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Abnormal Findings on Magnetic Resonance Images of the Cervical Spines in 1211 Asymptomatic Subjects

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Study Design. Cross-sectional study.

Objective. The purpose of this study was to determine the prevalence and distribution of abnormal findings on cervical spine magnetic resonance image (MRI).

Summary of Background Data. Neurological symptoms and abnormal findings on MR images are keys to diagnose the spinal diseases. To determine the significance of MRI abnormalities, we must take into account the (1) frequency and (2) spectrum of structural abnormalities, which may be asymptomatic. However, no large-scale study has documented abnormal findings of the cervical spine on MR image in asymptomatic subjects.

Methods. MR images were analyzed for the anteroposterior spinal cord diameter, disc bulging diameter, and axial cross-sectional area of the spinal cord in 1211 healthy volunteers. The age of healthy volunteers prospectively enrolled in this study ranged from 20 to 70 years, with approximately 100 individuals per decade, per sex. These data were used to determine the spectrum and degree of disc bulging, spinal cord compression (SCC), and increased signal intensity changes in the spinal cord.

Results. Most subjects presented with disc bulging (87.6%), which significantly increased with age in terms of frequency, severity, and number of levels. Even most subjects in their 20s had bulging discs, with 73.3% and 78.0% of males and females, respectively. In contrast, few asymptomatic subjects were diagnosed with SCC (5.3%) or increased signal intensity (2.3%). These numbers increased with age, particularly after age 50 years. SCC mainly involved 1 level (58%) or 2 levels (38%), and predominantly occurred at C5–C6 (41%) and C6–C7 (27%).

Conclusion. Disc bulging was frequently observed in asymptomatic subjects, even including those in their 20s. The number of patients with minor disc bulging increased from age 20 to 50 years. In contrast, the frequency of SCC and increased signal intensity increased after age 50 years, and this was accompanied by increased severity of disc bulging.

Key words: magnetic resonance image (MRI), abnormal findings, asymptomatic, cervical, disc degeneration, disc bulging, spinal cord compression, increased signal intensity, cervical myelopathy, aging, cross-sectional study.

Level of Evidence: 2

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Magnetic resonance image (MRI) is a useful tool for the diagnosis of cervical spine disorders. Surgeons plan spinal surgical procedures based on neurological symptoms and abnormal MRI findings. However, there is an ongoing debate on the validity of abnormal MRI findings to make such decisions because they are also frequently reported in asymptomatic subjects.[1–9] The relevance of abnormalities on MR image depends on the frequency and spectrum of asymptomatic structural abnormalities.

To our current knowledge, most of the previous studies relating to asymptomatic abnormal findings on cervical spine MR image were limited to small cohort studies[1–8] and the population were not equally distributed in each decade.[1–9] Moreover, few studies investigated abnormal findings in the spinal cord,[1,5,7,9] whereas majority of the studies reported on disc degeneration.[1–7] Finally, there are little data available on the frequency or severity of asymptomatic cervical spinal canal stenosis, or increased signal intensity (ISI) changes,[9,10] which is the representative sign on MR image for cervical compressive myelopathy.[11]

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In cervical compressive myelopathy, static and dynamic factors are the main contributing factors of cervical spinal cord compression (SCC).[12,13] The static factors are the structural spondylotic changes causing canal stenosis and subsequent compression.[12,13] Disc degeneration is suspected as the initiating event of these spondylotic changes that might result in SCC.[12,13] However, there are no data available on the relationship between disc degeneration and SCC.

The purpose of this study was to determine the frequency and severity of abnormal findings on cervical spine MR image in a large cohort of asymptomatic subjects, namely disc bulging, SCC, and ISI changes, and investigate the spatial relationship between disc bulging and SCC.

