Journal of Orthopaedic Science xxx (xxxx) xxx

Contents lists available at ScienceDirect

Journal of Orthopaedic Science

journal homepage: http://www.elsevier.com/locate/jos

Original Article

Clinical and radiographic characteristics of increased signal intensity of the spinal cord at the vertebral body level in patients with cervical myelopathy

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A R T I C L E I N F O

Article history:
Received 19 May 2022
Received in revised form
14 September 2022
Accepted 19 October 2022
Available online xxx

Keywords:
Cervical spondylotic myelopathy
Increased signal intensity
Vertebral body level
Spinal cord movement
Alignment
Range of motion

A B S T R A C T

Background: Increased signal intensity (ISI) is usually recognized at the disc level of the responsible lesion in the patients with cervical myelopathy. However, it is occasionally seen at the vertebral body level, below the level of compression. We aimed to investigate the clinical significance and the radiographic characteristics of ISI at the vertebral body level.
Methods: This retrospective study included 135 patients with cervical spondylotic myelopathy who underwent surgery and with local ISI. We measured the local and C2-7 angle at flexion, neutral, and extension. We also evaluated the local range of motion (ROM) and C2-7 ROM. The patients were classified into group D (ISI at disc level) and group B (ISI at vertebral body level).
Results: The prevalence was 80.7% (109/135) and 19.3% (26/135) for groups D and B, respectively. Local angle at flexion and neutral were more kyphotic in group B than in group D. The local ROM was larger in group B than in group D. Moreover, C2-7 angle at flexion, neutral and extension were more kyphotic in group B than in group D. Two years later, local angle at flexion, neutral, and extension were also kyphotic in group B than group D; however, local and C2-7 ROM was not significantly different between the two groups. There was no significant difference of clinical outcomes 2 years postoperatively between both groups.
Conclusions: Group B was associated with the kyphotic alignment and local greater ROM, compared to group D. As the spinal cord is withdrawn in flexion, the ISI lesion at vertebral body might be displaced towards the disc level, which impacted by the anterior components of the vertebrae. ISI at the vertebral body level might be related to cord compression or stretching at flexion position. This should be different from the conventionally held pincer-mechanism concept.

1. Introduction

Patients with cervical spondylotic myelopathy (CSM) often show an increased signal intensity (ISI) on T2-weighted magnetic resonance imaging (MRI). ISI is related to histopathological changes [1,2], severity of myelopathy, and surgical outcomes [3]. A previous analysis reported that higher ISI grade was correlated with severity of CSM and poor surgical outcomes [3–5].

ISI is usually recognized at the disc level of the responsible lesion. It is occasionally seen at the vertebral body level, below the level of compression; however, there are no reports on the presence of an ISI at the vertebral body level. Furthermore, the incidence and mechanism at vertebral body level remain unclear. We therefore aimed to investigate the prevalence and significance of ISI at the vertebral body level for this study.

2. Materials and methods

This research has been approved by the IRB of the authors' affiliated institutions. We retrospectively reviewed patients with

Abbreviations: CSM, cervical spondylotic myelopathy; ISI, increased signal intensity; MRI, magnetic resonance imaging; ROM, range of motion; JOA, Japanese Orthopaedic Association; OPLL, ossification of posterior longituidal ligament.

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https://doi.org/10.1016/j.jos.2022.10.010
0949-2658/

Table 1
Characteristics of the study participants.

	CSM without ISI	CSM with ISI		ISI >1 vertebrae
		Group D	Group B	
Prevalence in all CSM patients	24.0% (50/208)	52.4% (109/208)	12.5% (26/208)	11.1% (23/208)
Prevalence in ISI recognized patients	–	80.7% (109/135)	19.3% (26/135)	–

CSM: cervical spondylotic myelopathy, ISI: increased signal intensity, Group D: ISI recognized at disc level, Group B: ISI recognized at vertebral body level.

cervical spondylotic myelopathy who underwent surgery from January 2013 to December 2018, and eventually enrolled 208 patients. This study excluded 23 patients with an ISI extending more than the length of 1 vertebra and 50 patients without ISI (Table 1). All participants provided their written informed consent.

