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Analysis of the Relationship Between Modic Change and Spinopelvic Parameters in the Sagittal Plane

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

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Background: This study explored relationship between Modic change and spinopelvic parameters in the sagittal plane.

Material/Methods: We divided 80 patients into 4 groups: 60 subjects diagnosed with Modic changes (MC) were enrolled in the MC groups (MC1, MC2, and MC3) with each MC type consisting of 20 subjects, and 60 healthy subjects were enrolled in the control group. Spinopelvic parameters in the sagittal plane were calculated to assess their associations with MC. Multivariate logistic regression was used to explore possible risk factors for MC.

Results: PI and LL in the MC groups were significant smaller than in the control group ($p<0.05$). PI, SS, and PT were significantly correlated with LL with a correlation coefficient of 0.75_{PI}, 0.71_{SS} and 0.69_{PT} ($p<0.05$). Multivariate logistic regression of the significant variables showed that PI (less than 43.2°) is an independent significant risk factor for MC. ROC analysis showed that moderate diagnostic value was obtained for the significant variable, with an area under the curve (AUC) of 0.80 ($p>0.05$).

Conclusions: We concluded that PI is risk factor for MC, and smaller PI is associated with higher incidence of MC.

MeSH Keywords: **Logistic Models • Lumbar Vertebrae • Spine**

Abbreviations: **PI** – pelvic incidence; **LBP** – low back pain; **SS** – sacral slope; **BMI** – body mass index; **LL** – lumbar lordosis; **MRI** – magnetic resonance imaging; **PT** – pelvic tilt; **CT** – computed tomography; **LL** – lumbar lordosis; **ROC** – receiver operating characteristic; **AUC** – area under the curve; **MC** – modic change

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Background

Sagittal balance of the spine has become a research focus in recent years, mainly due to its influence on patient satisfaction and clinical outcomes, as shown in various biomechanical and clinical studies [1–3]. Sagittal alignment, often misrepresented as sagittal balance, describes the ideal and "normal" alignment in the sagittal plane, resulting from the interplay between various organic factors. Any pathology that alters this equilibrium instigates sagittal malalignment and its compensatory mechanisms. As a result, sagittal malalignment is not limited to adult spinal deformity; rather, it is pervasive in most spinal disorders.

Modic change (MC) is a common radiologic imaging finding, which was summarized by Modic et al. [4] in 1988, and is believed to be closely associated with rapidly advanced degeneration of the spine [5,6]. There are 3 types of MCs: MC1 involves edema and granulation tissue at the endplate area, with low T1 and high T2; MC2 involves adipose tissue at the endplate area, with high T1 and T2; and MC3 involves sclerosing bone at the endplate area, with low T1 and T2 [7,8]. Ma et al. [9] carried out a clinical trial to investigate the relationship between cervical sagittal alignment parameters and MC on magnetic resonance imaging (MRI) scans, and results showed that thoracic vertebra 1 slope (T1s) was an appropriate risk factor for use in assessing development of MC due to impaired sagittal balance.

Spinopelvic parameters in the sagittal plane correlate well with occurrence and development of degenerative spine disorders. MC was described as the result of spine endplate degeneration, but the actual relationship between spinopelvic parameters in the sagittal plane and MC remains unclear.

Material and Methods

Ethical considerations

The study protocol was approved by the hospital Ethics Committee. All procedures were performed in accordance with the relevant guidelines and regulations, and the study complied with the STROCSS criteria.

