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Radiographic Comparison between Cervical Spine Lateral and Whole-Spine Lateral Standing Radiographs

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Abstract

Study Design Retrospective radiologic study.

Objective The sagittal alignment of the cervical spine can be evaluated using either a lateral cervical radiograph or a whole-spine lateral view on which the cervical spine is included. To our knowledge, however, no report has compared the two. The purpose of this work is to identify the difference in radiographic parameters between the cervical spine lateral view and the whole-spine lateral view.

Methods We retrospectively analyzed 59 adult patients suffering from neck pain with cervical spine lateral radiographs and whole-spine lateral radiographs from November 2007 to December 2011. The radiographs were measured using standard techniques to obtain the following parameters from the two different radiographs: occipital–C2 angle, C2–C7 angle, C7–sternal angle, sternal slope, T1 slope, C2 central offset distance, the distance between C2 and C7 plumb lines, C4 anteroposterior (AP) diameter, the ratio of C2 central off distance to C4 AP diameter, the ratio of plumb lines' distance to C4 AP diameter.

Results We found that the occipital–C2 angle, sternal slope, and C4 AP diameter were similar, but the C2–C7 angle, C7–sternal angle, T1 slope, C2 central offset distance, distance between C2 and C7 plumb lines, ratio of C2 central off distance to C4 AP diameter, and ratio of plumb lines' distance to C4 AP diameter were different. However, the error of measurement was greater than the small angular and linear differences between the two views.

Conclusions Most numerical values of the measured radiographic parameters appear to be different between the two views. However, the two views are comparable because the numerical differences were smaller than the errors of measurement.

Keywords

- ▶ radiographic comparison
- ▶ cervical spine lateral radiograph
- ▶ whole-spine lateral radiograph

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Introduction

The sagittal alignment of the spine has important ramifications to the health-related quality of life.¹ It varies with age,^{2,3} gender,⁴ spinal disease,^{5,6} and body position.⁷⁻¹⁰ Many researchers have evaluated the sagittal alignment of the cervical spine. However, they used different neck positions,^{7,8} as well as different radiographic views. Most commonly, these are cervical spine lateral radiographs and whole-spine lateral radiographs.^{4,11-14} However, to the best of our knowledge, there is no literature comparing the sagittal cervical parameters between these two views. The purpose of this study is to determine if the radiographic parameters for sagittal cervical alignment are comparable between these two views.

Materials and Methods

Study Participants

This retrospective study included adult patients from a single institution who had the radiographs taken to evaluate the neck pain. The criteria for inclusion were as follows: (1) age 20 years or older at the time of evaluation; (2) no contraindication for radiographic exposure (e.g., pregnancy, tumor); (3) agreement of patients to take both radiographs. This study was approved by the institutional review board (2013-I093). All participants provided informed consent.

Radiographic Measurement

The radiographic protocol was standardized. For each subject, cervical spine lateral radiographs were obtained with a 10 × 12-inch cassette at a 72-inch (182 cm) distance with the radiographic tube centered at the C4–C5 disk space with no magnification (►Fig. 1). Subjects were instructed to stand in a comfortable position and keep their eyes forward with their arms extended on their chests (►Fig. 1). Immediately after taking the cervical lateral radiographs, whole-spine lateral

radiographs were taken with a 14 × 17-inch cassette at a 98.4-inch (250 cm) distance with the tube centered at the xiphoid process and with the subjects in a comfortable standing position, keeping their eyes forward and their arms crossed upon their chests without magnification (►Figs. 2, 3). These postures for the radiographs may be common in clinical practice. The digital X-ray images were obtained and measured on the PACS system (Π view, Infinitt, Seoul, Korea).

Cervical radiologic parameters were measured by two observers. Cervical spinal morphology was measured using the standard techniques to obtain the following parameters for the two different radiographs:

1. Occipital–C2 angle: Cobb angle between the McGregor line and the inferior end plate of axis (►Fig. 4)
2. C2–C7 angle: Cobb angle between the inferior end plate of C2 and the inferior end plate of C7 (►Fig. 4)
3. C7–sternal angle: Cobb angle between the inferior end plate of C7 and the anterior border of sternum (►Fig. 4)
4. Sternal slope: Cobb angle between the anterior border of sternum and the horizontal line (►Fig. 4)
5. T1 slope: Cobb angle between the superior end plate of T1 body and the horizontal line (►Fig. 5)
6. C2 central offset distance: the distance between the center of C2 body and the line tangential to the posterior cortex of C7 body (►Fig. 5)
7. Distance between the C2 and C7 plumb lines (►Fig. 6)
8. C4 anteroposterior (AP) diameter (►Fig. 6)

Additionally, we calculated the ratio of C2 central offset distance to C4 AP diameter and the ratio of plumb lines' distance to C4 AP diameter to reduce the radiographic magnification (►Figs. 5, 6).

