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Magnetic resonance imaging

A possible alternative to a standing lateral radiograph for evaluating cervical sagittal alignment in patients with cervical disc herniation?

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Abstract

Background and Objectives: Convincing evidence supporting the use of magnetic resonance imaging (MRI) as an effective tool for evaluating cervical sagittal alignment is lacking. This study aims to analyze the differences and correlations between cervical sagittal parameters on x-ray and MRI in patients with cervical disc herniation and to determine whether MRI could substitute for cervical x-ray for measurement of cervical sagittal parameters.

Methods: One hundred forty-three adults with cervical disc herniation were recruited. Each patient had both an x-ray and MRI examination of the cervical spine. The cervical sagittal parameters were measured and compared on x-ray and MRI including: C2–C7 Cobb angle, C2–C7 sagittal vertical axis (C2–C7 SVA), cervical tilt (CT), T1 Slope (T1S), and neck tilt (NT). The data were analyzed using a paired-samples *t* test, a Pearson correlation test, and linear regression.

Results: The values of C2–C7 Cobb angle, C2–C7 SVA, CT and T1S on X-ray were larger than those on MRI ($P<.05$) and NT on X-ray was smaller than that on MRI ($P<.05$). Each of the cervical sagittal parameters had a significant correlation with the corresponding one on MRI (r = 0.699, 0.585, 0.574, 0.579 and 0.613, respectively) (C2–C7 Cobb MRI = 0.957 + 0.721 C2–C7 Cobb X, C2–C7 SVA MRI = 6.423 + 0.500 C2–C7 SVAX, CT MRI = 3.121 + 0.718 CTX, T1S MRI = 7.416 + 0.613 T1SX, NT MRI = 22.548 + 0.601 NTX).

Conclusion: Although MRI and x-ray measurements of cervical sagittal parameters were different, there were significant correlations between the results. MRI could be used to evaluate the sagittal balance of the cervical spine with great reliability.

Abbreviations: C2–C7 SVA = C2–C7 sagittal vertical axis, CT = cervical tilting, MRI = magnetic resonance imaging, NT = neck tilting, T1S = T1 Slope, TIA = thoracic inlet angle.

Keywords: cervical sagittal parameters, mRI, t1 slope, x-ray

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1. Introduction

In recent years, the sagittal balance of the spine has been receiving more and more attention by spine surgeons, as the sagittal balance of the spine can maintain the balance of the body with minimal energy consumption to maintain the horizontal gaze. However, loss of balance leads to increased muscle forces, higher consumption of energy, and the development of clinical symptoms.[1,2] Therefore, a method to maintain the sagittal balance of the spine before surgery is required. To date, a large number of related studies on the effect of pelvic sagittal parameters on the thoracolumbar sagittal balance have been reported.[1–3] Cervical sagittal balance is as crucial as pelvic sagittal alignment and is related to the concept of TI alignment. However, because some bony structures such as shoulders, the upper edge of the sternum, T1 or even C7 end plate, and other anatomical signs of exposure are unclear on x-ray, the measurement results tend to be inaccurate and do not provide useful information about cervical sagittal balance. Compared to a standing lateral radiograph, MRI can clearly show the anatomic landmarks and thus produce accurate measurement results, and consequently we considered whether MRI could be used to assess cervical sagittal alignment. However, because MRI examination of patients is performed in a supine position while x-ray examination takes place in the upright position, the effect of this change in body position and center of gravity is bound to have a

