Dynamic somatosensory evoked potentials to determine electrophysiological effects on the spinal cord during cervical spine extension

Clinical article

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Object. The goal of this prospective study was to investigate somatosensory evoked potentials (SSEPs) during dynamic motion of the cervical spine and to evaluate the efficacy of analyzing dynamic SSEPs for predicting dynamic effects on the spinal cord in patients with cervical spondylotic myelopathy (CSM).

Methods. In total, 40 human subjects (20 CSM patients and 20 healthy volunteers as a control group) were examined prospectively using dynamic SSEPs with median nerve stimulation. The CSM patients showed cervical myelopathy due to cervical cord compression at the C4–5 segment. The SSEPs were examined with the cervical spine in a neutral position and at a 20° extension for 10 and 20 minutes. Changes in the N20 latency and amplitude were determined and analyzed. The authors defined the changes in the N20 latency and N20 amplitude between the neutral and extension positions of the cervical spine as percent latency and amplitude, respectively.

Results. In the CSM patients, SSEPs tended to deteriorate after cervical spine extension, and a statistically significant deterioration of the N20 amplitude after the extension was observed. Moreover, the percent latency and amplitude progressively increased during cervical spine extension in these patients. In the healthy controls, SSEPs tended to deteriorate with cervical spine extension, but these changes did not result in statistically significant differences. Moreover, in this group the percent latency and amplitude were almost identical during the extension. When the CSM patients and the healthy controls were compared, a significant difference in the percent amplitude was observed between the 2 groups during the cervical spine extension.

Conclusions. This study suggests the potential of dynamic SSEPs as a useful neurophysiological technique to detect the effect of dynamic factors on the pathogenesis of CSM.

Key Words • dynamic somatosensory evoked potential • spinal disorders • cervical spondylotic myelopathy • N20 latency • N20 amplitude

Abbreviations used in this paper: CSM = cervical spondylotic myelopathy; SSEP = somatosensory evoked potential.
Dynamic somatosensory evoked potentials

Somatosensory evoked potentials are a useful neurophysiological indicator to detect objective functional abnormalities of the spinal cord. When the clinical presentation of CSM is equivocal, neurophysiological investigations, such as those using SSEPs, may be useful to perform a clinical assessment. However, to the best of our knowledge, only a few studies have used SSEPs to report the mechanical effects of dynamic factors on spinal cord function. The purpose of this prospective study was to measure SSEPs during dynamic motion of the cervical spine in CSM patients and in healthy individuals and to determine the efficacy of dynamic SSEPs for predicting the effects of dynamic motion on the spinal cord.

Methods

Institutional review board approval was granted, and informed consent was obtained from all patients. In total, 40 individuals, consisting of 20 CSM patients (17 men and 3 women) with an average age of 64.9 years (range 47–77 years) and 20 healthy volunteers (13 males and 7 females) with an average age of 46.3 years (range 13–75 years), were prospectively examined with the use of dynamic SSEPs. The 20 CSM patients had disturbance of bilateral finger fine motion with myelopathic hand and gait disturbance with spastic gait due to a spondylocotic focus at the C4–5 segment identified by MRI (visible on T2-weighted images as an intensity change in the cervical cord) (Fig. 1). All patients received scores of less than 9 on the Japanese Orthopaedic Association scoring system for evaluation of cervical myelopathy and were ruled out to have carpal tunnel syndrome as determined by measurements of median nerve conduction velocity. The CSM patients presented with the following clinical manifestations: 2 patients had a cervical compression due to herniated cervical discs, 13 had cervical spondylosis, and 5 displayed segmental ossification of the posterior longitudinal ligaments. The 20 healthy volunteers did not show any neurological deficits or any cervical cord pathologies on MRI.