Statistical Analysis

The statistical analysis was performed using SPSS version 13.0 (IBM corporation, Armonk, NY, United States). The differences



Fig. 1 Cervical spine lateral radiographs were obtained with a 10 × 12-inch cassette at a 72-inch distance with the radiographic tube centered at the C4–C5 disk space with subjects in a comfortable standing position, keeping their eyes forward and their arms extended on their chests without magnification.



Fig. 2 Whole-spine lateral radiographs were taken with a 14 × 17-inch cassette at a 98.4-inch distance with the tube centered at the xiphoid process with subjects in a comfortable standing position, keeping their eyes forward and their arms crossed upon their chests without magnification.



Fig. 3 Whole-spine lateral radiographs.

in continuous variables between the two groups were examined with a paired *t* test. The power analysis was performed by G*Power version 3.1.5 (Universität Kiel, Germany). The power was 0.8 for paired *t* tests with the effect size of 0.5 and α error probability of 0.05. The sample size in each group should be more than 34. The statistical significance level was set at $p < 0.05$. The intraobserver and interobserver reliability were calculated using the reliability statistics by intraclass correlation for the Cobb angle and the distance. The intraclass correlation values were graded using previously described semiquantitative criteria: excellent for values in the 0.9 to 1.0 range, good for 0.7 to 0.89, fair/moderate for 0.50 to 0.69, low for 0.25 to 0.49, and poor for 0.0 to 0.24.

Finally, we compared the statistical difference of the previously mentioned parameters with the errors of measurement for the two different radiographs.

Results

Fifty-nine adults made up the study group (31 men and 28 women). The measurements of the Cobb angles in the cervical spine lateral radiographs had 0.979 intraobserver reliability and 0.966 interobserver reliability. The difference of the intraobserver measurements for the Cobb angles in the cervical spine lateral radiographs was 0.58 ± 2.74 degrees, and the difference of the interobserver measurements was 0.73 ± 3.43 degrees. The measurements of the C2 offset distance had 0.978 intraobserver reliability and 0.926 for interobserver reliability. The difference of the intraobserver measurements for the cervical spine distance in the lateral radiographs was 0.26 ± 3.05 mm, and the difference of the interobserver measurements was 0.90 ± 5.48 mm.

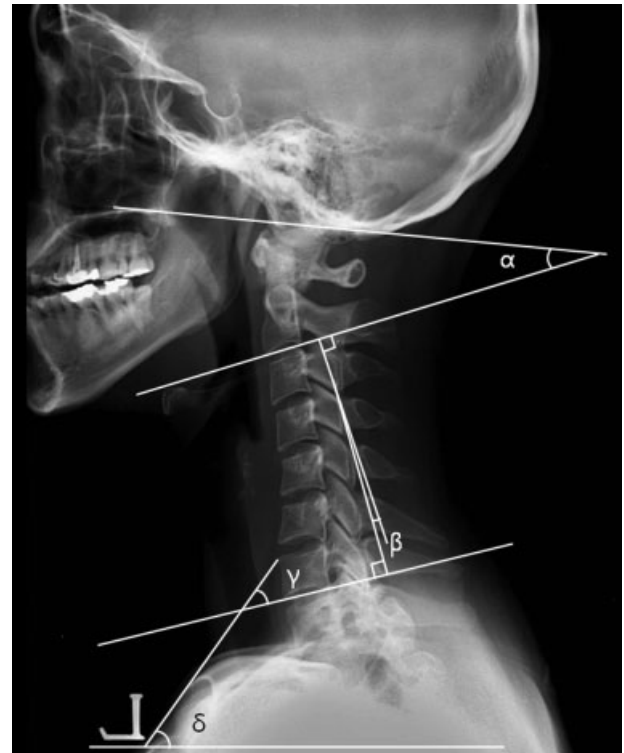


Fig. 4 Angle α (occipital–C2) is formed by McGregor line and the inferior end plate of the axis; angle β (C2–C7), by the inferior end plate of C2 and inferior end plate of C7; angle γ (C7–sternal), by the inferior end plate of C7 and the anterior border of sternum; angle δ (sternal slope), by the anterior border of sternum and the horizontal line.