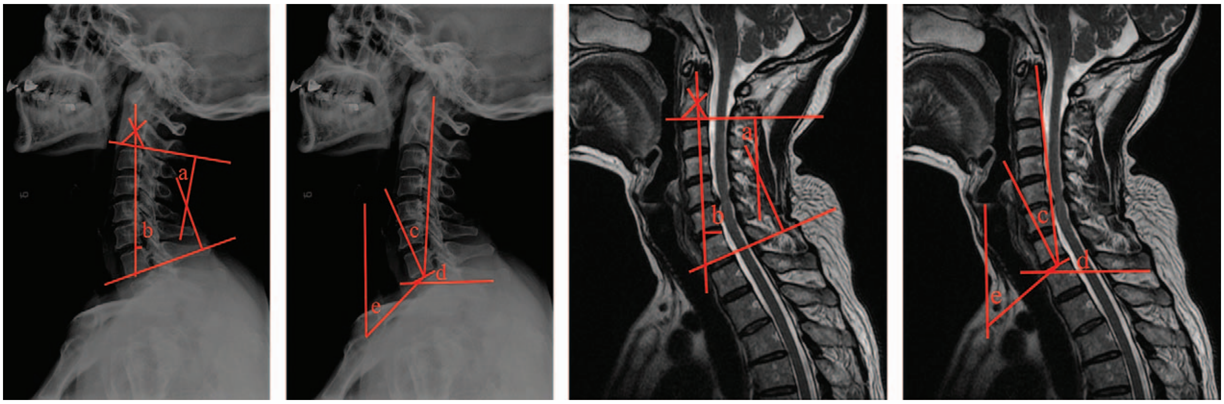

Figure 1. Measurements of cervical sagittal parameters on x-ray and MRI. (A) C2–C7 Cobb angle; (B) C2–C7 sagittal vertical axis; (C) cervical tilt; (D) T1 slope; (E): neck tilt.

nonnegligible impact on the final measurement results. Therefore, this study was based on analysis and comparison of the measurement results from cervical x-ray and magnetic resonance imaging (MRI) of 143 patients to explore the differences and correlations in the measurements of cervical sagittal parameters using x-ray and MRI.

2. Materials and methods

2.1. General data and inclusion criteria

A total of 1670 patients who experienced cervical disc herniation between January 2011 and December 2016 were reviewed. The inclusion criteria were as follows: age ≥20 years; patients underwent both cervical x-ray and MRI examination during the same period in our hospital and the complete imaging data were available. Patients that had other cervical diseases or had undergone previous spinal surgery or had any congenital deformity were excluded from this study. A total of 1005 patients were included. In each image, the visibility of the anatomic landmarks such as C7 lower endplate, T1, and the upper end of the sternum was graded according to previously reported criterion (0=not visible, measurement not possible or high degree of uncertainty; 1=moderately visible, but measurable with some uncertainty; 2=good visibility, measurable with definite certainty) [4] by 2 examiners and only the images with good visibility were included. As a result, 143 patients met the inclusion criteria, consisting of 70 males and 73 females, aged 26 to 78 years, mean age 52.12±9.52 years.

A standing lateral radiograph of the cervical spine of each patient was obtained in a comfortable standing position, with the upper extremities naturally relaxed on both sides of the body and a horizontal gaze. MRI of the cervical spine was acquired in a comfortable supine position. The cervical sagittal parameters, including C2–C7 Cobb angle, C2–C7 sagittal vertical axis (SVA), cervical tilt (CT), T1 slope, and neck tilt (NT) were measured and evaluated on both the cervical x-ray and MRI.

2.2. Cervical sagittal parameters

Measurements: (1) C2–C7 Cobb angle: using formal Cobb methods that measured the angle between the horizontal line of the C2 lower endplate and the horizontal line of the C7 lower endplate; (2) C2–C7 SVA: the distance from the vertical line from the center of the C2 body and the posterior superior corner of C7; (3) CT: an angle between the line extending from the center of the T1 upper endplate (T1UEP) to the tip of the dens and the vertical line from the center of the T1 upper endplate; (4) T1S: the angle between the T1UEP and the horizontal plate; (5) NT: the angle between a line drawn in the upper end of the sternum and a line connecting the center of the T1UEP and the upper end of the sternum (Fig. 1). All imaging parameters were measured and valued by 2 orthopedic spine surgeons each with >5 years of work experience.

