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Correlation of Cervical Disc Degeneration with Sagittal Alignments of Cervical Spine

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Objective: To determine the relationship between cervical sagittal parameters and the degree of the cervical disc degeneration at each cervical level by using cervical plain radiographs and disc degeneration grading. **Method:** This study analyzed 110 patients with posterior neck pain. Cervical radiographic measurements included the occipito-cervical (O～C2) angle; sagittal Cobb angles of C1～C2, C2～C7; and sagittal vertical axis (SVA) of C1～C7 and C2～C7. The degenerations of cervical discs at each level were evaluated through Pfirrmann grading system by magnetic resonance images of the cervical spine. The correlations between the cervical sagittal measurements and the disc degeneration at each level were analyzed by Spearman's correlation. **Results:** A significant correlation was found for the C2～C7 angle with disc degenerations at C2～C6 levels. O～C2 angle was correlated significantly with disc degenerations at C2～C4 and C5～C7 levels. There was significant correlation between C1～C2 angle and disc degeneration at C6～C7 level. No significant relationship was found between the cervical SVA and the cervical disc degeneration at all cervical levels. **Conclusion:** Cervical sagittal parameters representing cervical angles (C2～C7, O～C2, and C1～C2 angles) were significantly correlated with the degree of the cervical disc degeneration. These findings suggest that the loss of the natural cervical lordosis rather than loss of natural SVA could be correlated with progression of the cervical disc degeneration. **(Clinical Pain 2019;18:8-15)**

Key Words: Cervical vertebrae, Intervertebral disc degeneration, Kyphosis, Lordosis

INTRODUCTION

The loss of cervical lordosis is the most common cervical sagittal balance disorder.[1,2] Although the sagittal alignment of the cervical spine could vary with age and sex,[1,3] the natural sagittal curve of the cervical spine is known to have a lordotic shape.[4-6] Harrison et al. reported a mean C2～C7 lordotic angle of －26.89 ± 9.72º in 72 healthy participants.[5] Liu et al. demonstrated a mean C2～C7 lordotic angle of －21.40 ± 12.15º in 212 asymptomatic volunteers.[6] It has been reported that up to 42% estimated prevalence of loss of cervical lordosis in patients with posterior neck pain.[7]

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Recently, several studies have demonstrated that a spectrum of cervical disorders had the relationship with the loss of cervical lordosis, i.e. kyphosis.[1,8,9] One cross-sectional study revealed that decreasing natural cervical lordosis was correlated with increasing Neck Disability Index scores.[10] Another prospective cohort study reported that patients who had higher preoperative lordotic angles showed better outcomes than those with kyphotic alignment in patients with myelopathy.[9] Some researchers have found a negative effect of cervical malalignment on health-related quality of life.[1,11]

Increased sagittal vertical axis (SVA) is also common cervical sagittal imbalance condition found in the population with symptomatic neck pain.[10] The normal physiologic C2～C7 SVA was estimated to be 16.8 ± 11.2 mm in asymptomatic subjects.[12] Several studies found that increased SVA value had relationship with clinical symptoms.[11,13]

Most researches on the cervical sagittal balance have been performed by analyzing the radiographs of cervical spine and the comparing clinical symptoms,[1,13,14] whereas few studies focused on the relationship between cervical sagittal alignment and the disc degeneration presented by magnetic resonance imaging (MRI). There was a study that revealed the progression of the cervical disc degeneration had more related in the non-lordotic group than in the lordotic group, however it had a limitation that had analyzed categorically only concerning with the C2～C7 Cobb angle, without considering the other sagittal variables such as SVA nor occipito-cervical angle.[15]

The aim of this study is to examine the relationship between the cervical disc degeneration at each cervical level in MRI and the several parameters of cervical sagittal balance of plain radiographs in the participants with posterior neck pain.

