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Analysis of cervical kyphosis and spinal balance in young idiopathic scoliosis patients classified by the apex of thoracic kyphosis

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Abstract

Purpose. Sagittal balance has recently been the focus of studies aimed at understanding the correction force required for both coronal and sagittal malalignment. However, the correlation between cervical kyphosis and sagittal balance in AIS patients has yet to be thoroughly investigated. This study aimed to clarify the correlation between cervical alignment and spinal balance in patients with adolescent idiopathic scoliosis (AIS) patients. Here we hypothesized that cervical kyphosis patients can be classified into groups by the apex of thoracic kyphosis.

Methods. This study included 92 AIS patients (84 females, 8 males; mean age, 15.1 years). Patients were divided into the cervical lordosis (CL), cervical sigmoid (CS), or cervical kyphosis (CK) groups and further classified according to the apex of thoracic kyphosis into High (above T3), Middle (T4–T9), and Low (below T10) groups.

Results. There were 17 (18.5%), 22 (23.9%), and 53 (57.6%) patients with CL, CS, and CK, respectively. In the CK group, 13 had CK-High, 35 had CK-Middle, and 5 had CK-Low. The C7 sagittal vertical axis (C7SVA) measurements were most backward in CK-High and most forward in CK-Low. The T5-12 kyphosis (TK) measurement was significant lower in CK-High.

Conclusions. Most AIS patients had kyphotic cervical alignment. Patients with CK can be classified as having CK-High, CK-Middle, or CK-Low according to the apex of thoracic kyphosis. CK-High is due to thoracic hypokyphosis with a backward balanced C7SVA. CK-Middle is well-balanced cervical kyphosis. CK-Low has forward-bent global kyphosis of the cervicothoracic spine that positioned the C7SVA forward.

Key Words: scoliosis, cervical, sagittal, kyphosis, classification

Introduction

Sagittal balance has recently been the focus of studies aimed at understanding the correction force required for both coronal and sagittal malalignment. There were several literatures about cervical alignment and thoracic spine. Hilibrand et al. and Canavese et al. reported that cervical kyphosis is accompanied by a hypokyphotic thoracic spine [1,2]. Scheer et al. reported a correlation of cervical lordosis and thoracic kyphosis [3]. However, the correlation between cervical kyphosis and sagittal balance in adolescent idiopathic scoliosis (AIS) patients has not been thoroughly investigated. Pereira et al. found that sagittal balance correlate with C7 slope but not with cervical alignment, but cervical kyphosis patients were not separated by the sagittal balance or thoracic alignment [4]. Here, we hypothesized that cervical kyphosis patients have different sagittal alignment, such as the apex of thoracic kyphosis and should have some characteristics. Thus, this study aimed to classify the cervical kyphosis patients and clarify the correlation between cervical alignment and spinal balance in AIS patients.

Materials and Methods

Patients

Patients were divided into the cervical lordosis (CL), cervical sigmoid (CS), or cervical kyphosis (CK) group according to cervical spine alignment. CL was defined as a C2-7 angle ≥ 4°, whereas kyphosis was defined as a C2-7 < -4°. Straight neck was defined as -4° to 4°, and excluded form this study[5, 6]. CS was defined as cervical spine with cranial lordosis and caudal kyphosis or cranial kyphosis and caudal lordosis[7]. This study included 102 AIS patients; straight neck patients were excluded. Therefore, 92 AIS patients were enrolled (84 females, 8 males; mean age, 15.1 ± 3.2 years, all Japanese). Patients were further classified according to the apex of thoracic kyphosis: those with an apex above T3 were included in the High (H) group; those with an apex between T4 and T9 were included in the Middle (M) group; and those with an apex below T10 were included in the Low (L) group (Figure 1). The C2-7 angle was defined as the angle between the posterior C2 vertebral body and the C7 vertebral body. The C2 sagittal vertical axis (C2SVA) and C7 sagittal vertical axis (C7SVA) were defined as the distance along a plumb line from each to the superior posterior end plate of the S1 vertebral body. The T1 slope, T5-12 kyphosis (TK), T12- S lumbar lordosis (LL), pelvic incidence (PI), and sacral slope (SS) were also measured for all groups (lordosis > 4°, forward > 0 mm; kyphosis < -4°, backward < 0 mm). All sagittal radiographs were taken with the patients in the fists-on-clavicle position. Patients with a C2SVA < -5cm, +5cm <C2SVA, C7SVA < -5cm, or +5cm <C7SVA were defined as sagittal imbalanced.

