Does the sagittal alignment of the cervical spine have an impact on disk degeneration? Minimum 10-year follow-up of asymptomatic volunteers

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Abstract There have been few studies that investigated and clarified the relationships between progression of degenerative changes and sagittal alignment of the cervical spine. The objective of the study was to longitudinally evaluate the relationships among progression of degenerative changes of the cervical spine with age, the development of clinical symptoms and sagittal alignment of the cervical spine in healthy subjects. Out of 497 symptom-free volunteers who underwent MRI and plain radiography of the cervical spine between 1994 and 1996, 113 subjects (45 males and 68 females) who responded to our contacts were

enrolled. All subjects underwent another MRI at an average of 11.3 years after the initial study. Their mean age at the time of the initial imaging was 36.6 ± 14.5 years (11–65 years). The items evaluated on MRI were (1) decrease in signal intensity of the intervertebral disks, (2) posterior disk protrusion, and (3) disk space narrowing. Each item was evaluated using a numerical grading system. The subjects were divided into four groups according to the age and sagittal alignment of the cervical spine, i.e., subjects under or over the age of 40 years, and subjects with the lordosis or non-lordosis type of sagittal alignment of the cervical spine.

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During the 10-year period, progression of decrease in signal intensity of the disk, posterior disk protrusion, and disk space narrowing were recognized in 64.6, 65.5, and 28.3% of the subjects, respectively. Progression of posterior disk protrusion was significantly more frequent in subjects over 40 years of age with non-lordosis type of sagittal alignment. Logistic regression analysis revealed that stiff shoulder was closely correlated with females ($P = 0.001$), and that numbness of the upper extremity was closely correlated with age ($P = 0.030$) and male ($P = 0.038$). However, no significant correlation between the sagittal alignment of the cervical spine and clinical symptoms was detected. Sagittal alignment of the cervical spine had some impact on the progression of degenerative changes of the cervical spine with aging; however, it had no correlation with the occurrence of future clinical symptoms.

Keywords Cervical spine · Magnetic resonance imaging (MRI) · Sagittal alignment · Aging · Asymptomatic volunteers

Introduction

Disk degeneration occurs with aging [3], leading to structural changes of the intervertebral disks, including posterior bulging of the disks and narrowing of the disk space. Such structural changes in the disks may have influence on the sagittal alignment of the cervical spine [13], while, conversely, malalignment of the cervical spine may render excessive load to the disks, possibly promoting disk degeneration.

Sagittal alignment of the cervical spine is known to vary morphologically with age and gender [9]. Harrison et al. [13] conducted cross-sectional evaluation of the cervical spinal curvature in 72 healthy subjects using plain X-rays, and reported a mean lordosis angle of the cervical spine (C2–C7) of 34°. Nojiri et al. [23], who conducted a similar assessment in 313 healthy Japanese volunteers, reported a mean lordosis angle to be 16.2°. Gore et al. [10] conducted a 10-year longitudinal evaluation of the sagittal alignment of the cervical spine by plain radiography, and reported that the lordosis angle of the cervical spine tended to increase with aging. Thus, it appears that the cervical spine generally shows a lordotic curvature. On the other hand, Matsumoto et al. [21] reported that subjects younger than 40 years of age presented a non-lordotic cervical curvature more frequently than those over 40 years.

It is reported that neck pain is complained by 34.4% of the general population. Similar to low back pain, neck pain is one of the most common musculoskeletal complaints that most humans experience at some time in their lives [2].

However, many reports have shown the absence of any distinct correlation between the sagittal alignment of the cervical spine and the development of neck pain. Grob et al. [11] divided 107 patients with diseases of the lower extremities into groups with and without neck pain, and assessed the correlation between neck pain and the sagittal alignment of the cervical spine on plain lateral radiographs. They found no significant correlation between the sagittal alignment of the cervical spine and the presence of neck pain, and reported that any association between neck pain and the abnormality of the sagittal cervical alignment is purely coincidental.

