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CASE REPORT

Transcranial magnetic stimulation but not MRI predicts long-term clinical status in cervical spondylosis: a case series

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Study Design: Case series.
Objective: To compare transcranial magnetic stimulation (TMS) and magnetic resonance imaging (MRI) findings between patients who underwent surgery for cervical spondylotic myelopathy and those with spondylosis who were not operated upon, and to correlate these findings with clinical functionality at follow-up.
Setting: Private practice.
Methods: Of 16 consecutive patients with cervical spondylosis 8 underwent surgery (group I) and 8 were treated conservatively (group II). We compared TMS and MRI findings between these groups and we correlated central motor conduction times (CMCTs) and MRI-measured sagittal and parasagittal diameters of the spinal canal at baseline evaluation, with clinical functionality at 2-year follow-up.
Results: Group I CMCTs at the lower limbs correlated significantly with modified-JoA 2 years post surgery ($r=-0.71$, $P<0.05$), but MRI-measured diameters did not. In group II baseline TMS was unrevealing, contrary to significant spinal stenosis disclosed by MRI. The condition of none of these patients deteriorated at 2 years.
Conclusions: CMCTs at the lower limbs, but not cervical spinal canal diameters, correlate with long-term functional outcome following surgical or conservative treatment.
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INTRODUCTION

Whether magnetic resonance imaging (MRI) and transcranial magnetic stimulation (TMS) can predict long-term clinical outcomes in patients with cervical spondylosis is an issue of debate.[1–3] We compared TMS and MRI findings between a group of patients who underwent surgery for cervical spondylotic myelopathy and a second group with spondylosis, who were not operated upon, and we correlated these abnormalities with longitudinal clinical follow-up.

MATERIALS AND METHODS

We evaluated by TMS and MRI, in the context of our routine assessment protocol, 16 consecutive patients who presented with symptoms of (a) cervical myelopathy, (b) upper-limb radicular lesions or (c) pain localized at the cervix. TMS evaluation comprised determination of the central motor conduction times (CMCTs) at the upper and lower limbs, according to the f-wave method.[4] Motor Evoked Potentials were recorded from the abductors digiti minimi (ADM) and extensors digitorum brevis (EDB).

MRI evaluation comprised determination of the transverse diameter of the spinal canal at the midline ($d_{mri\_midline}$) and at 50% of the distance between the midline and the left (d_{mri_left}) and right (d_{mri_right}) borders of the spinal canal, at all intervertebral levels. We also looked for T_2 signal hyperintensities and we screened patients by EMG for radicular lesions.

Surgery was recommended to patients who had (1) clinical and/or TMS signs of myelopathy and (2) weakness or intolerable pain of radicular origin, or signs of acute denervation in the EMG. Patients with pain but without weakness or denervation in the EMG and with unrevealing TMS were treated conservatively. All patients were followed up for at least 2 years. Clinical functionality was expressed in terms of the modified Japanese Orthopedic Association (modified-JoA) scale, at baseline evaluation and at 2 years.

We correlated CMCTs at the upper and lower limbs with MRI-based measures and with the modified-JoA scale at baseline and at 2 years of follow-up. For each patient, we included one upper-limb and one lower-limb CMCT value (right or left) in the analysis, recorded from the most severely affected side, denoted as $CMCT_{mostaffected\_adm}$ and $CMCT_{mostaffected\_edb}$.

On the MRI we analyzed $d_{mri\_midline}$, d_{mri_left} and d_{mri_right} measured at the level shown to suffer the most severe stenosis. We denote the smallest of d_{mri_left}, d_{mri_right} as $d_{mri\_smallest\_parasagittal}$ and the parasagittal diameter ipsilateral to $CMCT_{mostaffected\_adm}$ or $CMCT_{mostaffected\_edb}$ as $d_{mri\_ipsilateral\_adm}$ and $d_{mri\_ipsilateral\_edb}$, respectively. We included in the statistical analysis the following MRI-based measures: (1) we correlated CMCTs on the most affected side ($CMCT_{mostaffected\_adm}$ and $CMCT_{mostaffected\_edb}$) with the ipsilateral parasagittal diameter ($d_{mri\_ipsilateral\_adm}$ and $d_{mri\_ipsilateral\_edb}$) and with the midline diameter of the spinal canal ($d_{mri\_midline}$); (2) we also correlated the smallest parasagittal diameter ($d_{mri\_smallest\_parasagittal}$) with $CMCT_{mostaffected\_adm}$ and $CMCT_{mostaffected\_edb}$. Our aim was to determine whether any of the spinal canal diameters shows a significant correlation with CMCTs. Finally (3) we correlated spinal canal diameters ($d_{mri\_smallest\_parasagittal}$ and $d_{mri\_midline}$) with the modified-JoA scale at baseline and at 2 years of follow-up.

We also compared our neurophysiology and imaging findings between patients who underwent surgical decompression and those who were treated by conservative measures. With regard to TMS, we compared between the groups $CMCT_{mostaffected\_adm}$ and $CMCT_{mostaffected\_edb}$, whereas for MRI we compared $d_{mri\_smallest\_parasagittal}$ and $d_{mri\_midline}$. Here we wanted to test whether the two groups were significantly different in terms of their most severe findings on the MRI and TMS evaluations.

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Table 1 Clinical presentation and demographic characteristics in surgically (group I) and conservatively (group II) treated patients

Symptom	*Number of patients in group I*	*Number of patients in group II*
Sex	5 females, 3 males	6 females, 2 males
Mean age ± s.d. (years)	47.75 ± 10.0 (range 34–64)	39.8 ± 15.8 (range 27–76)
Neck pain	5	8
Bladder dysfunction	3	—
Numbness of one upper limb	3	6
Hemi-body numbness	2	—
Walking difficulty	3	—
Numbness of one lower limb	2	—
Numbness of both upper limbs	3	3
Erectile dysfunction	2	—
Weakness of one upper limb	2	—
Clumsiness of the hands	2	—

Each patient may have presented with more than one symptom.

