# Motor conduction measurement in myelopathy hand

**Ryoichi Shibuya, MD**[a]
**Eiji Wada, MD, PhD**[b]
**Motoki Iwasaki, MD, PhD**[c]
**Kazuo Yonenobu, MD, PhD**[d]
**Hideki Yoshikawa, MD, PhD**[c]

[a] Department of Orthopedic Surgery, Kyoritu Hospital, Kawanisi, Japan
[b] Department of Orthopedic Surgery, Ehime Prefectural Central Hospital, Matsuyama, Japan
[c] Department of Orthopedic Surgery, Osaka University Medical School, Suita, Japan
[d] Department of Orthopedic Surgery, National Osaka-Minami Hospital, Kawachinagano, Japan

Correspondence to: Ryoichi Shibuya
E-mail: shibuyar1@yahoo.co.jp

## 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 = (the onset latency of M-waves + the onset latency of F-waves - 1)/2.

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 = (the onset latency of the tendon reflex)/2

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 (Statview 4.5J) was used to evaluate the significance between the values and the simple regression model (Stadview 4.5J) was used to analyze to 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).

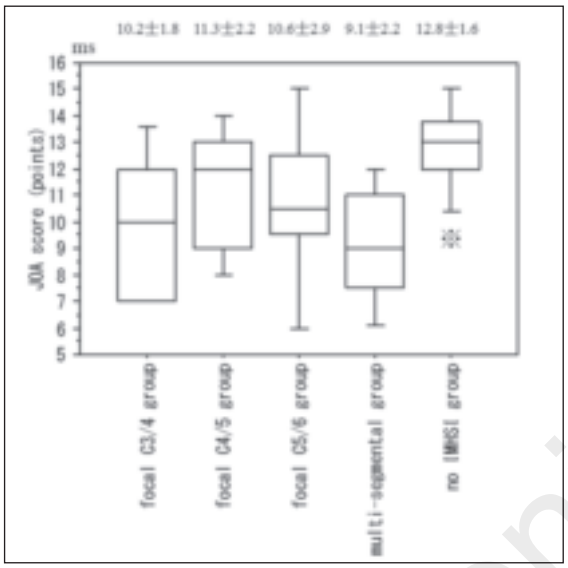


Figure 1 - The JOA scores of each group.
Only the JOA score of the no IMHSI group was significantly ($p<0.05$) shorter than those of the other groups. There was no significant difference between the JOA scores of the IMHSI-positive groups.

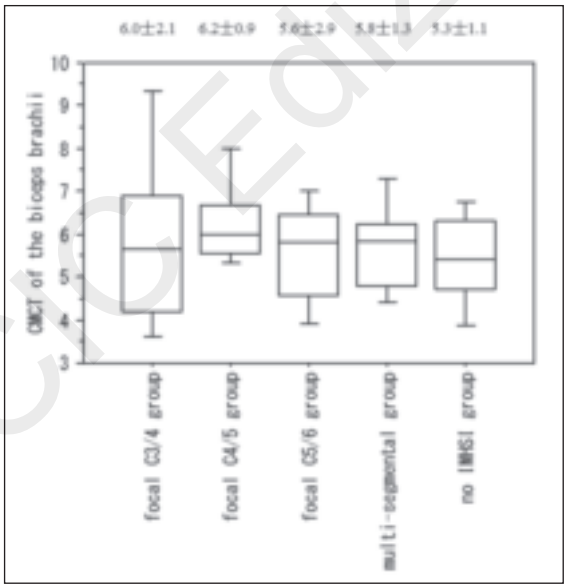


Figure 2 - The CMCT of the biceps brachii muscle in each group.
There was no significant difference between the biceps brachii muscle CMCT of the focal C3/4, focal C4/5, focal C5/6, multi-segmental, and no IMHSI groups.

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).

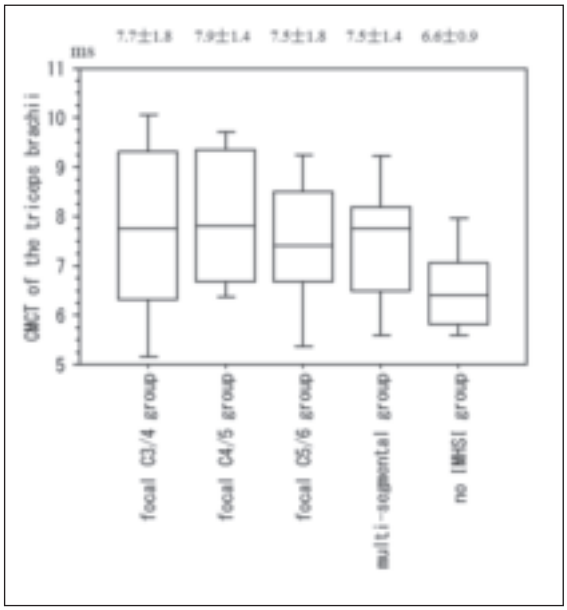


Figure 3 - The CMCT of the triceps brachii muscle in each group.
There was no significant difference between the triceps brachii muscle CMCT of the focal C3/4, focal C4/5, focal C5/6, multi-segmental, and no IMHSI groups.

