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Cervical spine lateral radiograph versus whole spine lateral radiograph

A retrospective comparative study to identify a better modality to assess cervical sagittal alignment

Dong-Ho Lee, MD, PhD[a,*], Sehan Park, MD[b], Dong Gyun Kim, MD[c], Chang Ju Hwang, MD, PhD[a], Choon Sung Lee, MD, PhD[a], Eui Seung Hwang[d], Jae Hwan Cho, MD, PhD[a]

Abstract

This study is aimed to compare whole-spine lateral radiograph (WLR) and cervical lateral radiograph (CLR) in terms of T1 slope visibility and cervical sagittal parameters and to identify the superior imaging modality for assessment of cervical sagittal parameters.

We retrospectively reviewed the radiographic data of 60 consecutive adult patients (male-to-female ratio, 38:22; mean age, 55.6 ± 1.3 years) who presented with only neck pain (without radiculopathy or myelopathy). All the patients underwent standing CLR and WLR. The following parameters were measured and analyzed:

1. T1 slope visibility,
2. T1 slope,
3. C7 slope,
4. C0–C2 Cobb angle (CAC0–C2),
5. C2–C7 Cobb angle (CAC2–C7), and
6. cervical sagittal vertical axis (cSVA).

The visibility of the T1 slope was significantly lower with WLR than with CLR (28.3% vs 83.3%, $P = .049$). The mean CAC2–C7 on WLR was significantly less lordotic than that on CLR (11.2 ± 9.2° vs 14.3 ± 11.3°; $P = .01$). The mean cSVA was translated more posteriorly on WLR than on CLR (9.9 ± 18.9 mm vs 15.0 ± 13.4 mm, $P = .04$). However, no significant differences in T1 slope, C7 slope, and CAC0–C2 were found between CLR and WLR.

This study shows that standing CLR could provide better visualization of the upper endplate of T1. Furthermore, WLR taken in hands on clavicle position distorted radiographic measurements such as CAC2-C7 and cSVA. Therefore, CLR performed in the standing position seems to allow more-accurate measurements of cervical sagittal parameters.

Abbreviations: CAC0–C2 = C0–C2 Cobb angle, CAC2–C7 = C2–C7 Cobb angle, cSVA = cervical sagittal vertical axis, CLR = Cervical lateral radiograph, WLR = whole-spine lateral radiograph.

Keywords: cervical lateral radiograph, cervical sagittal alignment, T1 slope, whole spine lateral radiograph

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[a] *Department of Orthopedic Surgery, Asan Medical Center, University of Ulsan College of Medicine, Seoul,* [b] *Department of Orthopedic Surgery, Dongguk University Ilsan Hospital, Goyangsi, Gyeonggido,* [c] *Department of Spine Center, Haeundae Bumin Hospital, Busan, Republic of Korea,* [d] *Emory University, College of Arts and Science, United States of America.*

[*] *Correspondence: Dong Gyun Kim, MD, Department of Spine Center, Haeundae Bumin Hospital 584, Haeundae-gu, Haeundae-ro, Busan, Republic of Korea (e-mail: iddongga@naver.com).*

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1. Introduction

Standing whole-spine lateral radiograph (WLR) is an essential imaging modality for evaluating global spine sagittal alignment. It is also commonly used to evaluate cervical sagittal parameters.[1–5] Among the many arm positions used during WLR imaging, the hands-on-clavicle position is the most widely applied position, as it provides the best visualization of thoracolumbar spine and can minimize position-related distortion of the thoracolumbar sagittal parameters. However, WLR in the hands-on-clavicle position has limitations for evaluating cervical sagittal alignment. The T1 slope, a key influencing factor of cervical sagittal balance, is frequently obscured by the shoulder and thoracic trunk in the hands-on-clavicle position.[6] The hands-on-clavicle position has been reported to distort the T1 slope, head position, or cervical lordosis, which limits its capacity to measure accurate cervical sagittal parameters.[7]

Besides WLR, cervical lateral radiograph (CLR) with arms in the neutral position (hands-on-thigh position) is another commonly used imaging modality to assess cervical sagittal parameters.[7] Although a few studies have evaluated the differences in cervical sagittal parameters between WLR and CLR, no consensus has been reached regarding the optimal position during imaging for cervical sagittal parameter measurement.[7–9] Moreover, visibility of T1 which is an important factor in operative planning, has not been compared between the two imaging methods.