MATERIALS AND METHODS

1. Participants

From January 2015 to July 2015, 421 patients with posterior neck pain who visited a spine center of a university hospital in metropolitan area were screened. Patients who took both cervical spine radiographs in standing position and cervical MRIs were included. The exclusion criteria were as follows: history of cervical spinal surgery or trauma, symptoms or signs of inflammatory back pain such as ankylosing spondylitis, imaging evidences of concurrent myelopathy, and fracture of the cervical spine. A total of 110 patients finally comprised our study population. The study was approved by the institutional review board of our institute (no. 2016-0558-001).

2. Measurements of parameters

1) Plain radiographs: All cervical plain radiographs were reviewed and analyzed using the Picture Archiving and Communication System. Plain radiographs were obtained with the patients who were requested to remain in a standing position. From the lateral cervical plain radiographs, several parameters were measured as follow; occipito-cervical angulation (O～C2 angle), sagittal Cobb angles of the C1～C2, C2～C7 (C1～C2 angle, C2～C7 angle) and the SVA of C1～C7, C2～C7 (Fig. 1).

2) MRIs: A 3.0-T cervical MRIs (Discovery MR750; GE Healthcare, Milwaukee, WI, USA) were performed to evaluate the disc degeneration. Sagittal and axial T2-weighted

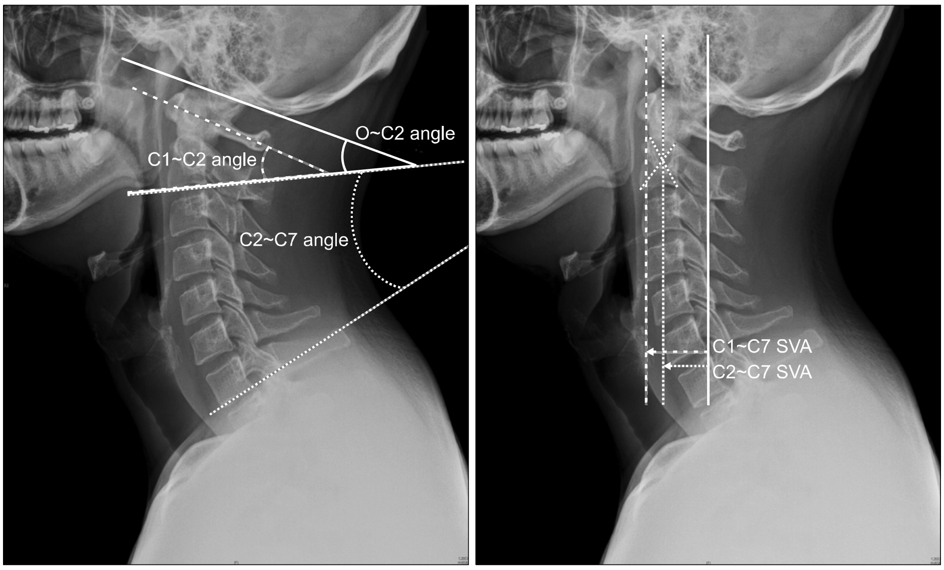

Fig. 1. Parameters of cervical sagittal alignment on plain radiographs. O～C2 angle, angle between the McGregor line and the lower endplate of C2; C1～C2 angle, angle between a line connecting the anterior tubercle to the posterior margin of the C1 spinous process and the lower endplate of C2; C2～C7 angle, angle between the lower endplate of C2 and C7 determined with Cobb method; C1～C7 SVA, distance between the plumb line from the anterior arch of C1 and the posterior-superior corner of C7; C2～C7 SVA, distance between the plumb line from the centroid of C2 and the posterior-superior corner of C7.

MR imaging was performed for each cervical level. The severity of disc degeneration for each cervical level from C2 to C7 was assessed according to the Pfirrmann grading system (Table 1). Pfirrmann grading assesses the disc structure by homogeneity and the distinction of annulus and nucleus by using T2-weighted mid-sagittal images.[16]

3) Lordotic and non-lordotic groups: To identify the specific correlation of the SVA with the cervical disc degeneration, the patients were divided into two groups (lordotic group and non-lordotic group) according to the C2～C7 Cobb angle on cervical plain radiographs. We set the cutoff of the C2～C7 lordotic angle as −17.17º, based on the study by Harrison et al.[5] According to the study by Harrison et al, we set lordotic angle presenting extension of cervical spine as negative value (Fig. 2A) and kyphotic angle presenting flexion of cervical spine as positive value (Fig. 2B).[5]