For the whole-spine lateral radiographs, the measurements of the Cobb angles had 0.969 intraobserver reliability and 0.803 interobserver reliability. The difference of the intraobserver measurements for the Cobb angles in the whole-spine lateral radiographs was 0.36 ± 3.65 degrees, and the difference of the interobserver measurements was 4.08 ± 7.78 degrees. The measurements of the C2 offset distance had 0.982 intraobserver reliability and 0.979 interobserver reliability. The difference of the intraobserver measurements for the distance in the whole-spine lateral radiographs was 4.67 ± 9.00 mm, and the difference of the interobserver measurements was 6.09 ± 9.48 mm.

The occipital–C2 angle, sternal slope, and C4 AP diameter were similar, but the C2–C7 angle, C7–sternal angle, T1 slope, C2 central offset distance, distance between C2 and C7 plumb lines, ratio of C2 central off distance to C4 AP diameter, and the ratio of plumb lines' distance to C4 AP diameter were statistically different (**Table 1**).

However, the error of measurement, especially interobserver measurements for the Cobb angles in the whole-spine lateral radiographs (4.08 ± 7.78 degrees) and distances (6.09 ± 9.48 mm), were greater than the angular statistical differences (-2.51 ± 7.86 degrees of C2–C7 angle) and linear statistical differences (-4.38 ± 10.04 mm of C2 central off distance) between the two types of radiographs (**Table 1**).



Fig. 5 C2 central offset distance (a) is the distance between the center of C2 body and the line tangential to the posterior cortex of C7 body; T1 slope (ϵ) is the angle between the superior end plate of T1 body and the horizontal line.



Fig. 6 The distance between C2 and C7 plumb lines (b to c) is the distance between C2 plumb line and C7 plumb line, the difference of b and c; C4 AP diameter (d) is anteroposterior diameter of C4 vertebral body.

Discussion

Several methods have been described to evaluate the sagittal alignment of the cervical spine.^{4,7,8,11-13} However, they have used different neck positions and different radiographic techniques,^{7,8} including cervical spine lateral radiographs and whole-spine lateral radiographs.^{4,11-14} However, to the best of our knowledge, there is no literature comparing the sagittal cervical parameters obtained from cervical spine lateral views versus whole-spine lateral views.

In the current study, the occipital–C2 angle, sternal slope, and C4 AP diameter were similar. However, the C2–C7 angle, C7–sternal angle, T1 slope, C2 central offset distance, distance between C2 and C7 plumb lines, ratio of C2 central off distance to C4 AP diameter, and ratio of plumb lines' distance to C4 AP diameter were different. However, the angular and linear differences between the two types of radiographs were smaller than the error of measurement for the two types of radiographs.

The lordotic curvature of the cervical spine is considered as normal³; however, the exact values and the recommended methods of measurement are not clearly described. Normal lordotic angles for C2–C7 have been reported to range from 20 to 35 degrees,¹³ but these values are highly related to the method of measurement used and the positioning of the patients while taking a radiograph. Moreover, the head posture can influence the sagittal curve of the cervical spine.⁸ In addition, the arm or shoulder posture can influence sagittal spinal balance.^{9,10} According to Vedantam et al,¹⁰ positioning the arms at 90 degrees rather than 30 degrees resulted in a negative shift of the sagittal vertical axis. According to Marks et al,⁹ shoulder flexion of 30 degrees is the best position to use when a lateral radiograph is made to repeatedly measure the sagittal vertical axis. Also, cervical lordosis is increased when the thoracic kyphosis of the trunk is increased.^{4,14} In analyzing spinal sagittal alignment, it is most important to standardize the patients' posture while taking radiographs. We tried to keep the patients' standing posture as identical as possible to limit the effect of positioning.

