Analysis of global spine sagittal parameters in cervical spondylotic patients and asymptomatic subjects

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Abstract

Background: Degenerative changes associated with cervical spondylotic can result in a change of normal sagittal alignment, and this may be the initial change of kyphosis and sagittal imbalance. Few studies have analyzed the correlations between the cervical spine lordosis and global spine balance in patients with cervical spondylotic. This study is applied to investigate the characteristics and relationships of cervical and global sagittal parameters in normal adults and cervical spondylotic patients. **Methods:** We reviewed 46 asymptomatic control subjects (normal group, NG) and 48 cervical spondylotic patients (cervical spondylotic group, CSG), who had both cervical MRI and global radiographs obtained together, between January 2016 and September 2018. Data includes C1-2 angle, C2–7 lordosis (CL), T1 slope (T1S), thoracic inlet angle (TIA), C2–7 sagittal vertical axis (CSVA), sagittal vertical axis(SVA), thoracic-kyphosis(TK), thoracic-lumbar lordosis(TL), lumbar lordosis (LL), pelvic incidence (PI), pelvic tilt (PT) and sacral slope (SS). The values were presented as the mean $\pm$ standard deviation. Student t-test and Pearson's correlation coefficient were used for statistical analysis. Probability values less than 0.05 were considered statistically significant. **Results:** 1.Comparison of global sagittal parameters between the normal group and cervical spondylosis group. A total of 48 cervical spondylotic patients with an average age of 57.91 ± 9.58 and 46 healthy people with an average age of 28.00 ± 8.09 were recruited in our study. CL in the NG was significantly lower than CSG ($P < 0.05$), while TK and TL were significantly lower than in the CSG ($P < 0.01$). However, a comparison of the NG and CSG yielded no significant differences in C1-2, TIA, TIS, LL, PT, PI, SS, CSVA, and SVA. 2.The relationship between cervical and global sagittal alignment. CL positively correlated with T1S ($r = 0.433$) and TK ($r = 0.335$) while negatively correlated with CSVA ($r = -0.309$) in cervical spondylosis group. TIA has positively correlated with T1S ($r = 0.376$ in NG and $r = 0.416$ in CSG) and no correlated with other parameters in both groups. **Conclusions** Cervical spondylosis causes changes in sagittal parameters of the cervical and thoracic spine but does not affect on lumbar and pelvic parameters. TIA is a relative constant parameter, not affected by cervical spondylotic.

Background

Disc degeneration has been recognized as the initiating event of spondylotic changes, which can lead to abnormal cervical spine biomechanics and loss of normal sagittal alignment. Abnormalities of the cervical sagittal alignment, in return, could contribute to spinal cord dysfunction [1]. On the other hand, neck pain and functional disability could be caused by loss of cervical lordosis[2].

Lee found a significant sequential relationship between C2–7 angle and T1 slope in asymptomatic volunteers without the history of symptoms related to the whole spine[3]. In Kim's study, nearly one-fourth of the asymptomatic participants (26.3%) have kyphotic cervical posture and no statistically significant correlations were found among cervical kyphosis and the global spine parameters (TK, LL, SS, PT, and PI)[4]. One study showed that C2–7 angle was the only predictor of CSVA in patients with cervical spondylotic myelopathy. Age combined with CSVA could predict the severity of myelopathy[1]. In one analysis of cervical and global spine alignment in Chinese cervical spondylotic patients and asymptomatic subjects, the authors found that the percentages of cervical lordosis were 28.3 % and 36.4 % in asymptomatic and spondylotic group and cervical angles were significantly related to the thoracic kyphosis[5]. One study reviewed the characteristics of cervical sagittal parameters in 50 healthy cervical spine adults and 50 patients with cervical disc degeneration. They found that T1S was involved in the occurrence and development of cervical disc degeneration, and TIA could be considered as a constant morphological parameter in both the normal population and cervical disc degeneration patients[6]. Yoon Ha reported that changes in the balance of the thoracolumbar spine caused reciprocal changes in cervical spine alignment. Cervical spine alignment may depend on changes in regional anatomic curvatures (thoracic or lumbar) and sagittal alignment[7]. The interaction between thoracic, lumbar spine and pelvis has been well documented in publications during the past decade[8, 9]. However, there is little research on the comparison of full-spine sagittal parameters between patients with cervical spondylosis and healthy adults. Moreover, the correlation between the parameters is not clear.

