의 학 석 사 학 위 논 문

Risk Factors for central canal stenosis in extension position on dynamic cervical spine Magnetic Resonance Imaging

동적 경부 척추 자기공명영상에서 신전 시에 유발되는 척추관 협착증의 위험요인

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이 은 채

Abstract

Risk Factors for central canal stenosis in extension position on dynamic cervical spine Magnetic Resonance Imaging

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Objective: To find risk factors associated with central canal stenosis in extension position on dynamic cervical spine magnetic resonance imaging (MRI).

Materials and methods: Of the 80 consecutive patients who underwent dynamic cervical spine MRI during the period from January 2009 to December 2010, 14 were excluded and 66 patients were analyzed. The MUS was defined as the disc level at which there was the greatest dynamic change in the spinal central canal in the flexion and extension positions. Basic imaging findings for the MUS were evaluated in the neutral position in terms of the presence of a herniated intervertebral disc (HIVD), severe disc height loss, ligamentum flavum (LF) buckling, osteophytes, posterior longitudinal ligament (PLL) thickening, facet joint hypertrophy, ankylosis or severe disc height loss at the level adjacent to the MUS, Modic-type endplate change, vertebral body dislocation, and cervical compressive myelopathy (CCM) .

Results: The MUS was most common at C5/6 in both total study and patients with extension-aggravation of the MUS. At the MUS, more than 30% of patients had HIVD, disc height loss, LF buckling, osteophytes, PLL thickening, Modic-type endplate change, retrolisthesis, and CCM. Among them, osteophytes were the most common finding (86.4%) followed by HIVD (48.5%) and disc height loss (48.5%). All MRI findings assessed on neutral images did not show a significant association with the presence of extension-aggravation of the MUS.

Conclusion: Osteophytes, HIVD, and disc height loss was the most significant risk factors for the MUS.

Keywords: central canal stenosis, dynamic cervical spine MRI

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Introduction

Cervical central canal stenosis is a degenerative disease caused by narrowing of the spinal canal with or without spinal cord compression [1]. Various conditions can cause central canal stenosis, such as the herniation of intervertebral discs, osteophytes, ossification of posterior longitudinal ligaments (OPLL), ligamentum flavum (LF) buckling, and facet joint degeneration [1-3]. It is also known that dynamic factors such as flexion or extension of the cervical spine can be associated with cervical central canal stenosis [4, 5]. Previous studies have shown the increased incidence or severity of spinal cord compression in the extension position upon magnetic resonance imaging (MRI) [6, 7]. Therefore, some pathologic findings can be underestimated using MRI in a neutral position, resulting in an insufficient correlation between imaging diagnosis and clinical symptoms.

It has been described by previous studies that dynamic factors such as cervical spinal motion reduces the diameter of spinal canal [8-10], so that neutral images have a limited role in determining the dynamic compressive level. If multi-level decompression surgery is scheduled for a patient with cervical spondylotic myelopathy, it is important to report all possible compressive levels in the surgical plan. If surgeons remain the dynamic compressive level untreated during decompression surgery, reoperation may be needed [11] or remaining untreated level can progress resulting insufficient relief of patient’s symptom after surgery. In this manner, preoperative dynamic (flexion/extension) cervical spine MRI can be helpful not to miss the possible presence of dynamic compressive level.

However, dynamic cervical spine MRI is not routinely performed for all symptomatic patients. If we know some MRI findings in the neutral position are associated with the aggravation of central canal stenosis in the flexion or extension position, we can decide which patients require additional dynamic cervical spine MRI before treatment. To the best of our knowledge, there has been no report describing the risk factors associated with an unstable segment, which potentially can be dynamic compressive level. Therefore, our study focused on basic MRI findings in the neutral position 1) which are associated with the most unstable segment (MUS) and 2) which lead to the aggravation of central canal stenosis in the extension position with conventional MR units that can allow a supine position.

Materials and Methods

Study population

The institutional review board approved this retrospective study and waived informed consent. Consecutive patients who underwent dynamic cervical spine MRI during the period from January 2009 to December 2010 were included in this study. Dynamic cervical spine MRI was requested by orthopedic surgeons or neurosurgeons. The indication for dynamic cervical spine MRI were: 1) patients being considered for decompression surgery for cervical compressive myelopathy, 2) patients with myelopathy symptoms and mild cord compression upon neutral MR, or 3) patients with aggravated myelopathy symptoms in the flexion or extension position. Of the 80 patients, we excluded 10 who had previously undergone cervical spine surgery, 3 who had trauma-related ligament injuries or cord contusions upon MRI, and 1 who had a tumor in the cervical spinal central canal. As a result, MR images of 66 patients (33 males and 33 females) with an average age of 59.65 ±11.86 years (range: 36–92 years) were included in the analysis.