They comprised 95 men and 40 women. Their mean age was 69.3 ± 11.0 years. All patients underwent high-resolution MRI with a 3.0-T Signa (GE Medical Systems, WI) imager before the surgery. We obtained T1-and T2-weighted images of sagittal views of the cervical cord. We used a spin echo sequence system and a fast spin echo sequence system for T1-and T2-weighted images, respectively.

The vertebral body was divided into four sections in the sagittal plane. An ISI at the two middle sections was considered to be at the vertebral body level (Fig. 1). The patients were classified into two groups as follows: group D (ISI at the disc level) and group B (ISI at the vertebral body level).

C2-7 angle (lordotic, +; kyphotic, -) at flexion, neutral, and extension were measured by the angle between the C2 inferior endplate of the vertebra body and the C7 inferior endplate of the vertebra body on X-ray. We calculated the C2-7 ROM was calculated by measuring the difference in alignment between flexion and extension (Fig. 2). Local angle at flexion, neutral, and extension were also measured by the angle between the two neighboring vertebrae, namely, the upper endplate of the upper vertebral body and the inferior endplate of the inferior vertebral body (Fig. 3). We also calculated the spondylolisthesis. Spondylolisthesis was defined as the displacement of 1 vertebral body on the adjacent level below of 3 mm or greater in the anterior or posterior direction as seen on the neutral image. Instability was defined as segmental translational motion exceeding 3 mm. For clinical evaluation, the Japanese Orthopeadic Association (JOA) scores for cervical myelopathy were evaluated before surgery and at 2 years' follow-up. The recovery rate according to JOA scores was calculated by ([postoperative JOA score - preoperative JOA score]/[17 - preoperative JOA score] * 100%). A recovery rate of 100% was the best possible postoperative improvement [6].

The radiographic patterns of cord compression were also analyzed. Anterior cord compression was defined as effacement of anterior cerebral spinal fluid buffer on the T2 sagittal and axial images, evidence of anterior compression of cord substance on T1 sagittal and axial images, and posterior smooth contour of the cord maintained. Posterior cord compression was also defined as effacement of posterior cerebral spinal fluid buffer on the T2 sagittal and axial images, evidence of posterior compression of cord substance on T1 sagittal and axial images, and posterior smooth, rounded contour distorted (V shaped) [7].

We used JMP Pro® 14.1 (SAS Institute Japan, Tokyo, Japan) for all statistical analyses. We conducted nonparametric analyses using the Mann-Whitney U test to assess the differences between the groups. $P < 0.05$ was considered statistically significant.

3. Results

Groups D and B comprised 109 (80.7%) and 26 patients (19.3%), respectively. There was no substantial difference in the basic characteristics between the groups (Table 1). Local angle at flexion was more kyphotic in group B than in group D (group D, −5.1 ± 8.6; group B, −11.2 ± 6.9; $p < 0.001$). Local angle at neutral was also less lordotic in group B than in group D (group D, 2.6 ± 7.2; group B, −1.8 ± 5.1; $p < 0.001$). Local angle at extension was also observed to be kyphotic in group B, but did not significantly differ between the groups (group D, 5.1 ± 7.3; group B, 3.8 ± 4.0; $p = 0.12$). Local

