Motor conduction measurement in myelopathy hand

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Summary

We studied the relationship between intramedullary high signal intensity (IMHSI) on T2-weighted magnetic resonance images and motor conduction in the spinal cords of cervical spondylotic myelopathy (CSM) patients.

There was no significant difference between the biceps or triceps central motor conduction times (CMCTs) of the patients who did and did not exhibit IMHSI, whereas the abductor pollicis brevis CMCT was significantly longer in the patients who exhibited IMHSI (p<0.05) than in those who did not. The CMCT of the abductor pollicis brevis is sensitive to the degree of damage in the cervical spinal cord. Hand dysfunction is a characteristic of CSM regardless of the cervical level affected by the condition. The motor fibers innervating the intrinsic muscles of the hand in the long tract of the cervical spinal cord are more sensitive than other motor fibers. For this reason, we consider that myelopathy hand is a characteristic impairment of CSM. Transcranial magnetic stimulation of the hand motor cortex is useful for the evaluation of cervical myelopathy.

KEY WORDS: cervical spondylotic myelopathy, central motor conduction time, intramedullary high signal intensity, magnetic resonance imaging, myelopathy hand

Introduction

Some authors have described hand dysfunction that does not always involve paresis of the lower extremities as a characteristic feature of cervical spondylotic myelopathy (CSM) (Good et al., 1984; Nakajima and Hirayama, 1995; Sonstein et al., 1996). Ono et al. (1987) coined the term myelopathy hand to refer to abnormalities such as reduced manual dexterity and/or wasting of the hands, which they found to be characteristic features in patients with CSM. However, they found no correlation between myelopathy hand and cervical cord involvement at any particular level. Although myelopathy hand is the most frequently recognized symptom of CSM, regardless of the cervical level involved, evaluations of motor function alone do not contribute to determining which cervical level has been affected by the condition.

Matsumoto et al. (2005) reported a 66% rate of agreement between neurological and neuroimaging tests performed to determine the cervical level affected by CSM, whereas the rate of agreement between manual muscle and neuroimaging tests was 19%. However, few articles have studied the cause such discrepancies (Matsumoto et al., 2005).

We retrospectively studied the medical records of patients with chronic compression myelopathy and evaluated the relationship between intramedullary high signal intensity (IMHSI) on T2-weighted magnetic resonance imaging (MRI) scans and conduction disturbances in the motor tract.

In order to compare IMHSI sites with vertebral levels exhibiting electrophysiological changes, we investigated the conduction of the motor fibers in the middle and lower cervical spinal segments that innervate the upper extremity muscles. Furthermore, we assessed the utility of measuring motor evoked potentials (MEPs) to evaluate the severity of myelopathy.

Materials and methods

Patients

From July 1998 to June 2003, 51 consecutive patients with cervical myelopathy [46 CSM patients and five cervical disc herniation (CDH) patients] were assessed. After obtaining institutional review board approval, we conducted a retrospective case-control study.
We retrospectively reviewed the patients’ medical records, electrophysiological measurement data, and MRI scans. Diagnoses of CSM and CDH were made on the basis of the results of neurological examinations and diagnostic imaging using various techniques including plain roentgenography and MRI. In all the patients, the cervical cord was compressed at some point between the C3/4 level and the C5/6 level. The mean age of the patients was 56 years (range: 41-78). Measurements were taken for all 102 hands of the 51 patients.

Motor evoked potentials

The patients were seated with their upper arms relaxed and the cathodes were placed on the motor points of the biceps brachii, triceps brachii and abductor pollicis brevis muscles. Reference electrodes were also placed on these muscles.

i) Following percutaneous electrical stimulation (amplitude: 30 mA, duration: 0.1 ms, rectangular wave) of the median nerve at the wrist, M- and F-waves were recorded from the abductor pollicis brevis at a bandwidth of between 5 Hz and 10 kHz using an electromyograph (Neuropack Four, MEM-4104, Nihon Kohden, Japan). The peripheral latency (PL) was calculated according to the formula devised by Kimura (1983):

\[ PL = \text{the onset latency of M-waves} + \text{the onset latency of F-waves} - 1 \]

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ii) The onset latency of the tendon reflex was measured in the biceps and the triceps tendon. A hammer (TA-420, Nihon Kohden, Japan) with a switch at the tip was then used to manually tap the biceps tendon, and 100 responses were averaged at a bandwidth of between 20 Hz and 10 kHz using a Neuropack Four (MEM-4104, Nihon Kohden, Japan). The PL was obtained in the manner described above and also described in detail by Tani et al. (1991).

\[ PL = \text{the onset latency of the tendon reflex} - 1 \]

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iii) MEPs elicited following transcranial (MEPcr) and cervical magnetic stimulation were recorded via the same electrodes using a magnetic stimulator (STM-1200, Nihon Kohden, Japan). We used a 14 cm (inner diameter) round 1.5 Tesla coil (YM-101) for the transcranial stimulation, as described in detail by Barker et al. (1985). To stimulate the motor roots, we used a 7 cm (inner diameter) round coil (YM-102). The central motor conduction time (CMCT) was obtained by subtracting the PL from the latency of the MEPcr.