MATERIALS AND METHODS

A total of 1230 healthy volunteers were examined using cervical spine MR image between February 2006 and February 2008. Subjects recruited were between 20 and 79 years. We recruited the patients *via* newspaper advertisements and posters in facilities having some sort of relationship with our hospital. Thus, the majority of subjects were not patients at our hospital but healthy residents of the area. The hospital where this study was performed is in one of the biggest cities, Nagoya in Japan, and the majority of the subjects lived within its city limits. The exclusion criteria included a history of brain or spinal surgery, comorbid neurological disease (*e.g.*, cerebral infarction or neuropathy), symptoms related to sensory or motor disorders (numbness, clumsiness, motor weakness, or gait disturbances), or severe neck pain. Pregnant females, and individuals who received workmen's compensation, or presented with symptoms after a motor vehicle accident were also excluded. Subjects with other comorbidities (smoking, diabetes, hypertension, and others) were included in this study. This study was approved by the institutional review board, and each patient signed a written consent form.

All participants underwent imaging analysis and clinical examination by 2 spinal surgeons (F.K. and K.S.). The MRI data from 1211 subjects were included in the analysis, after excluding those with measurement difficulties resulting from artifacts, such as motion or metals. MRIs were performed with a 1.5-T superconductive magnet (Signa Horizon Excite HD version 12; GE Healthcare, Britain, United Kingdom). The scans were taken at slice thicknesses of 3 and 4 mm in the sagittal and axial planes, respectively. T2-weighted images (fast spin echo TR, 3500 ms; TE, 102 ms) were obtained in sagittal scans. Axial scans were performed using T2-weighted images (fast spin echo TR, 4000 ms; TE, 102 ms). All images were transferred to a computer as Digital Imaging and Communications in Medicine data to measure the anteroposterior diameter of the spinal cord, disc bulging diameter, and axial cross-sectional area of the spinal cord, both at the disc and midvertebral level, using imaging software (Osiris4; Icestar Media Ltd., Essex, United Kingdom). Disc bulging, SCC, and ISI change in T2 sagittal images were individually recorded.

By definition, SCC was identified when the anteroposterior diameter of the spinal canal at the narrowest level is less than or equal to the anteroposterior diameter of the spinal cord at the mid C5 vertebral body level (Figure 1).[14] This definition is based on the fact that (1) a sagittal diameter of the spinal canal at the C5 vertebral body level on radiograph is generally used to define developmental stenosis of the cervical spinal canal and (2) there was no case of SCC at the mid C5 vertebral body level in our previous report.[14] Disc bulging was defined as the intervertebral disc protruding posteriorly by more than 1 mm. ISI changes in the spinal cord were classified into 3 groups based on sagittal T2-weighted images as shown in our previous article[10]: grade 0, none; grade 1, light (increased intensity, but less intense compared with cerebrospinal fluid signal); and grade 2, intense (similar intensity to cerebrospinal fluid signal). Grades 1 and 2 signal-intensity changes were included in this study.

Statistical Analysis

The Fisher exact test or *t* test was used to evaluate differences in abnormal findings between 2 consecutive decades. We plotted receiver operating characteristic analysis to determine the cutoff value to know (1) how big of a disc-bulge diameter would cause SCC to occur more frequently, and (2) how much SCC would increase ISI incidence. A *P* value less than 0.05 was considered statistically significant. All analyses were conducted using SPSS version 21 (SPSS, Chicago, IL).

Figure 1. Definition of spinal canal compression by cervical magnetic resonance imaging.[14] The AP diameter of the spinal canal at the narrowest level (white double arrow; B) AP diameter of the spinal cord at the mid C5 vertebral body (white double arrow; A). AP indicates anteroposterior.

RESULTS

The 1211 asymptomatic volunteers included in this study were equally distributed among age classes, from the third to the eighth decade of life (Table 1). Approximately, 50% of the subjects had passive occupations, mainly as office workers, teachers, or service providers, whereas 28% of them had physically demanding occupations, like housekeepers, builders, and manufacturers (Table 2).

Disc Bulging

Most asymptomatic volunteers (87.6%) had significant disc bulging. The incidence was already very high in the subjects in their 20s, with 73.3% of the males and 78.0% of the females having disc bulging (Figure 2A). The frequencies tended to increase with age from the 20s to the 50s, with a significant increase from the 30s to the 40s in males ($P < 0.05$). The number of bulging discs in each subject also increased with age (Figure 2B). In the subjects in their 20s, the average number of levels implicated was 1.5 ± 1.3 and 1.0 ± 1.4 for males and females, respectively. Thereafter, the sex difference was lost as the number of levels increased significantly from the 20s to 40s ($P < 0.05$ to 0.001), and reached a plateau (approximately 2 levels) in the 40s. The average disk displacement gradually increased with age from the 30s to the 60s ($P < 0.05$; Figure 2C), reaching 2.5 ± 0.7 mm and 2.0 ± 0.7 mm in males and females in their 70s, respectively.