Spine radiographs can be distorted by parallax.¹⁵ To limit the distortion, one can move the X-ray source away from the patient to reduce the divergence of the beam (conventional teleradiography) or translate the multiple focuses and coupled receptors simultaneously to scan the entire spine (digitalized teleradiography).¹⁵ The reasons for the differences in measurements for the two views include the differences in the centering target of the radiation beam, the distance from X-ray source to the cassettes, and the posture of arms between the two radiographs. Cervical spine lateral radiographs were taken at a 72-inch distance from the radiograph tube and centered at the C4–C5 disk space with the subject in a comfortable standing position with eyes forward and arms extended upon their chests. Whole-spine lateral radiographs were taken at a 98.4-inch distance from the tube and centered at the xiphoid process of the subject with eyes forward and arms crossed upon their chests.

The 95% confidence limits for intra- and interobserver variability of the Cobb method in the cervical lateral

Table 1 Comparison of sagittal Cobb angles between the cervical spine lateral radiographs and whole-spine lateral standing radiographs

Cobb angles	Cervical spine lateral radiographs	Whole-spine lateral standing radiographs	Difference between two radiographs	p Value
Occipital–C2 angle (degrees)	-16.40 ± 6.93	-15.42 ± 7.88	-0.98 ± 6.52	0.254
C2–C7 angle (degrees)	-8.35 ± 12.21	-5.84 ± 12.24	-2.51 ± 7.86	0.017
C7–sternal angle (degrees)	38.69 ± 7.70	42.42 ± 7.00	-3.73 ± 6.71	0.000
Sternal slope (degrees)	62.74 ± 6.60	62.35 ± 5.73	0.39 ± 4.30	0.486
T1 slope (degrees)	25.15 ± 8.79	20.80 ± 9.18	4.35 ± 6.36	0.000
C2 central off distance (mm)	-4.44 ± 13.56	-0.06 ± 12.51	-4.38 ± 10.04	0.001
Distance between C2 and C7 plumb lines (mm)	16.11 ± 11.52	11.70 ± 10.73	4.41 ± 7.63	0.000
C4 AP diameter (mm)	17.19 ± 4.65	16.93 ± 2.09	0.26 ± 3.90	0.611
Ratio of C2 central off distance to C4 AP diameter	-0.30 ± 0.78	-0.03 ± 0.75	-0.27 ± 0.57	0.001
Ratio of plumb lines' distance to C4 AP diameter	0.92 ± 0.67	0.70 ± 0.65	0.22 ± 0.44	0.000

Abbreviation: AP, anteroposterior.

radiographs were 5 and 9 degrees with the traditional manual method.¹⁶ In many cases, a 5-degree variation between the measurements in the whole-spine lateral radiographs by the traditional manual Cobb method is acceptable.¹⁷ In the current study, the mean difference of the intra- and interobserver measurements for the Cobb angles in the cervical spine lateral radiographs with digital methods was 0.58 and 0.73 degrees. The mean difference of the intra- and interobserver measurements for the Cobb angles in the whole-spine lateral radiographs was 0.36 and 4.08 degrees. The reproducibility of the Cobb angle measurements with digitalized images appears better than those with traditional manual methods.¹⁸ The difference in the intraobserver measurements on the digitalized images of the distance in the cervical spine lateral radiographs was 0.26 ± 3.05 mm and the difference in the interobserver measurements was 0.90 ± 5.48 mm in the current study. The reproducibility of the distance measurements with digitalized images may be better than those with traditional manual methods, similar to Cobb angle measurements in the current study. However, we did not compare the reproducibility of the distance measurements using digitalized images with those using traditional manual methods.

As with any study, the present investigation has limitations. Arm posture was one reason for the difference between the cervical and whole-spine lateral radiographs. Ideally, we should have taken the two radiographs in the same arm

posture to reduce the variables. However, we tried to compare the real-life situation in clinical practice and clinical research. To the best of our knowledge, this study is the first comparing sagittal cervical parameters between the cervical spine lateral view and whole-spine lateral view.

In conclusion, most numerical values of parameters for the two radiographic views appear to be different. However, the angular and linear numerical differences between the two radiographic views were smaller than the inter- and intraobserver errors of measurement for the two radiographic views. The two types of radiographs are comparable in clinical practice. Our results suggest that to determine the alignment of only the cervical spine, there is no advantage to using whole-spine lateral radiographs. However, this finding does not take into account the overall spinal alignment, for which whole-spine lateral radiograph are necessary.

Disclosures

Moon Soo Park, none
 Seong-Hwan Moon, none
 Tae-Hwan Kim, none
 Jae Keun Oh, none
 Hwa Jun Kang, none
 K. Daniel Riew, none

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