Evaluation of MRI

MRI examinations were performed using a clinical 1.5-T whole-body MRI system (VISART TM/EX, Toshiba, Tokyo, Japan). Images were acquired in the sagittal plane using a turbo spin echo T2-weighted (TR4000 ms/TE100 ms) sequence with a 3 mm section thickness and a 0.3 mm gap. The change in intramedullary signal intensity was evaluated on sagittal T2-weighted MRI scans of the cervical spine.

The patients were divided into five groups according to the location of any IMHSI.

1) Focal C3/4 group: focal IMHSI was seen at the C3/4 level on T2-weighted sagittal images (n = 22 hands of 11 patients)
2) Focal C4/5 group: focal IMHSI was observed at the C4/5 level on T2-weighted sagittal images (n = 12 hands of 6 patients)
3) Focal C5/6 group: focal IMHSI was noted at the C5/6 level on T2-weighted sagittal images (n = 32 hands of 16 patients)
4) Multi-segmental group: diffuse IMHSI was demonstrated at multiple levels on T2-weighted sagittal images (n = 16 hands of 8 patients)
5) No IMHSI group: No IMHSI was observed in the sagittal plane (n = 20 hands of 10 patients).

In the 33 patients in the focal C3/4, C4/5 and C5/6 groups, the vertebral level of the site of the most intense signal intensity was defined as the IMHSI site. None of the patients exhibited IMHSI at the C6/7 vertebral level.

Clinical assessment

The severity of myelopathy was evaluated using the score proposed by the Japanese Orthopedic Association (JOA score), and myelopathy hands were functionally evaluated using the grip-release test as follows: the patient was asked to form a tight grip and then release it as rapidly as possible whilst their forearm was in pronation. The number of complete grip-release cycles performed within 10 seconds was counted as described by Ono et al. (1987).

Statistics

Statistical software (Stadview 4.5J, SAS, Cary, NC) was used for data analysis. All values were presented as means ± standard deviation. The Mann-Whitney U-test (Stadview 4.5J) was used to evaluate the significance between the values and the simple regression model (Stadview 4.5J) was used to analyze the correlation between the measured values. All p values less than 0.05 were considered to indicate statistical significance.

Results

JOA scores

The JOA scores of the focal C3/4, focal C4/5, focal C5/6, multi-segmental, and no IMHSI groups were 10.2±2.6 points, 11.3±2.2 points, 10.6±2.9 points, 9.1±2.2 points, and 12.8±1.6 points, respectively. Only the JOA score of the no IMHSI group was significantly (p<0.05) higher than those of the other groups. There was no significant difference between the JOA scores of the IMHSI-positive groups (Fig. 1).
**CMCTs of the biceps, triceps and abductor pollicis brevis muscles**

**THE CMCTs of the biceps brachii muscle**

The CMCTs of the biceps brachii muscle in the focal C3/4, focal C4/5, focal C5/6, multi-segmental, and no IMHSI groups were 6.0±2.1 ms, 6.2±0.9 ms, 5.6±1.2 ms, 5.8±1.3 ms, and 5.3±1.1 ms, respectively. There was no significant difference in the CMCT of the biceps brachii muscle between any of the groups (Fig. 2).

**THE CMCTs of the triceps muscle**

The CMCTs of the triceps brachii muscle in the focal C3/4, focal C4/5, focal C5/6, multi-segmental, and no IMHSI groups were 7.7±1.8 ms, 7.9±1.4 ms, 7.5±1.8 ms, 7.5±1.4 ms and 6.6±0.9 ms, respectively. No significant difference in the CMCT of the triceps brachii muscle was detected between any of the groups (Fig. 3).

**THE CMCTs of the abductor pollicis brevis muscle**

The CMCTs of the abductor pollicis brevis muscle in the focal C3/4, focal C4/5, focal C5/6, multi-segmental, and no IMHSI groups were 12.7±3.7 ms, 13.2±3.3 ms, 12.6±3.9 ms, 14.3±3.9 ms and 8.1±1.4 ms, respectively. Only the CMCT of the no IMHSI group was significantly shorter than those of the other groups. However, there was no significant difference between the CMCTs recorded in the remaining groups (Fig. 4).

