Relationship Between Modic Changes and Sagittal Balance Parameters in the Cervical Spine

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Background: We explored the possible relationship between Modic changes (MCs) and sagittal parameters of the cervical spine.

Material/Methods: We enrolled 150 patients with cervical MC on the magnetic resonance imaging (MRI) scans in the MC (+) group and divided them into 3 sub-groups with 50 patients each: the MC1 sub-group, the MC2 sub-group, and the MC3 sub-group. Another 150 healthy subjects receiving routine health examinations were also enrolled in the study as the MC (–) group. The sagittal parameters in the cervical spine were measured and compared and multiple logistic regression analysis was performed to analyze the risk factor for the occurrence of MC.

Results: Four cervical sagittal parameters were measured and compared between all the enrolled groups, including neck tilt (NT), T1 slope (T1s), thoracic inlet angle (TIA), and Cobb C2–C7. The results confirmed that the parameter of Cobb C2–C7 was much smaller in the MC(+) group when compared with that in the MC(–) group (P<0.05), while no significant differences were detected between the MC(+) and MC(–) groups for the parameters of NT, T1 T1s, and TIA (P>0.05). Multiple logistic regression analysis showed that Cobb C2–C7 (less than 8.5°) could be regarded as the risk factor for the occurrence of MC, and the receiver operating characteristic (ROC) curve showed that moderate diagnostic significance was obtained with an area under curve (AUC) of 0.82.

Conclusions: The present study demonstrated that Cobb C2–C7 (less than 8.5°) is a potential risk factor for the development of MC.

MeSH Keywords: Logistic Models • Magnetic Resonance Imaging • Osteoarthritis, Spine

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Background

More attention has been paid to Modic change (MC) in recent years, which is a common and rapidly degenerative change observed in magnetic resonance imaging (MRI) in the degenerative spine summarized by Modic et al. in 1988 [1]. MC is usually observed as an abnormal bone signal under the vertebral endplate and can be divided into 3 types: Modic type 1 change (MC1) refers to edema and granulation tissue at the endplate area with low T1 and high T2 signal, MC2 refers to adipose tissue at the endplate area with high T1 and T2 signal, and MC3 refers to sclerosing bone at the endplate area with low T1 and T2 signal [2,3]. MC of the cervical spine is usually observed; as the cervical spine is the most mobile region of the spine and withstands the axial load of the head, overloading of the endplate may accelerate spine degeneration. The cervical MC degeneration may result in cervical morbidities, such as neck pain, motion disorder, and neurologic deficits, and thus warrants increased research attention [4,5].

The shape of the spine can be reflected by sagittal balance, which can allow humans to maintain standing position with little muscle effort [6]. Sagittal balance status has been demonstrated to be an independent predictor of many aspects of the spine, such as clinical status and outcomes in subjects with adult scoliosis, in patients undergoing surgery for adult deformity, and degenerative disc disease and degenerative spondylolisthesis [7–10]. The relationship between the occurrence of MC and sagittal balance is important because malalignment of the spine in the sagittal plane has been proven to accelerate segment degeneration and can also lead to MC. To the best of our knowledge, there have been no previously published studies evaluating the correlation between MC and sagittal alignment in the cervical spine; therefore, we performed the present study.

Material and Methods

Ethical considerations

The study protocol was approved by the Ethics Committee of Yixing People’s Hospital, Jiangsu University. Informed consent was obtained from all enrolled patients before the study began.

Subjects were selected and divided into 2 groups

From January 2010 to January 2018, 150 patients with cervical MC on MRI scans were enrolled in the MC (+) group and divided into 3 sub-groups of 50 patients each: the MC1 sub-group, the MC2 sub-group, and the MC3 sub-group. Another 150 healthy subjects receiving routine health examinations were also enrolled in the study as the MC (–) group. Inclusion criteria were: neck pain for more than 6 months; consecutive patients; only MC and no other structural findings; age range 30–60 years old; and seeking treatment at our institution. Patients with trauma, infectious spondylitis, rheumatoid arthritis, prior cervical fractures or dislocations, spinal tumors, or cervical spine surgery history were excluded from this study.

Radiographic method

All images of MC were taken using an MRI Scanner (Siemens, AG, Germany), while the sagittal parameter (SP) of the cervical vertebra were measured by spiral computed tomography (CT) (Siemens, AG, Germany). SP were measured by 2 senior orthopedic surgeons using Centricity Enterprise Web V3.0 software,
consisting of neck tilt (NT), T1 slope (T1s), thoracic inlet angle (TIA), and cervical lordosis (CL: Cobb C2–C7) (Figure 1) [8].

The basic characteristics were also evaluated, including patient age, sex, BMI, and MC segment.

### Statistical analysis

The values of all the parameters are presented as the mean±standard deviation (SD). We used the t test or $\chi^2$ test to assess continuous and categorical data to compare the MC group and control groups, while analysis of variance was carried out to compare the differences between the different MC groups. Multivariate logistic analysis was performed to identify factors independently associated with the incidence of MC. The receiver operating characteristic (ROC) curve was constructed. The area under the curve (AUC) is the concordant index, which was used to identify the parameters that best predicted MC. The cutpoint value was determined by calculating the maximum value of sensitivity adding specificity and it determines the normal value of a certain index to distinguish normal subjects from abnormal subjects. Tests were two-tailed and $p<0.05$ was considered significant. SPSS (version 21.0; SPSS, Chicago, IL) was used for statistical analyses.