This study was approved by the Institutional Review Board of Nagoya University Graduate School of Medicine.

Statistical Analysis

The data are presented as the mean ± standard deviation of the mean and measured twice independently by 2 spine surgeons to analyze the intraclass and interclass correlation coefficent. Statistical analysis was performed using SPSS for Windows, version 17.0 (SPSS Inc., Chicago, IL, USA). The Mann-Whitney U test and Fisher's exact test were used to analyze the differences between the 2 groups, while analysis of variance was used to analyze more than 3 groups. The analyses were performed using Pearson's correlation test.

Results

The intraclass correlation coefficient for the C2-7 angle measurements was found to be 0.98 (95% confidence interval, 0.98-0.99) and interclass was found to be 0.93 (95% confidence interval, 0.91-0.96).

There were 17 (18.5%), 22 (23.9%), and 53 (57.6%) patients with CL, CS, and CK, respectively. There were no patients with a High or Low apex of thoracic kyphosis in the CL and no patients with a High apex of thoracic kyphosis in the CS groups. Among the 53 patients in the CK group, 13 (24.5%) had a High apex (CK-H), 35 (66.0%) had a Middle apex (CK-M), and 5 (9.4%) had a Low apex (CK-L) (Table 1). The coronal curve was mean average 42.2 ± 19.7 degrees and mostly at the thoracic spine in every group, with no statistical significance seen among groups (Table 2). The results of each measurement in the CL, CS, CK-H, CK-M, and CK-L groups are shown in Table 3. C2SVA was backward only in the CK-H group, and especially forward in the CK-L group. C7SVA was backward in every cervical alignment group and especially backward in the CK-H group. The T1 slope and TK were significantly lower in the CK-H and CK-M groups. LL, PI, and SS showed no significant difference among groups (Table 3). There were 2 patients with imbalanced C2SVA (CK-L, 2 cases), 2 with imbalanced C2 and C7SVA (CK-H, 2 cases), and 3 with imbalanced C7SVA (CK-M, 2 cases; CL, 1 case) (Table 4.).

Discussion

Almost 60% of idiopathic scoliosis patients in this study had CK, and only CK patients had a High and Low apex of thoracic kyphosis in sagittal alignment. The CK patients could be divided into the CK-H, CK-M, and CK-L groups according to the apex of thoracic kyphosis. The CK in patients with AIS was not related to the coronal curves. To our knowledge, this is the first study to classify CK patients with idiopathic scoliosis according to the apex of thoracic kyphosis.

Incidence of CK in AIS patients

The incidence of CK in adolescent idiopathic scoliosis patients was 34/39 (89%) in a study by Hilibrand et al., and 48/120 (40%) as reported by Yu et al [1,8]. In our cohort, 60/102 patients (58.8%) had CK. In contrast, the incidence of CK in asymptomatic children was reported as 80/181 (44.2%) by Lee et al. who found that cervical lordosis decreased with increasing age up to 17 years [9]. Yukawa et al. reported that 54/205 (26.3%) asymptomatic subjects in the third decade had CK, which gradually decreased with increasing age [10]. The development of cervical alignment in idiopathic scoliosis patients should be impaired by poor growth of sagittal spinal balance.

Sagittal parameters in AIS patients classified by cervical alignment and the apex of thoracic kyphosis

Sagittal parameters showed typical features in each cervical alignment group in AIS patients. C2SVA was forward balanced in every cervical alignment group except CK-H. In AIS patients, C7SVA was reportedly backward by -9 to -28 mm [11,12]. In the present study, C7SVA was backward balanced in every group, but especially in the CK-H group (by -31mm). The T1 slope, a newly studied concept is reportedly 23-25°[13,14]. In our study, the T1 slope was nearly 19° in the CL group and 13.7° in the CS group. The CK-H, CK-M, and CK-L groups had a lower T1 slope of around 10°.