Thus, previous cross-sectional studies have failed to show any correlation between the sagittal alignment of the cervical spine and the clinical symptoms. However, no long-term longitudinal studies have been undertaken to date to clarify associations among the sagittal alignment, clinical symptoms and the development and progression of degenerative changes of the cervical intervertebral disks.

We conducted a cross-sectional survey of the cervical spine in 497 healthy volunteers using magnetic resonance imaging (MRI), and reported the occurrence of age-related changes of the intervertebral disks in 1998 [22]. In this study, we also obtained plain radiographs of the cervical spine of the subjects.

In the present study, we have obtained MRI of the cervical spine once again in the same cohorts approximately 10 years after the previous MRI study. The objectives of the present study were to evaluate if the degenerative changes of the cervical spine found in the previous study have progressed and to clarify the relationships among the sagittal alignment of the cervical spine, progression of disk degeneration, and the development of clinical symptoms.

Materials and methods

For the present study, we obtained approvals from the institutional review boards of all participating institutions. Four hundred ninety-seven asymptomatic healthy volunteers (262 males and 235 females) underwent MRI of the cervical spine in the initial study between 1993 and 1996. All participants in the previous study had no symptoms related to the cervical spine. The participants in the initial investigation were recruited by oral advertisement from the investigators to the hospital staffs and their acquaintances and to high school students close to the investigators' hospitals. No patient with known preexisting cervical, thoracic, or lumbar spinal disorders was included into the initial investigation. The occupations of the initial participants were as follows: office workers 214; doctors, nurses

and medical coworkers 138; manual workers (construction, farming, etc.) 12; students 75; others (housewives, retired, etc.) 58. Those with a history of neck injury and/or treatments for neck pain, and those with systemic diseases, such as rheumatoid arthritis, were excluded.

We asked the volunteers to participate again in the present survey by mail or telephone. Written informed consent for the participation was obtained from all participants after the explanation of the purpose and contents of the present study. Of the 497 subjects examined in the previous study, 113 subjects whose previous MRI and radiographs were both available participated in the present follow-up study. The reasons for drop-outs of 384 subjects at the follow-up study were as follows: 203 subjects were unable to be located; 71 refused or were unable to participate in the follow-up study; 110 did not have the initial radiographs available.

There were 45 males and 68 females, whose mean age at the time of the initial imaging was 36.6 ± 14.5 years (11–65 years), and the mean interval between the first and second imaging was 11.3 years (9.9–12.8 years) (Table 1). All subjects filled questionnaires regarding clinical symptoms and underwent neurological examination by orthopedic spine surgeons, then underwent MRI of the cervical spine. The previous MRI was conducted using 1.5 Tesla (T) or 0.5 T superconducting imagers, while in the present study, 1.5 T superconducting imagers were used for all subjects.

In the previous imaging, a 1.5-T (Signa, General Electronic, WI, USA) or 0.5 T (Resona, Yokogawa Medical System, Tokyo, Japan) superconducting imager was used. In the present investigation, a 1.5-T superconducting imager was used for all subjects. In the previous imaging, using phased array coils, a fast spin-echo technique was used with following sequences: a T1-weighted sagittal image [repetition time (TR)/echo time (TE), 520/12; echo train length, 4; thickness of slice, 5 mm; field of view (FOV), 24 cm; matrix size, 256×192 ; number of excitation (NEX), 4 times], T2-weighted sagittal image (TR/TE, 5000/102; echo train length, 16; the remaining items

were the same as those for T1-weighted sagittal images), and T1- and T2-weighted axial images (FOV, 16 cm; the remaining items were the same as those for T1-weighted sagittal images). When the 0.5-T system was used, images were taken by a spin echo technique using a surface coil for the cervical spine with following sequences: T1-weighted sagittal images (TR/TE, 450–500/25; thickness of slice, 5 or 7 mm; FOV, 25 cm; matrix size, 256×256 or 256×192 ; NEX, 4 times), T2-weighted sagittal images (TR/TE, 2000/100; thickness of slice, 5 or 7 mm; FOV, 25 cm; matrix size, 256×224 or 256×160 ; NEX, twice), and T1- and T2-weighted axial images (FOV, 20 or 22 cm; NEX, twice or four times; the rest items were the same as those for T1-weighted sagittal images).

