The reliabilities of radiographic measurements of cervical sagittal alignment in ankylosing spondylitis

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Conflicts of Interest: None

Source of Funding: This work was supported by the Convergence Research Grant funded by the Pusan National University(PNU, Convergence Research Grant)(PNU-2013-1312-0001).
**Study Design:** Prospective study.

**Objective:** To test the inter- and intra-observer reliabilities of five specific measures of global cervical sagittal alignment in patients with ankylosing spondylitis (AS), and to suggest a better means of measuring cervical sagittal alignment.

**Summary of Background Data:** The intraobserver and interobserver reliabilities of several different methods of measuring cervical lordosis have been reported. However, they have not been studied till yet in patients with AS.

**Methods:** Inter- and intra-observer reliabilities of five specific measures of cervical lordosis were evaluated in patients with AS. Eighty patients with AS were allocated to a non-ankylosis or an ankylosis group, and the reliabilities of the Cobb C1-C7, Cobb C2-C7, centroid, posterior tangent, and Ishihara index methods were evaluated.

**Results:** The intra- and interclass correlation coefficients (ICCs) of all five methods were generally high. For the 80 study subjects, ICCs were ≥0.84 (excellent) for all five radiographic methods. However, comparison of the ICCs, 95% confidence intervals (CI) and mean absolute differences (MAD) between groups with varying degrees of ankylosis showed that the reliability of lordosis measurements decreased as the severity of ankylosis increased. The five methods consistently demonstrated higher ICCs for both inter- and intra-observer comparisons in the non-ankylosis group. However, in the ankylosis group, the Cobb C1-C7 method demonstrated high ICCs for both inter- and intra-observer comparisons whereas the other 4 methods had high ICCs only for intra-observer comparisons. The intraobserver MADs were similar for the five methods (2.4-3.9), but the interobserver MADs of measurement methods in both groups showed low measurement reliability except for the Cobb C1-C7 methods.
**Conclusion:** This study provides a reliability analysis of different cervical lordosis measurement methods in AS, and shows that the Cobb C1-C7 method provides a reliable means for measuring cervical lordosis in AS.

**Key words:** ankylosing spondylitis, cervical lordosis, radiographic measure
Introduction

Relationships between sagittal alignment and cervical spine disorders have received considerable attention, as the configurations of sagittal spinal curves can influence cervical postsurgical outcomes and alignment affects load distributions on intervertebral discs. Therefore, appropriate measurements of the cervical curvature are important for clinical decision making. For this reason, several methods have been developed to measure cervical sagittal alignment,\(^1\)\(^-\)\(^7\) and the interobserver and intraobserver reliabilities of several methods of quantifying cervical lordosis have been reported.\(^6\),\(^7\) These devised methods include the Cobb, centroid, posterior tangent, and Ishihara index methods. Harrison et al\(^6\) compared the Cobb and the posterior tangent methods in cervical lordosis and demonstrated higher reliability for the centroid method. Ohara et al\(^7\) reported higher reliability for the Cobb C1-C7 method. However, no reports have been issued regarding cervical alignment measurements made under specific conditions, such as ankylosing spondylitis (AS).

Recognition of the importance of reliability analysis for spine disease has led to several studies and radiological analyses of AS before and after surgery have been demonstrated in several studies.\(^8\),\(^9\) However, to date the reliabilities of lordosis angle measurements in AS have not been reported. In particular, sagittal alignment of the cervical spine is an important value in AS, the role of which in deformity progression, symptoms, and outcomes needs to be determined.

AS is a chronic, inflammatory rheumatic disease characterized by inflammatory back pain and/or neck pain due to sacroiliitis and spondylitis, and the formation of syndesmophytes leading to ankylosis.\(^10\) In addition, AS is considered the most common and most typical form of
spondyloarthropathy. Arthritic changes and osteoporosis in a vertebral body could interfere accurate measurements of cervical sagittal alignment, and therefore, the availability of appropriate methods for measuring cervical sagittal alignment is important for clinical decision making in AS. The aim of this study was to test the inter- and intra-observer reliabilities of five specific measures of global cervical sagittal alignment in patients with AS, and to suggest a better means of measuring cervical sagittal alignment.

**Patients and Methods**

Eighty consecutive AS patients, 10 women and 70 men of average age 43.4 ± 12.3 years, were enrolled. AS patients were recruited from the patients attending an outpatient clinic. Demographic and disease characteristics were documented.