Table 2 Correlation coefficients for TMS, MRI parameters and modified-JoA, in patients that underwent surgery (group I)

Parameter 1	*Parameter 2*	*Pearson's* r	*Level of significance*
Modified-JoA at baseline	$CMCT_{mostaffected\_edb}$	−0.58	NS
Modified-JoA at baseline	$CMCT_{mostaffected\_adm}$	−0.56	NS
Modified-JoA at baseline	$d_{mri\_smallest\_parasagittal}$	0.05	NS
Modified-JoA at baseline	$d_{mri\_midline}$	−0.16	NS
$d_{mri\_smallest\_parasagittal}$	$CMCT_{mostaffected\_edb}$	−0.66	0.07
$d_{mri\_smallest\_parasagittal}$	$CMCT_{mostaffected\_adm}$	0.34	NS
$d_{mri\_ipsilateral\_edb}$	$CMCT_{mostaffected\_edb}$	−0.59	NS
$d_{mri\_ipsilateral\_adm}$	$CMCT_{mostaffected\_adm}$	0.58	NS
$d_{mri\_midline}$	$CMCT_{mostaffected\_edb}$	−0.4	NS
$d_{mri\_midline}$	$CMCT_{mostaffected\_adm}$	0.05	NS
Modified-JoA 2 years post surgery	$CMCT_{mostaffected\_edb}$	−0.71	<0.05
Modified-JoA 2 years post surgery	$CMCT_{mostaffected\_adm}$	−0.45	NS
Modified-JoA 2 years post surgery	$d_{mri\_smallest\_parasagittal}$	0.58	NS
Modified-JoA 2 years post surgery	$d_{mri\_midline}$	−0.10	NS

Abbreviations: CMCT, central motor conduction time; JoA, Japanese Orthopedic Association scale; MRI, magnetic resonance imaging; NS, not significant; TMS, transcranial magnetic stimulation.
The semantics of the parameters and the reasons why they were selected for reporting among all the parameters that we measured by TMS and MRI are discussed in the methods section.

For correlation, we used Pearson's (r). We tested for differences between groups using the two-sided Student's t-test. All calculations were performed in Microsoft Excel 2008.

RESULTS

Of the 16 patients, 8 underwent surgical decompression (group I), whereas 8 were treated by conservative measures (group II). Table 1 outlines patient demographic characteristics and clinical presentation.

In group I, baseline $CMCT_{mostaffected\_edb}$ correlated significantly with modified-JoA 2 years after surgery ($r = -0.71$, $P < 0.05$). None of the remaining correlations were statistically significant (Table 2). Table 3 compares the mean values of TMS and MRI parameters between group I and group II.

In group II, myelopathic symptoms were absent; thus, modified-JoA was not used. However, clinical functionality had not deteriorated in any of these patients at 2-year follow-up. In this group baseline TMS was unrevealing, contrary to the MRI, which in many cases disclosed signficant stenosis ($d_{mri\_midline} < 10$ mm).

Table 3 Comparison of the mean values of CMCTs and MRI-derived spinal canal diameters between patients who underwent surgery (group I) and those treated conservatively (group II)

Parameter	*Group I (mean value ± s.d.)*	*Group II (mean value ± s.d.)*	*Level of significance*
$CMCT_{mostaffected\_edb}$	18.13 ± 3.53	13.15 ± 1.45	<0.01
$CMCT_{mostaffected\_adm}$	7.62 ± 2.16	6.46 ± 1.28	NS
$d_{mri\_smallest\_parasagittal}$	4.75 ± 1.28	7.92 ± 2.3	<0.05
$d_{mri\_midline}$	7.62 ± 1.85	9.20 ± 2.13	NS

Abbreviations: CMCT, central motor conduction time; MRI, magnetic resonance imaging; NS, not significant.
The semantics of the parameters and the reasons why they were selected for reporting among all the parameters that we measured by TMS and MRI are discussed in the methods section.

Finally, there were no signal hyperintensities or EMG signs of denervation in any of the patients. All group I patients underwent anterior cervical discectomy and fusion.

DISCUSSION

Whether TMS can determine prognosis after surgical decompression in patients with cervical spondylotic myelopathy is an issue of debate.[3] We found that pre-surgical CMCT at the lower limbs can predict functional recovery. Thus, our work further supports this view[5] and refutes studies with opposite findings.[6,7]

In conservatively treated patients, normal CMCTs at baseline were in agreement with their sustained clinical functionality at 2-year follow-up, despite the significant stenosis seen in many of the MRIs. The average midline diameter of the spinal canal in this group was 9.2 mm—that is, below 10 mm, the widely accepted limit for surgical intervention.[8]

Although none of the MRI measures correlated with postsurgical outcome, the smallest parasagittal diameter of the spinal canal, $d_{mri\_smallest\_parasagittal}$, was significantly smaller in surgically treated patients compared with conservatively treated ones, whereas the midline diameter was not significantly different. This finding speaks against the use of the midline diameter alone when making a decision for surgery; as many disc hernias project more laterally than centrally, evaluation of the parasagittal diameters is also important.

Our findings suggest that, in addition to the clinical picture, TMS can be an important tool when making the decision to treat cervical spondylosis surgically and has the potential to predict the long-term postoperative outcome. Although the number of patients included in this series is small, our work supports the reappraisal of the value of TMS in this context in further studies with a larger sample size.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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