In the present investigation, images were taken by a fast spin-echo technique using a 1.5-T superconducting imager (Signa Excite HD 1.5 T, General Electronic, WI, USA) with the following sequences: T1-weighted sagittal images (TR/TE, 380/8.2; echo train length, 2; thickness of slice, 4 mm; FOV, 24 cm; matrix size, 256×192 ; NEX, three times), T2-weighted sagittal images (TR/TE, 5000/100; echo train length, 16; NEX, three times; remaining items were the same as those for T1-weighted sagittal images), and T1- and T2-weighted axial images (TR/TE, 5000/102; thickness of slice, 5 mm; FOV, 16 cm; remaining items were the same as those for T1-weighted sagittal images).

In the previous study, plain radiographs of the cervical spine were obtained with the subjects in a sitting position, gazing forward, and relaxed. The film-tube distance was set to 1.5 m. In the present study, a second X-ray was not obtained because of the ethical consideration to avoid an extra exposure to X-rays.

The sagittal alignment of the cervical spine was classified into two types, lordosis and non-lordosis type, the latter including straight sigmoid and kyphosis according to the classification reported by Chiba et al. [4] (Fig. 1). All participants were divided into four groups by their age (<40 years and ≥ 40 years) and the sagittal alignment (lordosis and non-lordosis) of the cervical spine: young lordosis (YL) group, $n = 29$; young non-lordosis (YNL) group, $n = 36$; old lordosis (OL) group, $n = 34$; and old non-lordosis (ONL) group, $n = 14$. The cut-off line of the age at 40 years was chosen according to the study reported by Boden et al. [1] regarding aging in the cervical intervertebral disks. The items evaluated on MRI were (1) decrease in signal intensity of disk, (2) posterior disk protrusion, and (3) disk space narrowing. Each item was evaluated using the Matsumoto's [22] classification with a minor modification, which was used in our previous report (Table 2).

All levels from C2–C3 to C7–T1 were evaluated. An increase by at least one grade in any item at one or more intervertebral levels was regarded as progression of

Table 1 Age and gender of study population

Age	No. of males	No. of females
10–19	8	7
20–29	17	11
30–39	8	14
40–49	5	12
50–59	4	22
>60	3	2
Total	45	68

Fig. 1 Sagittal alignment of cervical spine. A line is drawn between the lower posterior corner of the C2 and C7, and this line is defined as “A.” Perpendicular lines are drawn from the lower posterior edge of the bodies of C3–C6 to this line, and the length of these lines is defined as a1–a4. If every a1–a4 is anterior to “A” and one of them is more than 2 mm, the curvature is defined as lordosis. If every a1–a4 is posterior to “A” and one of them is more than 2 mm, the curvature is defined as kyphosis. If every a1–a4 is less than 2 mm, the curvature is defined as straight. If a1–a4 exists both anterior and posterior and one of them is more than 2 mm, the curvature is defined as sigmoid

Table 2 Grading system for MR evaluation

1. Decrease in signal intensity of intervertebral disk
Grade 0: as bright as or slightly darker than cerebrospinal fluid
Grade 1: markedly darker than cerebrospinal fluid
Grade 2: complete loss of signal
2. Posterior disk protrusion
Grade 0: no protrusion
Grade 1: disk material protruding beyond posterior margin of vertebral body without cord compression
Grade 2: beyond vertebral body with cord compression
3. Disk space narrowing
Grade 0: 100–75% of height of upper healthy disk
Grade 1: 75–50% of height of upper healthy disk
Grade 2: less than 50% of height of upper healthy disk

degeneration. The present and previous MRI films were graded independently by two experienced neuroradiologists in a blinded fashion. The results were finalized by the one neuroradiologist. The data on the progression of disk degeneration on MRI during the 10-year interval between the two examinations were statistically tested using χ^2 test. Multiple logistic regressions analysis was conducted to analyze the relationship between the sagittal alignment of the cervical spine and the progression of disk degeneration and between the sagittal alignment of the cervical spine and the occurrence of symptoms. The inter-observer reliability of the MRI-grading was tested by calculating kappa scores. A *P* value less than 0.05 was considered to be statistically significant. Dr. SPSS II for Windows (SPSS Japan Inc., Tokyo, Japan) was used for all analyses.