3. Statistical analysis

SPSS version 20.0 (IBM Corporation, White Plains, NY, USA) was used for data analyses. Continuous variables were examined for normality, using the Shapiro-Wilk test. The comparisons of baseline characteristics between two groups were tested with Mann-Whitney test, Chi-square test, and independent t-test. The O～C2 angles following the normal distribution were compared by parametric independent t-test, and the other non-normal distribution parameters were compared by non-parametric test between the two groups. The correlations among the cervical parameters which were measured from the lateral view of the cer-

Table 1. Grades of Disc Degeneration of Pfirrmann et al.[16]

Grade	Structure	Distinction of Nucleus and Annulus	Intensity of signal	Intervertebral Disc Height
I	Homogeneous, white	Clear	Isointense or hyperintense to CSF	Normal
II	Not homogenous with or without horizontal bands	Clear	Isointense or hyperintense to CSF	Normal
III	Not homogenous, gray	Unclear	Intermediate	Normal to slightly decreased
IV	Not homogenous, gray to black	Lost	Intermediate to hypointense	Normal to moderately decreased
V	Not homogenous, black	Lost	Hypointense	Collapsed disc space

CSF: cerebrospinal fluid.

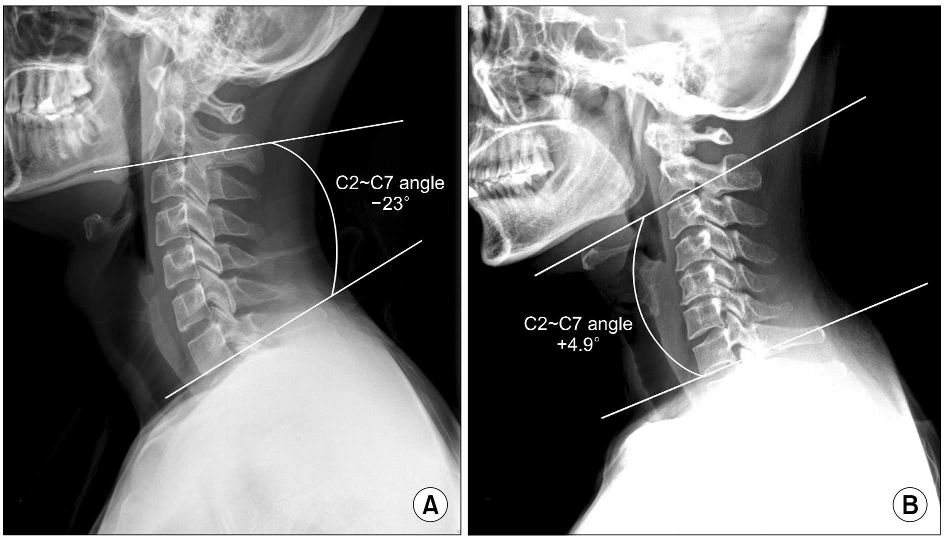

Fig. 2. The sagittal radiographs of the cervical spine in lordotic and non-lordotic patients. (A) The C2～C7 Cobb angle is measured as −23 degrees, which means normal lordotic curve. (B) The C2～C7 Cobb angle was measured as +4.9, indicating a loss of cervical lordosis.

vical plain radiographs were analyzed by Spearman's correlation test. Correlations between the parameters of cervical sagittal alignment and the degree of the cervical disc degeneration at each level were analyzed using Spearman's correlation test. p value less than 0.05 was defined to be significant.

RESULTS

1. Basic characteristics of the participants

The study included a total of 110 patients (53 male, 57 female). The basic characteristics of the patients are summarized in Table 2. 30 patients (11 male, 19 female) were classified into the lordotic group and 80 patients (42 male, 38 female) were classified into the non-lordotic group. The mean age of the patients was 52.0 (46.0～59.0) years; 53.5 (46.0～61.3) years for the lordotic group, 52.0 (46.5～58.0) years for the non-lordotic group. There were no statistical differences in age and sex between the lordotic and non-lordotic group. For O～C2 angle, C1～C2 angle, C2～C7 angle and SVA of C1～C7, there were significant differences between the two groups.