Subjects selected for the study

We retrospectively selected 60 subjects with MC and analyzed their medical records data. The 60 patients were divided into 3 groups of 20 subjects each with only 1 type of MC at only 1 or multiple levels from December 2012 to December 2017. The subjects with MC were divided into 3 groups, as each type of MC is a single disease, and they should be compared with the NC groups and compared between groups. The inclusion criteria were: low back pain (LBP) for more than 6 months, lumbar MC at 1 level or multiple levels, and age range 30–70 years old. Exclusion criteria were: previous history of spinal surgery, history of compression fracture of the vertebra, scoliosis more severe than 15°, spinal tumor or other disease related to lumbar spondylosis, more than 1 type of MC, and other advanced endplate disease. Another 60 healthy subjects with normal lumbar MRIs receiving health examination were also enrolled as the control group. We collected detailed and complete imaging data from all the enrolled subjects, including MRI and standard plain radiographs. Basic characters of all the enrolled subjects were also collected and analyzed, including the age, sex, body mass index (BMI), and location of the MC.

Radiographic evaluation

Radiographic measurements of spinopelvic parameters were carried. Measurements of spinopelvic parameters were: lumbar lordosis (LL) is the angle between the lower endplate of L5 and superior endplate of L1, pelvic incidence (PI) is the angle of a line perpendicular to the S1 endplate at its midpoint and a line connecting to the midpoint of the line connecting the centers of the femoral heads, pelvic tilt (PT) is the angle between a vertical line through the midpoint of the endplate of S1, and SS is measured as the angle between a horizontal line and the endplate of S1 [10]. The measurement was performed independently by 2 radiologists, and the mean value of measurements was used (Figure 1).

Statistical analysis

All statistical analyses were carried out using SPSS 21.0 (SPSS, Chicago, IL, USA). Data are described as mean± standard deviations. Multivariate logistic analyses were performed to find the factors associated with MC, and a ROC curve was constructed. Pearson product-moment correlation coefficient of the parameters was calculated for the spinopelvic parameters at the sagittal plane. A $p<0.05$ was considered significant.

Results

Main characteristics of enrolled patients

This study included 60 subjects diagnosed with MC, who were divided into 3 groups; while another 60 healthy subjects were enrolled into the control group. The main characteristics were as follow. For the age of the patients, no significant differences were observed between the MC and controls groups ($p=0.40$), and no significant differences were detected among the MC groups ($p=0.66$) (Table 1). For the result of sex, no significant differences were observed between the MC and controls groups

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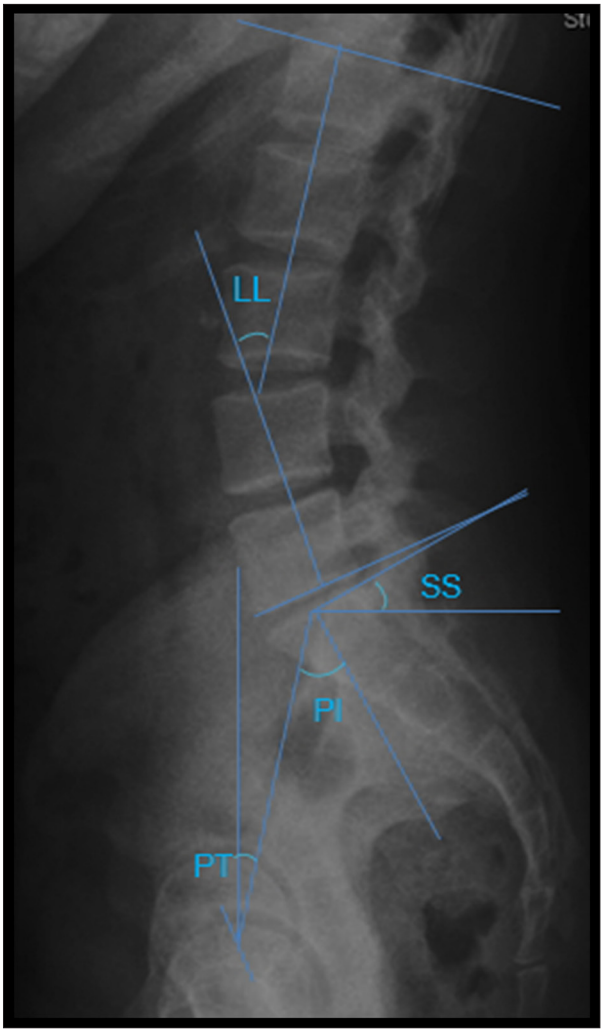

Figure 1. The radiographic spinopelvic parameters on lumbar X-ray. PI – pelvic incidence, SS – sacral slope, PT – pelvic tilt, LL – lumbar lordosis.