Dynamic SSEP Technique

An electrophysiological monitoring system (MEB-9102, Neuropack μ) was used to elicit and record the SSEPs. The SSEPs of the arm were recorded using surface electrodes on the scalp overlying the primary sensory area in the parietal lobe contralateral to the stimulated limb (2 cm behind the C-3 or C-4 locations of the 10–20 system) (N20). A reference electrode was placed on the Fz scalp position and impedances were set to less than 5000 Ω. The median nerve was stimulated at the right wrist using square wave electrostimulation at 5 Hz for 0.2 msec. The stimulus intensity was adjusted to produce a visible twitch of the abductor pollicis brevis muscle without causing any discomfort. The SSEPs were measured with the cervical spine in a neutral position and at 10 and 20 minutes after about 20° extension of the cervical spine using a device for elevating the neck and tilting the head slightly backwards without causing any discomfort to the subject (inset, Fig. 2 lower). To confirm the reproducibility of the SSEPs, each measurement was carried out at least 3 times. The N20 latency and amplitude were measured in all subjects for each position (Fig. 3). We defined the relative change of the N20 latency between the neutral and 20° extension positions as described in the following: percent latency = ([latency at extension − latency at neutral position]/latency at neutral position) × 100; the relative change of the N20 amplitude between the neutral and 20° extension positions was defined as: percent amplitude = ([amplitude at neutral position − amplitude at extension]/amplitude at neutral position) × 100.

The following individuals were excluded from this study: patients who underwent reoperation in the cervical region or those showing segmental instability in the cervical spine. Three patients with CSM did not show an N20 response, even in the neutral position, and the N20 response during cervical spine extension was lost in another CSM patient. Therefore, these 4 patients were also excluded from this study.

Statistical Analysis

The Mann-Whitney U-test was used for all statistical analyses. A p value of < 0.05 was considered statistically significant.
Results

The N20 latency and amplitude values are shown in Tables 1 and 2, respectively. The N20 latency and amplitude showed a gradual delay and decrease, respectively, in the CSM patients during the cervical spine extension, indicating deterioration of both variables during the extension, and the decrease in the N20 amplitude after extension for 10 and 20 minutes relative to the neutral position was statistically significant in the CSM group (Table 2). In the healthy control group, the N20 latency and amplitude at 10 minutes after cervical spine extension tended to show a delay and decrease, respectively, but no further changes were observed after 20 minutes (Tables 1 and 2). Comparisons of the CSM patients and healthy controls indicated statistically significant differences between the 2 groups in the N20 latency values in each position (Table 1) and in the N20 latency values in the extension position (Table 2).

Table 3 shows the N20 percent latency and amplitude values. In the CSM patients, the percent latency and amplitude progressively increased over time during the cervical spine extension, but no statistically significant differences between the 2 time points (10 and 20 minutes) were observed. Conversely, the percent latency and amplitude of the healthy controls showed almost no changes over time during the cervical spine extension. The percent amplitude showed statistically significant differences between the CSM patients and healthy controls at both time points.

Discussion

The relationship of dynamic factors with the onset of CSM caused by cervical instability has been reported previously. Penning17 has described the pincer mechanism, in which the spinal cord is pinched between the posteroinferior margin of the superior vertebral body and the anterosuperior margin of the lamina of the inferior vertebra. The body of the superior vertebra slides posteriorly on its inferior neighbor only when the cervical spine is extended. The relationship between these 2 vertebrae is

<table>
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<tr>
<th>TABLE 1: The values for N20 latency in the CSM patients and the healthy controls*</th>
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<td>Cervical Spine Group</td>
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<tr>
<td>CSM patients</td>
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<td>healthy controls</td>
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<td>* Values indicate msec (mean ± SD); the differences in the N20 latency values between the CSM patients and the healthy controls at each of the 3 different conditions were statistically significant (p &lt; 0.001).</td>
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<th>TABLE 2: The values of N20 amplitude in CSM patients and healthy controls*</th>
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<tr>
<td>Cervical Spine Group</td>
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<td>CSM patients</td>
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<td>healthy controls</td>
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<td>* Values are presented as µV (mean ± SD); the differences in the N20 amplitude values between the CSM patients and the healthy controls in the 3 different conditions were statistically significant (p &lt; 0.001). † In the CSM patients, the values for the N20 amplitude during the cervical spine extension were statistically significantly different from the amplitude values in the neutral position (p &lt; 0.05).</td>
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Dynamic somatosensory evoked potentials

### TABLE 3: Percentage latency and amplitude in CSM patients and healthy controls

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<th>Group</th>
<th>Latency (%)</th>
<th>Amplitude (%)†</th>
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<td></td>
<td>10 Mins</td>
<td>20 Mins</td>
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<tr>
<td>CSM patients</td>
<td>0.32 ± 2.19</td>
<td>1.06 ± 3.43</td>
</tr>
<tr>
<td>healthy controls</td>
<td>0.85 ± 1.07</td>
<td>0.85 ± 1.21</td>
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* Values are presented as the means ± SDs.
† The differences in percent amplitude between the CSM patients and the healthy controls at 10 and 20 minutes of extension were statistically significant (p < 0.01).