2.3. Statistical analysis

All measurements were determined by the picture archiving and communication system in the hospital and evaluated by 2 orthopedic spine surgeons. Each investigator measured and evaluated each different time-point twice and their average results were calculated. SPSS 20.0 (IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY) statistical software was used to analyze the measurement results, expressed as mean±standard deviation (x±s). The results of x-ray and MRI measurements were compared using the paired-samples t test. The correlation between the 2 measurement methods was analyzed by Pearson correlation test. The correlation coefficient r was calculated and linear regression was used to establish a linear model of the measurement results of different measurement methods. $P<.05$ was considered significant.

3. Results

The visibility of the anatomic landmarks on lateral standing x-rays is shown in Table 1. Of all the 1005 patients, only 14% demonstrated convincing visibility of the anatomic landmarks on lateral standing x-ray films.

The C2–C7 Cobb angle, C2–C7 SVA, CT, and T1S on x-ray were higher than those on MRI ($P<.05$), whereas NT was lower than that on MRI ($P<.05$) (Table 2).

Each of the cervical sagittal parameters on x-ray had a significant correlation with that on MRI (Table 3). Linear regression demonstrated C2–C7 Cobb MRI=0.957+0.721 C2–C7 Cobb X, C2–C7 SVA MRI=6.423+0.500 C2–C7 SVAX, CT MRI=3.121+0.718 CTX, T1S MRI=7.416+0.613 T1SX, NT MRI=22.548+0.601 NTX (Figure 2).

Table 1

Investigator-rated visibility of anatomic landmarks in x-ray and MRI.

Anatomic landmark visibility (percentage)

	x-ray			MRI		
Landmarks	Good	Average	Poor	Good	Average	Poor
C7 lower endplate	63	25	12	100	0	0
T1	23	49	28	100	0	0
Sternum	14	56	30	100	0	0

MRImagnetic resonance imaging.

Table 2

Measurement results of cervical sagittal parameters between X-ray and MRI.

	x-ray	MRI	*P*
C2–C7 Cobb angle (°)	16.55 ± 8.12	12.89 ± 8.38	.000
C2–C7 SVA, mm	15.44 ± 8.09	14.15 ± 6.93	.027
CT (°)	20.60 ± 6.67	17.91 ± 8.33	.000
T1S (°)	26.63 ± 6.80	23.75 ± 7.20	.000
NT (°)	47.74 ± 7.80	51.24 ± 7.64	.000

MRI = magnetic resonance imaging, NT = neck tilt, SVA = sagittal vertical axis, T1S = T1 slope.

4. Discussion

Sagittal imbalance of the spine will accelerate disc degeneration, resulting in postoperative pain and dysfunction. Therefore, a method to maintain the sagittal balance of the spine and to reconstruct the sagittal balance has become a hot spot in the field of spinal surgery.[1–3,5] It has been confirmed that T1S and other cervical sagittal parameters are closely related to the cervical sagittal balance.[6] Also, some researchers have reported that patients with higher T1S have more lordotic curvature before surgery and have a tendency to exhibit a greater loss of lordosis after laminoplasty at the 2-year follow-up.[7,8] Lee et al[9] believe that T1S and TIA can reflect the cervical sagittal balance, but are also important morphological parameters that could be used to predict postoperative cervical curvature. They also reported that a larger TIA could increase the T1 slope, and thereby cervical lordosis, to maintain NT at around 44 degree and vice versa. Similar to the PI in the pelvic sagittal parameters, TIA is a fixed morphological parameter that is not affected by posture and age, whereas T1S is affected by age and postural changes.[9] The thoracic inlet is a stable bony circle structure consisting of the T1 vertebrae, the first ribs on both sides, and the upper end of the sternum without any range of motion. The cervical spine is located on the thoracic inlet biomechanically and some important muscles are attached around it.[10] As a result, the orientation and shape of the thoracic inlet can greatly affect the physiological morphology and sagittal balance of the cervical spine. The T1 vertebral body, as the connection of cervical and thoracic vertebrae, cannot be ignored when studying the cervical spine. The changes in T1 vertebral body orientation and shape will greatly affect the cervical sagittal alignment. Previous studies[9,11] have measured the sagittal parameters of the cervical spine on x-ray. However, because of the occlusion of the shoulders, especially in obese people, the upper edge of the sternum and T1 vertebral body cannot be identified on most x-ray films. Park et al[12] reported that only 11% of x-ray films were able to clearly show the upper edge of the sternum and T1 vertebral body, which means that it is difficult to study the relationship between cervical sagittal parameters and cervical curvature on x-ray. In this study, we checked 1005 x-ray films, but only found 143 films (14%) that met the inclusion criterion with good visibility. Park et al[12] measured the cervical sagittal parameters on computed tomography, and believes that as T1S increases, the C2–C7 Cobb angle becomes larger. However, reports on whether cervical sagittal parameters could be measured on supine computed tomography or MRI are few. Also, MRI has the unique advantage of being radiation-free compared to computed tomography, so this method has been analyzed and studied to determine whether MRI could be used to evaluate the cervical sagittal parameters with great reliability.