Patients that met the current New York criteria\(^1\) were considered eligible to participate in this study if they had received medical treatment for at least 1 year. The exclusion criteria applied were an age of >60 years, or a concomitant neurological or psychiatric disease. Patients with a history of a spinal fracture, spinal disc herniation, spinal surgery, or another orthopaedic condition of the spine or lower extremities (as prosthesis) were also excluded. In addition, 16 patients with unclear lower margin of C7 in the cervical radiographs were excluded.

The 80 study subjects underwent plain cervical lateral radiography. Radiographs were taken by one technician using a standard technique and the same x-ray machine in the standing position. The distance between the radiographic tube and the film was 150cm and the film was centered on C4. According to the ankylosis status of the curve in the radiographs, the radiographs were divided into two groups: non-ankylosis (no osseous bridge in the cervical...

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spine) and ankylosis (cervical spines were partially or completely ossified). The radiographs were composed of 40 non-ankylosis and 40 ankylosis patients.

A delayed and repeated measurement design was used to evaluate the reliability of the three examiners. All 80 radiographs were measured twice by three examiners with 2 weeks delay between first and second measurements. All measurement were carried out using a computer-based digital radiogram on a picture achieving computer system (PACS Expertise, Marosis, South Korea), which allowed easy and accurate determinations. A total of 400 measurements were taken for each of the five different radiographic methods. The five methods included the Cobb C1-C7, Cobb C2-C7, centroid, posterior tangent C2-C7, and Ishihara index methods.

Cobb C1-C7 method and C2-C7 method (Fig. 1)

The angle between the inferior margin of C1 and the superior endplate of C7, and the angle between the inferior endplate of C2 and the superior endplate of C7 are measured.

Centroid method (Fig. 2)

The intersections of four vertebral body corner are connected diagonally as vertebral centroids (C3, C6, C7). The intersection of the perpendicular lines drawn from the proximal and distal line made the cervical lordosis. The proximal line connects the bisection of the inferior endplate of the C2 and C3 centroid, and the distal line the C6 and C7 centroids.
Posterior tangent C2-C7 (Fig. 3)

The posterior tangent method uses the superior-posterior and inferior-posterior body corners.

Ishihara index method (Fig. 4)

Posterior lines are drawn through the posterior inferior corners of C2 and C7. The 4 distances, a3, a4, a5, and a6, between the posterior line and the posterior inferior corners of C3-C6, respectively, were measured. The Ishihara index was then calculated using the following formula:

\[
\text{Ishihara index} = \frac{a3 + a4 + a5 + a6}{\text{posterior line length}} \times 100
\]

Statistical analysis was performed using SPSS 13 software for Windows (SPSS, Chicago, IL, USA) and MedCalc software (MedCalc, Mariakerke, Belgium). Data were expressed by mean ± standard deviation. Means, standard deviations, interclass and intraclass correlation coefficients (ICCs), and 95% confidence intervals (CI) were calculated. ICCs were considered by Shrout and Fleiss’s classifications (poor, <0.4; fair to good, 0.4-0.75; excellent, >0.75). The mean absolute differences (MAD) of observer measurements were used in the error analysis. All statistical calculations for reliability results were performed based on the assumptions that measurement is crossed with the examiner and patient, and that the examiner was a random factor rather than a fixed factor.
Results

Table 1 lists the overall means and standard deviations of the outcome measures for the two readings of the 80 radiographs by the three examiners. ICCs, 95% CIs and MADs are provided for the two Cobb methods and the centroid, posterior tangent, and Ishihara’s method. Table 2 provides the data for each group of radiographs classified by degree of curve ankylosis. In general, ICCs of all five methods were high. In the 80 study subjects, ICCs were all ≥0.84 (excellent) for the five radiographic methods (Table 1). However, a comparison of ICCs and 95% CIs between groups with varying degrees of ankylosis showed that the reliability of lordosis measurements decreased as the severity of ankylosis increased (Table 2). The five methods consistently demonstrated high ICCs for inter- and intra-observer comparisons in the non-ankylosis group. However, in the ankylosis group, the Cobb C1-C7 method produced high ICCs for both inter- and intra-observer comparisons, whereas the other 4 methods had high ICCs only for intra-observer comparisons.