Characteristics of CK in AIS patients classified by the apex of thoracic kyphosis

CK-H patients had an apex higher than T4 and thoracic hypokyphosis, whereas the LL and SS were normal and did not differ from those of the other groups. Because of thoracic hypokyphosis and normal LL, C7SVA was balanced backward and the T1 slope decreased. This suggested that cervical kyphosis was compensation for backward balanced C7SVA to maintain sagittal balance by translating the head forward. Previous reports stated that a hypokyphotic thoracic spine coexists with CK [1,2]. The hypokyphotic thoracic spine in these studies was influenced by the CK-H group. However, patients with CK were not categorized in the present study. Even in CK patients, the features of sagittal balance may differ and must be categorized.

CK-M patients were the most common (35 of 92, 38.0%). The CK-M patients had an apex of thoracic kyphosis between T4 and T9 and well balanced C2SVA and C7SVA values as seen in the CL and CS groups. The thoracic kyphosis and T1 slope were normal but lower than in the CL group. Thus, CK must be affected by a lower T1 slope or is independent of sagittal balance. In this group, there was transition at the cervico-thoracic junction and the apex of kyphosis occured at both the thoracic and cervical spine. The CK of CK-M patients were less than that of other kyphosis groups, which is thought to be because of good sagittal balance and normal thoracic kyphosis.

The CK-L patients had an apex of thoracic kyphosis lower than T9 and a forward C2SVA with a lower apex. The CK in CK-L is part of the global kyphosis that extends from the lower apex of the thoracic end to the upper cervical region. Thus, the C7SVA and C2SVA were more forward than those in the other groups (Figure 2).

Characteristics of sagittal imbalance

Imbalance was defined as more than 5 cm backward or forward from the SVA [15]. Seven patients with sagittal imbalance were divided into C2SVA imbalanced, C2 and C7 imbalanced, and C7SVA imbalanced groups. The 2 patients with a C2SVA imbalance were in the CK-L group. Because of the lower apex of thoracic kyphosis and global kyphosis, the cervico-thoracic spine is in a forward-bent posture, which leads to C7SVA forward and C2SVA forward imbalanced. The 2 patients with C2 and C7SVA imbalance were in the CK-H group. The thoracic hypokyphosis and low T1 slope result in C2SVA and C7SVA backward imbalance. The 3 patients with C7 imbalance were in the CK-M and CL group. This might have occurred because of greater LL; thus, C7SVA imbalance may occur in any group. The patients with sagittal imbalance had notable characteristics of the CK-L and CK-H groups.

Conclusion

Most AIS patients had kyphotic cervical alignment. Patients with CK can be classified as having CK-H, CK-M, or CK-L according to the apex of thoracic kyphosis. CK-H is compensated CK due to thoracic hypokyphosis with backward sagittal spinal balanced C7SVA. CK-M is well balanced but involves CK. CK-L is forward-bent global kyphosis of the cervico-thoracic spine that positions C2SVA and C7SVA forward.

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Figure legends

Figure 1. The apex of thoracic kyphosis above T3 were included in the High group;
those with the apex of thoracic kyphosis between T4 and T9 were included in the Middle group; and those with the apex of thoracic kyphosis below T10 were included in the Low group.

Figure 2. CK-H is the cervical kyphosis due to hypothoracic kyphosis with backward C2SVA and C7SVA. CK-M is well balanced but have cervical kyphosis. CK-L is the forward-bent global kyphosis of cervico-thoracic spine, so that C2 and C7SVA positioned forward.

The apex of thoracic kyphosis \ Cervical alignment		CL	CS	CK
High (Above T3)	C6			1
	C7			1
	T1			
	T2			7
	T3			4
Middle (T4-T9)	T4		3	5
	T5	4	4	11
	T6	4	6	10
	T7	7	6	7
	T8	2	1	2
	T9			
Low (Below T10)	T10			3
	T11		1	
	T12		1	2

Table 1.

The relations of number of the patients in cervical lordosis (CL), cervical sigmoid (CS), and cervical kyphosis (CK) groups and the apex of thoracic kyphosis with High, Middle, and Low groups.

Idiopathic scoliosis patients in this study with cervical kyphosis were almost 60% and only cervical kyphosis patients had high and low apex of thoracic kyphosis in sagittal alignment.

