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Research Paper: Comparison of Cobb Angles on Radiographs With Magnetic Resonance Imaging in Idiopathic Scoliosis

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ABSTRACT

Background: Patients with idiopathic scoliosis are exposed to repetitive x-ray for angle measurement. Therefore, the discovery or development of alternative techniques with less radiation has continuously been a major concern.

Objectives: In this study, we compared the Cobb angles on supine Magnetic Resonance Imaging (MRI) with those on standing plain radiographs to figure out how precisely the supine MRI can show the real curve. Consequently, the need for certain exposures throughout the management of idiopathic scoliosis might be eliminated.

Methods: A total of 103 patients with idiopathic scoliosis were included in this prospective study. The standing radiographs and supine MRI were obtained with less than a 1-month time lag. One senior author assessed Cobb angles of the major curves were on both standing radiographs and MR images. All the eligible patients had already signed the consent for diagnostic imaging, including MRI. The individuals, who were not requested for x-ray and MRI, were excluded from this study.

Results: The Mean±SD Cobb angle was 55.5±11.2° on the standing plain radiographs and 44.5±10° on MR images (P<0.001). The Mean±SD difference between the Cobb angles on the standing plain radiographs and MR images was 11±1.4°. A significant positive correlation was found between the Cobb angles calculated on plain radiographs and MRI (r=0.996, P<0.001). Accordingly, Cobb angles on MRI could be converted to Cobb angles on plain radiographs under the formula of MRI=0.9* XRAY-5.31 (absolute error of 5.31°).

Conclusion: Cobb angles on supine MRI correlates with measured ones on standing radiographs with an acceptable range of error and could be used as a valuable alternative for radiographic Cobb angle measurement.

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1. Introduction

Idiopathic scoliosis sometimes requires continuous monitoring of the curve to diagnose the effect of treatment. This monitoring is generally performed using repetitive radiographic evaluations and measurement of Cobb angles [1]. Although standing plain radiograph is considered the "gold standard" imaging to follow and manage these patients, repeated exposure to radiation is of significant concern, particularly in growing children. Based on the study of Nash et al., who evaluated the average doses of surface radiation exposure during treatment in 13 females with adolescent idiopathic scoliosis, there is a 7.5% increased risk of developing lung cancer and a 110% increased risk of breast cancer in this population [2]. This information calls for the development of some safe and efficacious techniques to measure the Cobb angle.

Magnetic Resonance Imaging (MRI) could be a radiationless alternative to plain radiographs for Cobb angle measurements [3, 4]. Standard MRI, however, is taken on the supine position. Therefore, it will underestimate the Cobb angles because the effect of gravity is eliminated [5].

Since gravity is a constant, we hypothesized that a direct correlation could be established between the Cobb angles obtained from supine MRI and standing plain radiographs. If so, MR images could be easily translated into Cobb angles on standing plain radiographs and be used as an alternative for standing plain radiographs in patients with adolescent idiopathic scoliosis.

In this study, we compared the Cobb angles obtained on supine MRI with Cobb angles measured on standing plain radiographs to find how these angles are associated with each other and also to figure out a way to reduce somehow the repetitive exposure to ionizing radiation in patients with idiopathic scoliosis.

2. Methods

In a prospective investigation, consecutive patients with idiopathic scoliosis who were referred to our center from 2015 to 2018 were evaluated for the eligibility criteria. The inclusion criteria were the confirmed diagnosis of idiopathic scoliosis, less than one month of lag time between the standing radiograph and the MRI, and no contraindication for MRI. Finally, 103 patients were identified as eligible for the study.

All plain radiographs were obtained using the same X-ray machine. All supine MR images were obtained with a 1.5T MRI scanner (Siemens Avanto, Munich, Germany). On MR images, Cobb angles were measured on the T1-weighted coronal plane cuts. The same end vertebrae were used for the measurement of Cobb angles on standing plain radiographs and supine MRI (Figure 1).

Cobb angles were only measured for the major curves to compare the corresponding levels on the MRI and plain radiograph. One senior author performed all the measurements.

Statistical analysis

SPSS V. 16 was used for all statistical assessments. Descriptive data were provided as the Mean±SD or number and percentage. A paired t test was used for the comparison of Cobb angles on MR images and plain radiographs. The Pearson correlation coefficient was used to test the correlation between Cobb angles on MR images and plain radiographs. A $P<0.05$ was considered significant.

3. Results

The Cobb angle was measured on the standing plain radiograph and MRI of 103 patients. The study population included 33 (32%) males and 70 (68%) females. The Mean±SD age of the patients was 16.7±5 years, ranging from 9 to 37 years. The most frequent involved level included T4-T11 (n=12), T5-T12 (n=12), T10-L3 (n=9), and T6-L1 (n=8). Table 1 presents the radiographic and demographic characteristics of the patients.

