and drawbacks for non-PD patients. Therefore, recommendation for the different approaches in PD patients should rely on the ones made for non-PD patients and on nonspecific considerations about instrumented surgery in PD patients. Future studies may analyze this subpopulation in order to better assess these aspects.

6. Group 6: Role of Neurophysiological Monitoring

In this group, the analysis of literature, as well as daily practice and expert opinion, found the more relevant modification. In fact, out of the 3 recommendations proposed by WFNS Spine Committee 2 statements were modified and 4 new were proposed.

The role of neurophysiological monitoring in the preoperative phase was discussed in detail in group 2. Severino et al.[19] tried to analyze the definition of patient selection and detection of best responders for surgical treatment in CSM. The authors suggest a multidisciplinary evaluation, especially in silent form, including the preoperative evaluation MEP/SEP and in this study, MEP notably appears to correlate with mJOA. According to different studies[20,21] MEP seems to be more sensitive in detecting the chronic form of CSM. Instead, preoperative SEP seems useful in predicting the development of CSM in cases of cervical stenosis, and show a good correlation with the prognosis of the disease.[13,22] The role of EMG in CSM is limited only in

cases associated with radiculopathy.[23]

Numerous studies have been published recently regarding the role of intraoperative monitoring (IOM) during surgery for CSM,[24,25] however, clear scientific evidence is still lacking. One of the most common drawbacks is the bias of alert criteria adopted during surgery. In particular, the role of IOM during anterior surgery remains unclear, while when a posterior approach is performed in cases of multilevel myelopathy, a combination of MEP and SEP may predict clinical worsening, allowing the modification of some surgical choices during surgery. Moreover, intraoperative MEP/SEP worsening is specific, but it does not show clinical worsening in every incidence.

The role of MEP/SEP in postoperative care and follow-up have still not been analyzed well. SEP are described as more sensitive with respect to preoperative data, especially when improvement is achieved. Based on the previous discussion and role of MEP and SEP, these evaluations may be suggested at 6-month follow-up after surgery in case of the absence of clinical changes or in persistent compression at MRI.

7. Group 7: Follow-up and Outcome

Literature analysis did not result in substantial innovations with respect to almost all the statements of this section, except for two. Their adjunct is mainly due to easy regional access to MRI studies for both preoperative evaluation and postoperative follow-up.

In the outcome measures section, the second statement was revised after literature review: in fact, though simple to apply in clinical practice, walking test is administered in such different ways that it is hard to obtain any universal validation. As for the JOA scale, it may easily reflect other pathological conditions, such as hip or knee osteoarthritis. On the other hand, the SF-36 seems to us an excellent tool in ascertaining the degree of QoL; however, it is too generic to evaluate CSM, which is a disease with several, and different, clinical and radiological aspects.

Literature review regarding the radiological variables affecting outcome showed new interesting studies. The growing interest toward sagittal balance of the spine led to the development and validation of several parameters for assessing the correct alignment of cervical elements. Several studies investigated the correlation between sagittal parameters and mJOA score. The multicenter AOSpine North America Cervical Spondylotic Myelopathy Study found that mJOA scores correlated negatively with C2–7 sagittal vertical axis (SVA), C2 tilt, C2 slope. The mJOA score correlated weakly with T1 slope minus C2–7 Cobb angle. It was not detected to correlate significantly with center of gravity-C7 SVA, C2–7 Cobb angle, or the posterior or anterior length of the spinal column (level of evidence III). These findings have been the pillars of the AOSpine North America study group statements regarding cervical radiographic alignment.[26,27]

Yuan et al.[28] demonstrated through multiple linear regression that age combined with C2–7 SVA is a sensitive predictor of mJOA (level II evidence). Lin et al.[29] found that myelopathy progresses slowly, in patients with C2–7 Cobb angle >29, whilst cervical curvature index change constant is the only independent risk factor for the Neck Disability Index increase (level II evidence). Buell et al.[30] detected that neurological improvement was significant related to preoperative normal cervical lordosis (level of evidence V). Roguski et al.[31] found that preoperative and postoperative C2–7 SVA measurements are independent predictors of clinical outcome (class III evidence). Contrariwise, Passias et al.[32] state that although global spine parameters are strictly interconnected with the outcome, there is no relationship between cervical-specific sagittal parameters and mJOA (level of evidence III).

