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Clinical Study

Increased spinal cord movements in cervical spondylotic myelopathy

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Abstract

BACKGROUND CONTEXT: Magnetic resonance imaging (MRI) is a very useful diagnostic test for cervical spondylotic myelopathy (CSM) because it can identify degenerative changes within the spinal cord (SC), disclose the extent, localization, and the kind of SC compression, and help rule out other SC disorders. However, the relationships between changes in cerebrospinal fluid (CSF) flow, cord motion, the extent and severity of spinal canal stenosis, and the development of CSM symptoms are not well understood.

PURPOSE: To evaluate if changes in the velocity of CSF and SC movements provide additional insight into the pathophysiological mechanisms underlying CSM beyond MRI observations of cord compression.

STUDY DESIGN: Prospective radiologic study of recruited patients.

PATIENT SAMPLE: Thirteen CSM subjects and 15 age and gender matched controls.

OUTCOME MEASURES: Magnetic resonance imaging measures included CSF and SC movement. Cervical cord condition was assessed by the Japanese Orthopaedic Association (JOA) score, compression ratio (CR), and somatosensory evoked potentials (SSEPs) of the tibial and ulnar nerves.

METHODS: Phase-contrast imaging at the level of stenosis for patients and at C5 for controls and T_2-weighted images were compared with clinical findings.

RESULTS: Cerebrospinal fluid velocity was significantly reduced in CSM subjects as compared with controls and was related to cord CR. Changes in CSF velocity and cord compression were not correlated with clinical measures (JOA scores, SSEP) or the presence of T_2 hyperintensities. Spinal cord movements, that is, cord displacement and velocity in the craniocaudal axis, were increased in CSM patients. Increased SC movements (ie, total cord displacement) both in the controls and CSM subjects were associated with altered spinal conduction as assessed by SSEP.

CONCLUSIONS: This study revealed rather unexpected increased cord movements in the craniocaudal axis in CSM patients that may contribute to myelopathic deteriorations in combination with spinal canal compression. Understanding the relevance of cord movements with

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respect to supporting the clinical CSM diagnosis or disease monitoring requires further long-term follow-up studies.

Keywords: Magnetic resonance imaging; Phase contrast; Somatosensory evoked potentials; Cervical spondylotic myelopathy; Spinal cord movement; Stenosis

Introduction

Cervical spondylotic myelopathy (CSM) is the leading cause of spinal cord (SC) dysfunction in people older than 55 years in North America, with the most common level of abnormality at C5–C6 [1,2]. Diagnosis of CSM is primarily based on clinical symptoms that can include clumsy hands and numbness of feet, increased reflexes, and gait disturbance. Magnetic resonance imaging (MRI) is the most useful diagnostic imaging test for CSM because it can confirm degenerative changes within the SC, disclose the extent, localization, and kind of SC compression, and help rule out other SC disorders (eg, tumors, syringomyelia, or cord malformation). In CSM, cord damage is typically associated with a narrowing of the spinal canal, called stenosis, which can also alter the flow of cerebrospinal fluid (CSF) through the canal [3,4]. The area of stenosis is often characterized by T_2 hyperintensities on conventional MRI [5]. However, the relationships between changes in CSF flow, cord motion, the extent and severity of spinal canal stenosis, and the development of CSM symptoms are not well understood.

Previous studies of CSF flow using cine phase-contrast MRI with cardiac gating show a pulsatile motion in the cranial to caudal direction synchronized to the blood pulse flow [6]. The amplitude of the pulsatile CSF flow has been found to be correlated with the severity of the myelopathy [4,7], with flow amplitude decreasing because of stenosis.

Spinal cord motion has been first reported in the 1980s using intraoperative ultrasonography, where in some cases SC motion was rated as increased in subjects with SC compression [8], while studies of cord motion in controls could not be performed. The development of phase imaging for measuring motion with MRI allowed SC motion to be characterized in healthy controls [9,10]. Shortly after cardiac systole, the SC is reported to initially move in a caudal direction and then recover in the cranial direction [9,10]. The maximum velocity of the SC was found to range from 7 to 13 mm/s, but differed between individuals. Previous measurements of maximal cord displacement in healthy controls showed values ranging from 0.22 [11] to 0.5 mm [10].

Complementary to clinical testing, recordings of somatosensory evoked potentials (SSEPs) are highly sensitive in the diagnosis of SC disorders and provide measures of cord function, that is, conductivity within dorsal columns that cannot be determined by clinical means [12]. Specifically in disorders that frequently present changes in sensory function (such as numbness or paraesthesia), objective measures of sensory function independent of patient rating can be of value in the appreciation of neurologic impairment [13].

The purpose of this study was to compare velocity patterns of CSF and cord movements between CSM subjects and controls. It was hypothesized that degenerative changes of the cervical spine with increased spinal canal stenosis will not only compromise CSF flow but will also affect cord movements, whereas the interaction between these changes and how they relate to the development of CSM might be less predictable.

Materials and methods

Subjects

Thirteen subjects (mean age, 62 years, range 50–77 years) with diagnosed CSM and 15 age and gender matched controls (mean age, 58 years, range 50–73 years) were recruited. Both groups underwent MRI and electrophysiological and clinical evaluations. The examinations of Japanese Orthopaedic Association (JOA), stenosis grading, and SSEP were performed by independent examiners that were blinded to the results in other domains. Written informed consent was obtained with approval from the Clinical Research Ethics Board of our institution.

Magnetic resonance imaging and analysis

Magnetic resonance imaging scans were performed with a phased array spine coil, using only the first four coil elements in the vicinity of the cervical spine, on a Philips 3.0T Achieva system (Philips Healthcare, Best, The Netherlands). All subjects were scanned with a localizer and sagittal T_2-weighted imaging (T_2WI) sequence (repetition time (TR)/echo time (TE)=3,314/120 ms, 11 3 mm thick slices) to orient axial slices perpendicular to the SC, as illustrated in Fig. 1; an additional axial higher resolution T_2WI sequence (TR/TE=1,500/12 ms, field of view (FOV) $150\times112\times67$ mm^3, reconstructed matrix $336\times250\times12$) was acquired for improved grey and white matter contrast and to identify any T_2 hyperintense regions. Velocity imaging was performed using a three-dimensional phase contrast sequence, retrospectively gated to the peripheral pulse (TR/TE=13/8.6 ms, flip angle=10°, two averages, FOV $140\times140\times25$ mm^3, partial parallel imaging acceleration factor=2, reconstructed matrix $256\times256\times5$, velocity encoding parameter=5 cm/s in the craniocaudal direction). The single five slice stack was oriented perpendicular to the SC at the level of the stenosis for CSM subjects and at the C5 level for controls. If a subject had more than one stenosis within the cervical spine then the stack was centered on the stenosis closest to C5.

Phase images are defined in the interval between 0 and 2π. Quantities that influence the phase of the MRI signal, such as flow or magnetic susceptibility, are mapped into this