Spinal Cord Compression

The diagnosis of SCC was confirmed in 64 (5.3%) subjects. The age and sex distribution of the SCC cases is presented in Figure 3A. Ossification of the posterior longitudinal ligament (OPLL) was observed in 5 people (0.4%) as in our previous report.[14] Although our population was Japanese, the majority of SCC cases were due to other degenerative changes. There was no case of SCC in the subjects in their 20s, and the number increased gradually with age. In addition, SCC was more common in males than in females in all generations. Thirty-seven cases had SCC in 1 level, 24 in 2 levels, 2 in 3 levels, and 1 in 4 levels; they were located predominantly at C5–C6 (41%) and C6–C7 (27%; Figure 3B). The axial cross-sectional area of the dural sac was 112.5 ± 23.3 mm^2 in cases of SCC. The most severe case of SCC had a 77.6% reduction in cross-sectional area at C5–C6, compared with the C5 mid-vertebral body (Figure 4).

TABLE 1. Age and Sex of 1211 Asymptomatic Subjects

Age (yr)	Males	Females
20–29	101	100
30–39	104	99
40–49	100	100
50–59	99	103
60–69	101	103
70–79	101	100
Total	606	605

TABLE 2. Occupation of 1211 Asymptomatic Subjects

Occupation	No.
Office workers	196
Teachers	196
Service providers	101
Doctors, nurses, and medical coworkers	58
Sales persons	57
Students	16
Subtotal = 624 (51.5%)	
Housekeepers	193
Builders	78
Manufacturers	54
Carriers	15
Farmers	3
Subtotal = 343 (28.3%)	
Unemployed persons	124
Others	100
Unknown	20
Subtotal = 244 (20.1%)	
Total	1211

Increased Signal Intensity

A small fraction of the subjects (N = 28; 2.3%) exhibited significant changes in ISI on T2 sagittal images. The distribution of ISI cases per decade and sex is shown in Figure 5A. This MRI abnormality was more common in males than females of all generations, as in the case of SCC. The incidence of ISI increased with age, particularly after the 50s, reaching 9% and 4% for males and females in their 70s, respectively. Most cases of ISI (89%) involved 1 level. Every ISI coincided with the level of SCC, primarily at C4–C5 (36%) and C5–C6 (54%) (Figure 5B).

The Relationship Between Disc Bulging, SCC, and ISI

A disc bulge of more than 1.35 mm was a risk factor for SCC (area under curve = 0.87, $P < 0.0001$, Figure 6A), and an SCC area of less than 128.5 mm^2 was a risk factor for ISI (area under curve = 0.92, $P < 0.0001$, Figure 6B).

Presentation of the Most Severe Case of SCC

The patient was a 77-year-old male with no clinical subjective symptoms, such as gait disturbance or numbness in his extremities. His manual muscle test results were 5. The result of the 10-second grip and release test[15] was 21/22 times in the