Therefore, we prospectively observed the radiological characteristics of the cervical spine in 46 normal people and 48 cervical spondylotic patients, then analyzed the relationship between cervical and global spine alignment parameters.

Materials And Methods

A retrospective analysis was performed of data from 46 normal control subjects whose cervical spine are healthy (normal group, NG) and 48 patients with cervical spondylosis (cervical spondylosis group, CSG), who visited the outpatient department or physical examination center of our hospital between January 2016 and September 2018. Each individual had both a full-length spine lateral X-ray radiographs and cervical MRI scans(Fig. 1 and Fig . 2).

Inclusion criteria of NG Enrolled asymptomatic volunteers whose ages are between 20 and 40 years and no history of diagnosis or treatment related to any part of the spine. No evidence of cervical spondylosis with clinical manifestations, physical examination, and MRI scan.

Inclusion criteria of CSG Combined with clinical manifestations, physical examination, X-ray and MRI examination, confirmed as cervical spondylotic. Patients were only suffering from the cervical disease but free from chronic back pain, deformity or other orthopedic diseases. No history of spinal surgery, trauma, deformities, or tumors.

Data including C1–C2 angle ,C2–7 lordosis (CL), T1 slope (T1S), thoracic inlet angle (TIA), C2–7 sagittal vertical axis (CSVA), TL, TK, LL, PI, PT, SS and SVA on radiographs were collected and analyzed.

Cervical sagittal parameters (Fig. 3)

C1–C2 angle: an angle between C1 and the C2 lower endplate was measured using the Cobb method.

C2–C7 angle(CL): the Cobb angle between the lower endplates of C2 and C7.

C2–7 sagittal vertical axis (CSVA): the distance from the posterosuperior corner of C7 to a vertical line from the center of the C2 vertebra.

T1S: the angle between the horizontal and the upper endplate of T1.

TIA: an angle formed by a vertical line from the center of the T1 upper endplate, and a line connecting the center of the T1 upper endplate and the upper end of the sternum.

Global sagittal parameters (Fig. 4 and Fig. 5)

TK: the Cobb angle between the lower endplates of T4 and T12.

TL: the Cobb angle between the lower endplates of T10 and L2.

LL: the Cobb angle between the lower endplates of L1 and S1.

SVA: the horizontal distance between the vertical line passing through the center of the seventh cervical vertebral body and the posterior superior angle of the sacrum.

PI: the angle subtended by a line drawn from the hip axis to the midpoint of the sacral endplate and a line perpendicular to the center of the sacral endplate.

PT: the angle between the line connecting the midpoint of the upper endplate of the sacrum and the center of the bilateral femoral head and the vertical line through the upper endplate.

SS: the angle subtended by a horizontal reference line and the sacral endplate.

PACS full-spine imaging and SPSS version 17.0 were used for the statistical analyses. The values were presented as the mean $\pm$ standard deviation. Student t-test and Pearson's correlation coefficients were used to examining the correlation between variables. The statistical significance level was set at $P < 0.05$.

Results

1. Comparison of parameters between the normal group and cervical spondylosis group.

A total of 48 CSM patients with an average age of 57.91 ± 9.58 and 46 healthy people with an average age of 28.00 ± 8.09 were recruited in our study. The mean of CL(8.18 ± 9.06), TK(18.45 ± 7.67) and TL (5.38 ± 11.44) in NG which was significant lower than CSG (CL 11.87 ± 6.99 , TK 23.25 ± 8.40 , TL 12.04 ± 9.79 respectively). However, a comparison of the NG and CSMG yielded no significant differences in C1-2, TIA, TIS, LL, PT, PI, SS, CSVA and SVA. Radiographic parameters in the current study were listed in Table 1.

