Original Article

Upper and lower cervical alignment parameters measured on supine magnetic resonance imaging with the occipital slope as a key marker of cervical alignment

ABSTRACT

Objectives: Cervical spine alignment is evaluated by measuring the cervical angles or parameters on standing plain radiography. In this study, we aimed to evaluate mainly the upper cervical alignment and the correlation between upper and lower cervical sagittal parameters measured on supine magnetic resonance imaging (MRI).

Materials and Methods: Cervical MRIs of 210 outpatients were reviewed to measure the upper and lower cervical sagittal parameters. Their mean values were compared with normative values measured on standing X-ray from the literature. Correlations between the parameters were analyzed using the Pearson's correlation coefficient.

Results: The C0 slope was correlated with all other parameters, except for the C2–7 sagittal vertical axis. The strongest correlations ($r > 0.500$) were between the CL and C2 slope, between the CO_2 and C0 slope, and between the C2 slope and C0 slope.

Conclusion: On supine MRI, the C0 slope is a key marker of cervical spinal alignment. A strong correlation was observed between the C2 slope and C0 slope; therefore, the relationship between upper and lower cervical alignment could be assessed using slopes on MRI.

Keywords: Cervical lordosis, cervical sagittal parameters, cervical spine, magnetic resonance imaging, supine position

INTRODUCTION

The cervical spine has two main functions: first, bearing the head and second, maintaining the horizontal gaze with head and neck movements.[1,2]

Disorders of the cervical spine may affect the cervical spine alignment and cause higher energy consumption with neck pain, fatigue, and increased muscular tonus, whereas a sagittal balanced cervical spine is associated with minimum energy consumption.[3,4]

Classically, cervical spine alignment is evaluated by measuring the cervical angles or parameters on standing plain radiography.[4,5] However, standing X-ray used to measure cervical sagittal parameters has two major disadvantages. The first is the radiation effect,[6] and the second is the unclear visibility of anatomical landmarks, such as the T1 vertebral body and the upper edge of the sternum, because of the superposition of the shoulders.[7] Therefore, some authors have considered that supine magnetic resonance imaging (MRI) is a good alternative to standing X-ray for measuring cervical sagittal parameters, although there is a significant difference in most parameters obtained from the two imaging modalities.[7-12] Such studies are few and

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usually focused on cervical lordosis (CL) and the following parameters – thoracic inlet angle, T1S, and neck tilt, which could be better measured using MRI.[7-13] In this study, we aimed to evaluate mainly the upper cervical alignment and the correlation between the upper and lower cervical sagittal parameters measured on supine MRI.

MATERIALS AND METHODS

This was a retrospective single center study. After the approval of the study protocol by the Institutional Review Board, the study was conducted at the Department of Neurosurgery, Harran University, Şanlıurfa, Turkey. The study protocol was coherent with the ethical principles of the second Helsinki Declaration. In the study, MRI examinations of outpatients admitted to the Neurosurgical Department presenting with neck pain and radiculopathy of the upper extremities between January 2020 and December 2020 were reviewed. The inclusion criteria were as follows: (1) patients aged between 18 and 60 years, (2) those with body mass index between 18 and 40 kg/m^2, and (3) those with a length between 1.50 and 1.95 m. The exclusion criteria were as follows: (1) patients with a history of spinal surgery, (2) those with cervical trauma, fracture, tumor, and infection, (3) those with spinal deformity or congenital anomaly, (4) those with advanced spondylosis associated with spinal stenosis, and (5) those with cervical spondylolisthesis.

Finally, 210 outpatients (116 females and 94 males) were enrolled in this study. MRI scans were obtained in the supine position with a standard head holder [Figure 1] using a 3 Tesla MRI Scanner (MAGNETOM Skyra, Siemens Healthcare, Erlangen, Germany). Written informed consent about the use of radiological data had been obtained from all patients before MRI examination, and any additional informed consent was not obtained. All cervical sagittal parameters were measured on midsagittal T2-weighted images.