The Mean±SD Cobb angle was 55.5±11.2° on the standing plain radiographs, ranging from 35° to 90°. The mean Cobb angle was 44.5±10° on MR images, ranging from 25° to 74°. The mean obtained Cobb angle on plain radiographs was significantly different from the mean obtained Cobb angle on MR images ($P<0.001$). The mean difference between the Cobb angles on the standing plain radiographs and MR images were 11±1.4°, ranging from 7° to 16° (Figure 2).

A significant positive correlation was found between the Cobb angles calculated on plain radiographs and MRI ($r=0.996$, $P<0.001$) (Figure 3). Based on this correlation value, the translation of Cobb angles on MRI into Cobb angles on plain radiographs is achievable with an absolute error of 5.31° and under the formula of MRI=0.9* XRAY-5.31.

Table 1. The radiologic and demographic characteristics of the patients with idiopathic scoliosis (The data are presented as Mean±SD or No. (%))

Variable		Idiopathic Scoliosis Patients (N=103)
Age (y)		16.7±5
Gender	Male	33 (32)
	Female	70 (68)
Involved level	T4-T11	12 (11.7)
	T5-T12	12 (11.7)
	T10-L3	9 (8.7)
	T6-L1	8 (7.8)
	T5-L1	6 (5.8)
	T6-T12	6 (5.8)
	T4-L1	5 (4.9)
	T4-T12	5 (4.9)
	T5-T11	5 (4.9)
	Other	35 (33.8)
Cobb angle on standing plain radiographs		55.5±11.2
Cobb angle on supine MRI		44.5±10.1
Cobb angle difference (X-ray-MRI)		11±1.4

4. Discussion

Ionizing radiation contains significant potential and long-term health consequences, including the increased risk of developing a variety of cancers. Therefore, measuring Cobb angles using techniques that do not expose the idiopathic scoliosis patients to ionizing radiation is of critical value, particularly in the adolescents who are subjected to repetitive Cobb angle measurement [6].

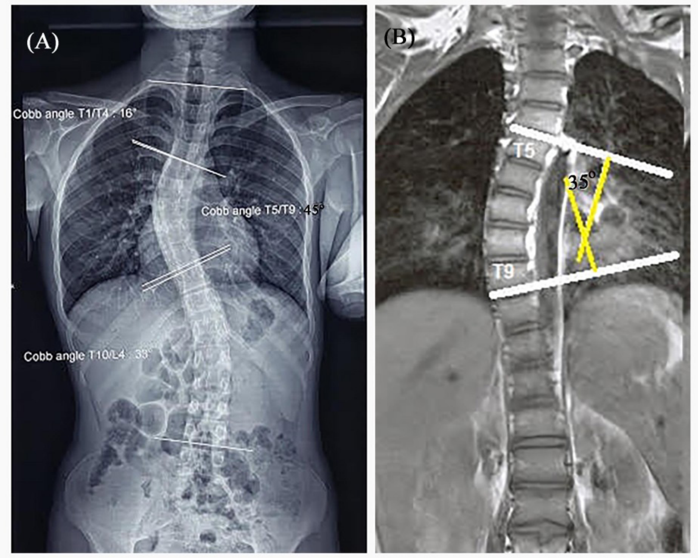

Figure 1. Evaluation of Cobb angle

A. Evaluation of Cobb angle on standing plain radiograph; B. Evaluation of Cobb angle of the same patients on supine MRI

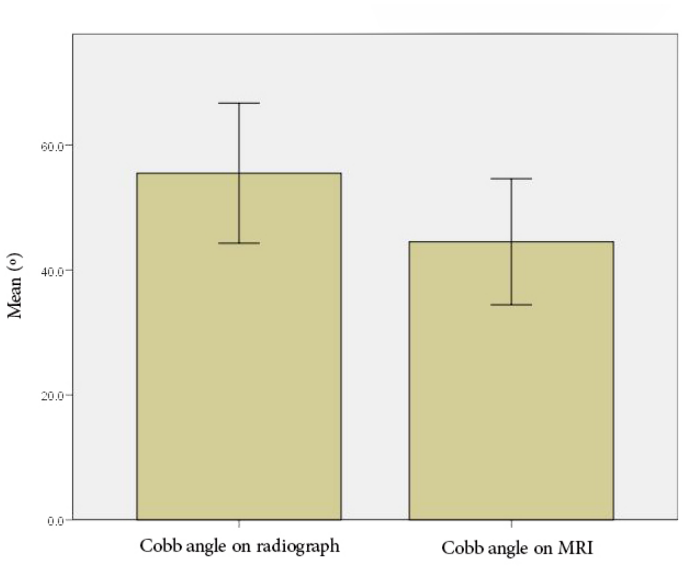

Figure 2. Comparison of mean Cobb angle on standing plain radiograph and supine MRI

Journal of Research in Orthopedic Science

In this study, we aimed to find how Cobb angles calculated on the standing plain radiographs and supine MRI are associated with each other and how this association could serve patients with idiopathic scoliosis and prevent repetitive exposure to ionizing radiation. Based on the results of this study, supine MRI calculation significantly underestimates the Cobb angles (nearly 11°). However, a significant positive correlation was found between the Cobb angles calculated on MR images and standing plain radiographs allowing the obtained Cobb angles on MRI to be easily translated into Cobb angles on standing plain radiographs with an absolute error of 5.31°.