Table 1
Data of normal group and cervical spondylotic group

	NG	CSG	P
NO. Subjects	46	48	
Age (years)	28.00 ± 8.09	57.91 ± 9.58	0.000*
C1-2	26.47 ± 5.64	25.82 ± 6.30	0.603
TIA	67.32 ± 7.81	68.18 ± 7.45	0.584
T1S	23.11 ± 6.61	25.88 ± 9.26	0.101
CL	8.18 ± 9.06	11.87 ± 6.99	0.029*
TK	18.45 ± 7.67	23.25 ± 8.40	0.005*
TL	5.38 ± 11.44	12.04 ± 9.79	0.003*
LL	-35.13 ± 23.80	-42.87 ± 12.24	0.049
PT	9.91 ± 7.52	12.07 ± 8.58	0.200
PI	41.39 ± 9.85	44.63 ± 8.75	0.094
SS	31.46 ± 9.80	32.56 ± 9.34	0.580
CSVA(mm)	21.89 ± 11.44	21.81 ± 12.70	0.978
SVA(mm)	7.17 ± 39.73	16.15 ± 38.08	0.266

2. The relationship between cervical and global sagittal alignment.

When examining the correlations among the parameters in NG, we found statistically significant correlations among the following variables (Table 2): age with TL ($r = 0.339$, $P < 0.01$), age with PT ($r = -0.306$, $P < 0.05$), C1-2 with LL ($r = -0.291$, $P < 0.05$), CL with T1S ($r = 0.382$, $P < 0.01$), CL with T1S ($r = 0.382$, $P < 0.01$), CL with CSVA ($r = -0.062$, $P < 0.05$), TIA with T1S ($r = 0.376$, $P < 0.05$), T1S with TK ($r = 0.48$, $P < 0.05$), T1S with CSVA ($r = 0.322$, $P < 0.05$), TK with TL ($r = 0.62$, $P < 0.01$), TL with PI ($r = -0.695$, $P < 0.01$), TL with SS ($r = -0.485$, $P < 0.01$), PT with PT ($r = 0.387$, $P < 0.01$), PT with SS ($r = -0.378$, $P < 0.01$), PI with SS ($r = 0.708$, $P < 0.01$), CSVA with SVA ($r = 0.305$, $P < 0.05$).

Table 2
Pearson correlation of the parameters in the NG

	C1-2	CL	TIA	T1S	TK	TL	LL	PT	PI	SS	CSVA	SVA
Age	-.027	-.134	.032	-.073	.146	.339*	.270	-.136	-.306*	-.202	.005	.200
C1-2		.228	-.193	-.008	-.012	-.184	-.291*	.114	.177	.090	.011	-.111
CL			.112	.382**	.119	.153	-.169	.333	-.110	.145	-.062*	.435
TIA				.376*	.176	-.072	-.079	.217	.329	.166	.186	.124
T1S					.480**	-.013	-.165	-.060	.166	.212	.322*	.272
TK						.620**	-.063	-.283	-.271	-.054	.282	.037
TL							.276	-.276	-.695**	-.485**	.195	.256
LL								-.016	-.341*	-.331*	-.224	.008
PT									.387**	-.378**	-.093	-.114
PI										.708**	-.098	-.177
SS											-.028	-.090
CSVA												.305*
SVA												

** Significant correlation at the 0.01 level

* Significant correlation at the 0.05 level

When examining the correlations among the parameters in CSG, we found statistically significant correlations among the following variables (Table 3): age with TIA ($r = 0.345$, $P < 0.05$), age with TK ($r = 0.321$, $P < 0.05$), age with PT ($r = 0.364$, $P < 0.05$), age with CSVA ($r = 0.366$, $P < 0.05$), age with SVA ($r = 0.349$, $P < 0.05$), C1-2 with CL ($r = -0.312$, $P < 0.05$), C1-2 with CSVA ($r = 0.430$, $P < 0.05$), CL with T1S ($r = 0.433$, $P < 0.01$), CL with CSVA ($r = -0.309$, $P < 0.05$), TIA with T1S ($r = 0.416$, $P < 0.01$), T1S with TK ($r = 0.638$, $P < 0.05$), T1S with CSVA ($r = 0.388$, $P < 0.01$), T1S with SVA ($r = 0.404$, $P < 0.01$), TK with TL ($r = 0.398$, $P < 0.01$), TK with LL ($r = -0.363$, $P < 0.05$), TL with LL ($r = 0.438$, $P < 0.01$), TL with PI ($r = -0.398$, $P < 0.01$), TL with SS ($r = -0.6539$, $P < 0.01$), LL with PT ($r = 0.501$, $P < 0.01$), LL with PI ($r = -0.455$, $P < 0.01$), LL with SS ($r = -0.876$, $P < 0.01$), PT with PT ($r = 0.419$, $P < 0.01$), PT with SS ($r = -0.525$, $P < 0.01$), PT with SVA ($r = 0.299$, $P < 0.05$), PI with SS ($r = 0.553$, $P < 0.01$), PI with SVA ($r = 0.362$, $P < 0.05$), CSVA with SVA ($r = 0.416$, $P < 0.05$).