**Grip-release test**

Although the biceps brachii and triceps brachii muscle CMCTs did not exhibit any relationship with the JOA score, the CMCT of the abductor pollicis brevis muscle displayed a strong relationship with the JOA score (r=-0.70, p<0.0001, Fig. 5).
Discussion

Transcranial magnetic stimulation (TMS) is a non-invasive technique that can be used to study conduction in the descending corticospinal tract (Barker et al., 1985; Hess et al., 1986). Lo et al. (2004) detected a strong correlation between TMS and MRI findings and stated that “TMS can be recommended as a non-invasive, less costly, and less time-consuming technique for screening and serial evaluation of cervical spondylotic myelopathy.” We also consider it useful for detecting cervical disorders.

In some clinical reports, IMHSI was not found to be associated with the severity of myelopathy (Wada et al., 1999; Yone et al., 1992). However, in other reports the patients who displayed IMHSI were in a worse clinical condition (Matsuda et al., 1991). Takahashi et al. (1987) observed localized areas of high signal intensity within the spinal cord on T2-weighted images in cases of compression of the spinal cord and reported that high signal intensity was seen more frequently in cases involving severe degrees of spinal cord compression and in severely clinically impaired patients. In the current study, the no IMHSI group displayed significantly shorter abductor pollicis brevis muscle CMCTs than the IMHSI-positive groups, and the JOA score of the no IMHSI group was higher than those of the other groups. This suggests that IMHSI indicates the presence of damage involving the corticospinal tract.

Ono et al. (1987) used the term myelopathy hand to describe hand disability combined with CSM. In addition, in order to evaluate the severity of the damage to the pyramidal tract, they counted the number of grip-release cycles that patients with the condition could perform within ten seconds (Ono et al., 1987). Recently, many physicians have employed this ten-second test. Doita et al. (2006) performed several hand function tests in cervical myelopathy patients and healthy controls and reported that hand function showed a good relationship with extent of cervical myelopathy.

As regards the electrophysiological diagnosis, Lyu et al. (2004) reported that the CMCT of the abductor pollicis brevis muscle was more sensitive than that of the tibialis anterior for diagnosing CSM. Previous reports demonstrated that the CMCT of the biceps brachii muscle was longer in patients who had suffered damage at a cervical level above C4/5 than in those who had suffered damage below C5/6 (Di Lazzaro et al., 1992; Tavy et al., 1994). However, in the current study the biceps brachii muscle CMCTs of the focal C3/4 and focal C4/5 groups were not found to be significantly different from those of the focal C5/6, multi-segmental, and no IMHSI groups. On the contrary, the CMCT of the abductor pollicis brevis muscle was longer in the patients who exhibited strong IMHSI than in the patients who did not display IMHSI. Hence, the corticospinal tract for the abductor pollicis brevis is considered to be more susceptible to causative lesions of IMHSI than the corticospinal tract for the biceps brachii and triceps...
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brachii muscles. This suggests that the corticospinal tract is damaged inhomogeneously at IMHSI sites. Therefore, it is difficult to diagnose the most affected level on the basis of motor dysfunction. Studies performed in 1929 and 1937 reported that spinal cord compression involving the upper cervical spine or the foramen magnum results in more severe functional disturbances in the upper extremities than in the lower extremities (Elsberg, 1929; Symonds and Meadows, 1937). Furthermore, Good et al. (1984) and Nakajima and Hirayama (1995) described the typical symptoms of CSM as numbness and reduced manual dexterity without functional disturbance of the lower extremities. Sonstein et al. (1996) observed atrophy of the intrinsic muscles of the hand in 13/25 patients with meningioma involving the foramen magnum. In addition, an experimental laceration of the pyramidal tract induced dysfunctions of the upper extremities, especially of the hand (Lawrence and Kuypers, 1968).

Central cord injuries were also found to demonstrate similar characteristic symptoms, i.e. the upper extremities were predominantly affected (Schneider et al., 1954).

As regards the question of why the corticospinal tract for the upper extremities is more vulnerable than that for the lower extremities, the somatotopic organization hypothesis states that the corticospinal tract for the hand muscles is nearer to the center of the spinal cord than the portions of the corticospinal tract for other muscles. However, Levi et al. (1996) pointed out that there is little anatomical evidence to support this hypothesis. The descending fibers for the innervation of the hand and arm are considered to be relatively common in the corticospinal tract, and a high proportion of the large fibers in the corticospinal tract are considered to innervate the anterior horn cells responsible for the hand muscles (Bortoff and Strick, 1993; Davidoff, 1990; Courtoine et al., 2007). The electrophysiological measurements obtained in the current study support these findings, which explain why hand function might be valuable in indicating the severity of myelopathy. TMS of the hand motor cortex is useful for the evaluation of cervical myelopathy.

References


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