Results

In the initial MRIs, decrease in signal intensity of the disk was observed in 6 (21%) and 11 (31%) of the subjects in the YL and YNL groups (*P* = 0.271), and 13 (93%), and 28 (82%) of the subjects in the OL and ONL groups, respectively (*P* = 0.329). Posterior disk protrusion was observed in 5 (17%) and 7 (19%) of the subjects in the YL and YNL groups (*P* = 0.540), and 19 (56%) and 5 (36%) of the subjects in the OL and ONL groups (*P* = 0.171). Disk space narrowing was observed in none of the YL and YNL groups, and 8 (24%) and 4 (29%) of the subjects in the OL and ONL groups (*P* = 0.489). Thus, there were no significant differences in the frequency of any of the MRI changes evaluated between the YL and YNL groups or between the OL and ONL groups.

Progression of decrease in signal intensity of the disk, posterior disk protrusion, and disk space narrowing were recognized in 73 (64.6%), 74 (65.5%), and 32 (28.3%), respectively, of all subjects.

No significant difference in the incidence of progression of decrease in signal intensity of the disk or disk space

Table 3 Incidence of progression of each MR finding

	Decrease in signal intensity		Posterior disk protrusion		Disk space narrowing	
	Prevalence (%)	<i>P</i> value	Prevalence (%)	<i>P</i> value	Prevalence (%)	<i>P</i> value
Young lordosis group	17/29 (58.6)	0.521	17/29 (58.6)	0.341	5/29 (17.2)	0.239
Young non-lordosis group	22/36 (61.1)		24/36 (66.7)		3/36 (8.3)	
Old lordosis group	25/34 (73.5)	0.379	20/34 (58.8)	0.020*	15/34 (44.1)	0.171
Old non-lordosis group	9/14 (64.3)		13/14 (92.9)		9/14 (64.3)	

Asterisks indicate statistical significance

Table 4 Logistic regression analyses of MR findings and sagittal alignment of cervical spine

	Decrease in signal intensity		Posterior disk protrusion		Disk space narrowing	
	<i>P</i> value	Odds ratio (95% CI)	<i>P</i> value	Odds ratio (95% CI)	<i>P</i> value	Odds ratio (95% CI)
Sagittal alignment (non-lordosis)	0.970	0.9846 (0.44–2.33)	0.033*	2.645 (0.15–0.93)	0.785	1.143 (0.34–2.29)
Age (>40 years)	0.116	2.033 (0.84–4.92)	0.082	2.281 (0.90–5.78)	0.000*	8.564 (3.05–24.02)
Sex (male)	0.054	2.349 (0.99–5.60)	0.025*	2.871 (1.14–7.21)	0.336	1.631 (0.60–4.42)

Asterisks indicate statistical significance

95% CI 95% confidence interval

Table 5 Incidence of clinical symptoms

	Neck pain		Shoulder stiffness		Numbness in the upper limbs	
	Prevalence (%)	<i>P</i> value	Prevalence (%)	<i>P</i> value	Prevalence (%)	<i>P</i> value
Young lordosis group	4/29 (13.8)	0.239	7/29 (24.1)	0.230	1/29 (3.4)	0.446
Young non-lordosis group	2/36 (5.6)		5/36 (13.9)		0/36 (0.0)	
Old lordosis group	6/34 (17.6)	0.329	12/34 (35.3)	0.265	1/34 (2.9)	0.069
Old non-lordosis group	1/14 (7.1)		7/14 (50.0)		3/14 (21.4)	

Table 6 Logistic regression analyses of clinical symptoms and sagittal alignment of cervical spine