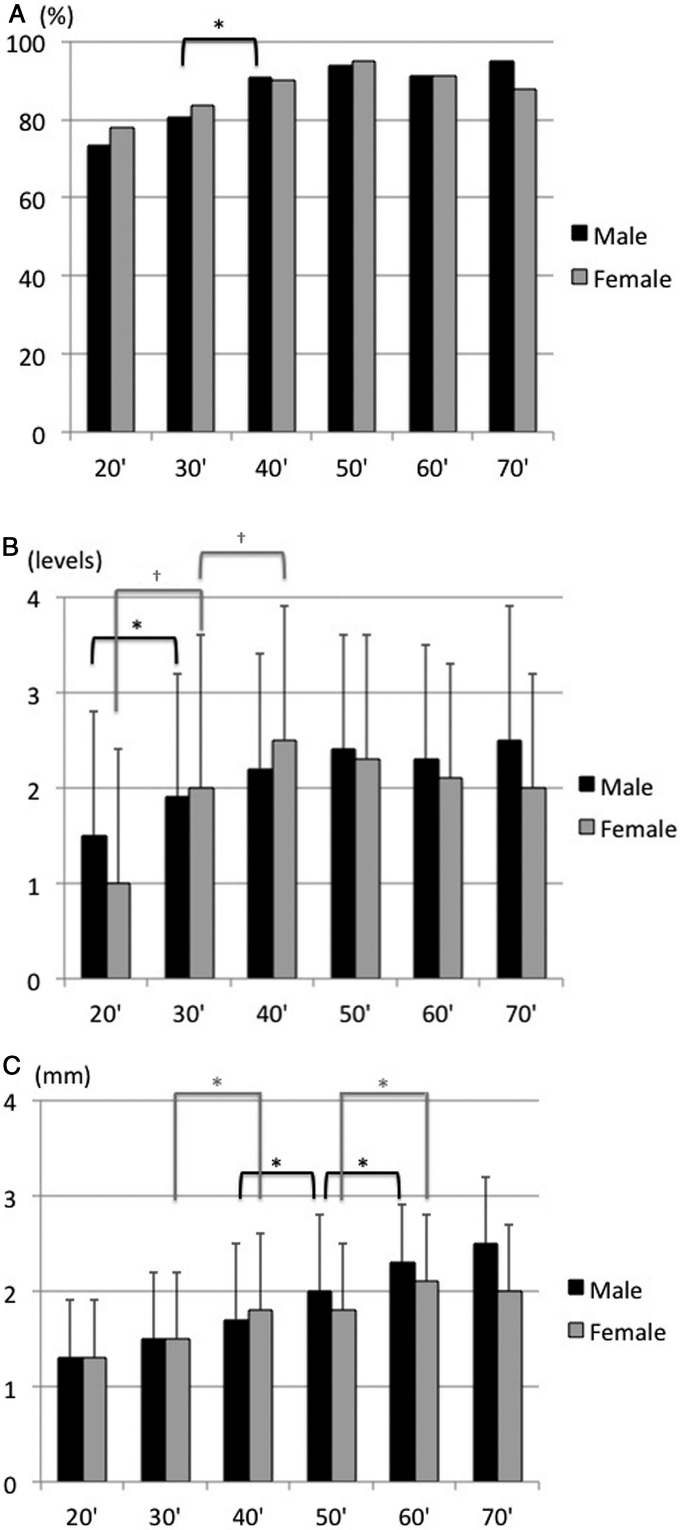

Figure 2. Frequency distribution of disc bulging in asymptomatic subjects. A, Frequency distribution of disc bulging with age and sex. B, Frequency distribution of the number of levels involved in disc bulging. C, Impact of age and sex on disc displacement (mm). Values are mean + SD. **P* < 0.05, †*P* < 0.001. SD indicates standard deviation.

right/left hand, respectively, and the result of the 10-second step test[16] was 15. The deep tendon reflex, triceps, patella, and Achilles tendon reflex were hyper, whereas the deltoid,