MRI protocol

MRI was performed at 1.5 T (Gyroscan Intera; Philips, Best, the Netherlands) with a respiratory compensated (RC) Syn-head/neck coil and at 3.0 T (Achieva;

Philips, Best, the Netherlands) with an RC sensitivity encoding (SENSE)-neurovascular-16 coil or RC SENSE-spine coil.

T2-weighted sagittal images were obtained for the cervical spine in the neutral, flexion, and extension positions. Flexion and extension positions were maintained by positioning a foam wedge (30 degrees, Phillips) in the supine position (Figure 1). A T1-weighted turbo spin-echo (sagittal scan, 460-520/10 [repetition time msec/echo time msec] at 1.5 T and 420-550/8-9 at 3.0 T) and a T2-weighted turbo spin-echo (axial, sagittal-neutral, sagittal-flexion, sagittal-extension scan 3400-3500/120 at 1.5 T and 3000-5800/80-120 at 3.0 T) were routinely acquired. The axial images were obtained parallel to each disc level. Slice thickness was 2–3 mm and the field of view was 120 x 120–160 x 160 mm^2 for the axial scan and 230 x 230–250 x 250 mm^2 for the sagittal scan.

Image evaluation

All images were initially analyzed by a resident radiologist with three years of experience, who underwent a training session for two weeks with 25 cases of randomly selected cervical spine MRI under supervision of staff radiologist. During the actual image analysis, all ambiguous findings were assessed under consensus with a musculoskeletal staff radiologist (who had 10 years of experience). The following characteristics were evaluated on sagittal T2-weighted images in the neutral, flexion, and extension positions. Sagittal T1-weighted images and axial T2-weighted images were also used when additional information was needed.

Overall imaging findings in the neutral position

The main causative pathology for central canal narrowing was reviewed and categorized as follows: spondylosis, OPLL, herniated intervertebral disc (HIVD), or congenital segmental anomaly. Overall alignment was assessed using three categories (1, normal lordotic; 2, hyperlordotic; 3, kyphotic). Number of level of severe disc height loss was evaluated, which was defined as height loss of more than 50% of the normal disc height. A cervical compressive myelopathy (CCM) segment was defined as a segment with central narrowing and hyperintensity on T2WI in the spinal cord as previously described in other study [1]. We evaluated the presence of CCM (0, absent; 1, present), segments with the presence of CCM (C1/2, C2/3, C3/4, C4/5, C5/6, C6/7, C7/T1), and the number of CCM-positive segments.

Basic findings in most unstable segment (MUS)

A MUS was defined as a disc level showing the greatest dynamic change of the spinal central canal diameter in neutral/flexion/extension position on midline sagittal images (Figure 2). After determining the MUS, the following basic imaging findings at the MUS were evaluated in the neutral position: the presence of HIVD, the presence of severe disc height loss, the presence of LF buckling, the presence of osteophytes, the presence of posterior longitudinal ligament (PLL) thickening, the presence of facet joint hypertrophy, the presence of ankylosis or severe disc height loss at the level adjacent to the MUS, the presence of Modic-type endplate change, vertebral body dislocation, and changes in spinal cord signal intensity. Severe disc height loss was defined as height loss of more than 50% of the normal disc. Vertebral body displacement was evaluated using a three-point scale (0, normal; 1, spondylolisthesis; 2, retrolisthesis). The association between CCM level and the MUS was also analyzed.

Dynamic changes of the most unstable segment (MUS)

After reviewing neutral/flexion/extension midline sagittal images, the narrowest position and the widest position at the MUS of each patient were chosen. The narrowest position was defined as the position with the narrowest central canal in the MUS among neutral, flexion, and extension positions. The widest position was defined as the position with the widest central canal in the MUS among the neutral, flexion, and extension positions (i.e.: patient-No. 1; MUS-C4/5, narrowest position- flexion, widest position- extension).