The degrees of cervical disc degeneration assessed at each level in all patients. In the assessment of disc degeneration according to Pfirrmann grading system, grade I was most commonly observed at the C2～C3 level. Grade V was more common at the C5～C6 level than at any other level (Fig. 3).

2. Analysis of cervical sagittal parameters

The correlations among cervical sagittal parameters in all patients are presented in Table 3. The C2～C7 angle was significantly correlated with the O～C2 angle. The O～C2 angle was significantly correlated with the C1～C2 angle, C1～C7 SVA and C2～C7 SVA. The C1～C2 angle was significantly correlated with both C1～C7 SVA and C2～C7 SVA. The C1～C7 SVA and C2～C7 SVA were significantly correlated. There was no significant correlation between age and all cervical radiographic parameters.

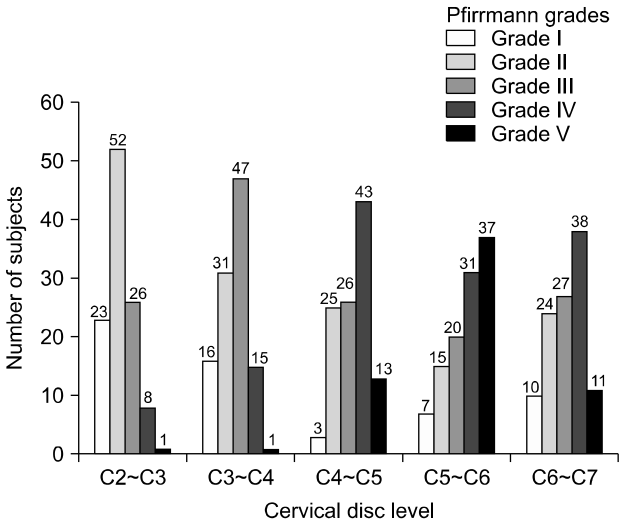

Fig. 3. Number of patients with the cervical disc degeneration assessed by using Pfirrmann grades in all patients.

Table 2. Basic Characteristics of Participants

	Total patients (n = 110)	Lordotic group (n = 30)	Non-lordotic group (n = 80)	p value
Age (years)	52.0 (46.0～59.0)	53.5 (46.0～61.3)	52.0 (46.5～58.0)	0.566
Sex: male/female, n (%)	53 (48.2%)/57 (51.8%)	11 (36.7%)/19 (63.3%)	42 (52.5%)/38 (47.5%)	0.139
Sagittal parameters				
O～C2 angle	−23.4 ± 7.4	−17.7 ± 5.8	−25.6 ± 6.7	0.000*
C1～C2 angle	−26.0 (−21.0 to −30.0)	−22.5 (−16.8 to 26.0)	−28.0 (−24.0 to −31.8)	0.000*
C2～C7 angle	−1.50 (9.0 to −18.0)	−21.5 (−19.0 to −25.5)	−11.0 (6.0 to −14.9)	0.000*
SVA of C1～C7	25.5 (18.0～34.0)	20.5 (15.8～29.3)	26.5 (19.3～36.0)	0.010*
SVA of C2～C7	17.0 (12.0～25.0)	14.5 (11.5～23.3)	18.0 (12.3～35.0)	0.123

SVA: sagittal vertical axis.
The negative value of the cervical angle presents the extension of the cervical spine.
*Statistically significant at $p<0.05$.

Table 3. Correlations among Cervical Sagittal Parameters in All Patients

	Age	C2～C7 angle	O～C2 angle	C1～C2 angle	C1～C7 SVA
C2～C7 angle	0.009 (*p*=0.922)				
O～C2 angle	0.007 (*p*=0.945)	−0.283 (*p*=0.003)*			
C1～C2 angle	0.109 (*p*=0.257)	0.180 (*p*=0.060)	0.701 (*p*=0.000)*		
C1～C7 SVA	0.150 (*p*=0.118)	0.187 (*p*=0.050)	0.320 (*p*=0.001)*	0.320 (*p*=0.001)*	
C2～C7 SVA	0.179 (*p*=0.061)	0.114 (*p*=0.236)	0.488 (*p*=0.000)*	0.304 (*p*=0.001)*	0.950 (*p*=0.000)*

*Correlation was significant at the $p<0.05$ level.
SVA: sagittal vertical axis.