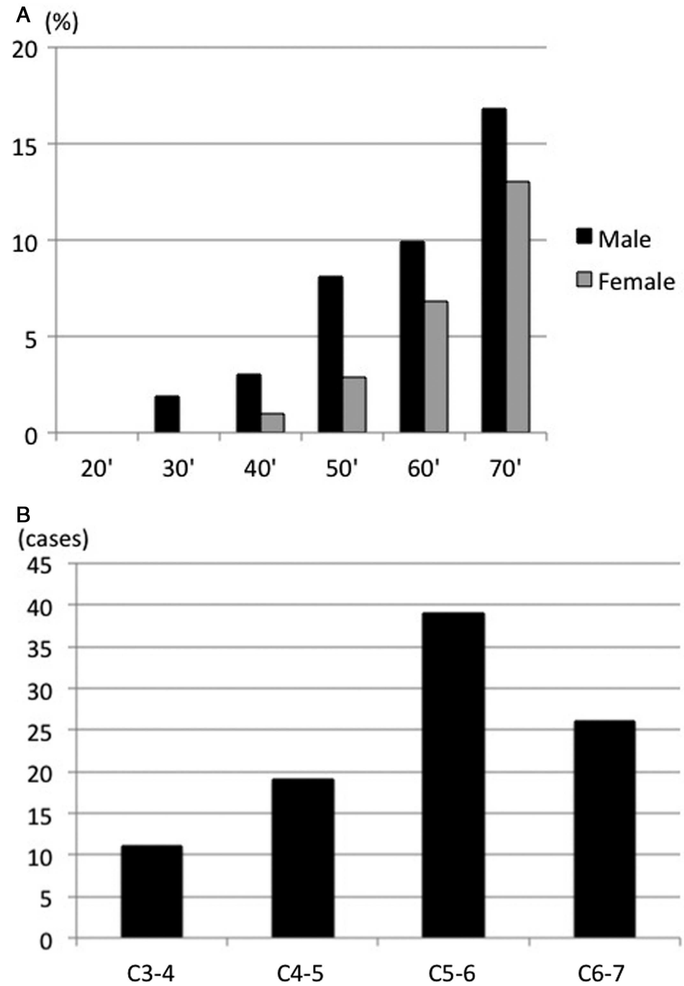

Figure 3. Frequency distribution of cervical SCC in asymptomatic subjects. A, Frequency distribution of SCC with age and sex. B, Frequency distribution of SCC along the spine. SCC indicates spinal cord compression.

biceps, and brachioradialis tendon reflex were normal. Tromner-Hoffman sign[17] were negative on both sides, but the Wartenberg sign[15] was positive on both sides. MR image showed fusion of the C5 and C6 vertebrae, and local kyphosis at C4–C6 (Figure 4). SCC was detected at C4–C5 and C5–C6, with ISI at C5–C6.

DISCUSSION

This study constituted the largest prospective evaluation of cervical spine MR image in asymptomatic subjects. This comprehensive survey demonstrated that small disc bulging was frequently observed even in the subjects in their 20s. In addition, the number of patients with minor disc bulging and the number of levels with small disc bulging increased from age 20 to 50 years. In contrast, the frequency of SCC and ISI increased after age 50 years, and this was accompanied by increased severity of disc bulging.

The increasing incidence of cervical disc bulging with aging among asymptomatic subjects has been extensively documented.[1–8] Cervical disc degeneration or bulging is frequently reported in asymptomatic subjects in their 40s and 50s.[1,3] In

Figure 4. Spine magnetic resonance imaging T2-weighted sagittal image of a 77-year-old asymptomatic male. There is fusion of the C5 and C6 vertebrae, and local kyphosis at C4–C6. Spinal cord compression detected at C4–C5 and C5–C6, with high-signal intensity change at C5–C6.