Regarding error analysis, in all study subjects, intraobserver MADs for the five methods and interobserver MAD for the Cobb C1-C7 method were similar (2.9-3.8), whereas the other 4 methods showed higher interobserver MAD. A comparison of MADs between the ankylosis and non-ankylosis groups showed that the reliability of lordosis measurements decreased as the severity of ankylosis increased. Intraobserver MADs were similar for the five methods (2.4-3.9), but interobserver MADs of the Cobb C2-C7, centroid, posterior tangent and Ishihara index methods showed less measurement reliability than Cobb C1-C7 method in the ankylosis and non-ankylosis groups.
Discussion

Intra- and interobserver reliabilities of several different measurements of cervical lordosis in the normal population have been reported. Ohara et al.\(^7\) compared the Cobb C1-C7, Cobb C2-C7, centroid, sagittal tangent, and Ishihara index methods with respect to measures of global cervical lordosis in a normal population. They reported that the inter- and intra-observer reliabilities of all global angles were high. Harrison et al.\(^6\) compared the Cobb C1-C7, Cobb C2-C7 and posterior tangent methods in measurement of global and segmental cervical lordosis, and reported intra- and inter-observer reliabilities of measuring all cervical lordotic angles were high (ICC>0.7). Furthermore, they concluded that the posterior tangent method is more reliable for measuring cervical lordosis than the Cobb method. However, reliability might be different under specific conditions such as AS.

In this study, we assumed that ICCs of cervical lordosis measurement methods would differ for AS radiographs. Measurements of cervical lordosis are important for treatment of AS. These patients often show cervical hypolordosis and cervicothoracic kyphosis, which can cause significant disability due to loss of horizontal gaze, functional limitation, chin-on-chest deformity with swallowing difficulties, neck pain, and weakness due to stretching of the spinal cord over the apex, and they also increase the risk of fall-related injuries.\(^{14-19}\) Surgery aims to restore horizontal gaze, sagittal balance, improve function, diminish social disability and provide durable correction.\(^{14,16,17,20-23}\) Thus, cervical lordotic angle is an important factor in AS, and accurate measurements are needed, but measurements of cervical lordosis in AS are difficult due to spondylitis and the formation of syndesmophytes in vertebral bodies and endplates. In addition, osteopenic changes of the spine often blur the vertebral silhouette. For these reasons, we considered that the reliabilities of cervical lordosis measurements in AS may be different.
from that in the normal population. In this study, we analyzed the reliability of cervical lordosis measurement methods with the aim of suggesting a better method in AS patients. Measures of segmental cervical lordosis are also clinically important in AS surgery. However, it is difficult to draw multiple lines in a small deformed segment and global cervical lordosis is more valuable than segmental lordosis in AS patients because AS is a systemic disease which often involves whole spine. Therefore, in the present study, we did not compare the reliabilities of segmental lordosis measurement methods.

We found that the ICCs of the 80 radiographs were all high (ICCs≥0.84). However, in the ankylosis group, intra- and interobserver reliabilities were lower than in the non-ankylosis group. In the ankylosis group, the intraobserver reliabilities of five methods showed consistently high ICCs (≥0.75). However, higher ICC for interobserver reliability (ICC=0.84) and lower MADs (≤3.6) were demonstrated only in the Cobb C1-C7 method.

MAD has been useful for determining the most reliable method when the reliabilities of methods are similar. Harrison et al5 concluded that high ICCs and a low MAD mean high reliability, and proposed that MAD should be utilized in error analysis during reliability studies. Similarly, Lee et al24, who compared several methods for measuring lumbar lordosis in AS, found that the Cobb L1-L5 method had the lowest MAD, and concluded that the Cobb L1-L5 method was better than the other methods, which had high ICCs and low MAD.

In the present study, only the Cobb C1-C7 method showed higher reliability. Furthermore, the Cobb method is the technique most commonly used by clinicians because it provides a simple and quick measurement of cervical lordosis. Previous studies have reported that the Cobb method is sensitive to contour changes, such as wedge, biconcave and brush, which resulted

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from osteoporosis.\textsuperscript{4,25} Harrison et al\textsuperscript{6} reported that the Cobb C1-C7 angle overestimated the cervical lordosis, whereas the Cobb C2-C7 angle underestimated the lordosis. On the other hand, Ohara et al\textsuperscript{7} reported that the Cobb C1-C7 method showed better reliability than the other methods. For the above reasons, several authors have used other measurement methods, such as the posterior vertebral body tangent, centroid and Ishihara index methods. However, it might be different in AS patients.