## 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 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 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

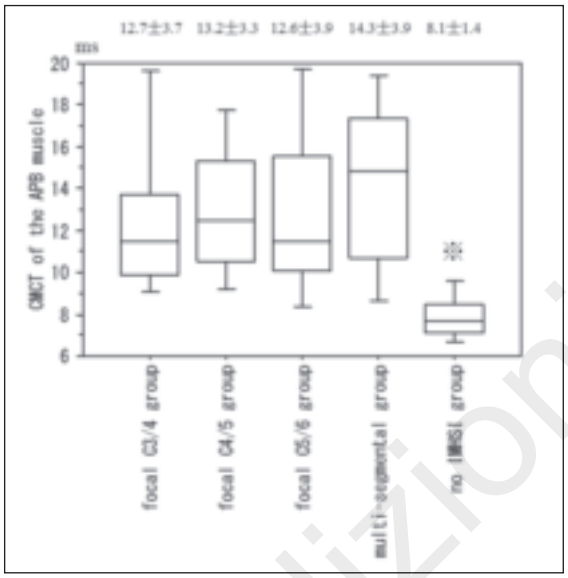


Figure 4 - The CMCT of the APB muscle in each group.
The abductor pollicis brevis (APB) muscle CMCT of the no IMHSI group was significantly shorter than those of the focal C3/4, C4/5, C5/6, and multi-segmental groups. There was no significant difference in the APB CMCT between the focal C3/4, C4/5, C5/6, and multi-segmental groups.

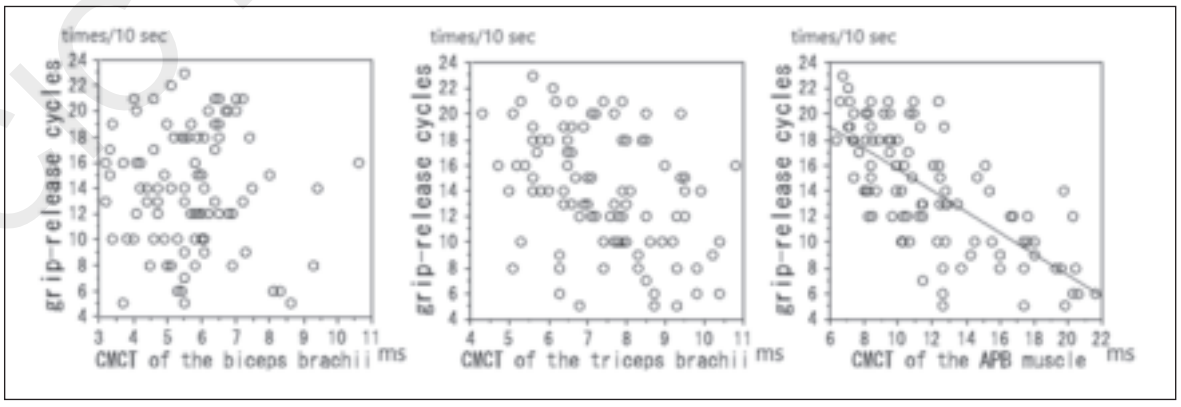


Figure 5 - The relationships between the CMCTs and the number of grip-release cycles performed within 10 seconds.
The CMCT of the biceps brachii muscle and triceps brachii muscle did not exhibit any relationship with the JOA score, whereas that of the abductor pollicis brevis muscle displayed a strong relationship with the JOA score (r=-0.70, p<0.0001).

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; Courtine 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


Barker AT, Jalinous R, Freeston IL (1985). Non-invasive magnetic stimulation of the human motor cortex. Lancet 1: 1106-1107.

Bortoff GA, Strick PL (1993). Corticospinal terminations in two new-world primates: further evidence that corticomotoneuronal connections provide part of the neural substrate for manual dexterity. J Neurosci 13: 5105-5118.

Courtine G, Bunge MB, Fawcett JW, et al (2007). Can experiments in nonhuman primates expedite the translation of treatments for spinal cord injury in humans? Nat Med 13: 561-566.