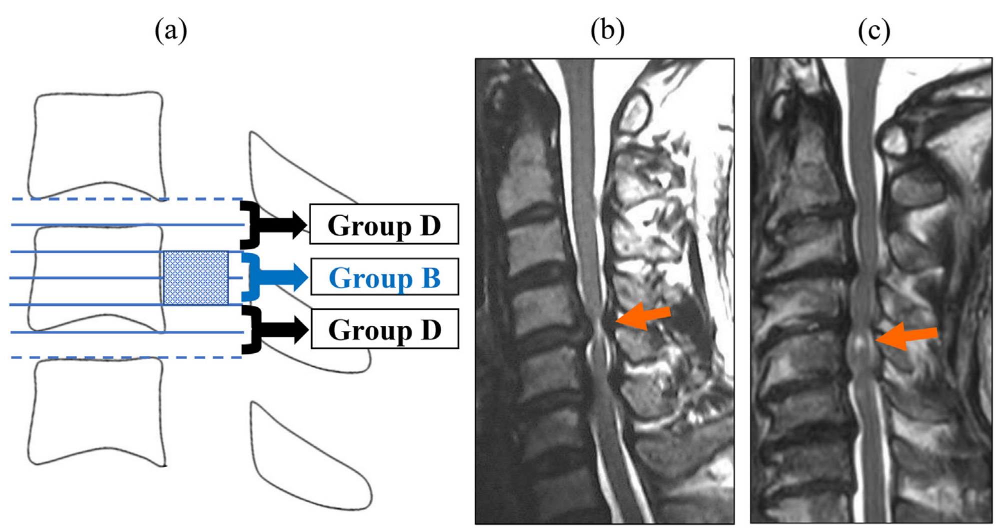

Fig. 1. Grouping according to the increased signal intensity (ISI) location, the vertebral body has been divided into four sections in the sagittal plane. ISI in the two middle sections is considered to be at the vertebral body level (group B). If ISI is at the disk level, and the upper one quarter and lower, it was considered to be at the disk level (group D) (a). The representative images show the following: Figure (b) illustrates the location of ISI at the disk level and is classified as group D and Figure (c) shows the presence of ISI in the upper two quarters of the vertebral body and is classified as group B.

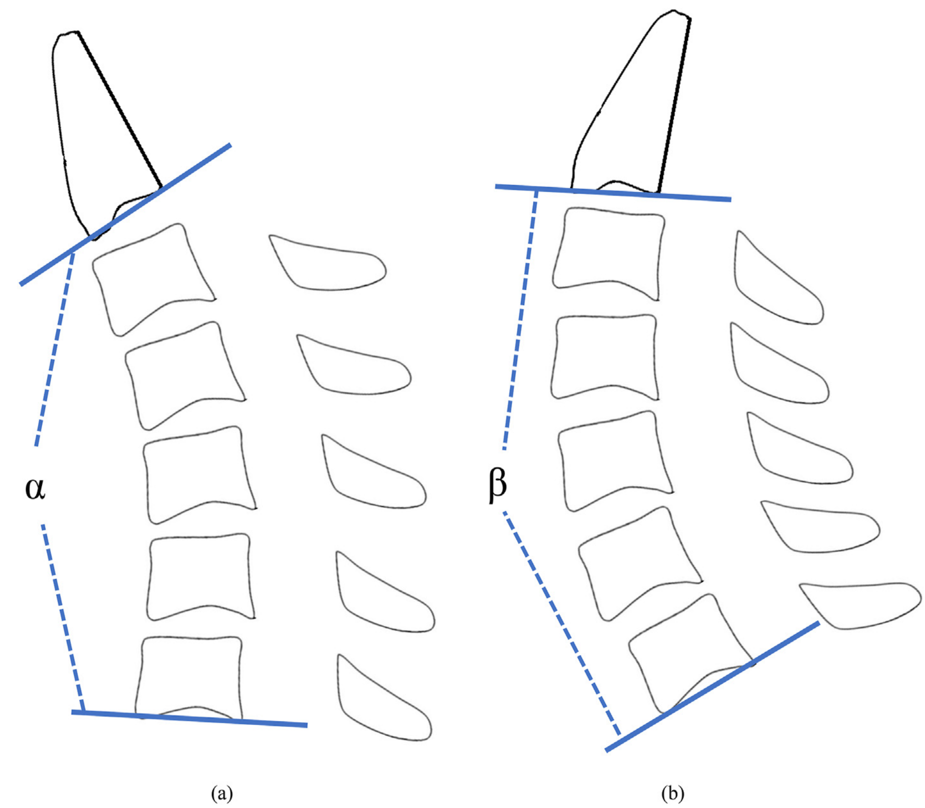

Fig. 2. C2-7 angle at flexion (α) and at extension (β) (lordotic, +; kyphotic, -). C2-7 range of motion was calculated by β - α.