Whether CLR can replace WLR completely for cervical sagittal parameter assessment with regard to visibility and accuracy or WLR would provide additional information has not been clarified. Therefore, the present study aimed to evaluate differences in T1 upper endplate visibility and various cervical sagittal parameters measured on WLR and CLR and to clarify which imaging modality provides better information in the assessment of cervical sagittal alignment.

2. Materials and methods

2.1. Patient characteristics and study design

Sixty consecutive patients who visited the outpatient clinic between July 2017 and March 2018 for axial neck pain alone without radiculopathy or myelopathy were retrospectively evaluated. The study protocol was approved by institutional review board of Asan Medical Center (2018-0942). Informed consent was waived owing to the retrospective nature of the study. Patients who had undergone previous spine operations or diagnosed with spine deformities have been excluded. All the patients underwent both standing CLR and WLR for evaluating regional and global spinal balance. T1 visibility, sagittal parameters measured in WLR were compared with those measured in CLR.

2.2. Data collection

CLR was performed with the patient standing in a comfortable position with horizontal gaze and arms extended to the sides. The radiation tube was centered at the disc space between C4 and C5. WLR was performed in the hand-on-clavicle position with flexed elbows and wrists, and relaxed fists and fingers placed in the supraclavicular fossa. The radiation tube was centered at the xyphoid process during WLR (Figure 1).

The following parameters were measured on CLR and WLR:

Figure 1. Cervical lateral radiograph obtained in a comfortable standing position with horizontal gaze and arms extended to the sides (A) and whole-spine lateral radiograph obtained in the hand-on-clavicle position with the elbows and wrist flexed, the fist relaxed, and the fingers placed into the supraclavicular fossa. Adopted from Society 20 Suppl 5:602–608. doi:10.1007/s00586-011-1927-y.

1. T1 slope visibility,
2. T1 slope,
3. C7 slope,
4. C0–C2 Cobb angle (CAC0–C2),
5. C2–C7 Cobb angle (CAC2–C7), and
6. cervical sagittal vertical axis (cSVA).

The radiographic measurements were performed by two spine fellowship-trained orthopedic surgeons.

The visibility of the T1 slope was determined according to the visibility of the T1 superior endplate. Visibility was defined as a clearly visible T1 superior endplate or sufficient visibility of part of the endplate for drawing a line. Non-visibility was defined as a T1 superior endplate obscured by surrounding structures (Figure 2). T1 slope was defined as the angle between a horizontal line and a line parallel to the superior endplate of T1. C7 slope was defined as the angle between a horizontal line and the C7 superior endplate. CAC0–C2 was defined as the angle between two lines on the inferior endplates of C0 and C2 that are extended until they intersect. CAC2–C7 was defined as the angle between two lines on the inferior endplates of C2 and C7 that are extended until they intersect. cSVA was defined as the horizontal distance between the centers of C2 and the C7 vertebral body (Figure 3).

2.3. Statistical analyses

Data management and statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS version 18.0; SPSS Inc., Chicago, IL, USA). The visibility of the T1 slope was analyzed using a chi-square test, while the T1 slope, C7 slope, CAC0–C2, and CAC2–C7 were analyzed using a Student *t* test. The interobserver reliability was calculated