The CL, C0–1, C0–2, C2–7 sagittal vertical axis (SVA), T1 slope, C2 slope, T1 slope minus CL (T1S-CL), and C0 slope were measured from X-ray and MRI images by HK and ACI thrice in different times, and the main values were obtained.

Radiological parameters:

1. CL: The Cobb angle between the lines of the C2 and C7 lower endplates. A lordotic cervical spine has positive values, whereas a kyphotic cervical spine has negative values
2. C0–2 Cobb angle: The angle between the McRae line (the line connecting the anterior and posterior edges of the foramen magnum) and the C2 inferior endplate

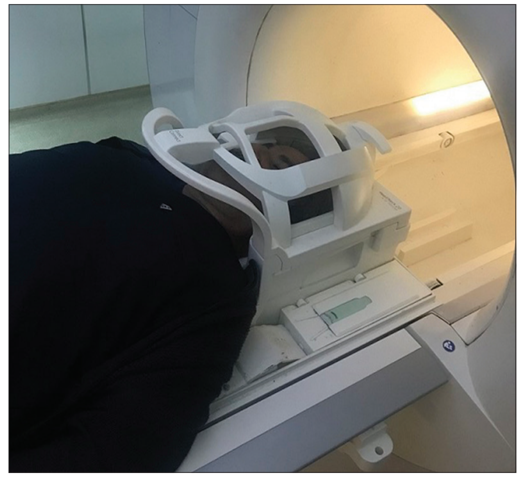

Figure 1: Standard head stabilizer was used for the magnetic resonance imaging examination

3. C0–1 Cobb angle: The angle between the McRae line and the line connecting the anterior and posterior parts of the C1 vertebra
4. C1–2 Cobb angle: The angle between the line connecting the anterior and posterior parts of the C1 vertebra and the line of the C2 inferior endplate
5. T1 slope: The angle between T1 superior endplate and the horizontal line
6. C0 slope: The Cobb angle between the McRae line and the horizontal plane
7. C2–7 SVA: The distance between the vertical plane crossing through the center of C2 and the posterior superior edge of the C7 vertebra
8. T1S-CL: (C2 slope) T1 slope minus CL. The T1S-CL is an equal of the C2 slope.

Statistical analysis

The interclass correlation coefficient (ICC) was used to assess the interobserver and interobserver reliability of the measurements. ICC values of 0.60–0.74 and 0.75–100 were considered to be good and excellent, respectively. The mean values of each parameter were calculated. Correlations between the parameters were analyzed using the Pearson's correlation coefficients, and $P < 0.05$ was accepted as statistically significance. According to the number of patients, critical value of r was 0.137 (values of $r > 0.137$ was considered statistically significant). Values of 0.8–1, 0.6–0.79, 0.4–0.59, and 0.2–0.39 were considered very strong, strong, moderate, and weak correlations, respectively.

RESULTS

The ICC of the cervical parameters was excellent and more than 0.85. The average age of the patients was 39.93 ± 11.28 years. The mean CL and C0–2 Cobb angles were

10.6 ± 8.35 and 21.61 ± 6.92, respectively. The mean values of all parameters are shown in Table 1. The upper cervical angular parameters were correlated with each other, i.e. CL was correlated with all slope parameters, whereas the upper CL was correlated with the C0 slope only. The C0 slope was correlated with all other parameters, except for the C2–7 SVA. As a sagittal balance parameter, the C2–7 SVA was correlated with the upper and lower angular parameters (i.e., C0–1, C1–2, C0–2, and C2–7 Cobb angles), but not with the slope parameters. The results of the Pearson's correlation analysis of the cervical parameters are shown in Table 2.