	Neck pain		Shoulder stiffness		Numbness in the upper limbs	
	<i>P</i> value	Odds ratio (95% CI)	<i>P</i> value	Odds ratio (95% CI)	<i>P</i> value	Odds ratio (95% CI)
Sagittal alignment (non-lordosis)	0.154	0.365 (0.68–10.94)	0.788	0.872 (0.42–3.12)	0.314	2.786 (0.49–2.63)
Age (>40 years)	0.646	1.348 (0.37–4.82)	0.208	1.898 (0.70–5.15)	0.030*	13.555 (1.29–142.83)
Sex (male)	0.955	1.038 (0.290–3.71)	0.001*	0.720 (0.16–0.325)	0.038*	11.826 (1.15–121.33)

Asterisks indicate statistical significance

95% CI 95% confidence interval

narrowing was observed between the YL and YNL groups or the OL and ONL groups, while incidence of progression of posterior disk protrusion was significantly higher in the ONL than the OL group ($P = 0.020$) (Table 3).

Logistic regression analysis using the sagittal alignment, age, and gender as the covariates revealed that the odds ratio of posterior disk protrusion in the non-lordosis group over the lordosis group was 2.646 ($P = 0.033$). The odds for progression of disk space narrowing was significantly higher in the older group, including OL and ONL groups ($P < 0.001$), and the risk for progression of posterior disk protrusion was significantly higher in the male subjects ($P = 0.025$) (Table 4).

Of all the subjects who used to be asymptomatic at the time of the initial study, 13 subjects (11.5%) had neck pain, 31 (27.4%) stiff shoulder, and five (4.4%) numbness in the upper extremities, at the time of the present study. The inter-group evaluation revealed no statistically significant differences between the YL and YNL groups or between

the OL and ONL groups in terms of the frequency of neck pain, stiff shoulder, and numbness of the upper extremities (Table 5).

We then conducted logistic regression analysis using the sagittal alignment, age and gender as the covariates, and the occurrence of clinical symptoms as the dependent variable. The presence of stiff shoulder was closely correlated with the female gender ($P = 0.001$), and that of numbness in the upper extremities was closely correlated with the age ($P = 0.030$) and male gender ($P = 0.038$). However, the sagittal alignment of the cervical spine was not significantly correlated with the development of any symptoms (Table 6).

Regarding the inter-observer reliability of MR grading, the kappa scores for decrease in signal intensity of disks, posterior disk protrusion, and disk space narrowing were 0.60, 0.72, and 0.71, respectively. Thus, the inter-observer reliability of MR reading was favorable.

Case presentation: Figs. 2 and 3.

Case #110:

Fig. 2 Case presentation. The 49-year-old male had no clinical symptoms at the time of the previous study and was classified into the old non-lordosis group

Fig. 3 Case presentation. Twelve years later, progression of decrease in signal intensity, posterior disk protrusion at C5–C6 was demonstrated on the follow-up MR images. However, he still remained free of clinical symptoms related to the cervical spine at the follow-up. **a** Sagittal T2-weighted MR image obtained at the previous study. **b** Axial T2-weighted MR image at C5–C6 level demonstrating posterior disk protrusion of grade 1. **c** Sagittal T2-weighted MR image of the same subject 12 years later showing progression of decrease in signal intensity (grade 1) at C3–C4 to C6–C7 and posterior disk protrusion at C5–C6 (grade 2) and at C6–C7 (grade 1). **d** Axial T2-weighted MR image at C5–C6 at the follow-up demonstrating progression of posterior disk protrusion

Discussion

Previous studies have shown that age-related degenerative changes of the cervical spine occur at a constant rate even in healthy persons. There have been a number of reports on the evaluation of age-related changes of the cervical spine using plain radiography. Freidenburg et al. [8] conducted a plain radiographic evaluation in healthy individuals, and recognized spondylotic changes of the cervical spine in 25 and 75% of the subjects in their fifties and seventies, respectively. With regards to the evaluation by MRI, Boden et al. [1] reported that age-related changes of the cervical spine could be detected in at least 90% of healthy males over the age of 50 and 90% of healthy females over the age of 60.