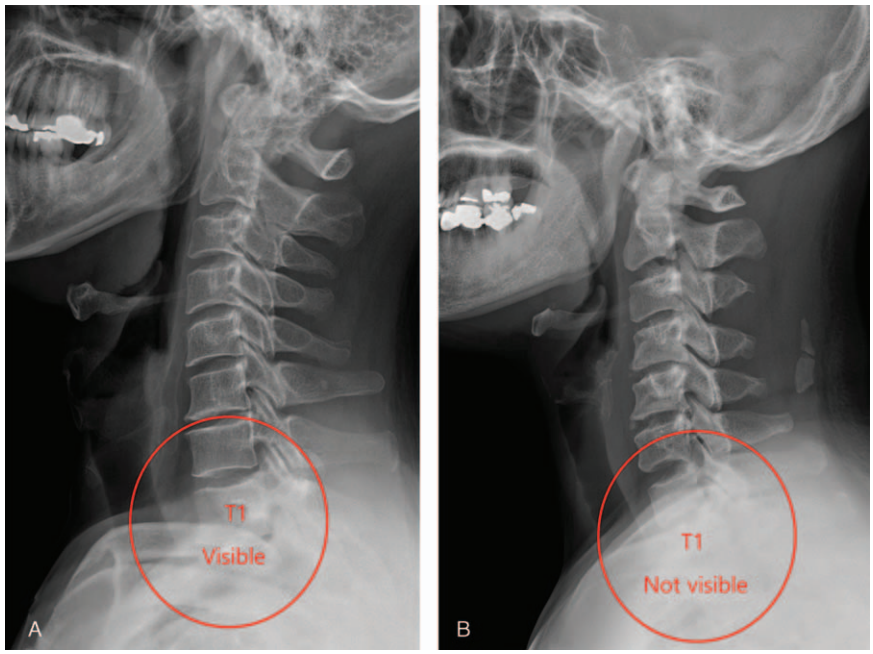

Figure 2. (A) T1 slope visible on the cervical spine lateral radiograph. (B) T1 slope not visible on the whole-spine lateral radiograph.

using the intraclass correlation coefficient (ICC) for the cervical sagittal parameters and the kappa test for T1 upper endplate visibility. A *P*-value of $< .05$ was considered statistically significant.

3. Results

The study included 38 men (63.3%) and 22 women (36.7%). The mean age of the patients was 55.6 years (range, 36–75 years). The interobserver reliability for sagittal parameter measurement

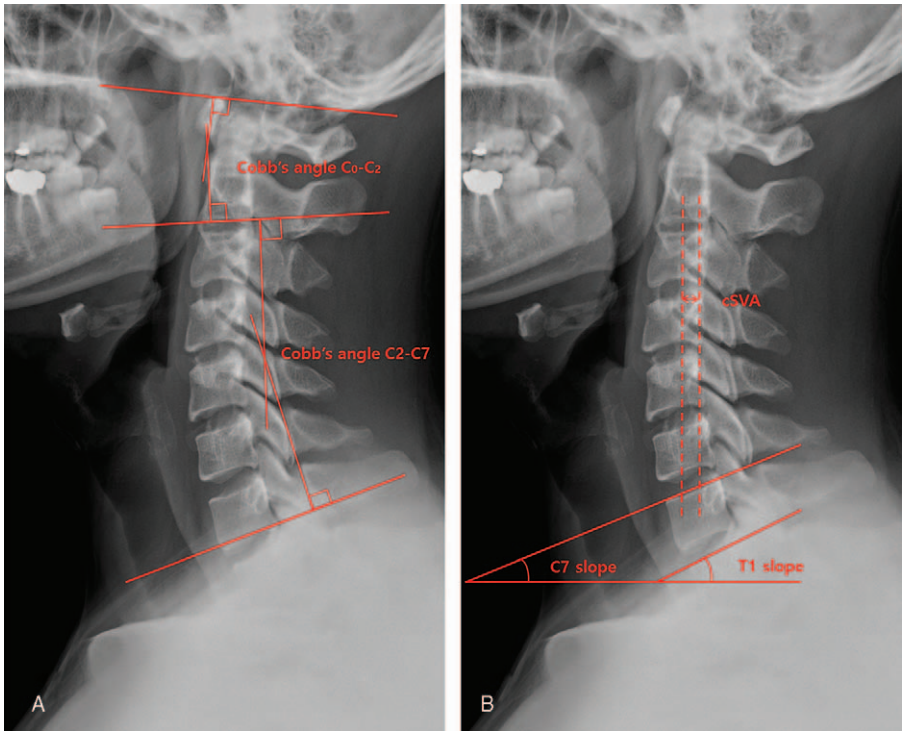

Figure 3. Schematic drawing of the parameters. Radiograph showing several sagittal parameters measured in this study: CAC0–C2: angle between two lines on the inferior endplates of C0 and C2 that are extended until they intersect. CAC2–C7: angle between two lines on the inferior endplates of C2 and C7 that are extended until they intersect (A). T1-slope: angle between a horizontal line and a line parallel to the superior endplate of T1. C7 slope: angle between a horizontal line and the C7 upper endplate. cSVA: horizontal distance between the centers of C2 and C7 vertebral body (B).

Table 1

Visibility rates of the T1 endplate on radiography.