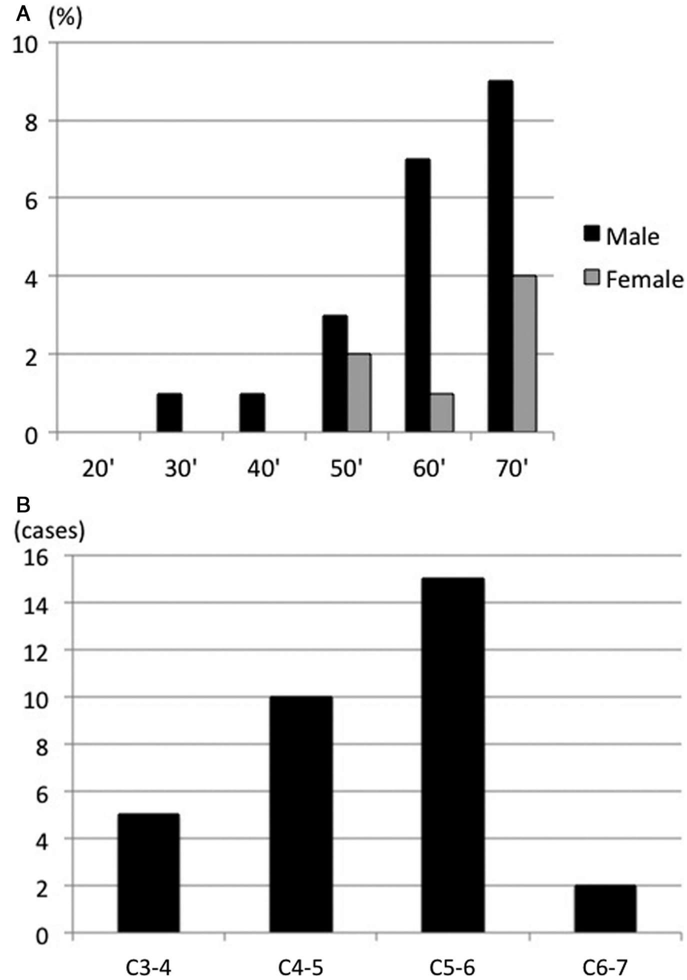

Figure 5. Frequency distribution of ISI changes on MR image in asymptomatic subjects. A, Frequency distribution of ISI with age and sex. B, Frequency distribution of ISI along the spine. ISI indicates increased signal intensity; MRI, magnetic resonance image.

this study, the number of cases and levels with small disc bulging increased and reached a plateau in the 50s. However, the severity of disc displacement continued to increase even after the 50s. Such disc bulging enlargement with age is highly suspected as a cause of spinal canal stenosis after the 50s.

Spinal canal stenosis is also known to gradually increase with age.[1,9,14] The reduction in spinal canal size occurred more frequently at the disc level than at the midvertebral level, particularly at C5–C6.[14] In addition to disc bulging, cervical spine alignment change could be another cause of SCC. Cervical lordosis in the neutral position increases with age, particularly in the 60s.[18] Changes in cervical alignment could compensate for the growing spinal canal stenosis with age. Spinal canal stenosis occurs by pincers effect, which defines pinching of the spinal cord between the ligamentum flavum and intervertebral disc. This effect is more pronounced in the lordotic alignment.[19] Accordingly, more severe pincer effects could occur in older populations with large disc bulging and lordotic alignment.

Few reports mentioned the severity of spinal canal stenosis in an asymptomatic population.[7] Teresi *et al*[7] noted that the reduction in cross-sectional area of the spinal cord never exceeded 16% in the asymptomatic population. However, in this study, the most severe case of SCC showed the reduction of the cross-sectional area exceeding 75%. Although the critical value at which symptoms manifest is not clear, a significant degree of SCC can be tolerated without any symptoms. Hamburger *et al*[20] reported the axial cross-sectional area of the dural sac in patients with cervical myelopathy; the preoperative and postoperative areas were 92 ± 37 mm^2 and 154 ± 36 mm^2, respectively. The axial cross-sectional area of the dural sac was 113 mm^2 in cases of SCC in our asymptomatic subjects, and the cross-sectional area in cases of SCC in asymptomatic subjects was not as severe as in cases with symptomatic cervical myelopathy. The severity of stenosis was just midway between that of the pre- and postoperative conditions of patients with symptomatic cervical myelopathy. This result could be valuable for knowing the degree of stenosis in symptomatic patients.

Although we performed receiver operating characteristic analysis to detect a relationship between disc bulging, SCC and ISI, disc bulge of more than 1.35 mm is not particularly severe, and so it seems likely that the combination of developmental canal stenosis, hypertrophy of ligamentum flavum,