Spinal cord indentation in the MUS was defined as a focal depressed or sunken lesion in the spinal cord by adjacent structures including HIVD, ligamentum flavum thickening and other pathologies. Spinal cord indentation was evaluated in the neutral, flexion, and extension images, using four categories (0, absent; 1, spinal cord indentation at anterior aspect only; 2, spinal cord indentation at posterior aspect only; 3, spinal cord indentation at both anterior and posterior aspect).

Flexion/extension change (aggravation, relief) of the MUS was defined when there was a change (aggravation, relief) in spinal cord indentation at the MUS on flexion/extension images compared with neutral images. The change was evaluated comparing the presence of indentation at anterior or posterior aspect of spinal canal (based on the change of categories of spinal cord indentation described above) on midline sagittal images in each position, and axial image was also used if necessary. If there was additional spinal cord indentation in extension than in neutral we considered it as presence of extension-aggravation (i.e.: neutral, 0 and extension, 1 or 2 or 3; neutral, 1 or 2 and extension,3). In this manner, flexion-aggravation, extension-aggravation, flexion-relief, and extension-relief of the MUS was determined (Figure 3). Extension-no-aggravation of the MUS was defined when there was no aggravation (no change or relief) in spinal cord indentation at the MUS on extension images compared with neutral images.

Association between extension-aggravation of the MUS and MRI findings on the neutral image

The association between the presence of extension-aggravation of the MUS and other variables such as age, gender, and the following MRI findings on the neutral image was analyzed: main pathology, overall alignment, the presence of OPLL, the presence of severe disc height loss, the presence of CCM, HIVD in the MUS, severe disc height loss in the MUS, LF buckling in the MUS, osteophytes in the MUS, PLL thickening, facet joint hypertrophy, severe ankylosis or severe disc height loss at the level adjacent to the MUS , Modic-type change in the MUS, vertebral body dislocation in the MUS (normal, anterolisthesis, retrolisthesis), spinal cord indentation in the MUS, and spinal cord signal change in the MUS. The association between the presence of extension-relief or flexion-relief was not analyzed because we only focused on aggravation rather than relief in flexion and extension position from neutral position. The association between the presence of flexion-aggravation of the MUS and MRI findings on the neutral image was not analyzed because the number of patients who showed flexion-aggravation of the MUS was too small.

Statistical analysis

A t-test, Pearson chi-square test, and generalized linear model analysis were used to verify the association or correlation between the presence of extension-aggravation of the MUS and other variables such as age, gender, and MRI findings on the neutral image. A p-value of less than 0.05 was considered a significant difference. Statistical analysis for calculations was performed using statistical software (SPSS 12.0, SPSS, Chicago, IL, USA).

Results

Overall imaging findings on neutral position

The most common causative pathologies for central canal narrowing in our study population (Table 1) were spondylosis (33 patients, 50.0%), followed by HIVD (24 patients, 37.9%) and other pathologies. Overall alignment was mainly kyphotic (40 patients, 60.6%), followed by normal lordotic and hyperlordotic curvature (Table 1). Many patients had severe disc height loss of more than one level (29 patients, 43.9%) (Table 1). CCM was found in 26 patients (39.4%, 16 males and 10 females) with 37 levels (Table 1). Of these 26 patients, most had a single level with CCM (65.4%), followed by two levels and three levels with CCM. CCM was most common at C3/4 (32.4%), followed by C4/5 (27.0%) and C5/6 (24.3%). Of the 26 patients with CCM, 24 (92.3%) had CCM in the MUS level (Table 1).

Basic findings on the MUS

Most patients had a MUS at C5/6 (25 patients, 37.9%) or C4/5 (24 patients, 36.4%) (Table 2). At the MUS, more than 30% of patients had HIVD, disc height loss, LF buckling, osteophytes, PLL thickening, Modic-type endplate change, normal alignment or retrolisthesis, and increased spinal cord signal intensity (Table 2). Of these, osteophytes were the most common finding (86.4%) followed by

HIVD (48.5%) and disc height loss (48.5%). Facet joint hypertrophy, ankylosis, and severe disc height loss at the level adjacent to the MUS were less common (less than 30%) at the MUS (Table 2).

Dynamic changes of the MUS

The position with the narrowest central canal in the MUS was extension (60 patients, 90.0%) and that with the widest central canal was flexion (60 patients, 90.9%) (Table 3).