Matsumoto et al. [21] compared the alignment of the cervical spine in 495 asymptomatic subjects with those in 488 patients with acute whiplash injury. They reported that there was no difference between the asymptomatic and the patient group in terms of the absence of lordosis or presence of local kyphosis. They also reported that there was no correlation between the alignment of the cervical spine and the presence of any clinical symptoms.

Thus, numerous reports published in the literature to date have concluded that there is no direct correlation between age-related changes of the cervical spine and the occurrence of any clinical symptoms [1, 10, 22].

Several reports have shown that some of the factors [5] promoting the progression of degenerative changes of the cervical spine were excessive load on the spine [6, 19], a past history of lumbar vertebral diseases [17], smoking [12], and hemodialysis [20, 25, 27]. Jumah et al. [19] investigated the factors promoting degeneration of the cervical spine in 305 Ghanans and found that 63.6% of the subjects who routinely carried baggage on their head had spondylotic changes of the cervical spine, while only 36.0% of those who did not habitually carry loads showed such changes. These observations indicated that excessive load on the neck is a promoting factor of degenerative changes of the cervical spine.

Although alignment of the cervical spine was frequently studied in cases of cervical myelopathy or radicular pain in relation to surgical outcomes [7, 15, 16, 18, 24, 26], scarce attention has been paid to the cervical alignment in healthy populations, and no study has dealt with the impact of the alignment of the cervical spine on the progression of degenerative changes of the cervical spine.

The results of the present study revealed that the frequency of progression of age-related changes of the cervical disks during 10 years was significantly higher in the non-lordosis and older groups, and in the male subjects. Harrison et al. [14] have reported that the vertical load exerted to the vertebral body of the cervical spine was at least ten times stronger at the apex of kyphosis than that of

lordosis. This biomechanical information may explain the high frequency of posterior disk protrusion in the non-lordosis group in our study.

On the other hand, there was no significant correlation between the sagittal alignment of cervical spine at the time of the first MRI and the occurrence of clinical symptoms over the next 10 years. The occurrence of clinical symptoms was rather more closely correlated with age and gender.

One of the limitations of the present study is the fact that the sagittal alignment of the cervical spine was only evaluated on radiographs taken at the time of the first study because of the ethical consideration against repeated exposures to radiation. We were not able to evaluate the longitudinal changes in the alignment of the cervical spine. Some subjects may have had changes in the alignment during the 10-year period. The sagittal alignment of the cervical spine evaluated on MRI taken in the supine position might not be correlated with those evaluated on sitting radiographs. Another limitation is that, in both studies, superconducting imagers were used and the fast spin echo sequence was mainly used, but the types of MR imagers and softwares were not identical between two studies, which could have led to some difference in the quality of images between the first and second MRI. To minimize the impact of such differences in the image quality, we used the same classification for image grading, e.g., signal intensity of the disk was compared with the intensity of the cerebrospinal fluid at the same level to maintain universality of the results of image assessment. The inter-observer agreement between the two readers on the image evaluation using the kappa score was acceptable. The third limitation is some bias in the patient selection at the initial investigation and at the follow-up. Because, in the initial study, the participants were recruited using oral advertisement by study investigators, medical workers accounted for a large percent of the study population. The bias in participants at the follow-up study was related to the low follow-up rate of the original cohorts due to various reasons as described in “[Materials and methods](#)”.

Nonetheless, for these limitations, this is the first study of the long-term observation that elucidated the relationship between the alignment of the cervical spine and the progression of disk degeneration in healthy individuals. The present study revealed that the alignment of the cervical spine had some impact on the progression of the degenerative changes of the cervical spine.

Conclusion

The incidence of progression of posterior disk progression was significantly higher in older subjects with non-lordotic alignment than those with lordotic alignment.

Sagittal alignment of the cervical spine was not correlated with the occurrence of future clinical symptoms, but it did have an impact on the progression of degenerative changes of the cervical spine.

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