	Visible	Invisible	*P* value
Cervical spine lateral radiography	83.3% (50/60)	16.7% (10/60)	.049*
Whole-spine lateral radiography	28.3% (17/60)	71.7% (43/60)	

Statistical analysis was performed using a chi-square test.
* *P* value < .05

based on the ICC was 0.836. The kappa coefficient for the interobserver reliability of the T1 upper endplate visibility was 0.825.

On CLR, the T1 endplate was visible in 83.3% (50/60) of the patients but not clearly identifiable in 17.6% (10/60). On WLR, the T1 endplate was visible in only 28.3% (17/60) of the patients but not identifiable in 71.7% (43/60). The visibility rate of the T1 slope was significantly higher with CLR than with WLR (28.3% vs 83.3%, $P = .049$; Table 1).

The T1 slopes on CLR and WLR were 22.82 ± 6.37^{o} and 21.29 ± 5.01^{o}, respectively ($P = .161$). The C7 slopes on CLR and WLR were 18.79 ± 6.84^{o} and 18.35 ± 7.63^{o}, respectively ($P = .681$). No significant differences in T1 and C7 slopes were found between the measurements using CLR and WLR. Furthermore, there were no significant difference in CAC0–C2 measured on CLR (15.58 ± 9.31^{o}) and WLR (16.14 ± 9.65^{o}) ($P = .580$). The CAC2–C7 on CLR and WLR were 14.73 ± 11.31^{o} and 11.20 ± 9.24^{o}, respectively. The CAC2–C7 on WLR in the hands-on-clavicle position was significantly less lordotic than that on CLR with the arms extended ($P = .01$). The cSVA on CLR and WLR were 14.96 ± 13.44 mm and 9.92 ± 18.86 mm, respectively. The sagittal balance of the cervical spine measured using cSVA was more translated posteriorly on WLR than on CLR ($P = .040$, Table 2).

4. Discussion

Spine sagittal global imbalance is associated with pain, disability, and deterioration of health-related quality of life.[10,11] Moreover, increasing evidence suggests that cervical sagittal malalignment can lead to increased neck pain and poor neurological recovery after decompressive operations.[6,12] Many parameters have been studied, including T1 slope, C7 slope, cSVA, and Cobb's angle, that can aid in operation planning and predicting prognosis and accurate assessment of these parameters would lead to appropriate clinical decision. However, although CLR and WLR are the two most common radiographic modalities utilized to assess cervical sagittal alignment, the optimal radiological protocol for accurate assessment has not been clarified.

Table 2.

Comparison of the parameters measured on cervical spine lateral radiography and whole-spine lateral radiography.

	CLR	WLR	*P* values
T1 slope (°)	22.82 ± 6.37	21.29 ± 5.01	.161
C7 slope (°)	18.79 ± 6.84	18.35 ± 7.63	.681
C0–C2 Cobb angle (°)	15.58 ± 9.31	16.14 ± 9.65	.580
C2–C7 Cobb angle (°)	14.73 ± 11.31	11.20 ± 9.24	<.001*
Cervical sagittal vertical axis (mm)	14.96 ± 13.44	9.92 ± 18.86	.040*

CLR, cervical lateral radiography; WLR, whole spine lateral radiography. Statistical analysis was performed using the Student *t* test.
* *P* value < .05

Among the parameters, the T1 slope suggested by Knot et al is one of the most commonly assessed sagittal parameters of the cervical spine during preoperative planning.[2,13] However, assessment of the T1 slope has some drawbacks. First, it can be distorted depending on the arm position. Several studies have evaluated whether the hands-on-clavicle or arm-clearing position is better for visualizing the thoracic and lumbar spine and reflecting the actual spine global balance on WLR.[14–16] However, the T1 slope has often differed between the two positions.[7,9] Park et al reported that the hands-on-clavicle position on WLR caused the T1 slope to decrease and the head position to translate posteriorly, which resulted in cervical sagittal alignment distortion into a hypo-lordotic or kyphotic alignment to compensate for the gravity line and sustain the horizontal gaze.[9] Furthermore, in WLR, the tube center is usually at the xiphoid process, which is more distant from T1 and the cervical spine than in CLR, in which the tube is at the C4–C5 level; this results in a distortion of the cervical spine area because of beam divergence.[17] Previous studies reported that the T1 slope was smaller on WLR than on CLR owing to the above-mentioned reasons.[7,9] The results of the present study also demonstrated decreases in the T1 and C7 slopes on WLR as compared with CLR, although the difference was not statistically significant.