In conclusion, the relationship between postsurgical cervical sagittal alignment and clinical outcome remains controversial and has not yet been proved. We found 2 studies (level of evidence class II and IV) that cannot identify a clear correlation, and 3 studies (2 with level of evidence class II and 1 class III) that do not detect any correlation.[19,33-36]

Although conventional MRI is an excellent modality for the determination of spondylotic changes, it is known to have a sensitivity as low as 65% in the identification of myelopathy.[37]

Several novel techniques have been employed to improve detection of increased signal intensity, namely double diffusion encoding, spinal cord perfusion and diffusion MRI, MR spectroscopy, functional MRI. Interestingly, these methods also appear to be related to clinical outcomes.[38]

In a prospective multicenter study, Ozawa et al.[39] observed that preoperative intramedullary Gd-DTPA enhancement was indicative of poor prognosis. DTI effectiveness in predicting prognosis of CSM patients has been widely investigated and accepted (7 studies level of evidence II, 1 study level of evidence III).[20,40-45]

Furthermore, Rao and Severino's findings were concordant in identifying transfer area (TA) values of 0.55 as a cutoff for the prognosis of CSM patients. Rao et al.[45] found preoperative TA <0.55 to be associated with significantly poorer outcome (class II evidence). Severino et al.[20] detected higher TA amongst "best responder" patients to surgery. Thus, they identified TA

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> 0.55 as a predictor of a better postoperative outcome (class III evidence).

Eicker et al.[46] demonstrated that patients in the acute-onset phase of symptomatic CSM, and also patients with chronic-stable myelopathy and new-onset symptoms, exhibit a focally increased glucose hypermetabolism (18F-fluorodeoxyglucose uptake) at level of stenosis and cord compression. Decompressive surgery during the phase when hypermetabolism is present results in a better clinical recovery and favorable outcome. Whilst the chronic phase of CSM is featured by a post stenotic glucose hypometabolism occurring, suggesting an irreversible impairment of the spinal cord.[46]

CONCLUSION

These recommendations reflect the more contemporary treatment concepts for CSM as presented in the highest quality clinical literature and best clinical practices available on this subject. The WFNS recommendation represents the road-map to be followed, but with this paper the spinal section of the SINch reconsider it considering the different possibilities and facilities of our Society and of the National Health Care System.

NOTES

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ORCID

Costa Francesco: 0000-0002-5191-9477
Carla Daniela Anania: 0000-0002-5893-2201
Umberto Agrillo: 0000-0001-8407-1735
Assietti Roberto: 0000-0002-5279-4645
Bernucci Claudio: 0000-0001-8279-6185
Bistazzoni Simona: 0000-0001-7940-0151
Bongetta Daniele: 0000-0003-3620-2600
Brembilla Carlo: 0000-0003-3356-3144
Cappelletto Barbara: 0000-0002-3382-0158
De Rosa Andrea: 0000-0002-9459-4588
Del Vecchio Carlo: 0000-0001-8964-6657
Dobran Mauro: 0000-0001-7305-6951
Fiorenza Vito: 0000-0002-0981-4639
Garbossa Diego: 0000-0002-4838-0327
Guizzardi Giancarlo: 0000-0002-3452-553X
Iaccarino Corrado: 0000-0002-5133-6327
Gualtiero Innocenzi: 0000-0002-8311-2213
Landi Alessandro: 0000-0003-3627-5535
Lastrucci Giancarlo: 0000-0002-1680-026X
Maida Giuseppe: 0000-0003-1267-0282
Maugeri Rosario: 0000-0002-4954-9817
Meglio Vincenzo: 0000-0002-6069-2542
Montemurro Nicola: 0000-0002-3686-8907
Pinna Giovanni: 0000-0003-1362-3322
Ricci Alessandro: 0000-0003-2018-2940
Rispoli Rossella: 0000-0001-6770-6858
Romoli Stefano: 0000-0002-2028-6646
Somma Teresa: 0000-0001-7864-1607
Tessitore Enrico: 0000-0002-7116-6302
Vitali Matteo: 0000-0002-1001-6343
Alberto Zerbi: 0000-0003-3918-5543
Zona Gianluigi: 0000-0002-3577-7894

REFERENCES

1. Costa F, Innocenzi G, Guida F, et al. Degenerative lumbar spine stenosis consensus conference: the Italian job. Recommendations of the Spinal Section of the Italian Society of