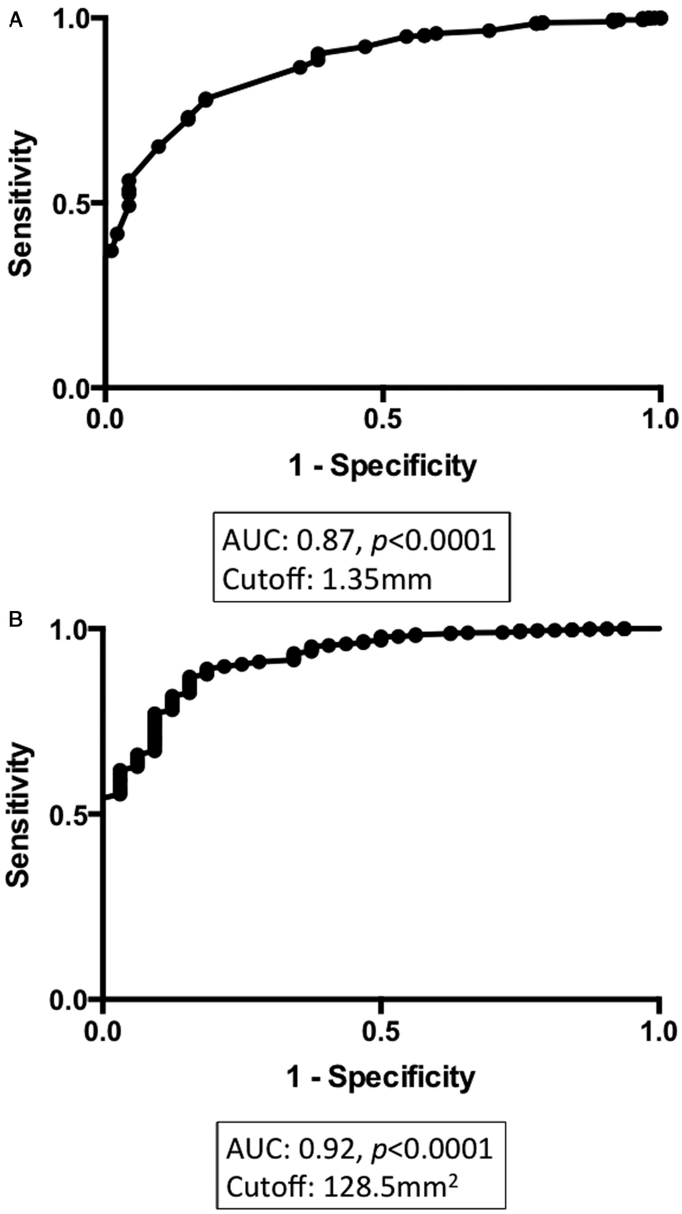

Figure 6. The ROC curves to determine (A) how big of a disc-bulge diameter would cause SCC to occur more frequently, and (B) how much SCC would increase ISI incidence. A, The relationship between disc bulging and SCC. B, The relationship between SCC and ISI. SCC indicates spinal cord compression; ISI, increased signal intensity; ROC, receiver operating characteristic.

and deformity of cervical spine is what is important for the occurrence of SCC.[12,13]

This study has some limitations. First, the survey was limited to the Japanese population, which does not rule out racial differences. Second, this large cohort included subjects with a wide variety of occupations in terms of physical demand, which may influence the progression or severity of cervical degenerative disease. Third, we used our original definition of SCC. To objectively and quantitatively evaluate SCC in asymptomatic subjects, we newly established this definition of SCC. In the other previous articles, SCC was defined as the presence of a defect in the cord, a definition that was subjective and not quantitative.[1,21] Especially in asymptomatic cases, interobserver reliability in SCC is not very high because canal compression in those cases was not severe.[21] Our definition is useful in asymptomatic subjects, however this might not be useful in symptomatic cases, especially ones with severe deformity or continuous type OPLL, and so further discussion is needed.

CONCLUSION

This large prospective analysis of cervical spine MRI data in asymptomatic subjects demonstrates the high frequency and multiple levels of degenerative change in the spinal cord and discs. Then, it is dangerous to make interventional decisions only by judging degenerative changes using MR images alone.

The results in this study alerted us to the fact that clinical decision making should be prudent, correlating MRI findings with clinical signs and symptoms. Future studies are required to monitor the progression of asymptomatic SCC to identify the MRI abnormalities that would predict the emergence of symptomatic cervical degenerative disease.

➢ Key Points

- ❑ Cervical disc bulging, SCC, and ISI changes were evaluated on cervical MR images of 1211 healthy volunteers.
- ❑ Most subjects presented with disc bulging (87.6%); the frequency, severity, and number of levels involved significantly increased with age.
- ❑ The frequency of SCC and ISI was 5.3% and 2.3%, respectively.
- ❑ The number of patients with minor disc bulging and the number of levels with small disc bulging increased from age 20 to 50 years.
- ❑ In contrast, the frequency of SCC and ISI increased after age 50 years, and this was accompanied by increased severity of disc bulging.

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