Davidoff RA (1990). The pyramidal tract. Neurology 40: 332-339.

Di Lazzaro V, Restuccia D, Colosimo C, et al (1992). The contribution of magnetic stimulation of the motor cortex to the diagnosis of cervical spondylotic myelopathy. Correlation of central motor conduction to distal and proximal upper limb muscles with clinical and MRI findings. Electroencephalogr Clin Neurophysiol 85: 311-320.

Doita M, Sakai H, Harada T, et al (2006). Evaluation of impairment of hand function in patients with cervical myelopathy. J Spinal Disord Tech 19: 276-280.

Elsberg CA (1929). Tumors of the spinal cord: Problems in their diagnosis and localization: Procedures for their exposure and removal. Arch Neurol Psychiatry 22:949-965.

Good DC, Couch JR, Wacaser L (1984) "Numb, clumsy hands" and high cervical spondylosis. Surg Neurol 22: 285-291.

Hess CW, Mills KR, Murray NMF (1986) Measurement of central motor conduction in multiple sclerosis by magnetic brain stimulation. Lancet 2; 355-358.

Kimura J (1983). Electrodiagnosis in Diseases of Nerve and Muscle: Principles and Practice. Philadelphia, Davis.

Lawrence DG, Kuypers HG (1968). The functional organization of the motor system in the monkey. I. The effects of bilateral pyramidal lesions. Brain 91:1-14.

Levi AD, Tator CH, Bunge RP (1996). Clinical syndromes associated with disproportionarte weakness of the upper versus the lower extremities after cervical spinal cord injury. Neurosurgery 38: 179-185.

Lo YL, Chan LL, Lin W, et al (2004). Systematic correlation of transcranial magnetic stimulation and magnetic resonance imaging in cervical spondylotic myelopathy. Spine (Phila Pa 1976) 29: 1137-1145.

Lyu RK, Tang LM, Chen CJ, et al (2004). 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 75: 256-261.

Matsuda Y, Miyazaki K, Tada K, et al (1991). Increased MR signal intensity due to cervical myelopathy; analysis of 29 surgical cases. J Neurosurg (74): 887-892.

Matsumoto M, Ishikawa M, Ishii K, et al (2005). Usefulness of neurological examination for diagnosis of the affected level in patients with cervical compressive myelopathy: prospective comparative study with radiological evaluation. J Neurosurg Spine 2: 535-539.

Nakajima M, Hirayama K (1995). Midcervical central cord syndrome: numb and clumsy hands due midline cervical disc protrusion at the C3-4 intervertebral level. J Neurol Neurosurg Psychiatry 58: 607-613.

Ono K, Ebara S, Fuji T, et al (1987). Myelopathy hand. New clinical signs of cervical cord damage. J Bone Joint Surg Br 69: 215-219.

Quencer RM, Bunge RP, Egnor M, et al (1992). Acute traumatic central cord syndrome: MRI-pathological correlations. Neuroradiology 34: 85-94.

Schneider RC, Cherry G, Pantek H (1954). The syndrome of acute central cervical spinal cord injury; with special reference to the mechanisms involved in hyperextension injuries of cervical spine. J Neurosurg 11: 546-577.

Sonstein WJ, LaSala PA, Michelsen WJ, et al (1996). False localizing signs in upper cervical spinal cord compression. Neurosurgery 38:445-448.

Symonds CP, Meadows SP (1937). Compression of the spinal cord in the neighborhood of the foramen magnum. Brain 60: 52-84.

Takahashi M, Sakamoto Y, Miyawaki M, et al (1987). Increased MR signal intensity secondary to chronic cervical cord compression. Neuroradiology 29:550-556.

Tani T, Kida K, Yamamoto H, et al (1991). Reflex in various human muscles during voluntary activity. In: Shimoji K, Kimura J, Tamaki T, Willis Jr, WD (Eds) Spinal Cord Monitoring and Electrodiagnosis. Berlin, Heidelberg, Springer-Verlag, pp 226-236.

Tavy DL, Wagner GL, Keunen RW, et al (1994). Transcranial magnetic stimulation in patients with cervical spondylotic myelopathy: clinical and radiological correlations. Muscle Nerve 17:235-241.

Wada E, Yonenobu K, Suzuki S, et al (1999). Can intramedullary signal change on magnetic resonance imaging predict surgical outcome in cervical spondylotic myelopathy. Spine (Phila Pa 1976) 24: 455-462.

Yone K, Sakou T, Yanase M, et al (1992). Preoperative and postoperative magnetic resonance image evaluations of the spinal cord in cervical myelopathy. Spine (Phila Pa 1976) 17 (10 Suppl): S388-392.