3. Correlation between parameters of the cervical spine and the cervical disc degeneration

1) Cervical angles and the cervical disc degeneration at each level: The Spearman's correlations for cervical sagittal angles and degree of disc degeneration at each level in all patients are presented in Table 4. The C2～C7 angle revealed a significant correlation with Pfirmann grades in C2～C3 (r = 0.246, *p*=0.009), C3～C4 (r = 0.240, *p*=0.012), C4～C5 (r = 0.239, *p*=0.012) and C5～C6 (r = 0.215, *p*=0.024) levels. The O～C2 angle was correlated with Pfirmann grades in C2～C3 (r = 0.217, *p*=0.023), C3～C4 (r = 0.235, *p*=0.013), C5～C6 (r = 0.234, *p*=0.014) and C6～C7 (r = 0.296, *p*=0.002) levels. The C1～C2 angle had only significant correlation with Pfirmann grade in C6～C7 (r = 0.213, *p*=0.025) levels.

2) SVA and the cervical disc degeneration at each level: The C2～C7 SVA and C1～C7 SVA had no significant correlation with Pfirrmann grades at any cervical level in all subjects (Table 5). Subgroup analysis in both lordotic and non-lordotic group also revealed that C2～C7 and C1～C7 SVA had no significant correlation with Pfirmann grades in all cervical levels (Table 5).

Table 4. Spearman's Correlation between Sagittal Angles of the Cervical Spine and the Degree of the Cervical Disc Degeneration at Each Level in All Patients

Cervical Disc Level		C2～C7 angle	O～C2 angle	C1～C2 angle
C2～C3	Coefficient	0.246*	0.217*	0.110
	p	0.009	0.023	0.252
C3～C4	Coefficient	0.240*	0.235*	0.163
	p	0.012	0.013	0.089
C4～C5	Coefficient	0.239*	0.162	0.160
	p	0.012	0.090	0.095
C5～C6	Coefficient	0.215*	0.234*	0.137
	p	0.024	0.014	0.153
C6～C7	Coefficient	0.176	0.296*	0.213*
	p	0.065	0.002	0.025

*Statistically significant at $p<0.05$.

DISCUSSION

In this study, there were significant correlations between cervical angles such as C2～C7, C1～C2 and O～C2 and disc degenerations at multiple cervical levels. The cervical spine naturally maintains a lordotic curvature as a compensation for the thoracic kyphotic curvature.[3] Once loss of cervical lordosis progresses, the deformity tends to accelerate its own progression by producing abnormal forces to the head and neck.[1] Even with mild sagittal imbalance, detrimental symptoms can develop that become worse in a linear fashion as the sagittal imbalance progresses.[17] The normal vertebral disc is designed to maintain an isotropic form by transmitting axial load uniformly across the disc and vertebral endplate.[18,19] In any position of the cervical spine, such as extension, flexion, or lateral bending, the load of the disc is known to be transmitted uniformly over the endplates.[18] Progression of loss of cervical lordosis may alter this isotropic nature of disc loading and consequently contributes to continuous irregular loading, which then accelerates disc degeneration.[18,20] This degeneration can be aggravated by normal aging, calcification of the endplate, and decreased peripheral blood supply.[21] Abnormally increased mechanical pressure has also been shown to reduce the nutritional support of the disc and to lead to disc degeneration.[22]

The whole spinal levels (including the cervical, thoracic,

Table 5. Spearman's Correlation between Cervical Sagittal Vertical Axis and Degree of the Cervical Disc Degeneration at Each Level