Table 3
Pearson correlation of the parameters in the CSG

	C1-2	CL	TIA	T1S	TK	TL	LL	PT	PI	SS	CSVA	SVA
Age	-.005	.041	.345*	.336*	.321*	.284	.170	.364*	.160	-.184	.366*	.349*
C1-2		-.312*	.123	.035	-.111	-.196	-.005	.001	.113	.104	.430**	.146
CL			.257	.433**	.335*	.136	.049	.069	-.033	-.096	-.309*	.235
TIA				.416**	.263	.022	.016	.030	.027	-.002	.253	.228
T1S					.638**	-.014	-.197	.117	.265	.141	.388**	.404**
TK						.398**	-.363*	.085	.147	.058	.283	.230
TL							.438**	.181	-.398**	-.539**	.024	.257
LL								.501**	-.445**	-.876**	-.080	.207
PT									.419**	-.525**	.122	.299*
PI										.553**	.283	.362*
SS											.153	.065
CSVA												.416**
SVA												
** Significant correlation at the 0.01 level												
* Significant correlation at the 0.05 level												

CL lordosis positively correlated with T1S and TK while negatively correlated with CSVA in the cervical spondylosis group. TIA has positively correlated with T1S and no correlated with other parameters in both groups.

Discussion

The global spine lateral radiograph is a key image to evaluate global spinal sagittal alignment. Previous studies have attempted to find out the relationship between the cervical spine sagittal parameters and global spine sagittal parameters, but do not form a unified opinion[1, 10, 11].

Usually, we use the C2-C7 angle to represent cervical lordosis(CL), but the relationship between cervical degeneration and cervical lordosis has been controversial. Wang observed no significant difference in the C2-7 angle between the normal group and the degenerative cervical spondylolisthesis group[12]. Generally speaking, the presence of a kyphotic cervical alignment may indicate substantial deformity and be linked to poor clinical outcomes. But in an author's report, 29% of patients without cervical complaints have kyphotic cervical alignment. Kyphotic alignment of the cervical spine cannot alone define cervical deformity[10, 13]. Kim's report showed that nearly one-fourth of asymptomatic people have kyphotic cervical posture[4]. Yoshida's study demonstrated that the pathology of the responsible lesion was related to global sagittal balance but not regional cervical alignment, which might be due to compensation against global malalignment during aging[11]. On the other hand, the C2-7 angle increased with age in the normal population[14, 15]. In our study, the cervical lordosis in CSG is higher than NG(11.87 ± 6.99 VS 8.18 ± 9.06 $P < 0.05$) and the age of the CSG is also higher than NG(57.91 ± 9.58 VS 28.00 ± 8.09 $P < 0.01$). Therefore, we speculate that age combined with cervical lordosis reflects the disease status of cervical spondylosis.

Sang-Hun Lee found that no significant relationship between CL and TK in seventy-seven asymptomatic volunteers without the history of symptoms ($p=0.154$) [3]. Also, Our study suggests that CL and TK are not related in the NG($P = 0.119$). Bassel found that as thoracic kyphosis increased, the amount of lower cervical lordosis increased in patients with a diverse range of thoracolumbar pathologies[13]. Jeffrey 's study revealed there was a significant association between the thoracic kyphosis and cervical lordosis for females ($r = 0.33$, $P < 0.001$), and for males ($r = 0.27$, $P < 0.03$) in post-mortem lateral spinal radiographs[15]. In our study, CL has positively correlated with TK($r = 0.335$ $P < 0.05$) in CSG. It may be that cervical spondylosis changes the relationship between CL and TK. Cervical lordosis could increase as a compensatory reaction against sagittal imbalance or hyperthoracic kyphosis in with adult spinal deformity[10].