Overall, the incidence of spinal cord indentation was lower on the flexion images (41 patients, 62.1%) than on the neutral images (52 patients, 78.8%) and was higher on the extension images (57 patients, 86.1%) than on the neutral images (Table 3). The incidence of anterior spinal cord indentation was lower on both flexion (40 patients, 69.6%) and extension images (43 patients, 65.2%) than on neutral images (50 patients, 75.8%) (Table 3). The incidence of posterior spinal cord indentation was lower on flexion images (5 patients, 7.5%) than on neutral images (14 patients, 21.2%) but was much higher on extension images (39 patients, 59.1%) than on neutral images (Table 3).

The flexion/extension change (aggravation/relief) in the MUS was mainly relieved on the flexion images (16 patients, 24.2%) and aggravated on the extension images (26 patients, 39.4%) (Table 3).

Association between extension-aggravation of the MUS and MRI findings in the neutral image

Twenty-six patients (39.4%) had extension-aggravation of the MUS and 40 patients (65.2%) had extension-no-aggravation of the MUS; there were 26 patients with aggravation, 39 patients with no change and 1 patient with relief on extension image from neutral image (Table 3). For the patients with extension-aggravation, the MUS was C4/5 (10/26, 38.5%) and C5/6 (10/26, 38.5%). There was no association between age, gender, and the presence of extension-aggravation of the MUS (p=.279, p=.401). All MRI findings assessed on the neutral image including osteophytes and HIVD did not show significant association with the presence of extension-aggravation of the MUS (Table 4).

Discussion

In our study, the result of flexion/extension change (aggravation/relief) on the MUS was mainly relieved on flexion images and aggravated on extension images (Table 3). The MUS was most common at C5/6 in both 1) total study population (25 of 66 patients, 37.9%) and 2) patients with extension-aggravation of the MUS (12 of 26 patients, 46.1 %). At the level of the MUS on neutral images, osteophytes were the most common finding (86.4%) followed by HIVD (48.5%) and disc height loss (48.5%). LF buckling, PLL thickening, Modic type endplate change, and CCM was also common (over than 30%), whereas facet joint hypertrophy, ankylosis, and severe disc height loss at the level adjacent to the MUS belong to least common findings (less than 30%) among all variables (Table 2). All MRI findings assessed on neutral images did not show a significant association with the presence of extension-aggravation of the MUS (Table 4).

As there was no significant association between the presence of extension-aggravation of the MUS and MRI findings on neutral images in our study, we could not suggest definite risk factors for dynamic stenosis. It has been previously reported that greater disc bulge, more severe disc degeneration, greater angular motion, segmental kyphosis, and developmental stenosis were significant risk factors for dynamic stenosis [12]. The inconsistent results between previous study and our study may be due to the differences in study design; both studies assessed central canal stenosis based on spinal cord indentation, but previous study focused on missed central canal stenosis by excluding patients who have central canal stenosis on neutral images [12], whereas our study focused on aggravation on extension from neutral image, regardless of presence of central canal stenosis on neutral image.

It has been reported in previous study that spinal central canal stenosis on neutral position and missed dynamic stenosis in both extension and flexion positions was most frequent at C5/6 [12], and this is consistent with the results of our study.

Hayashi et al [12] reported that the incidence rates of missed dynamic stenosis in extension and flexion were 16.1% and 3.7%, respectively. Muhle et al [8] reported that the incidence of cord impingement significantly increase on extension and flexion than neutral image using kinematic MRI; 27% (22 of 81 patients) increase on extension and 5% (4 of 81 patients) increase on flexion images. Zhang et al [13] reported functional cord impingement in 37 of 50 (74%) in extension and in 6 of 50 patients (12%) in flexion. Our study used conventional MRI with flexion and extension positions, and the incidence of extension-aggravation of the MUS was 39.4% (26 of 66 patients) and that of flexion-aggravation of the MUS was 6.1% (4 of 66 patients) (Table 3). The inconsistent results among these studies may be due to the differences in study design including the analysis object such as patients versus segments versus clinical symptoms of the study group.