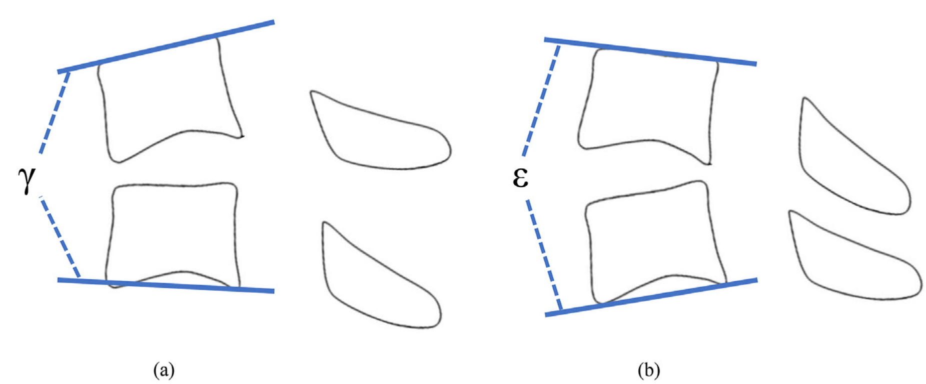

Fig. 3. Local angle at flexion (γ) and extension (ε) (lordotic, +; kyphotic, -). Local range of motion was calculated by ε - γ.

ROM was larger in group B than group D (group D, 9.8 ± 5.7; group B, 15.3 ± 4.8; $p < 0.001$). C2-7 angle at flexion was more kyphotic in group B than in group D (group D, −16.1 ± 16.1; group B, −25.1 ± 9.4; $p = 0.003$). Furthermore, C2-7 angle at a neutral was less lordotic in group B than in group D (group D, 9.8 ± 15.1; group B, 5.1 ± 7.6; $p = 0.031$), and at extension (group D, 22.4 ± 13.6; group B, 16.2 ± 9.2; $p = 0.009$). However, C2-7 ROM did not significantly differ between the groups (group D, 38.8 ± 15.6; group B, 41.5 ± 12.1; $p = 0.52$). Anterior cord compression was more frequently in group B than group D. Anterior and posterior cord compression pattern was more recognized in group D than group B. Most of the pattern of cord compression in group D was anterior and posterior type (anterior; 14 (12.8%), posterior; 2 (1.8%), anterior and posterior; 93 (85.3%)). In contrast, most of the pattern of cord compression in group B was anterior pattern (anterior; 18 (69.2%), posterior; 0 (0%), anterior and posterior; 8 (30.8%)) ($p < 0.001$). Spondylolisthesis in group D was non; 70 (64.2%), anterior; 17 (15.6%), and posterior; 22 (20.2%), but in group B anterior spondylolisthesis significantly increased (non; 18 (69.2%), anterior; 8 (30.8%), and posterior; 0 (0.0%)) ($p = 0.019$). However, there were no significant difference in instability between group D (non; 97 (89.0%), anterior instability; 10 (9.2%), and posterior instability; 2 (1.8%)) and group B (non; 22 (84.6%), anterior instability; 4 (15.4%), and posterior instability; 0 (0.0%)) ($p = 0.52$) (Table 2).