As a key vertebra, T1 joins the cervical and thoracic vertebra, fixed on both sides of the ribs not altered by position. Therefore, T1S parameter may provide a reference value for determining the correction of the sagittal balance of the cervical spine[16]. Also, T1S was involved in the occurrence and development of cervical disc degeneration[6]. In our study, CL is influenced by T1S($r = 0.382$ in NG and $r = 0.433$ in CSG respectively $P < 0.01$). T1S exhibited a significant correlation with CL in previous research [3, 16–18]. Rong found that T1S positively correlated to CL patients with cervical disc degeneration. Lower T1S decreased the CL to obtain a sagittally balanced cervical spine and led to a relatively straight cervical spine[6]. T1S is the site that mainly bears the stress from the head weight. Long-term exposure to the stress could result in T1 tilting forward. To maintain a horizontal gaze, CL would increase along with the increased T1S in a compensatory manner [3]. In our study, T1S has a positive relation with TK, CSVA, and SVA in CSG. As T1 slope is the angle between T1 and the global horizontal line, T1 slope becomes greater when thoracic kyphosis becomes greater or positive sagittal imbalance becomes larger[10, 13].

In our study, the mean TIA of the NG and CSG were 67.32 ± 7.81 and 68.18 ± 7.45 , similar to data in the previous study that the mean TIA of the NG and DG were 70.22 ± 6.8 and 71.5 ± 8.0 , respectively. There were no significant differences in the TIA between the two groups in our study, indicating that TIA was not involved in the development of cervical disc degeneration, which could be considered a constant parameter of approximately 70° . TIA could be considered as a constant morphological parameter in the normal population and cervical disc degeneration patients[6]. TIA concerning cervical sagittal balance may be as important as pelvic incidence in lumbar lordosis[3]. There were positive correlations between TIA and T1S ($r = 0.475$) in Xing's study.[6] In our study, TIA has positively correlated with T1S in the two groups ($r = 0.376$ and $r = 0.416$). TIA is a more important parameter than TK and that it influences cervical spine sagittal balance to achieve physiologic posture with horizontal gaze in the spine without sagittal imbalance[3].

CSVA is an important parameter for evaluating cervical sagittal balance. According to the previous studies, the CSVA values in asymptomatic normal volunteers are maintained in a tight range within 20 mm[11, 19]. In Yuan's report, the mean CSVA value in patients with CSM was 17.2 ± 12.1 mm, within the normal value, indicating that most patients with CSM before surgery presented normal sagittal balance[1]. These are different from our findings. In our report, there is no difference in C2-7 SVA between NG and CSG(21.89 ± 11.44 mm VS 21.81 ± 12.70 mm $P > 0.05$). In the normal group, the value of CSVA is also higher than that reported in the previous literature. We suspect that a considerable number of people in the asymptomatic group also have a cervical sagittal imbalance, which requires further research in the future. In Rong's report, C2-7 lordosis was correlated with CSVA in the normal group($r=-0.482$ $P < 0.01$) [6]. In Yuan's report, C2-7 lordosis was also correlated with CSVA in patients with cervical spondylotic myelopathy ($r=-0.395$, $p = 0.001$)[1]. Kwon also reported that C2–7 lordosis was significantly correlated CSVA in patients with spondylotic myelopathy and/or radiculopathy for ossification of the posterior longitudinal ligament and degenerative disc disorders. ($r=-0.631$, $P < .001$)[20]. These above studies are the same as the results of our study. In our study, C2-7 lordosis was negatively correlated with CSVA in NG and CSG ($r=-.062$ and $r=-0.309$, $P < 0.05$). It means an excessively large CSVA that caused cervical spine decompensation would contribute to an imbalance in the cervical spine[1]. CSVA should be corrected by surgeons to improve the clinical outcomes when treating CSM. The restoration of C2–7 lordosis is critical to achieving a satisfactory CSVA[20].