Lee et al. aimed to demonstrate a relationship between Cobb angle measurements obtained with the standing plain radiographs and standard supine MRI in patients with adolescent idiopathic scoliosis. Based on their results, supine MR images underestimated Cobb angles by 10° on average. However, a strong positive correlation was noticed between the radiographical and MRI measures allowing the development of a simple linear equation for converting MRI Cobb angles to radiographic Cobb angles with an absolute acceptable error of ±5°. Accordingly, they suggested standard supine MRI as a viable substitute for plain radiographs in the serial evaluation of Cobb angles in adolescent idiopathic scoliosis [7].

Wessberg et al. hypothesized that axially loaded MRI using a compression device simulates imaging of the

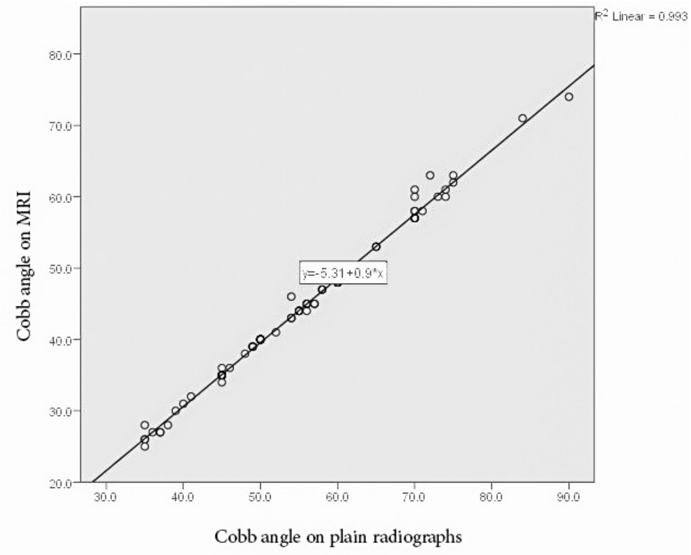

Figure 3. Correlation of Cobb angle on standing plain radiograph and supine MRI

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lumbar spine in standing position, thereby resolving the need for converting MRI data to radiographic data using an equation. They compared Cobb angles in 30 patients with idiopathic scoliosis using routine standing thoracolumbar spine radiograph and a supine MRI with and without axial loading. Based on their results, the mean Cobb angle for the major curve was 31° on standing plain radiographs, 23° on supine MRI without axial loading, and 31° on supine MRI with axial loading. They concluded that supine MRI with axial loading produces Cobb angles similar to standing plain radiographs and could be reliably used as a substitute for plain radiographs in the repetitive measurement of Cobb angles in patients with idiopathic scoliosis [7].

Despite the similarity of Cobb angles obtained on the standing radiographs and loaded supine MRI in the study of Wessberg et al., using axially loaded MRI is associated with several concerns. As the most notable concern, there is still no consensus regarding the amount and distribution of the introduced load. In the standing position, the load on the vertebrae increases gradually from the cervical to the lumbar spine. Therefore, introducing the same load to all parts of the spine cannot simulate the natural standing spine load [8-10]. Moreover, the axial loading device is not readily available in all healthcare settings. Even if possible, the use of an axial loading device in MRI can be difficult.

The present study reveals that an axial load device is not necessary to estimate a Cobb angle using MR images reliably. Instead, using a simplified equation, the Cobb angle derived from an MR image could be translated into Cobb angle on plain radiographs with an absolute error of 5°. Such error is within the currently accepted error range for Cobb angle measurement of plain radiographs (7° to 10°) [11, 12].

This study has some limitations, too. The main limitation of this study was the absence of observer reliability testing for measuring Cobb angles on the standing radiographs as well as on supine MR image. Therefore, we suggest future investigations to include observer reliability testing in their study design.

5. Conclusion

Calculation of Cobb angles on supine MRI simulates the obtained Cobb angles on the standing radiographs with an acceptable range of error. These results suggest supine MRI as a valuable alternative for radiographic Cobb angle measurement to avoid repetitive exposure to ionizing radiation in patients with idiopathic scoliosis.

Ethical Considerations

Compliance with ethical guidelines

The Review Board approved the study of our institute, and the patients provided written consent before participation in the study.

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Authors' contributions

Conceptualization: Hasan Ghandhari; Methodology: Hasan Ghandhari, Amir Aghaie Aghdam; Writing – original draft: Amir Aghaie Aghdam; Writing – review & editing: Amir Aghaie Aghdam, Naveed Nabizadeh; Investigation, funding acquisition, resources: All authors; Supervision: Hasan Ghandhari, Naveed Nabizadeh.

Conflict of interest

The authors declared no conflict of interest.

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