**Abstract:** It is necessary to assess coronal Cobb angle in the diagnosis and treatment of patients with adult degenerative scoliosis (ADS). But as most ADS patients are elderly patients who are difficult or unable to stand upright without assistance, it is difficult to obtain standing posteroanterior X-ray radiographs. Whether it is possible to use Cobb angle obtained on a supine posteroanterior X-ray radiograph to predict Cobb angle in a standing position remains unanswered.

To study the correlation between X-ray plain radiographic parameters obtained from the supine position and those obtained from the standing position in ADS patients.

Medical records and radiological information were obtained from ADS patients prospectively. Posteroanterior X-ray views of the spine were taken in both standing and supine positions simultaneously in the same ADS patients to record information about the position of the apical and end vertebrae in the coronal position and measure Cobb angle and rotation degree of the apical vertebra. Correlation and linear regression were used to analyze the correlation between the Cobb angle and the rotation degree of the apical vertebra on the X-ray plain radiographs obtained from the supine and standing positions.

Of 94 ADS patients who met the inclusion criteria, 14 (15%) patients were male and 80 (85%) patients were female who ranged in age from 41 to 92 years with a mean of 67 years. The mean Cobb angle on the supine X-ray radiographs was 21 ± 10° versus 26 ± 12° on the standing posteroanterior radiograph, the difference being statistically significant ($P < 0.01$). The rotation angle of the apical vertebra in the supine and standing positions was 1.8 ± 0.7 and 1.9 ± 0.7, respectively, the difference being statistically significant ($P < 0.05$). Correlation analysis showed a strong correlation in Cobb angle between the supine and standing X-ray plain radiographs ($r = 0.92, P < 0.01$). The correlation coefficient of the rotation of the apical vertebra was $\rho = 0.81$ ($P < 0.01$). The equation of predicting the standing Cobb angle from the supine position as shown by the linear regression analysis is as follows: standing Cobb angle = 1.15 × supine Cobb angle + 1.53 ($R^2 = 0.838$). There was no significant difference between supine Cobb angle +5° and standing Cobb angle ($P = 0.413$).

The posteroanterior X-ray plain radiograph of the spine can provide information similar to that obtained from the standing coronal position in ADS patients, including the position of the apical and end vertebrae. There was a strong correlation between the Cobb angle and the degree of rotation of the apical vertebra on the X-ray radiographs obtained from the supine and standing positions, indicating that the supine Cobb angle can be used to predict the Cobb angle on the standing X-ray radiograph. The supine X-ray radiograph can replace the standing posteroanterior radiograph in terms of the coronal parameters.

**INTRODUCTION**

Adult degenerative scoliosis (ADS) can be defined as a type of spinal scoliosis in elderly adults without a history of scoliosis who develop coronal scoliotic curvature after skeletal maturation due to spinal degeneration. With the advent of the super-aged society, the incidence of ADS is on the rise. Coronal Cobb angle, the rotation degree of the apical vertebra, and the position of the end and apical vertebrae are no less important in the assessment of ADS than they are in the assessment of adolescent idiopathic scoliosis (AIS). In addition, coronal Cobb angle is not only used for determining ADS classification but an important factor in selecting surgical approaches.

The parameters above are usually obtained from standing posteroanterior radiographs. But as most ADS patients are elderly adults, they are difficult or unable to assume an upright standing position stably without assistance due to diseases of knee and hip joint or other coexisting diseases.

Although supine X-ray radiography is an imaging examination that could possibly replace standing X-ray radiography, one of the problems in using supine X-ray radiographs in the diagnosis and assessment of spinal scoliosis is that the curve Cobb angle on the supine X-ray radiograph is usually smaller than that on the standing plain X-ray radiograph due to gravity effect. In their study on AIS, Yazici et al. found that if the patient lies supine, the scoliosis curve corrects spontaneously to some degree on both transverse and coronal planes. Wessberg et al. reported that applying a certain weight to the axial position of the spine to simulate the gravity effect when the patients take supine radiographs, the Cobb angle measured from them could...
obtain a very good correlation with standing Cobb angles. The correlation between the supine and standing Cobb angles has been clarified in AIS. Whether this correlation also exists between them in ADS, or whether standing Cobb angle can be predicted by plain X-ray radiographs obtained from a supine position remains unanswered. The aim of the present study was to explore the difference and correlation between supine and standing plain X-ray radiographs in ADS.