DISCUSSION

MRI is the most commonly used and informative diagnostic tool for cervical spine disorders. It can easily show the neural structures and anatomical landmarks. Some authors thought that MRI could be an alternative to evaluating cervical spinal alignment, which is traditionally assessed on standing X-ray. However, cervical alignment in the supine position differs from that in the standing position due to the absence of axial loading.[4] CL, T1 slope, and C2–7 SVA are the most common cervical parameters measured on supine MRI. However, the values of these parameters are reduced significantly in the supine position, although they are correlated with their equivalents measured on standing X-ray.[8-10,12-14] Based on this correlation, linear regression analysis was performed, and similar formulas that estimated standing CL were developed.[12,15] However, according to these formulas, only 20% of the values were within ±2° of the estimated values.[12] More recently, Oh *et al*. found a significant correlation between standing CL and the difference between standing and supine CL values.[13]

Table 1; Mean values and standard deviations of cervical sagittal parameters measured on supine MRI with normative values measured on standing X-ray from literature and changes from standing to supine position

	MRI	Standing X-ray	From standing to supine
C0-1	1,06±5.85	-2--9	↓
C1-2	20,55±5031	28	↓
C0-2	21,61±6,92	23,4-27,4	↓
C2-7	10,68±8,35	13-15,2	↓
C2-7SVA	7,27±4,14	18,7-22,4	↓
T1S	14.83±6,97	24,5-25,7	↓
C2S	4,11±8.18	10-15	↓
COS	17,30±9.84	9.3-14	↑

Table 2; Pearson correlation analysis of cervical parameters measured on MRI

	C0-1	C1-2	C0-2	C2-7	C2-7SVA	T1S	C2S	COS
C0-1	X	**-0,2332**	**0,665**	**-0,230**	**0,201**	**-0,150**	0,106	**0,383**
C1-2		X	**0,570**	0,100	**0,305**	**0,259**	0,117	**0,306**
C0-2			X	-0,117	**0,404**	0,072	**0,180**	**0,559**
C2-7				X	**-0,293**	**0.436**	**-0,646**	**0,461**
C2-7SVA					X	**-0,156**	**0,165**	**0,147**
T1S						X	**0,404**	**-0,289**
C2S							X	**-0,694**
COS								X

Boldface indicates statistical Significance: $P<0.05$ and $r>0.137$ statistically significant

The T1 slope also reduces by 6°–10° from the standing position to the supine position.[8,14] In only one study, the values of T1S-CL from standing X-ray and supine MRI were compared and found that T1S-CL was increased on supine MRI.[10] T1S-CL is an important parameter and is the equal of the C2 slope.[16,17] However, the normal value of the C2 slope is controversial. In the cervical deformity classification, values <15° are accepted as normal.[18,19] In this study, the average C2 slope value was 4°. In the supine position, the T1 slope decreased by 6°–10°, CL decreased by >6°–10°, and the C2 slope increased. Therefore, in a less lordotic and kyphotic cervical spine, the C2 slope is decreased in the supine position.

However, the upper cervical alignment parameters measured on supine magnetic resonance have not been reported previously, although, in only one study, a decreased C0–2 angle was reported.[9] When we compared the upper cervical alignment parameters measured on MRI with those measured on normative standing X-ray from the literature, we found that C0–2, C0–1, and C1–2 values were lesser on MRI; however, the occipital slope (measured using the McRae line) was greater.[20-23] We used the McRae line, instead of the McGregor line, to measure the occipital slope and C0–2 and C0–1 angles. On standing X-ray, the McGregor line could be determined more easily than the McRae line, and most radiological studies preferred using the McGregor line.[23] However, in our study, in many cases, the edge of the hard palate was not within the frame; therefore, we preferred the McRae line for measuring the occipital slope and other upper cervical parameters. The C0–2 angle is the sum of the C2 slope and occipital slope; therefore, in patients with increased C2 slopes in the supine position, the occipital slope should be decreased and vice versa.[24] In our study, the C2 slope decreased; therefore, the occipital slope increased.