normal in both neutral and flexed positions. Radiographic analysis of cervical extension shows that the posterior sliding of the superior vertebrae results in a narrowing of the spinal canal as the superior vertebral body approaches the lamina of the inferior vertebra. A canal pinch diameter of less than 12 mm indicates the presence of dynamic canal stenosis.

Several authors have investigated the dynamic MRI changes of the cervical spine in healthy individuals and in CSM patients. Muhle et al. demonstrated that in healthy individuals, compared with its size in the neutral and flexed positions the cervical subarachnoid space was smallest during cervical spine extension. In patients with increasing stages of degenerative disease of the cervical spine, Muhle et al. observed an increasing prevalence of functional cord impingement from the posterior aspect and from the anterior and posterior aspects (pincer effect) during cervical spine extension. Moreover, Zhang and colleagues demonstrated that the length of the cervical cord was longest during cervical spine flexion and shortest during cervical spine extension. Furthermore, during physiological cervical spine extension loading, an increased CSF pressure has been noted.

In our study, the median nerve SSEPs deteriorated during cervical spine extension in both the CSM patients and the healthy controls. In our CSM patients, the N20 latency and amplitude both tended to progressively deteriorate during the cervical spine extension, and a significant decrease in the N20 amplitude was observed during the cervical spine extension in these patients. We hypothesize that the increased transient and acute direct dynamic cervical cord compression due to the pincer effect may disrupt the flow of both CSF and blood in the cervical cord. Transient or reversible cervical cord injury due to short-term direct dynamic cervical cord compression may lead to the progressive deterioration of the electrophysiological characteristics of the spinal cord.

In our healthy volunteers, the N20 latency and amplitude values also tended to deteriorate during the cervical spine extension. However, this deterioration was almost identical for both time points measured (Table 3). There was no direct cervical cord compression; however, the pincer effect may cause a narrowing of the subarachnoid space during cervical spine extension. Thus, the pincer effect may lead to increased CSF pressure and a disruption of the CSF flow. Therefore, we hypothesize that the disruption of the CSF flow due to the cervical spine extension may lead to the electrophysiological dysfunction of the spinal cord without a clinical neurological manifestation, even in the absence of direct cervical cord compression.

Our results suggest the potential use of dynamic SSEPs as a useful neurophysiological diagnostic technique to detect the effects of dynamic factors on CSM pathogenesis. If a deterioration of the dynamic SSEP is observed in CSM patients, decompression surgery may be recommended. However, some questions remain unanswered even in the current study. The average age of the subjects with CSM was different from that of the healthy individuals and this difference may have had an impact on the results. Moreover, we did not examine asymptomatic subjects who showed direct cervical cord impingement on MRI scans, and we did not discuss the relationship between the severity of cervical myelopathy and the degree of SSEP deterioration during cervical spine extension. Therefore, using the current investigation as a pilot study, further research using a larger patient population may help to resolve the questions raised in this study; moreover, the mechanical effects of the dynamic factors on the function of the spinal cord should be clarified in more detail.

### Conclusions

The goal of this prospective study was to investigate SSEPs during dynamic motion of the cervical spine and to evaluate the efficacy of analyzing dynamic SSEPs for predicting dynamic effects on the spinal cord in patients with CSM. Findings of the study suggest that dynamic SSEPs are a potentially useful neurophysiological technique for detecting the effect of dynamic factors on CSM pathogenesis.

### Disclosure

The authors report no conflict of interest concerning the materials or methods used in the study or the findings specified in the paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Morishita. Acquisition of data: Morishita. Analysis and interpretation of data: Morishita. Drafting the article: Morishita. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Morishita. Statistical analysis: Morishita. Administrative/technical/material support: Morishita, Shiba. Study supervision: Morishita, Maeda, Naito, Shiba.

### References


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Accepted May 30, 2013.

Please include this information when citing this paper: published online July 12, 2013; DOI: 10.3171/2013.5.SPINE12933.

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