Major curve area \ Cervical alignment	CL (n=17)	CS (n=22)	CK-H (n=13)	CK-M (n=35)	CK-L (n=5)
Thoracic (n/%)	11 (64.7%)	15 (68.2%)	10 (76.9%)	28 (80%)	5 (100%)
Thoracolumbar (n/%)	3 (17.5%)	1 (4.5%)	2 (15.4%)	5 (14.3%)	0 (0%)
Lumbar (n/%)	3 (17.5%)	6 (27.3%)	1 (7.7%)	2 (5.7%)	0 (0%)
Mean Cobb angle (°)	37.0 ± 19.7	39.2 ± 17.4	44.4 ± 15.7	43.8 ± 20.5	56.4 ± 28.4

Thoracic curve (apex: T2-T11/12disc), Thoracolumbar curve (apex: T12-L1), Lumbar curve (apex:L1/2disc-L4)

Table 2.

The relations of number of the patients in cervical alignment and the coronal major curve area.

The cervical kyphosis in patients with AIS is not related with the coronal curves.

	CL	CS	CK-H	CK-M	CK-L
n	17	22	13	35	5
C2-7 angle (°)	14.9 ± 7.1	4.1 ± 5.5**	-15.4 ± 8.0**	-12.3 ± 6.0**	-14.2 ± 8.1**
C2SVA (mm)	5.0 ± 24.16	3.5 ± 25.9	-10.1 ± 35.1	7.5 ± 11.9	21.2 ± 47.7
C7SVA (mm)	-15.2 ± 19.9	-16.8 ± 18.7	-30.9 ± 24.9	-12.6 ± 24.1	-3.1 ± 40.6
T1slope (°)	18.9 ± 7.5	13.7 ± 6.2	12.8 ± 9.1*	13.0 ± 6.0*	9.4 ± 6.0
TK (°)	24.4 ± 11.2	19.9 ± 9.7	5.4 ± 3.6**	14.9 ± 9.8**	18.8 ± 14.8
LL (°)	49.1 ± 13.7	50.0 ± 14.4	42.4 ± 6.6	47.6 ± 10.6	47.6 ± 8.1
PI (°)	40.5 ± 9.8	43.7 ± 11.4	41.8 ± 6.6	46.5 ± 7.9	41.5 ± 4.7
SS (°)	34.2 ± 8.3	36.1 ± 8.6	31.7 ± 4.7	37.1 ± 6.9	33.3 ± 6.5

*P<0.05, ** P <0.01 ANOVA, post hoc Tukey

lordosis > 4 degrees, forward > 0 mm, kyphosis < -4 degrees, backward < 0 mm

Table 3.

Sagittal spinal parameters in cervical lordosis (CL), cervical sigmoid (CS), cervical kyphosis-High (CK-H),

cervical kyphosis-Middle (CK-M), and cervical kyphosis-Low (CK-L) groups.

C2SVA was only backward in CK-H, but especially forward in CK-L. C7SVA was backward in every cervical alignment group, and especially backward in CK-H. T1 slope and TK were significantly lower in CK-H and CK-M.

Imbalanced	C2SVA (n=2)		C2&C7SVA (n=2)		C7SVA (n=3)		
Cervical alignment	CK-L	CK-L	CK-H	CK-H	CK-M	CK-M	CL
C2-7 angle (°)	-17.6	-5.7	-11.5	-18.4	-21.5	-19.8	16.6
C2SVA (mm)	62.0	80.0	-61.6	-92.0	-14.4	-31.6	-24.0
C7SVA (mm)	39.0	40.0	-68.4	-85.2	-57.2	-66.4	-53.2
T1 slope (°)	11.0	14.0	4.3	7.1	6.3	10.4	24.4
TK (°)	6.0	10.0	8.9	6.0	23.5	27.9	21.7
LL (°)	41.0	38.0	60.6	45.9	58.8	57.9	67.3
PI (°)	42.6	37.8	43.3	41.2	43.2	38.7	33.5
SS (°)	35.4	22.2	38.9	37.0	36.3	32.5	41.8

Table 4.
The cases and datum of sagittal imbalance patients.
Imbalanced was defined as more than 5 cm backward or forward from sagittal vertical axis (SVA).
The sagittal imbalanced patients had remarkable characters of forward balanced in CK-L and backward balanced in CK-H group.