Correlations between the cervical sagittal parameters on standing X-ray are well known. CL is significantly negative correlated with upper CL (Cobb angles) associated with a compensatory mechanism to maintain horizontal gaze. Increase of the C0–2 angle reduces CL, making the lower cervical spine less lordotic or kyphotic and vice versa.[23,25-27] The negative correlation between C0–2 and C2–7 angles is also present between the C1–2 and C2–7 angles. According to Núñez-Pereira *et al*., this correlation was present in all subjects including asymptomatic subjects and symptomatic patients, although it was weaker in males and symptomatic patients.[23] However, in our study, significant correlations were observed between the upper cervical Cobb angles; no correlation was observed between the C0–2 and C2–7 angles. Only a weak correlation between the C0–1 and C2–7 angles was present. This finding is supported by Oshina *et al*., who reported that the C0–2 angle was not correlated with the C2–7 angle measured on supine MRI.[9]

The T1 slope is a marker for predicting the lower cervical alignment, thoracic kyphosis, and overall sagittal balance.[28] It is well correlated with CL and the C2–7 SVA. According to Núñez-Pereira *et al*. and Knott *et al*., the T1 slope was also correlated with the C0–2 angle.[23,28] It is generally accepted that there was no correlation between the T1 slope and C0–2 angle on standing X-ray and supine MRI.

The C2 slope (T1S-CL) is a new parameter connecting the upper and lower cervical parameters. It is significantly correlated with pain, disability, and reduction of health-related quality of life scores. The C2 slope is also significantly correlated with CL and the C0–2 angle.[16,17] However, the C2 slope was not correlated with the C0–2 angle in our study, although it was correlated with the C2–7 angle and T1 slope.

The importance of occipitocervical alignment and its effect on cervical alignment were investigated more recently.[29,30] The C0–2 angle is a complex angle and has two components: the C2 and occipital slopes that were negatively correlated with each other.[24] The occipital slope is a parameter associated with horizontal gaze and is related with the upper and lowers cervical Cobb angles on standing X-ray.[31,32] In our study, the occipital slope was correlated with all cervical parameters, except for the C2–7 SVA. The C2 slope had the strongest correlation with the C2–7 angle, whereas the occipital slope had the strongest correlation with the upper CL. In summary, on supine MRI, no correlation was observed between the upper and lower cervical angles although there was a very strong correlation between the occipital and C2 slopes, which resembles upper and lower cervical alignment. As pointed in our previous study, the interdependency between upper and lower cervical alignment on MRI should be assessed by the way of the slopes instead of the cervical angles.[24] The occipital slope is the key marker of upper and lower cervical alignment.

The supine position reflects the lying posture associated with daily activities, such as sleeping and rest. Changes in the cervical spinal parameters on flexion and extension are well known.[33-36] However, the supine position is more complex than simple extension and flexion.[33,34] CL and upper cervical angles are decreased in the supine position, and this is the flexion effect. We previously simulated standing CL by extending the cervical spine in the supine position, although other parameters, except for the cervical tilt, could not be simulated.[14] However, decreased T1 and C2 slopes and increased occipital slope that means that the T1 line turns cranially can be observed during extension. Decreased C2–7 SVA is also seen during extension.[36]

It also shows dynamic changes and the flexibility of the cervical spine. Anterior cervical operations and more sophisticated diagnostic examinations, such as computed tomography and MRI, are performed in the supine position. Therefore, possible changes in the cervical sagittal parameters in the supine position should be considered during operations and radiological examinations.

This study has some limitations. First is the absence of standing cervical X-ray examinations of the patients due to the retrospective nature of the study. Only a small percentage of the patients had a standing X-ray obtained simultaneously. However, we decided to conduct this study with much more samples by comparing the cervical sagittal parameters with the reported ones. Second, the values from the literature were the values of asymptomatic cohorts, whereas our patients were mildly symptomatic. However, we excluded all patients with deformities; therefore, the values of the cervical sagittal parameters from our study were comparable with those of asymptomatic subjects. There is no significant difference between the cervical sagittal alignment parameters between symptomatic patients without deformity and asymptomatic subjects.[23]

CONCLUSION

All cervical sagittal parameters, except for the C0 slope, were lower on MRI. There is no relationship between the upper (CO2) and lower (C2–7) Cobb angles on supine MRI. However, there is a strong relationship between the C2 and C0 slopes; therefore, the relationship between upper and lower CL could be assessed using slopes on MRI. On supine MRI, the C0 slope is a key marker of cervical spinal alignment. It is significantly correlated with all other cervical parameters, except for C2–7 SVA.

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Conflicts of interest

There are no conflicts of interest.

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