In our study, of the 26 patients with CCM, 24 (92.3%) had CCM in the MUS level, meaning the MUS is strongly prone to have central canal stenosis than other segments of cervical spine. In symptomatic patients without cervical myelopathy in neutral image, the MUS can be potential segments of dynamic stenosis. Reviewing results of previous studies and our study, the main cervical level of concern of stenosis is C5/6, and the main position of concern is extension on which central canal stenosis becomes aggravated most commonly. Our study show increased incidence of the MUS with several MRI findings including osteophytes, HIVD, and disc height loss, and these findings can be called as risk factors for the MUS. So, suppose a patient have clinically symptomatic corresponding to C5/6 level myelopathy and MR finding in neutral image. The neutral MRI show several risk factors for the MUS at C5/6 without definite CCM. The combination of MRI finding and clinical situation might suggest presence of possible hidden dynamic stenosis. So if patient have 1) myelopathy symptom corresponding to C5/6 level, 2) without definite compressive myelopathy on neutral image, and 3) MRI findings show findings of risk factors for the MUS such as osteophyte, HIVD or disc height loss at the C5/6 level, then additional dynamic cervical spine MRI might be useful to find out explainable spinal cord compression on extension image. Further study may be needed to find out definite risk factors for dynamic aggravation of stenosis which can be a powerful predictor and is useful to decide whether to perform additional cervical dynamic MRI or not.

When analyzing dynamic findings for the MUS in our study (Table 3), the incidence of anterior spinal cord indentation was lower in the extension position than in the neutral position. On the other hand, the incidence of posterior spinal cord indentation was higher in the extension position than in the neutral position and this was consistent with previous study [8]. Therefore, explaining the cause of highest incidence of central canal narrowing in the MUS in the extension position rather than in the neutral and flexion position (Table 3), it is posterior structures such as LF buckling and facet joint hypertrophy rather than anterior structures such as disc herniation, osteophytes, and PLL thickening that mainly contribute to the extension-aggravation of the MUS. So further study in the future may have to consider that the posterior structures may have important role inducing dynamic stenosis and can be risk factors for dynamic stenosis.

Our study has several limitations. First, our study was a retrospective study done at a single-center tertiary hospital, so there may have been a selection bias in the patient population. Second, the sample size was relatively small. Third, the study population included patients who already underwent cervical dynamic MRI, so there may have been a selection bias in the patient population again. However, in a usual clinical setting, it is difficult to obtain cervical dynamic MR imaging for asymptomatic normal patients. Fourth, the correlation between symptoms and spinal cord indentation was not reported in previous studies, so it is not clear whether the symptoms of patients who had spinal cord indentation without cervical compressive myelopathy actually originated from cervical central canal stenosis.

In summary, osteophytes, HIVD, and disc height loss was the most significant risk factors for the MUS, although all MRI findings assessed on neutral images did not show a significant association with the presence of extension-aggravation of the MUS. The MUS was most common at C5/6 in both total study population and patient group with presence of extension-aggravation of the MUS.

Tables

Table 1. Overall imaging findings in the neutral position

Total 66 patients		Number of patients (%)
Main causative pathologies	**Spondylosis**	**33 (50.0%)**
	HIVD*	**24 (37.9%)**
	OPLL*	6 (9.1%)
	Congenital anomaly	1 (1.5%)
Overall alignment	Normal lordotic	24 (36.4%),
	Hyperlordotic	2 (3.0%)
	Kyphotic	**40 (60.6%).**
Severe disc height loss	Absent	37 (56.1%)
	Present	**29 (43.9%)**
	One level	15 (22.7%),
	Two level	9 (13.6%)
	Three level	5 (7.5%).
CCM*: total 26 patients, 37 segments		**Number of patients (%)**
Number of level of CCM	**One level**	**17/26 (65.4%)**
	Two level	7 /26 (26.9%)
	Three level	2 /26 (7.7%)
Level of CCM	C1/2	1/37 (2.7%)
	C2/3	3/37 (8.1%)
	C3/4	**12/37 (32.4%)**
	C4/5	**10/37 (27.0%)**
	C5/6	**9/37 (24.3%)**
	C6/7	2/37 (5.4%)
Consistency of CCM* with the MUS*	C1/2	0/1 (0%)
	C2/3	2/3 (66.7%)
	C3/4	7/12 (58.3%)
	C4/5	7/10 (70%)
	C5/6	6/9 (66.7%)
	C6/7	2/2 (100%)
	Total	**24/26 (92.3%) patients 24/37 (76.9%)segments**

*HIVD = herniated intervertebral disc, OPLL = ossification of posterior longitudinal ligament, CCM = cervical compressive myelopathy, MUS = most unstable segment