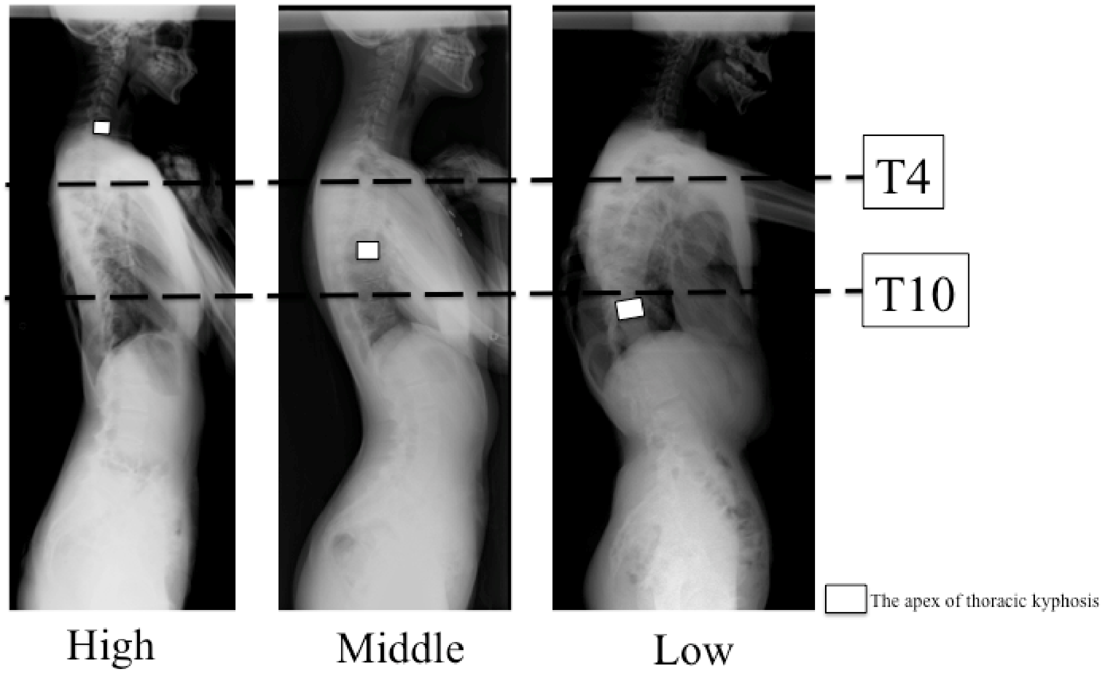

Figure 1.

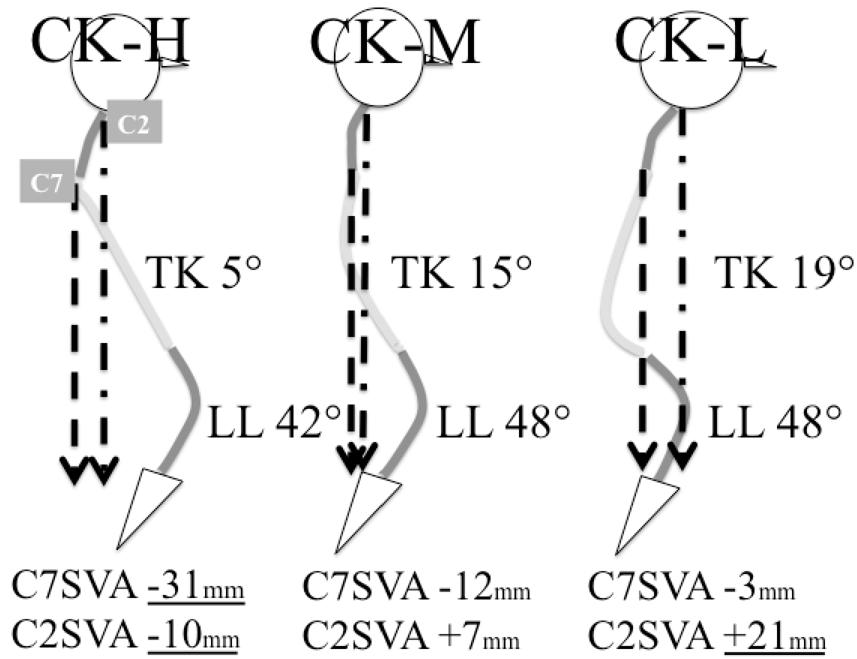
CK-H
CK-M
CK-L
C2
C7
TK 5°
TK 15°
TK 19°
LL 42°
LL 48°
LL 48°
C7SVA -31mm
C2SVA -10mm
C7SVA -12mm
C2SVA +7mm
C7SVA -3mm
C2SVA +21mm

Figure 2.