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Kinetic change of spinal cord compression on flexion-extension magnetic resonance imaging in cervical spine

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ABSTRACT

Objective: We aimed to determine the changes in cervical canal diameters and spinal cord compression at each level from C2-3 to C7-T1 in flexion and extension positions and to study the use of flexion-extension magnetic resonance imaging (MRI). We also aimed to assess the changes in the length of the spinal cord in flexion and extension positions of the cervical spine.

Patients and methods: Flexion-extension MRI scans were performed consecutively on sixty-six patients with neck pain with/without neurogenic symptoms of the cervical spine. All patients were treated conservatively. We investigated the length of the cervical spinal cord (LSC), length of the cervical spinal anterior column (LAC), length of the cervical spinal posterior column (LPC), spinal canal diameter, and severity of cord compression in flexion, neutral, and extension positions.

Results: At each intervertebral level (from C2-3 to C7-T1), the average spinal canal diameter showed significant decrease from flexion to extension positions ($P < 0.05$). The average LSC, LAC, and LPC were decreased on extension of the neck compared with flexion ($P < 0.05$). Higher stages were found in extension position than in flexion position with statistically significant differences ($P < 0.05$).

Conclusion: The use of flexion-extension MRI may demonstrate true pathology that contributes in the pathogenesis of cervical degenerative disease (CDD). Higher stages in spinal cord compression were found in extension position than in flexion position. However, higher stages in spinal cord compression in extension position did not necessarily cause severe myelopathy. This finding is an important evidence for conservative therapy on patient neck position education.

1. Introduction

Magnetic resonance imaging (MRI) has largely replaced computerized tomography-myelography as the standard investigation for cervical degenerative disease (CDD) [1]. The cervical spine has normally the greatest sagittal motion within the total spine, and its dynamic factors sometimes cause cervical spondylotic myelopathy in elderly persons [2,3] and overstretching myelopathy in juvenile persons [4,5]. Conventional MRI is acquired with patients lying supine with the neck in a position of comfort, which may not represent the neck motion of day to day physiology. Hence, clinical findings of cervical myelopathy may often not correlate with the cervical MRI findings. Cervical spine MRI with the neck in extension has been well described over the last decade but its clinical value remains unknown [1]. MRI in flexion and extension positions can be considered when a clinical suspicion is present where conventional MRI would be equivocal. Moreover, when the compression is at multiple levels, flexion-extension MRI may help to identify and decide the exact level of pathology and the management plan and it may supply a more thorough investigation of each patient and allow us to better understand the true nature of the pathology. In the present study, we hypothesized that a significant change occurs in compression of the cervical cord on flexion and extension of the cervical spine at sub-axial level causing cord changes and symptoms. In this study, we aimed to determine the changes in the length of cervical canal stenosis at each level from C2-3 to C7-T1 in flexion and extension positions and to study the use of flexion-extension MRI for evaluation of spinal cord compression. We also aimed to assess the changes in the length of the spinal cord in flexion and extension positions of the cervical spine.

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2. Materials and methods

2.1. Patient data

Flexion-extension MRI scans were performed consecutively on sixty-six patients with neck pain with/without mild neurogenic symptoms (radiating pain to upper limb, tingling sensation of upper limb, numbness, decreased sensation of cervical dermatomes) and no muscle weakness and no deep tendon hyperreflexia from December 2014 to December 2016. There were 41 males and 25 females. The mean age of the participants was 52.9 years (range, 24–84 years). All patients were performed conventional neutral MRI previously, however it could not reveal the origin of the symptoms, therefore flexion-extension MRI scans were performed. All patients were treated conservatively. Patients with recent trauma, rheumatoid arthritis, ossification of the posterior longitudinal ligament, infectious spondylitis, spinal tumors, prior cervical fractures or dislocations, or prior cervical spine surgery were excluded from this study. Participants with severe neck pain who were expected to aggravate their symptoms by moving their neck or who were unable to remain still during flexion-extension MRI scans were also excluded from this study.

2.2. MRI positioning and technique

Participants were positioned with their chins angled toward their chests till they are comfortable and placed a pillow below their head. This position was used to obtain flexion images. Next, the participants were positioned with their chins angled toward the ceiling till they are comfortable and placed a pillow under their shoulder. This position was used to obtain extension images. Thus, angles were not the same for all the patients. For each of these positions, cervical coil was placed around the participants' necks, and the back of their heads and necks was supported and kept in place.

All MRI scans were performed at 1.5 T unit (Magnetom Avanto; Siemens, Germany). The sequence included sagittal T1 spin echo, T2 fast spin echo, and STIR fat-suppressed echo sequence with a maximum slice thickness of 3 mm. We examined the T1-weighted sagittal spin echo images [repetition time, 671 ms; echo time, 17 ms; thickness, 3.0 mm; field of view, 24 cm; matrix, 256_200; and number of excitations (NEX), 2] and T2-weighted sagittal fast spin echo images (repetition time, 3432 ms; echo time, 160 ms; thickness, 3.0 mm; field of view, 24 cm; matrix, 256_224; and NEX, 2) of each patient.