Table 2. Basic findings in the neutral position in the MUS

Total 66 patients		
Basic findings in the neutral position		**Number of patients (%)**
Level	C1/2	2 (3.0%)
	C2/3	3 (4.5%)
	C3/4	9 (13.6%)
	C4/5	**24 (36.4%)**
	C5/6	**25 (37.9%)**
	C6/7	3 (4.5%)
HIVD*	**present**	**32 (48.5%)**
Disc height loss	**present**	**32 (48.5%)**
LF* buckling	**present**	**23 (34.8%)**
Osteophytes	**present**	**57 (86.4%)**
PLL* thickening	**present**	**23 (34.8%)**
Facet joint hypertrophy	present	10 (15.2%)
Ankyloses or severe disc height loss at adjacent level of the MUS*	present	14 (21.2%)
Modic type endplate change	**present**	**21 (31.8%)**
Alignment	**normal**	**43 (65.2%)**
	anterolisthesis	2 (3.0%)
	retrolisthesis	**21 (31.8%)**
CCM*	**present**	**23 (34.8%)**

* HIVD = herniation of intervertebral disc), LF = ligamentum flavum, PLL = posterior longitudinal ligament, MUS = most unstable segment, CCM = cervical compressive myelopathy.

Table 3. **Dynamic findings in the MUS**

Total 66 patients			
Narrowest/widest position			
	Neutral	**Flexion**	**Extension**
Narrowest position	5 (7.6%)	1 (1.5%)	**60 (90.9%)**
Widest position	4 (6.1%)	**60 (90.9%)**	2 (3.0%)
Spinal cord indentation			
	Neutral	Flexion	Extension
Absent	14 (21.2%)	25 (37.9%)	9 (13.6%)
Present	**52 (78.8%)**	**41 (62.1%)**	**57 (86.1%)**
Anterior only	38 (57.6%)	36 (54.5%)	18 (27.3%)
Posterior only	2 (3.0%)	1 (1.5%)	4 (6.1%)
Both	12 (18.2%)	4 (6.1%)	35 (53.0%)
Total anterior	**50 (75.8%)**	**40 (69.6%)**	**43 (65.2%)**
Total posterior	**14 (21.2%)**	**5 (7.5%)**	**39 (59.1%)**
Meaningful change of spinal cord indentation from neutral image			
	Neutral	**Flexion**	**Extension**
No change	-	46 (69.7%)	39 (59.1%)
Changed	-	20 (30.3%)	27 (40.9%)
Aggravated	-	4 (6.1%)	**26 (39.4%)**
Relieved	-	**16 (24.2%)**	1 (1.5%)

* MUS = most unstable segment

Table 4. Association between extension-aggravation of the MUS and MRI findings in the neutral image

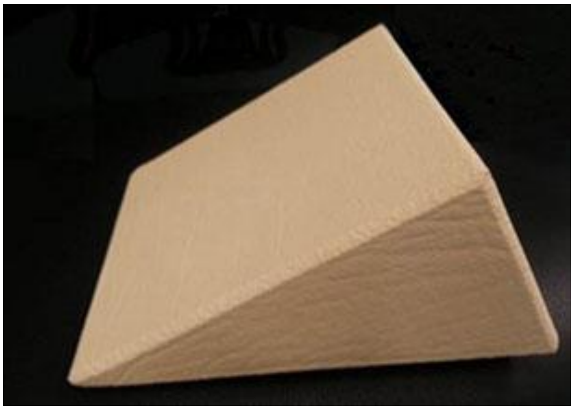
Findings in the neutral image		Meaningful aggravation at the MUS (total 66 patients) Negative (40 patients)	Positive (26 patients)	p-value
Spondylosis as main pathology	Absent	19 (47.5%)	14 (53.8%)	.401
	Present	21 (52.5%)	12 (46.2%)	
HIVD as main pathology	Absent	27 (67.5%)	14 (53.8%)	.258
	Present	13 (32.5%)	12 (46.2%)	
Kyphotic overall alignment	Absent	16 (40.0%)	10 (38.5%)	.554
	Present	24 (60.0%)	16 (61.5%)	
Presence of OPLL	Absent	36 (90.0%)	24 (92.3%)	.557
	Present	4 (10.0%)	2 (7.7%)	
Presence of severe disc height loss	Absent	25 (62.5%)	12 (46.2%)	.146
	Present	15 (37.5%)	14 (53.8%)	
Presence of CCM	Absent	27 (67.5%)	13 (50.0%)	.122
	Present	13 (32.5)%	13 (50.0%)	
HIVD in MUS	Absent	21 (52.5%)	13 (50.0%)	.521
	Present	19 (47.5%)	13 (50.0%)	
Severe disc height loss in MUS	Absent	31 (77.5%)	16 (61.5%)	.521
	Present	9 (22.5%)	10 (38.5%)	
LF buckling in MUS	Absent	15 (37.5%)	8 (30.8%)	.386
	Present	25 (62.5%)	18 (69.2%)	
Osteophyte in MUS	Absent	8 (20.0%)	1 (3.8%)	.061
	Present	32 (80.0%)	25 (96.2%)	
PLL thickening in MUS	Absent	25 (62.5%)	18 (69.2%)	.386
	Present	15 (37.5%)	8 (30.8%)	
Facet joint hypertrophy in MUS	Absent	36 (90.0%)	20 (76.9%)	.137
	Present	4 (10.0%)	6 (23.1%)	
Adjacent level	Absent	33 (82.5%)	19 (73.1%)	.270