The development of cervical spondylotic is a dynamic process. Accordingly, it is practical to assess each patient based on the individual conditions of global sagittal balance and regional alignment. [21]Now more researches reported that cervical lordosis has less related to spinopelvic parameters. Lee found no direct correlation between pelvic parameters and thoracic or cervical spine alignment[12]. Kim found no statistically significant correlations were found among cervical kyphosis and the global

spine parameters[4]. Miao found that the cervical angles were related to thoracic angles, but not with the lumbar angles. They conclude that the cervical alignment is more liable to be influenced by the local parameters as an independent degenerative disease but is seldom influenced by the global spinal degeneration[5]. These results agree with our current research. In our study, CL has no relation with LL, PT, SS PT and SVA. In our opinion, cervical lordosis is mainly affected by cervical and thoracic parameters such as T1S, TIA, and TK, but not by lumbar-pelvic parameters.

There are some limitations in this study. Firstly, due to the small sample size, we are unable to further group according to the level of cervical spondylotic. Secondly, this study lacked scores like JOA and NDI. Our next work is to explore the relationship between JOA and NDI and the sagittal balance of the whole spine.

Conclusion

Cervical spondylosis causes changes in sagittal parameters of the cervical and thoracic spine but does not affect on lumbar and pelvic parameters. TIA could be considered as a constant morphological parameter in the normal population and cervical spondylotic.

Abbreviations

CL: C2–7 lordosis

T1S: T1 slope

TIA: thoracic inlet angle

CSVA: C2–7 sagittal vertical axis

SVA: sagittal vertical axis

TK: thoracic kyphosis

TL: thoracic-lumbar lordosis

LL: lumbar lordosis

PI: pelvic incidence

PT: pelvic tilt

SS: sacral slope

NG: normal group

CSG: cervical spondylotic group

Declarations

Ethics approval and consent to participate

The study design was approved by the Ethical Committee of Shanghai General Hospital, Shanghai Jiao Tong University . All of the participants provided written informed consent.

Consent for publication

Not applicable.

Availability of data and materials

All data generated or analyzed during this study are included in this published article and its additional files.

Competing interest

We declare that we do not have any competing interests.

Funding

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Authors' contributions

Liang Zhu and Xiaojun Ma contributed to interpreting the data and writing the final manuscript. Bao Sun was responsible for the original data collection. Qiang Shen contributed to reviewing the accuracy of the data. Qiang Fu was in charge and contributed to all stages of the present study. All authors read and approved the final manuscript.

Acknowledgments

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Figures

Figure 1

Full-length spine lateral X-ray

Figure 2

MRI scan of the cervical spine

Figure 3

Cervical lateral X-ray C1–C2 angle: an angle between C1 and the C2 lower endplate was measured using the Cobb method (by line a and line b); C2–7 lordosis (CL): the Cobb angle between the lower endplates of C2 (line b) and C7 (line c); Cervical sagittal vertical axis (CSVA): the distance from the posterosuperior corner of C7 to a vertical line from the center of the C2 vertebra (the length of line e); T1S: the angle between the horizontal and the upper endplate of T1 (line d); TIA: an angle formed by a vertical line from the center of the T1 upper endplate, and a line connecting the center of the T1 upper endplate and the upper end of the sternum (by line f and line g);

Figure 4

Thoraco-lumbar lateral X-ray TK: the Cobb angle between the lower endplates of T4 (line b) and T12 (line c); TL: Thoracolumbar kyphosis (T10–L2) was defined by the angle between the cranial endplate of T10 (line b) and the caudal endplate of L2 (line d); LL: defined as the angle subtended by a line drawn along the superior endplate of L1 (line c) and S1 (line e); SVA: The horizontal distance between the vertical line passing through the center of the seventh cervical vertebral body and the posterior superior angle of the sacrum (the length of line f);

Figure 5

Pelvic lateral X-ray SS: The angle subtended by a horizontal reference line and the sacral endplate; PI: The angle subtended by a line drawn from the hip axis to the midpoint of the sacral endplate and a line perpendicular to the center of the sacral endplate; PT: The angle between the line connecting the midpoint of the upper endplate of the sacrum and the center of the bilateral femoral head and the vertical line through the upper endplate.

Supplementary Files

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- [rawdataNG.xlsx](#)
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