Second, the T1 upper endplate is frequently obscured by the shoulder and thoracic trunk, which limits its measurement.[8,18] Therefore, research data using the T1 slope commonly depend on the poorly visible T1 upper endplate on lateral radiographs.[19,20] The passive flexion of the shoulder required in the hands-on-clavicle position for WLR often causes the shoulder to migrate upward, which would further obscure the T1 upper endplate.[16,21,22] Although Nunez et al proposed the use of the C7 slope to overcome the limitations of the T1 slope,[23] whether the C7 slope is more likely to be visible than the T1 slope is unclear, and few studies have examined the relationship between the C7 slope and other cervical parameters.[24–26] In the present study, the T1 visibility reached 83.3% when assessed on CLR and 28.3% when assessed using WLR, signifying that the T1 slope would be more accurately measured using CLR. Koji et al reported 37% T1 slope visibility on CLR in the sitting position, which is rather low when compared with the results of the present study.[24] The difference could have been caused by the difference in position between the two studies. Hwee et al reported that gravity applied to the center of the head in sitting CLR results in a more forward translation of the head and that increased cervical lordosis is needed to maintain the horizontal gaze.[27] Increased cervical lordosis would also increase the T1 slope, and a more vertically positioned T1 upper endplate would be easily obscured by surrounding structures. Therefore, during lateral radiography, the standing position with arms extended would be a better position to assess the T1 slope compared to sitting position.

CAC2–C7 and cSVA measured on WLR were significantly different from those measured on CLR, signifying a hypolordotic change and posterior migration of the cervical alignment in the hands-on-clavicle position in WLR. These findings were also demonstrated in the study by Park et al.[9] It seems that true cervical sagittal alignment should be assessed using CLR since hands on clavicle position utilized for WLR causes significant distortion in sagittal parameter measurements.

To summarize, CLR seems to have several advantages over WLR in the assessment of cervical sagittal alignment parameters. CLR is performed with the patient's arm extended to the sides. This would minimize the change in the cervical sagittal parameters such as decrease in lordosis and posterior translation of sagittal balance caused by the hands-on-clavicle position required in WLR. Furthermore, the radiation beam is centered at the cervical spine to limit the distortion caused by divergence.[17] Moreover, CLR performed while the patient is in the standing position with arm extended provides the best T1 upper endplate visibility as demonstrated in the present study, thereby allowing accurate assessment of the T1 slope. These findings suggest that CLR in the standing position with arms extended to the sides would be the single best imaging modality when cervical sagittal alignments are the measurements of interest. WLR would provide additional information regarding thoracolumbar alignment and its relationship to cervical spine. However, WLR does not add to the assessment of cervical sagittal parameters because of position- and beam divergence-related distortion and invisibility of the T1 slope.

Our study has several limitations. First, it was not conducted with healthy, symptom-free patients. Although the patients did not have an underlying deformity or myeloradiculopathy, neck pain would have possibly affected the cervical sagittal parameters. Second, the present study was conducted with a relatively small sample size. Third, we did not consider the sagittal parameters of the thoracic and lumbar spine and their relationships to cervical sagittal parameters.

In conclusion, T1 visibility was significantly higher on CLR than on WLR. Furthermore, CAC2–C7 and cSVA were significantly greater when measured using CLR, signifying the position- and radiation divergence-related distortions in WLR. CLR performed in the standing position with arms extended seems to allow more-accurate measurements of cervical sagittal parameters. Therefore, CLR would be a better radiographic modality than WLR to assess cervical sagittal alignment in terms of accuracy and visibility. Repeated WLR would not be necessary for evaluation unless accompanying thoracolumbar spine lesions are found in the initial examination.

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Author contributions

Conceptualization: Dong-Ho Lee.
Data curation: Dong-Ho Lee, Sehan Park, Dong Gyun Kim, Choon Sung Lee, Eui Seung Hwang.
Investigation: Dong-Ho Lee, Sehan Park, Dong Gyun Kim.
Methodology: Dong-Ho Lee, Dong Gyun Kim, Chang Ju Hwang, Jae Hwan Cho.
Project administration: Dong-Ho Lee.
Formal analysis: Sehan Park.
Software: Sehan Park.

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