Table 3

Correlation between cervical sagittal parameters between x-ray and MRI.

	r value	*P*
C2–C7 Cobb angle	0.699*	.000
C2–C7 SVA	0.585*	.000
CT	0.574*	.000
T1S	0.579*	.000
NT	0.613*	.000

MRI = magnetic resonance imaging, NT = neck tilt, SVA = sagittal vertical axis, T1S = T1 slope.
* Indicates a correlation at the 0.01 level (bilateral).

In this study, we compared the differences and correlations of cervical sagittal parameters on x-ray and MRI. The results showed that the C2–C7 Cobb angle, C2–C7 SVA, CT, and T1S on x-ray were higher than those of MRI ($P < .05$), while NT was smaller than that of MRI ($P < .05$). Our findings are similar to studies on computed tomography.[13] The authors believe that the weight of the head may account for the differences in the results. As the x-ray examination is performed in an upright position, and the MRI examination is in the supine position, cervical lordosis becomes larger in the supine position compared to the upright position because of the weight of the head, causing a physiological change in lordosis, resulting in an increase in the C2–C7 Cobb angle and thereby an increase in T1S. Meanwhile,

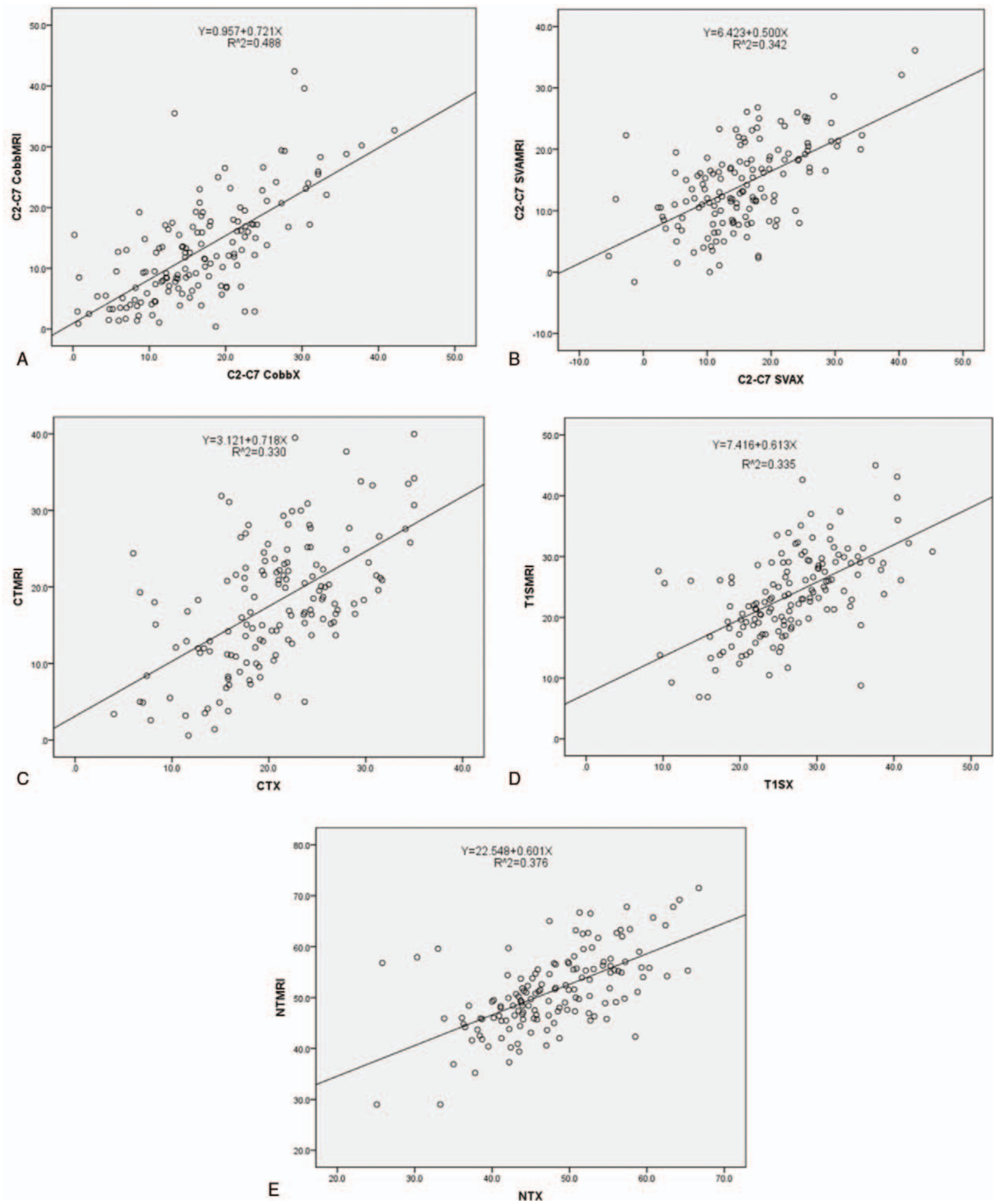

Figure 2. Linear regression analysis of the cervical sagittal parameters. (A–E) Linear regression analysis of C2-C7 Cobb, C2-C7 sagittal vertical axis, cervical tilt, T1 lopes, and neck tilt, respectively.

we found that there was no significant difference in TIA measurements between the supine position and upright position, which further confirms that the TIA is a constant morphological parameter that does not vary with position. However, the authors also noted that another study reported that no significant difference was found in terms of sagittal parameters of the cervical spine.