Cervical Disc Level		Total patients (n = 110)		Lordotic group (n = 30)		Non-lordotic group (n = 80)	
		C1～C7 SVA	C2～C7 SVA	C1～C7 SVA	C2～C7 SVA	C1～C7 SVA	C2～C7 SVA
C2～C3	Coefficient	0.066	0.012	0.102	0.109	0.126	0.135
	p	0.495	0.899	0.591	0.567	0.266	0.234
C3～C4	Coefficient	0.129	0.082	0.082	0.060	0.002	0.007
	p	0.180	0.396	0.667	0.754	0.986	0.954
C4～C5	Coefficient	0.110	0.066	0.084	0.056	0.004	0.004
	p	0.251	0.497	0.660	0.767	0.971	0.974
C5～C6	Coefficient	0.137	0.091	0.090	0.013	0.029	0.019
	p	0.154	0.345	0.636	0.947	0.800	0.866
C6～C7	Coefficient	0.170	0.129	0.131	0.091	0.090	0.091
	p	0.076	0.179	0.491	0.632	0.426	0.421

SVA: sagittal vertical axis.

and lumbar regions) have been described to affect each other.[1,23] Contractions of the neck muscles due to vestibulocollic or cervicocolic reflexes, which induce anterior shifting of the gravity center of the head and neck, result in changes in the whole spine alignment.[24,25] Through these reflexes, the cervical muscle spasm occurs, representing the shortening of the posterior neck extensor muscles and the tightening of the anterior neck muscles, which finally may increase the SVA.[26] One previous study revealed that a larger C2～C7 SVA is related to higher Neck Disability Index scores.[11] The results of this study also showed that the C2～C7 SVA had significant correlation with the O～C2 angle and the C1～C2 angle.[11] However, the possible clinical consequence of increased cervical SVA on the cervical disc degeneration was not discussed. In this study, the change of SVA was not correlated with the cervical disc degeneration in any cervical level. Both in the lordotic and non-lordotic groups, it does not seem that the SVA itself was correlated with the cervical disc degeneration. These findings indicate that the SVA may have little effect on disc degeneration. The cervical disc degeneration progressing with normal aging could be aggravated mainly by the loss of natural sagittal angles rather than the increased cervical SVA.

The optimal position and angle of the occipital bone and the cervical axis have been topics of discussion.[27-29] In this study, there was a significant correlation between the O～C2 and the C2～C7 angle, and parameters of cervical angle had a significant correlation with the SVA. These results meant that the cervical sagittal angles, occipito-cervical axis and SVA had some correlations each other, with the preceding relationship unknown. In addition, there was a significant correlation between the occipito-cervical angle and the cervical disc degeneration in this study. A recent cohort study showed that an increased occipito-cervical angle may result in large biomechanical stress on the adjacent structures or the deformation of the cervical alignment.[28] A previous study has already shown that the loss of the natural C2～C7 angle facilitates the cervical disc degeneration.[15] In addition, our finding suggests that loss of normal occipito-cervical angle may accelerate the disc degeneration.

This study has some limitations. The Pfirmmann grading system which originally developed to classify the degree of lumbar disc degeneration may be less appropriate to be applied directly to the cervical disc. The pathophysiologic mechanism of the disc degeneration due to the loss of the cervical lordosis remained unknown. Because the analyses were cross-sectional, determining cause-and-effect relationships was difficult. As the cervical disc degeneration progresses, the neck pain or uneven loading to the cervical disc can induce the deformity of the sagittal alignments including both cervical and occipito-cervical angles. Long-term changes of the cervical sagittal parameters and the disc degeneration were also not evaluated. Further prospective studies are necessary to investigate the clinical implications and the interactions between the alignment of the cervical spines and the discs. Finally, as we did not include an asymptomatic group of the results may not be generalizable to whole populations. Future long-term longitudinal studies in a general asymptomatic population are needed.

CONCLUSION

This study showed that the SVA, the occipito-cervical angle and the loss of cervical lordosis had correlation with each other and only the latter two had the correlations with the cervical disc degeneration in patients with posterior neck pain. Although the cause-and-effect relationship is unknown, these results revealed that loss of natural cervical lordosis rather than loss of natural SVA could be correlated substantially with cervical disc degeneration.

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