MATERIALS AND METHODS
This prospective study was approved by the Ethics Committee of our institution. Included in this study were ADS patients older than 40 years who sought medical help on the outpatient basis in the department of spine surgery of the hospitals between January 1, 2012 and January 1, 2014. Exclusion criteria were patients with a previous history of known scoliosis types such as congenital scoliosis or AIS, and those who were unable to assume a standing position during radiography.

General data of the patients were recorded. Posteroanterior X-ray views of the spine were taken in both standing and supine positions simultaneously in the same ADS patients, and all imaging data are expressed in the digital form and stored in the Picture Archiving and Communication Systems (PACS). The main curve direction of ADS, the position of the upper and lower end and apical vertebrae, and rotation of the apical vertebra (Nash–Moe method) on the 2 X-ray radiographs were recorded, and coronal Cobb angle was measured using the angle measurement tool provided by the PACS. Specific measurement methods are indicated in Figure 1. Cobb angle measurements were performed twice by 2 of the authors at different time. The mean values of the measurements made by the 2 authors were used for the final analyses.

The consistency rate in selecting the end and apical vertebrae on the X-ray radiographs obtained from the 2 positions was calculated, and Cobb angle of the 2 groups was compared using paired t test. The degree of rotation of the apical vertebra was compared between the 2 groups using rank-sum test, and correlations of Cobb angle and the degree of rotation of the apical vertebra between the 2 groups were calculated by Pearson and Spearman rank correlation, respectively. The obtained results were analyzed by linear regression to obtain a regression equation. After further simplification, the supine Cobb angle +5° was used to predict the standing Cobb angle of scoliosis. This value was compared with the actual value using paired t test. All statistical analyses were performed by SPSS 17. Values of P < 0.05 were considered statistically significant.

RESULTS
A total of 94 ADS patients who met the inclusion criteria were enrolled in this study, including 14 (15%) males and 80 (85%) females who ranged in age from 41 to 92 years with a mean of 67 years. Of the 94 ADS cases, there were 52 (55%) cases of right scoliosis, and 42 (45%) cases of left scoliosis. The distributions of the end and apical vertebrae of the main curvature in the standing and supine positions are shown in Tables 1 and 2, respectively. End vertebrae, apical vertebra and apical vertebra rotation of the main curve varied in 28 (30%), 14 (15%), and 18 (19%) patients respectively among a total of 94 patients in supine films compared with standing radiographs.

The mean Cobb angle on standing radiographs was 26 ± 12°, which was corrected to 21 ± 12° in supine films, the difference between them was statistically significant (P < 0.01). The mean degree of apical vertebra rotation on the standing and supine positions was 1.8 ± 0.7 and 1.9 ± 0.7, respectively, the difference between them being statistically significant (P < 0.05).

Correlation analysis showed a strong linear correlation between the Cobb angles on the standing and supine X-ray plain radiographs (r = 0.92, P < 0.01). In terms of the degree of apical vertebral rotation, the correlation coefficient between the supine and standing positions was 0.81 (P < 0.01). An equation used for the final analyses.