Local angle at 2 years postoperatively were more kyphotic at flexion (group D, −2.0 ± 7.4; group B, −6.4 ± 6.3; $p = 0.011$), neutral (group D, 2.2 ± 6.4 group B, −1.2 ± 6.4; $p = 0.041$) and extension (group D, 4.8 ± 6.4; group B, 0.9 ± 6.2; $p = 0.018$) in group B than group D. However, the local ROM was not significantly different in both groups (group D, 7.0 ± 5.3; group B, 7.3 ± 3.8; $p = 0.32$). C2-7 angle at 2 years after the operation were more kyphotic in group B at flexion (group D, −8.5 ± 15.4; group B, −14.8 ± 12.6; $p = 0.056$)

Table 2
Comparison between the increased signal intensity recognized at disk level group (Group D) and the vertebral body level group (Group B) at preoperation.

	Group D	Group B	P value
Prevalence	80.7% (109/135)	19.3% (26/135)	
Male/Female	Male: 75, Female: 34	Male: 20, Female: 6	0.47
Age	69.2 ± 11.3	69.6 ± 10.1	0.89
BMI	23.9 ± 3.5	24.4 ± 2.7	0.20
ISI grade	grade 1; 91, grade 2; 18	grade 1; 15, grade 2; 11	0.01
Duration of disease	24.1 ± 25.2	16.7 ± 15.3	0.28
Local ROM	9.8 ± 5.7	15.3 ± 4.8	<0.001
Local angle (lordotic;+, kyphotic;-)			
at flexion	−5.1 ± 8.6	−11.2 ± 6.9	<0.001
at neutral	2.6 ± 7.2	−1.8 ± 5.1	<0.001
at extension	5.1 ± 7.3	3.8 ± 4.0	0.12
C2-7 ROM	38.8 ± 15.6	41.5 ± 12.1	0.52
C2-7 angle (lordotic;+, kyphotic;-)			
at flexion	−16.1 ± 16.1	−25.1 ± 9.4	0.003
at neutral	9.8 ± 15.1	5.1 ± 7.6	0.031
at extension	22.4 ± 13.6	16.2 ± 9.2	0.009
pattern of cord compression	anterior; 14 (12.8%), posterior; 2 (1.8%), anterior and posterior; 93 (85.3%)	anterior; 18 (69.2%), posterior; 0 (0%), anterior and posterior; 8 (30.8%)	<0.001
spondylolisthesis	non; 70 (64.2%), anterior; 17 (15.6%), and posterior; 22 (20.2%)	non; 18 (69.2%), anterior; 8 (30.8%), and posterior; 0 (0.0%)	0.019
instability	non; 97 (89.0%), anterior instability; 10 (9.2%), and posterior instability; 2 (1.8%)	non; 22 (84.6%), anterior instability; 4 (15.4%), and posterior instability; 0 (0.0%)	0.52

BMI: body mass index, ISI: increased signal intensity, ROM: range of motion.

Table 3
Comparison between the increased signal intensity recognized at disk level group (Group D) and the vertebral body level group (Group B) 2 years after the operation.

	Group D	Group B	P value
Local ROM	7.0 ± 5.3	7.3 ± 3.8	0.32
Local angle (lordotic;+, kyphotic;-)			
at flexion	−2.0 ± 7.4	−6.4 ± 6.3	0.011
at neutral	2.2 ± 6.4	−1.2 ± 6.4	0.041
at extension	4.8 ± 6.4	0.9 ± 6.2	0.018
C2-7 ROM	27.4 ± 13.9	26.0 ± 12.6	0.74
C2-7 angle (lordotic;+, kyphotic;-)			
at flexion	−8.5 ± 15.4	−14.8 ± 12.6	0.056
at neutral	9.7 ± 13.8	5.0 ± 9.3	0.062
at extension	18.5 ± 15.8	11.2 ± 7.5	0.006
Sutgical procedure	MEL; 28 (25.7%), Fusion; 22 (20.2%), LAP; 59 (54.1%)	MEL; 0 (0.0%), Fusion; 6 (23.1%), LAP; 20 (76.9%)	
JOA score at preoperation	10.8 ± 3.2	10.0 ± 3.0	0.21
JOA score 2 years later	13.7 ± 2.5	13.5 ± 2.6	0.52
JOA recovery rate 2 years later	49.1 ± 31.3	50.1 ± 28.0	0.86