### Results

#### Results of the main characteristics

A total of 300 subjects were finally enrolled in the study, including 150 cases with MC (MC1, 50; MC2, 50; and MC3, 50) and 150 healthy subjects. No significant ($p>0.05$) differences were observed between the MC(+) and the MC(–) groups for the main characteristics: (P_Age of the patients 0.58, P_Sex 0.73, P_BMI 0.36, P_MC segment 0.22) (MC group vs. control; MC1 group vs. MC2 group vs. MC3 group) (Table 1).

### Results of radiograph measurements in sagittal plane

We measured 4 cervical sagittal parameters in all the enrolled groups, including NT, T1 T1s, TIA, and Cobb C2–C7. The results confirmed that the parameter of Cobb C2–C7 was much smaller in the MC(+) group when compared with that in the MC(–) group ($p<0.05$), while no significant differences were detected between the MC(+) and MC(–) groups for the parameters of NT, T1 T1s, or TIA ($p>0.05$) (Table 2).

### Results of multivariate logistic regression

Multiple logistic regression analysis was carried out for the significant parameters, showing that Cobb C2–C7 (less than 8.5°) is as an independent significant risk factor of the incidence of MC (Table3). The ROC showed that moderate diagnostic value was obtained for the significant variable with the area under the curve (AUC) of 0.82 (Figure 2).

### Discussion

Although the MC was first described in the lumbar spine, it is also observed in the cervical spine. The occurrence of MC has been confirmed to be related to the presence of cervical...
spondylosis and Modic typing also applies to cervical spondyloptic myelopathy (CSM) [11,12]. The occurrence of MC can be changeable and MC1 and MC2 are interconvertible over time and can eventually convert to MC3, and about 20% of the MC lesion are mixed-type (MC1/2 or MC2/3) [13–16]. Many risk factors have been proven to relate to the occurrence of MC, systemic factors (aging, smoking, genetics, male sex), disc/endplate damage (disc herniation, endplate defects) and hyperloading (obesity, spinal deformities, high occupational load) [17–21]. Despite an abundance of imaging data from MC studies, fewer studies report details on the relationship between occurrence of MC and sagittal balance in the cervical spine. Malalignment of the cervical spine in the sagittal plane has been proven to accelerate segment degeneration, which results in the occurrence of cervical MC.

A previous study conducted a retrospective review of 100 subjects, discussing the relationship between the cervical sagittal parameters, and the results concluded that T1 slope is a potential risk factor for the development of MC due to impaired sagittal balance, especially in the C5–C6 cervical segment [22]. Due to the limited sample size of the enrolled subjects of the previous study, we performed the present study with a total number of 300 subjects to explore the correlation between the occurrence of MC and sagittal alignment in the cervical spine. Four cervical sagittal parameters were measured and compared between all the enrolled groups: NT, T1s, TIA, and Cobb C2–C7. The results showed that Cobb C2–C7 was much smaller in the MC(+ group when compared with that in the MC(−) group (P<0.05), while no significant differences were observed between the groups for the other parameters (NT, T1s, and TIA) (P>0.05). The lower Cobb C2–C7 (less than 8.5°) can also be regarded as a risk factor for predicting the occurrence of MC, and moderate diagnostic significance was obtained for the parameter (AUC, 0.82). Cobb C2–C7 could be a good reflection of the cervical curvature, which plays important roles in maintaining the physiological curve of the spine and the balance of the human body, while its biological function is to increase the ability of the cervical spine to resist longitudinal compression load, as well as to buffer concussions. The curvature of the cervical spine is an important factor affecting the balance of the sagittal plane; a smaller curvature of the cervical vertebra corresponds to shifting of the center of head gravity, resulting in the redistribution of stress. The shear force between the intervertebral disc of the vertebral body gradually reduces and the pressure loading on the sagittal position increases gradually. The endplate is particularly

Table 2. Results of parameters in sagittal plane of cervical vertebra.

| Characteristics | Control group (n=150) | MC groups (n=50/n=50/n=50) | t | P |
|-----------------|----------------------|-----------------------------|---|---|
| NT (°)          | 46.7±9.8             | 45.0±6.5, 44.6±8.2, 45.3±7.4 | 0.11 | 0.82 | 0.96 | 0.13 |
| T1s (°)         | 24.3±2.6             | 22.1±3.4, 24.1±6.6, 23.2±4.1 | 0.33 | 0.70 | 0.71 | 0.19 |
| Cobb C2–C7      | 11.2±0.9             | 7.9±3.0, 7.4±0.6, 7.3±1.2 | 0.60 | 0.31 | 6.01 | 0.00 |
| TIA             | 70.1±12.6            | 67.6±7.3, 68.2±5.9, 68.9±15.3 | 2.01 | 0.10 | 1.197 | 0.06 |

NT – neck tilt; T1s – T1 slope; TIA – thoracic inlet angle.

Table 3. Multivariate logistic regression analysis of risk factors.

| Risk Factors | B   | S.E. | Wald | df | p      | Exp(B) | 95% CI       |
|--------------|-----|------|------|----|--------|--------|-------------|
| Cobb C2–C7   | −0.20 | 0.07 | 6.59 | 1  | 0.01   | 0.32   | 0.12–0.44   |

Figure 2. ROC curve of the Cobb C2–C7. The area under the curve (AUC) is 0.82. ROC: receiver operating characteristic.
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Conclusions

The present study demonstrated that Cobb C2–C7 (less than 8.5°) is a potential risk factor for the development of MC.