![FIGURE 1.](image)

**TABLE 1.** Cobb Angle Distribution at the Main Curvature in Standing and Supine Positions

| Main Curvature Distribution | Standing (%) | Supine (%) |
|-----------------------------|-------------|------------|
| T11–L3                      | 11 (11.70%) | 12 (12.77%)|
| T11–L4                      | 9 (9.57%)   | 11 (11.70%)|
| T12–L3                      | 9 (9.57%)   | 10 (10.64%)|
| T12–L4                      | 22 (23.40%) | 18 (19.15%)|
| L1–L4                       | 18 (19.15%) | 23 (24.47%)|
| Others                      | 25 (26.6%)  | 20 (21.3%) |
| Total                       | 94 (100%)   | 94 (100%)  |

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of predicting the standing Cobb angle from the supine Cobb angle could be concluded from the linear regression analysis as follows:

\[
\text{Standing Cobb angle} = 1.15 \times \text{supine Cobb angle} + 1.53 \quad (R^2 = 0.839) \quad (\text{Figure } 2).
\]

To facilitate clinical applications, we further simplified the equation as follows:

\[
\text{Standing Cobb angle} = \text{supine Cobb angle} + 5^\circ.
\]

The result of statistical analysis showed no significant difference between the predicted value and the actual measurement \((P = 0.413)\).

**DISCUSSION**

With the advent of the super-aged society, the incidence of ADS is on the rise. Posteroanterior X-ray radiograph of the spine is necessary in the process of ADS diagnosis, but it is often difficult for ADS patients to assume an upright standing position stably without assistant. Although measurement of the curve Cobb angle in ADS is not as important as that in AIS, it is still an in ignorable factor in the assessment of the condition or choosing fusion level. It is therefore necessary to find an imaging method instead of the standing position to assess the curve Cobb angle in ADS patients.

In their study on AIS, Lee et al. found a strong linear correlation between the Cobb angle on the standing X-ray radiograph and that on the supine magnetic resonance imaging (MRI), based on which they obtained an optimal fitting equation. Their result is similar to the finding of Wessberg et al. that there was a 0.78 correlation coefficient between the Cobb angle on the X-ray plain radiograph and MRI, based on which they obtained a simplified equation: Cobb angle obtained on MRI + 6° = Cobb angle obtained on X-ray plain radiograph, and the error was within 5°.7,8

The results of the above studies showed that there is a close correlation between the standing and supine radiographic parameters. It is therefore possible to use heterogenic parameters obtained in the supine position to predict the standing parameters. But as the above studies were performed in AIS patients, whether these correlations still exist in ADS patients remains unanswered.

The results of the present study showed that the position of the end and apical vertebrae of the main curve was similar between the supine and standing positions in most ADS patients, and there was a strong correlation in Cobb angle and rotation of the apical vertebra between the 2 positions. Supine Cobb angle + 5° could be used to predict the standing Cobb angle.

Surgical treatment can be considered in ADS patients whose conservative management has failed. Surgical indications include intractable back and/or leg pain, curve progression, progressive neurological deficits, and aggravation of coronal and/or sagittal decompensation.1,9,10 Pritchett and Bortel11 found that ADS patients with a coronal Cobb angle >30° tend to run a higher risk of curve progression and often need surgical intervention. Therefore, supine Cobb angle >25° could be used as an indication for surgical treatment according to the simplified equation.

These results indicate that radiographic parameters obtained in the supine position can be used to predict the corresponding parameters of the standing position in ADS, as is the cases with AIS. This is beneficial to ADS patients, because it not only solves the problem of standing difficulty in some ADS patients but saves the time and money on examination.

Although the present study has demonstrated that supine X-ray radiography can be used to replace standing X-ray radiography in the diagnosis and follow-up of ADS patients, information provided by supine X-ray plain radiography for surgical planning is limited, especially that concerning the sagittal parameters that are particularly important for ADS. Further study is required to explore whether it is possible to use supine sagittal parameters to predict standing sagittal parameters. As it is technically impossible to obtain a full-length radiograph of the spine cord in our institution, we are unable to do research in this respect at present.

**CONCLUSIONS**

Supine posteroanterior X-ray radiography can provide coronal information similar to that obtained in a standing position in ADS patients. Cobb angles, as well as apical vertebra rotation (Nash–Moe method) obtained from supine and standing radiographs are strongly correlated. The supine X-ray Cobb angle can be used to predict the standing X-ray Cobb angle, and the supine X-ray radiograph can replace the standing X-ray radiograph in terms of coronal parameters.

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