ROM: range of motion, MEL: microendoscopic laminectomy, LAP: laminoplasty, JOA: Japanese Orthopaedic Association..

and neutral (group D, 9.7 ± 13.8 group B, 5.0 ± 9.3; p = 0.062), but there were not recognized significantly. C2-7 angle at 2 years after the operation at extension (group D, 18.5 ± 15.8; group B, 11.2 ± 7.5; p = 0.006) was more kyphotic in group B than group D; however, there was no significant difference in local ROM between both groups (group D, 27.4 ± 13.9; group B, 26.0 ± 12.6; p = 0.74). There were no significant differences in JOA scores at the pre-operative stage (group D, 10.8 ± 3.2 group B, 10.0 ± 3.0; p = 0.21) and 2 years later (group D, 13.7 ± 2.5 group B, 13.5 ± 2.6; p = 0.52). The JOA recovery rate 2 years later (group D, 49.1 ± 31.3 group B, 50.1 ± 28.0; p = 0.86) was similar in both groups (Table 3).

We show the representative case, a 74-year-old woman without any pertinent medical history. She visited our department, complaining of numbness in her forearms, reduced dexterity, and unsteady gait. Radiography of the cervical spine revealed signs of cervical spondylosis. MRI showed an ISI at the vertebral body level. The C2-7 angles were −7°, 42°, and 50° at the flexion, neutral, and extension positions, respectively. Furthermore, the C4-5 local angles were 2°, 16°, and 19° at the flexion, neutral, and extension positions, respectively (Fig. 4). Kinematic MRI facilitated the recognition of ISI at the disc level upon flexion, which was conversely observed at the vertebral body level upon extension to neutral positions (Fig. 5).

4. Discussion

We identified the prevalence of ISI at the vertebral body level, and investigated its relationship with cervical posture. The prevalence of ISI at the vertebral body level was approximately 12.5% of the all of CSM patients. Preoperative ISI on T2-weighted sagittal MRI at the vertebral body level was correlated with the cervical kyphotic posture during neutral and flexion positions. Furthermore, the patients with ISI at the vertebral body level have more local-ROM than those at the disc level. This is the first report to suggest an association between ISI at vertebral body level and radiographic characteristics.

ISI is considered the result of myelomalacia or necrosis because of mechanical compression and venous inflammation [1,2]. Light ISI reflects mild neuropathologic alteration in the spinal cord and reflects greater recuperative potential; however, intense ISI reflects severe alteration and less recuperative potential [3]. ISI grade was negatively correlated with the preoperative and postoperative neurological outcomes.

However, ISI has never been examined in reference to the level at which it occurs upon conduct of T2-weighted MRI. Furthermore, most patients with CSM have had observable ISI at the disc level. In this study, 80.7% of ISI was observed at the disk level and 19.3% was observed at the vertebral body level. We determined that the ISI at vertebral body level was correlated with kyphotic alignment of C2-7, local kyphosis during flexion to neutral, and greater local-ROM. Cervical cord compression in patients with CSM was generally induced upon extension by the pincer mechanism [8]. The