SA/SDHL	Present	7 (17.5%)	7 (26.9%)	
Modic type change in MUS	Absent	29 (72.5%)	16 (61.5%)	.252
	Present	11 (27.5%)	10 (38.5%)	
Abnormal alignment in MUS	Absent	27 (67.5%)	16 (61.5%)	.406
	Present	13 (32.5%)	10 (38.5%)	
Cord indentation in MUS	Absent	9 (22.5%)	5 (19.2%)	.501
	Present	31 (77.5%)	21 (80.8%)	
CCM in MUS	Absent	27 (67.5)%	16 (61.5%)	.406
	Present	13 (32.5%)	10 (38.5%)	

*HIVD = herniated intervertebral disc, OPLL = ossification of posterior longitudinal ligament, MUS = most unstable segment, CCM = cervical compressive myelopathy, adjacent level SA/SDHL= severe ankylosis or severe disc height loss at adjacent level of MUS, LF = ligamentum flavum

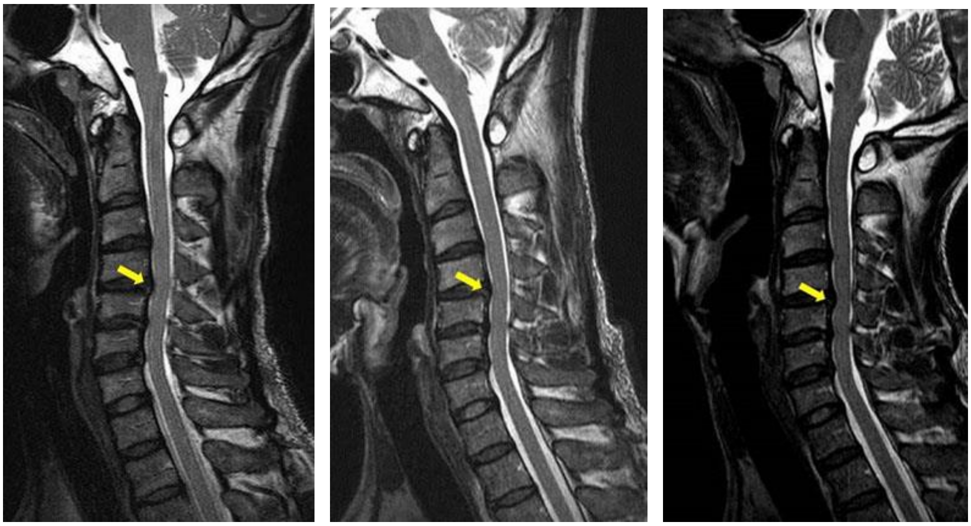
Figures and Figure legends

Figure 1. Foam wedge (30 degrees)



A foam wedge (30 degrees, Phillips) positioned to maintain flexion and extension positions while in a supine position