Neurosurgery. J Neurosurg Sci 2021;65:91-100.
2. Zileli M. Recommendations of WFNS Spine Committee. Neurospine 2019;16:383-5.
3. Zileli M, Borkar SA, Sinha S, et al. Cervical spondylotic myelopathy: natural course and the value of diagnostic techniques -WFNS Spine Committee Recommendations. Neurospine 2019;16:386-402.
4. Parthiban J, Alves OL, Chandrachari KP, et al. Value of surgery and nonsurgical approaches for cervical spondylotic myelopathy: WFNS Spine Committee Recommendations. Neurospine 2019;16:403-7.
5. Deora H, Kim SH, Behari S, et al. Anterior surgical techniques for cervical spondylotic myelopathy: WFNS Spine Committee Recommendations. Neurospine 2019;16:408-20.
6. Bajamal AH, Kim SH, Arifianto MR, et al. Posterior surgical techniques for cervical spondylotic myelopathy: WFNS Spine Committee Recommendations. Neurospine 2019;16:421-34.
7. Zileli M, Maheshwari S, Kale SS, et al. Outcome measures and variables affecting prognosis of cervical spondylotic myelopathy: WFNS Spine Committee Recommendations. Neurospine 2019;16:435-47.
8. Bednarik J, Kadanka Z, Dusek L, et al. Presymptomatic spondylotic cervical myelopathy: an updated predictive model. Eur Spine J 2008;17:421-31.
9. Wilson JR, Barry S, Fischer DJ, et al. Frequency, timing, and predictors of neurological dysfunction in the nonmyelopathic patient with cervical spinal cord compression, canal stenosis, and/or ossification of the posterior longitudinal ligament. Spine (Phila Pa 1976) 2013;38(22 Suppl 1):S37-54.
10. Badhiwala JH, Ahuja CS, Akbar MA, et al. Degenerative cervical myelopathy - update and future directions. Nat Rev Neurol 2020;16:108-24.
11. Bednarik J, Kadanka Z, Dusek L, et al. Presymptomatic spondylotic cervical myelopathy: an updated predictive model. Eur Spine J 2008;17:421-31.
12. Deftereos SN, Kechagias E, Ioakeimidou C, et al. Transcranial magnetic stimulation but not MRI predicts long-term clinical status in cervical spondylosis: a case series. Spinal Cord 2015;53 Suppl 1:S16-8.
13. Feng X, Hu Y, Ma X. Progression prediction of mild cervical spondylotic myelopathy by somatosensory-evoked potentials. Spine (Phila Pa 1976) 2020;45:E560-7.
14. Koyanagi I. Options of management of the patient with mild degenerative cervical myelopathy. Neurosurg Clin N Am 2018;29:139-44.
15. Badhiwala JH, Hachem LD, Merali Z, et al. Predicting outcomes after surgical decompression for mild degenerative cervical myelopathy: moving beyond the mJOA to identify surgical candidates. Neurosurgery 2020;86:565-73.
16. Bond M, McIntosh G, Fisher C, et al. Treatment of mild cervical myelopathy: factors associated with decision for surgical intervention. Spine (Phila Pa 1976) 2019;44:1606-12.
17. Kotter MRN, Tetreault L, Badhiwala JH, et al. Surgical outcomes following laminectomy with fusion versus laminectomy alone in patients with degenerative cervical myelopathy. Spine (Phila Pa 1976) 2020;45:1696-703.
18. McAllister BD, Rebholz BJ, Wang JC. Is posterior fusion necessary with laminectomy in the cervical spine? Surg Neurol Int 2012;3(Suppl 3):S225-31.
19. Severino R, Nouri A, Tessitore E. Degenerative cervical myelopathy: how to identify the best responders to surgery? J Clin Med 2020;9:759.
20. Lyu RK, Tang LM, Chen CJ, et al. The use of evoked potentials for clinical correlation and surgical outcome in cervical spondylotic myelopathy with intramedullary high signal intensity on MRI. J Neurol Neurosurg Psychiatry 2004;75:256-61.
21. Simó M, Szirmai I, Arányi Z. Superior sensitivity of motor over somatosensory evoked potentials in the diagnosis of cervical spondylotic myelopathy. Eur J Neurol 2004;11:621-6.
22. Ding Y, Hu Y, Ruan DK, et al. Value of somatosensory evoked potentials in diagnosis, surgical monitoring and prognosis of cervical spondylotic myelopathy. Chin Med J (Engl) 2008;121:1374-8.
23. Nardone R, Höller Y, Brigo F, et al. The contribution of neurophysiology in the diagnosis and management of cervical spondylotic myelopathy: a review. Spinal Cord 2016;54:756-66.
24. Ajiboye RM, D'Oro A, Ashana AO, et al. Routine use of intraoperative neuromonitoring during ACDFs for the treatment of spondylotic myelopathy and radiculopathy is questionable: a review of 15,395 cases. Spine (Phila Pa 1976) 2017;42:14-9.
25. Hu Y, Ding Y, Ruan D, et al. Prognostic value of somatosensory-evoked potentials in the surgical management of cervical spondylotic myelopathy. Spine (Phila Pa 1976) 2008;33:E305-10.
26. Smith JS, Lafage V, Ryan DJ, et al. Association of myelopathy scores with cervical sagittal balance and normalized spinal cord volume: analysis of 56 preoperative cases from the AOSpine North America Myelopathy study. Spine (Phila Pa 1976) 2013;38(22 Suppl 1):S161-70.