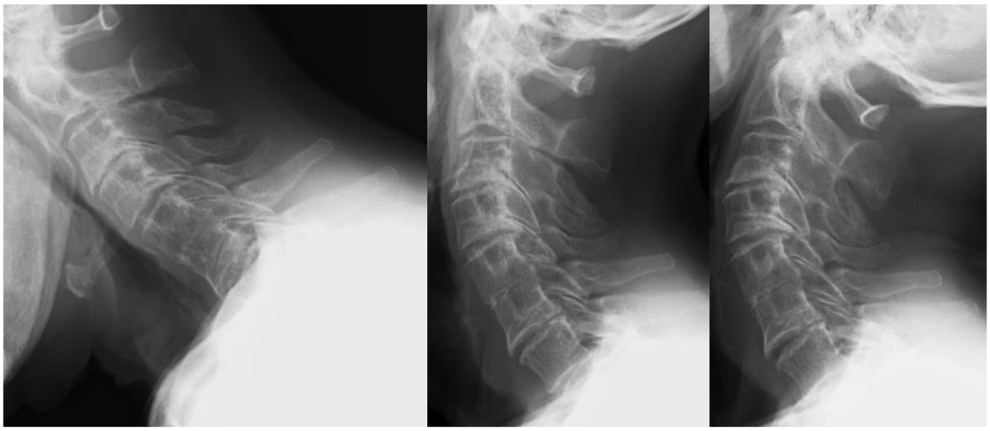

Fig. 4. A representative case showing a 74-year-old female. The C2-7 angle was -7° at flexion (a), 42° at neutral (b), and 50° at extension (c). The C4-5 local angle was 2° at flexion (a), 16° at neutral (b), and 19° at extension (c) (lordotic; +, kyphotic; -).

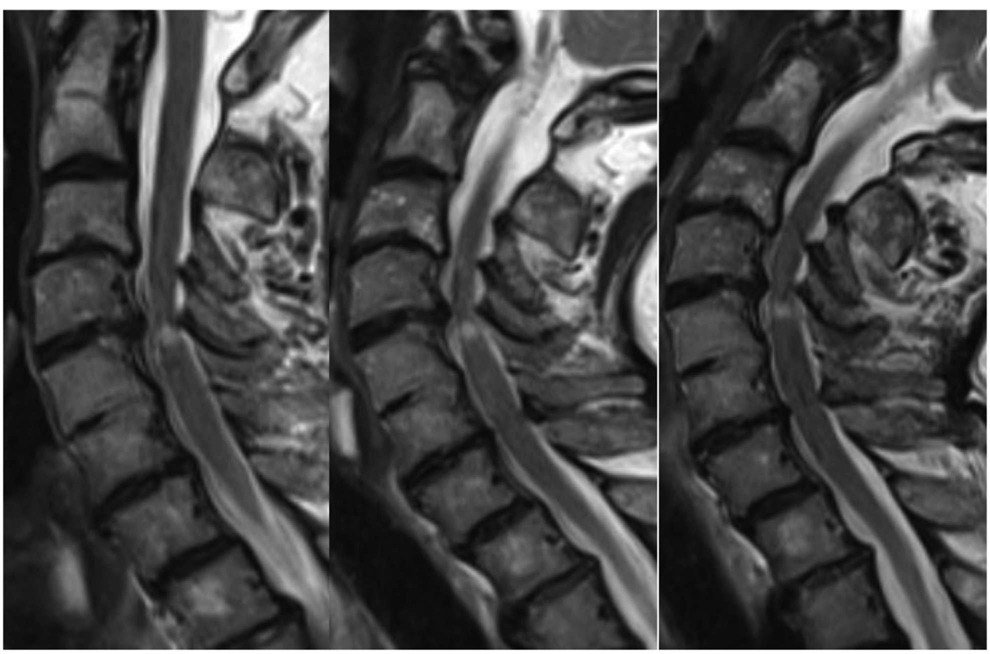

Fig. 5. Increased signal intensity (ISI) was seen at the upper quarter level on magnetic resonance imaging at flexion position (a); however, it shifted more towards the caudal at neutral (b) and extension (c).

ligamentum flavum buckles inward during neck extension. This in turn decreases the cross-sectional area of the cervical canal [9]. The spinal cord is compressed between the posteroinferior margin of one vertebral body and the lamina or ligamentum flavum at the next caudal level, at the articular segment, in extension [10]. Moreover, our study findings revealed that ISI at the vertebral body level was not rare. In addition, patients with ISI at the vertebral body level were more likely to have kyphosis during flexion and neutral than that at the disc level.