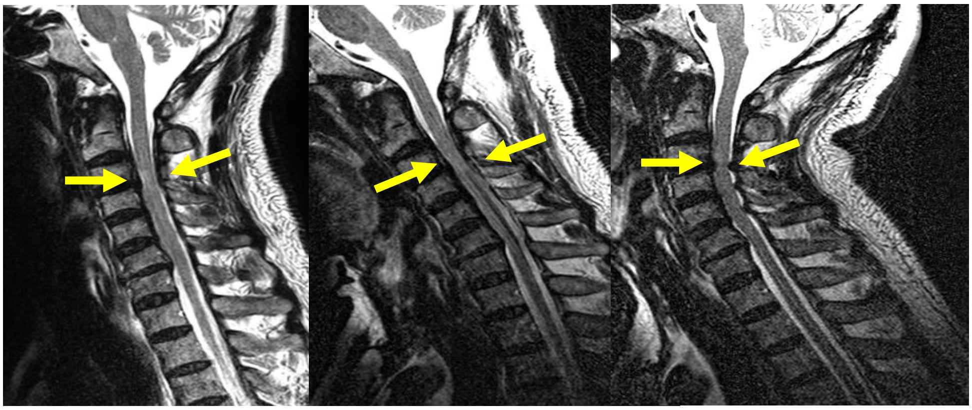
Figure 2. 56-year-old man neck pain



(a) (b) (c)

A 56-year-old man neck pain. C4/5 (arrow) was determined as the MUS because the level shows the greatest dynamic change in the spinal central canal according to flexion (b) and extension (c) positions from the neutral (a) position on T2-weighted sagittal images. Spinal cord indentation is absent at the neutral (a) and flexion (b) positions, but anterior spinal cord indentation is induced at the extension position (c) in the MUS; thus, extension-aggravation is present in the MUS in this patient.

Figure 3. 49-year-old woman with myelopathy symptom



(a) (b) (c)

A 49-year-old woman with myelopathy symptom. The MUS was C4/5 (arrows) showing the greatest dynamic change in the spinal central canal according to flexion (b) and extension (c) positions from the neutral (a) position on T2-weighted sagittal images. Spinal cord indentation is noted in anterior side at the neutral (a) and the flexion (b) positions, but both anterior and posterior spinal cord indentation is induced at the extension position (c) in the MUS; thus, extension-aggravation is present in the MUS in this patient. Suspicious signal change in spinal cord was noted at C4/5 in the neutral (a) position image.

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요약

동적 경부 척추 자기공명영상에서 신전 시에 유발되는 척추관 협착증의 위험요인

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목적: 경부 척추 자기공명영상에서 신전 시에 유발되는 척추관 협착증과 관련된 요인을 찾는 것.

방법: 2009년 1월부터 2010년 12월 사이에 동적 경부 척추 자기공명영상을 촬영한 80명의 환자 중 수술, 종양 등으로 14명을 제외하고 나머지 66명의 환자에 대하여 분석하였다. 가장 불안정한 분절은 중립, 굽힘, 젖힘 영상 중에서 척추강 직경 변화가 가장 큰 디스크 분절로 정의하였다. 중립 자세에서 시행한 이미지에서의 가장 불안정한 분절에서의 기본 영상 소견을 분석하였으며 그 항목들은 디스크 탈출, 디스크 높이의 심한 감소, 황색인대의 찌그러짐, 골극, 후방종단인대, 측면관절의 비후, 척추골 유착이나 가장 불안정한 분절의 주위 분절에서의 디스크높이의 심한 감소, 모딕형 골단판 변화, 척추체의 전위, 경부 응축성 척수병증이다.

결과: 가장 불안정한 분절은 경추 디스크 5/6 번에서 가장 흔하였다. 가장 불안정한 분절에서 디스크 탈출, 디스크높이의 심한 감소, 황색인대의 찌그러짐, 골극, 후방종단인대의 비후, 모딕형 골단판 변화, 척추체 후방전위, 경부 응축성 척수병증은 30% 이상의 환자에서 발견되었다. 이들 중 골극은 가장 흔한 소견이었으며 (86.4%), 그 외에도 디스크 탈출과 디

스크 높이의 심한 감소가 48.5% 로 환자들에게서 높은 비율로 발견되었다. 현 연구에서 중립자세에서 분석한 모든 자기공명영상 소견들은 가장 불안정한 분절에서 젖힘-악화를 보인 여부와는 유의한 관련성을 보이지 않았다.

결론: 골극, 디스크 탈출, 디스크 높이의 심한 감소는 가장 불안정한 분절에서의 위험요소였다.

주요어: 경추 척추관 협착증, 동적 경추 자기공명영상

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