[14] The population recruited in that study consisted of adolescents with idiopathic thoracolumbar/lumbar scoliosis, which is obviously different to the population with cervical disc herniation in our study; therefore, their results are not comparable with ours. Consequently, although the results of cervical sagittal parameters using the 2 measurement methods are different, our study found that there is a significant correlation between the 2 measurement methods and a linear regression equation of the 2 measurement results can be established. Therefore, the authors believe that the parameters obtained from imaging in the supine position can also be used to predict the balance of the upright position and cervical physiologic alignment in surgical decision-making. We believe that it is feasible to analyze the cervical sagittal parameters using MRI.

The sagittal balance of the cervical spine refers to the balance of the upright position, consistent with the position used for x-ray examination; meanwhile, anterior cervical surgery is performed in the supine position, which is consistent with the posture of MRI examination. According to our study, there was a significant correlation between the sagittal parameters of the cervical spine in the upright position and the supine position. This could be an important reference for orthopedic spine surgeons when choosing the appropriate fusion angle and to guide the reconstruction of cervical sagittal balance in anterior cervical spine surgery.

A limitation of this study is that this investigation only included patients with cervical disc herniation and did not include normal individuals as a control group. In future, a further study of an asymptomatic population with a large sample may be needed to confirm the potential use of MRI to evaluate cervical sagittal alignment.

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