2.3. Image analysis

All radiologic MRI data were recorded using computer-based measurements, which were all performed with Picture Archiving and Communication System software. Sagittal MR images were analyzed in flexion, neutral, and extension positions. We evaluated a total of 396 levels for cervical stenosis in flexion, neutral, and extension positions from C2-C3 to C7-T1 levels for 66 patients.

The average sagittal diameter of the cervical spinal canal was defined as the average of the sagittal canal diameters at the intervertebral disc level from C2-3 to C7-T1. It was measured as the shortest distance from the posterior disc bulging to the anterior ligamentum flavum buckling at the intervertebral disc level (Fig. 1).

The length of the spinal cord (LSC) was defined as the length between a line at the caudal side of the pons and the continuation of the line at the lower endplate of C7. The length of the cervical spinal anterior column (LAC) was defined as the length between the tip of the dens and the lower endplate of the C7 vertebra. Similarly, the length of the cervical spinal posterior column (LPC) was defined as the length between the upper border of the C1 posterior arch and the lower end of the C7 lamina (Fig. 2) [5].

The grade and severity of spinal cord compression in flexion and extension were classified according to the grading system of Muhle et al. [7] (Table 1) from C2-3 intervertebral discs to C7-T1 intervertebral discs. Cervical cord compression was defined as the obliteration of the subarachnoid space resulting from compression due to disc herniation, osteophyte formation, or hypertrophy of the ligamentum flavum. Cervical cord compression at each segment was evaluated using a 4-point scale (range 0–3). A score of 0 indicated normal width of the spinal canal and no signs of anterior and posterior subarachnoid space narrowing; a score of 1, partial obliteration of the anterior or posterior subarachnoid space or of both; a score of 2, complete obliteration of the anterior or posterior subarachnoid space or of both; and a score of 3, anterior or posterior cord impingement or both (pincer effect).

Two independent observers measured each parameter without knowing the patient's history and clinical findings. We investigated the reliability of the measurement techniques and observed good to excellent intra- and interobserver agreement for each parameter (kappa > 0.70).

2.4. Statistical analysis

Data are presented as the number of subjects in each group or mean ± SD. Each independent variable was compared between the groups using analysis of variance for continuous variables. Interobserver reliability was assessed by reporting both the observed agreement and by computing the Kappa statistic. The Kappa statistic corrects the observed agreement for possible chance agreement among the observers. We analyzed the mean of Muhle's grades at each level and at both flexion and extension positions. The stage of stenosis has been considered as a quantitative variable. The means of stages at each level and at each position were analyzed using analysis of variance and compared with each other with the Tukey test. We set the statistical significance at $P < 0.05$. We conducted all the analyses using SPSS 17.0 (IBM, Armonk, NY, USA).

3. Results

3.1. Cervical spinal canal diameter in neutral and extension positions

The results of the average spinal canal diameter are shown in Table 2. The average spinal canal diameter exhibited a significant decrease from flexion to extension position at each level ($P < 0.05$). The results were as follows: C2-3 (flexion 1.02 ± 0.19 *vs.* extension 0.96 ± 0.20 mm, $P < 0.05$), C3-4 (flexion 0.87 ± 0.21 *vs.* extension 0.72 ± 0.28 mm, $P < 0.05$), C4-5 (flexion 0.88 ± 0.18 *vs.* extension 0.65 ± 0.23 mm, $P < 0.05$), C5-6 (flexion 0.90 ± 0.19 *vs.* extension 0.67 ± 0.22 mm, $P < 0.05$), C6-7 (flexion 0.99 ± 0.19 *vs.* extension 0.78 ± 0.20 mm, $P < 0.05$), and C7-T1 (flexion 1.17 ± 0.16 *vs.* extension 1.07 ± 0.20 mm, $P < 0.05$).

3.2. LAC, LPC, and LSC in flexion, neutral, and extension positions

During flexion MRI, the average LAC, LPC, and LSC were 11.30 ± 1.00, 10.71 ± 0.95, and 13.93 ± 1.15 mm, respectively. Similarly, during extension position, the mean LAC, LPC, and LSC were 10.55 ± 0.83, 9.25 ± 0.88, and 12.93 ± 1.02 mm, respectively (Table 3). The average LAC, LPC, and LSC showed a significant decrease from flexion position to extension position at each level ($P < 0.05$).

3.3. Severity of cervical spinal cord compression in neutral and extension positions

Table 4 shows the distribution of Muhle's stages (0, 1, 2, and 3) in flexion, neutral, and extension positions in each intervertebral level. Overall, in flexion position, 46 levels had stage 2 grading and 17 levels had stage 3 grading. In extension position, 78 levels had stage 2 grading and 137 levels had stage 3 grading (Fig. 3). Stage 3 was found in the