 https://doi.org/10.14245/ns.2244996.498

27. Ames CP, Blondel B, Scheer JK, et al. Cervical radiographical alignment: comprehensive assessment techniques and potential importance in cervical myelopathy. Spine (Phila Pa 1976) 2013;38(22 Suppl 1):S149-60.
28. Yuan W, Zhu Y, Zhu H, et al. Preoperative cervical sagittal alignment parameters and their impacts on myelopathy in patients with cervical spondylotic myelopathy: a retrospective study. PeerJ 2017;5:e4027.
29. Lin T, Wang Z, Chen G, et al. Is cervical sagittal balance related to the progression of patients with cervical spondylotic myelopathy? World Neurosurg 2020;137:e52-67.
30. Buell TJ, Buchholz AL, Quinn JC, et al. Importance of sagittal alignment of the cervical spine in the management of degenerative cervical myelopathy. Neurosurg Clin N Am 2018; 29:69-82.
31. Roguski M, Benzel EC, Curran JN, et al. Postoperative cervical sagittal imbalance negatively affects outcomes after surgery for cervical spondylotic myelopathy. Spine (Phila Pa 1976) 2014;39:2070-7.
32. Passias PG, Horn SR, Bortz CA, et al. The relationship between improvements in myelopathy and sagittal realignment in cervical deformity surgery outcomes. Spine (Phila Pa 1976) 2018;43:1117-24.
33. Lee CK, Shin DA, Yi S, et al. Correlation between cervical spine sagittal alignment and clinical outcome after cervical laminoplasty for ossification of the posterior longitudinal ligament. J Neurosurg Spine 2016;24:100-7.
34. Kaptain GJ, Simmons NE, Replogle RE, et al. Incidence and outcome of kyphotic deformity following laminectomy for cervical spondylotic myelopathy. J Neurosurg 2000;93(2 Suppl):199-204.
35. Wei L, Cao P, Xu C, et al. Comparison of the prognostic value of different quantitative measurements of increased signal intensity on T2-weighted MRI in cervical spondylotic myelopathy. World Neurosurg 2018;118:e505-12.
36. Wei L, Cao P, Xu C, et al. The relationship between preoperative factors and the presence of intramedullary increased signal intensity on T2-weighted magnetic resonance imaging in patients with cervical spondylotic myelopathy. Clin Neurol Neurosurg 2019;178:1-6.
37. Lee S, Lee YH, Chung TS, et al. Accuracy of diffusion tensor imaging for diagnosing cervical spondylotic myelopathy in patients showing spinal cord compression. Korean J Radiol 2015;16:1303-12.
38. Martin AR, Tadokoro N, Tetreault L, et al. Imaging evaluation of degenerative cervical myelopathy: current state of the art and future directions. Neurosurg Clin N Am 2018;29: 33-4.
39. Ozawa H, Aizawa T, Tateda S, et al. Spinal cord swelling after surgery in cervical spondylotic myelopathy: relationship with intramedullary Gd-DTPA enhancement on MRI. Clin Spine Surg 2018;31:E363-7.
40. Yang YM, Yoo WK, Bashir S, et al. Spinal cord changes after laminoplasty in cervical compressive myelopathy: a diffusion tensor imaging study. Front Neurol 2018;9:696.
41. Wang KY, Idowu O, Thompson CB, et al. Tract-specific diffusion tensor imaging in cervical spondylotic myelopathy before and after decompressive spinal surgery: preliminary results. Clin Neuroradiol 2017;27:61-9.
42. Vedantam A, Rao A, Kurpad SN, et al. Diffusion tensor imaging correlates with short-term myelopathy outcome in patients with cervical spondylotic myelopathy. World Neurosurg 2017;97:489-94.
43. Jones JG, Cen SY, Lebel RM, et al. Diffusion tensor imaging correlates with the clinical assessment of disease severity in cervical spondylotic myelopathy and predicts outcome following surgery. AJNR Am J Neuroradiol 2013;34:471-8.
44. Maki S, Koda M, Kitamura M, et al. Diffusion tensor imaging can predict surgical outcomes of patients with cervical compression myelopathy. Eur Spine J 2017;26:2459-66.
45. Rao A, Soliman H, Kaushal M, et al. Diffusion tensor imaging in a large longitudinal series of patients with cervical spondylotic myelopathy correlated with long-term functional outcome. Neurosurgery 2018;83:753-60.
46. Eicker SO, Langen KJ, Galldiks N, et al. Clinical value of 2-deoxy-[18F]fluoro-D-glucose positron emission tomography in patients with cervical spondylotic myelopathy. Neurosurg Focus 2013;35:E2.