Although regardless of degenerative change, the posterior vertebral body margins of C2 and C7 are quite visible in the normal population, it is difficult to draw the posterior body margin precisely for AS patient because of spondylitis and formation of the syndesmophytes. In the present study, the intra- and interobserver reliabilities for the global C1-C7 Cobb angle was high with ICCs≥0.84 in all groups, and Cobb C1-C7 method showed better reliability than the Cobb C2-C7 and posterior tangent method. This result is in line with the fact that the C2 vertebra is often affected by degenerative changes and its contour is usually invisible in arthritic patients.\textsuperscript{25} In addition, the reliability of the Ishihara method was less that of the Cobb methods. The Ishihara index value is calculated using 4 numerators and 1 denominator, which are not angles. Furthermore, when there is no lordosis, the Ishihara index value is extremely small because the 4 numerators are small and the denominator is large. Actually, of the 5 methods examined, when alignment was straight, Ishihara index values approached zero and varied very little, which indicates that the Ishihara method is not very reliable when the alignment is straight.

Some limitations of this study require consideration. In particular, only AS patients with radiographs in which C1-C7 were clearly visible were enrolled: those in which C7 was not clearly seen were excluded (16 patients).
The present study is the first to undertake reliability analysis on different global cervical lordosis measurement methods in AS. The findings of this study show that the Cobb C1-C7 method is reliable for measuring the global cervical lordosis in AS. Clinicians may find these results useful when interpreting cervical sagittal alignment values obtained using different measurement methods.

**Disclosures** None
References


21. **Khoueir P, Hoh DJ, Wang MY.** Use of hinged rods for controlled osteoclastic correction


Legend

Fig. 1 The Cobb C1-C7 and C2-C7 methods

Fig. 2 The centroid method

Fig. 3 The posterior tangent C2-C7 method

Fig. 4 The Ishihara index method
Tables

Table 1. Mean, standard deviations and ICC values of each measurement method

<table>
<thead>
<tr>
<th>Methods</th>
<th>Mean and SD</th>
<th>Intraobserver reliability</th>
<th>Interobserver reliability</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>ICC</td>
<td>95% CI</td>
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<tr>
<td>Cobb C1-C7</td>
<td>43.0 ± 11.3</td>
<td>0.96</td>
<td>0.95-0.97</td>
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<tr>
<td>Cobb C2-C7</td>
<td>14.2 ± 10.7</td>
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<td>Centroid</td>
<td>14.1 ± 8.2</td>
<td>0.93</td>
<td>0.91-0.95</td>
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<tr>
<td>Posterior tangent</td>
<td>20.3 ± 10.5</td>
<td>0.96</td>
<td>0.95-0.97</td>
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<tr>
<td>Ishihara</td>
<td>15.1 ± 9.5</td>
<td>0.96</td>
<td>0.95-0.97</td>
</tr>
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</table>
Table 2. Mean, standard deviations and ICC values of each measurement method for each group divided by the severity of ankylosis

<table>
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<th>Intraobserver reliability</th>
<th>Interobserver reliability</th>
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<tr>
<td></td>
<td></td>
<td>ICC</td>
<td>95% CI</td>
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<tr>
<td>Non-ankylosis</td>
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<tr>
<td>Cobb C1-C71</td>
<td>42.9 ± 14.9</td>
<td>0.97</td>
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<tr>
<td>Cobb C2-C7</td>
<td>15.7 ± 12.8</td>
<td>0.97</td>
<td>0.95-0.98</td>
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<tr>
<td>Centroid</td>
<td>15.4 ± 11.2</td>
<td>0.96</td>
<td>0.94-0.97</td>
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<tr>
<td>Posterior tangent</td>
<td>20.8 ± 12.9</td>
<td>0.98</td>
<td>0.97-0.99</td>
</tr>
<tr>
<td>Ishihara</td>
<td>15.7 ± 12.6</td>
<td>0.97</td>
<td>0.96-0.98</td>
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<td>0.91</td>
<td>0.87-0.94</td>
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<tr>
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<td>0.88-0.94</td>
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<td>Centroid</td>
<td>12.6 ± 5.1</td>
<td>0.75</td>
<td>0.64-0.82</td>
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<tr>
<td>Posterior tangent</td>
<td>20.1 ± 8.3</td>
<td>0.89</td>
<td>0.85-0.93</td>
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<tr>
<td>Ishihara</td>
<td>13.9 ± 4.6</td>
<td>0.88</td>
<td>0.82-0.91</td>
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