A previous experimental study reported on the cranially-oriented movement of the spinal cord upon flexion of the neck and head in monkeys [11]. The cervical cord was reportedly withdrawn to the cranial side and was accordingly stretched upon flexion in a cadaver study [12]. Despite no information on the ISI level, previous MRI studies reported on superiorly-oriented migration of ISIs upon flexion in patients with Hirayama disease [13,14]. The representative MRI enabled the recognition of ISI at the vertebral body level upon extension; however, ISI was observed at the disc level in the flexion position. This then suggests that traction occurs on the cord, lifting the ISI from the level of the vertebral body to the level of the disc, when moving from extension to flexion, respectively.

Furthermore, as the spinal cord stretches in the flexion position and takes the shortest pathway through the spinal canal, the spinal cord takes the dorsal pathway upon flexion. Therefore, the anterior component, osteophyte, or disc bulging might have created an impact on the spinal cord [15]. A biomechanical study reported on the case of spinal cord damage from overstretching upon adopting the flexion position [16]. A finite element study also reported on the impact of maintaining a flexion position on spinal cord damage [17]. ISI at vertebral body had more local kyphosis and larger mobility compared to that of disk level. The pathology of ISI at the vertebral body level comprises the withdrawal of the cervical cord from the vertebral body level to the disc level, followed by cord compression or stretching during flexion.

It was reported that cervical spine ROM decreased after laminoplasty [18,19] and the decrease of motion in flexion and extension was an average of 50% [20]. In this study, there were no significance in C2-7 and local ROM, especially local ROM 2 years later between Group D and Group B. The clinical outcome was not recognized significantly between Group B and group D, nevertheless spinal cord was much compressed by anterior factor in group B than group D. Most patients in group B (76.9%) underwent laminoplasty. It was reported that postoperative restriction of segmental motion could occur in rotational motion, which have the possibility of the positive effect on the clinical outcomes of decompression surgery in patients with CSM [21,22]. It was also reported that there was a significantly negative correlation between clinical outcome after cervical decompression surgery and range of motion in the presence of anterior compression of the spinal cord [23]. This study showed that large range of motion was recognized in group B preoperatively, but it decreased after surgery. It might be related to the improvement of neurological status in group B as well as group D despite the presence of anterior compression of the spinal cord and anterior spondylolisthesis.

Our study had several limitations. First, it is still unclear whether ISI at the vertebral body level was associated with neurological status. This study revealed that ISI at disc level was related to the anterior cord compression, and greater local mobility, which was expected that anterior cervical discectomy and fusion was better on the view of surgical procedure than posterior decompression surgery, but there was not significance between surgical outcome in fusion procedure and only decompression surgery. This might be cause of the small sample size. Second, this study had a retrospective design and the sample size of group B was relatively small. These calls for the need of a larger sample size and prospective studies. Third, this study did not include the ossification of the posterior longitudinal ligament (OPLL) patient, but OPLL was gradually less mobility and it was considered that OPLL was not different from CSM of the ISI at disk level. It was necessary following study. Fourth, we could not take MRI for all patients because kinematic MRI has much more time and the cervical cord was compressed and several symptoms were appeared during MRI. So, we don't have kinematic MRI for all patients. However, this study illustrated the possibility of withdrawn of spinal cord to cranial side at flexion position. Nowadays, we have prospectively taken kinematic MRI in patients who were ISI at vertebral body level. So far, we have taken MRI five patients, which illustrated the translation of spinal cord at ISI to the cranial disk level from extension to flexion position.

5. Conclusions

This was the first study demonstrate that ISI at the vertebral body level was associated with the local hyper mobility and kyphosis at the C2-7 area upon movement from flexion to a neutral position. Therefore, it was assumed that the mechanism of myelopathy in group B (ISI at vertebral body level) was that the spinal cord was retracted from the vertebral body to the disc level, and subsequently damaged (compressed or stretched). This idea differs from the conventional pincer-mechanism concept. Cervical alignment and ROM should be evaluation when the patients demonstrate ISI at vertebral body level.

Conflict of interest

The authors declare that they have no conflict of interest.

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