(p=0.44), and no significant differences were detected among the MC groups (p=1.00) (Table 1). For the result of BMI, no significant differences were observed between the MC and control groups (p=0.61), and no significant differences were detected among the MC groups (p=0.51) (Table 1). For the position of MC, no significant differences were detected among the MC groups (p=0.95) (Table 1).

Radiograph measurements at sagittal plane

Four spinopelvic parameters were measured and compared between the MC and control groups, including PI, PT, SS, and LL. PI and LL in the MC groups were much smaller when compared with the control group ($p<0.05$). No significant differences were detected, including the SS, PT, and PI-LL ($P>0.05$). No significant differences were observed between the 3 MC groups for all the radiograph parameters in the sagittal plane, including PT, PI, SS, LL, and PI-LL ($p>0.05$) (Table 2).

Results of multivariate logistic regression and ROC curve

To explore the relationship between the occurrence of MC and spinopelvic parameters in the sagittal plane, multiple logistic regression analysis was performed to assess the relative effect of variables on the occurrence of MC. The variables associated with the occurrence of MC were PI and LL, and the multivariate logistic regression analysis showed that PI (less than 43.2°) is a risk factor for the MC (Table 3). The ROC analysis showed that moderate diagnostic value was obtained with an AUC of 0.80 (Figure 2).

Correlation analysis of the spinopelvic parameters

Correlation analysis was performed between PI and LL, PT and LL, and SS and LL. The results of correlation analysis show that

Table 1. Characteristics of enrolled subjects.

Characteristics	Control group (n=20)	MC groups (n=20/n=20/n=20)					χ^2 or t	P
		MC1	MC2	MC3	F or χ^2	P		
Age of the patients (years)	41.2±10.3	41.8±8.9	43.5±9.3	44.5±10.	0.42	0.66	–0.84	0.40
Sex								
Male	12	10	10	10				
Female	8	10	10	10	0.00	1.00	0.60	0.44
BMI	21.4±9.6	22.9±11.6	21.6±8.6	23.1±9.0	0.51	0.70	0.52	0.61
Position of MC								
L3–L4		10	8	8				
L4–L5		12	13	11				
L5–S1	5	7	5	0.59	0.95			

BMI – body mass index.

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Table 2. Results of spinopelvic parameters at the sagittal plane.

Characteristics	Control group (n=20)	MC groups (n=20/n=20/n=20)					t	P
		MC1	MC2	MC3	F	P		
PI (°)	48.3±6.4	43.1±3.8	42.1±7.6	41.2±6.2	0.27	0.76	4.65	0.00
PT (°)	20.6±2.6	19.4±2.9	19.1±5.0	18.4±2.8	0.40	0.68	1.87	0.06
SS (°)	26.2± 6.9	25.3±5.1	24.1±7.4	23.9±5.9	0.30	0.74	–1.10	0.27
LL (°)	29.9±10.6	26.1±8.5	25.8±9.5	22.9±4.9	1.02	0.36	–2.27	0.03
PI-LL (°)	18.1 ± 6.6	17.4±8.1	17.9±4.6	18.0±6.5	0.79	0.60	1.01	0.30

PI – pelvic incidence; PT – pelvic tilt; SS – sacral slope; LL – lumbar lordosis.

Table 3. Multivariate logistic regression of risk factors.

Risk factors	B	S.E.	Wald	df	p	Exp(B)	95% CI
PI	–0.25	0.07	13.42	1	0.00	0.65	0.42~0.87
LL	1.02	0.56	25.62	1	0.08	1.10	0.94~1.22

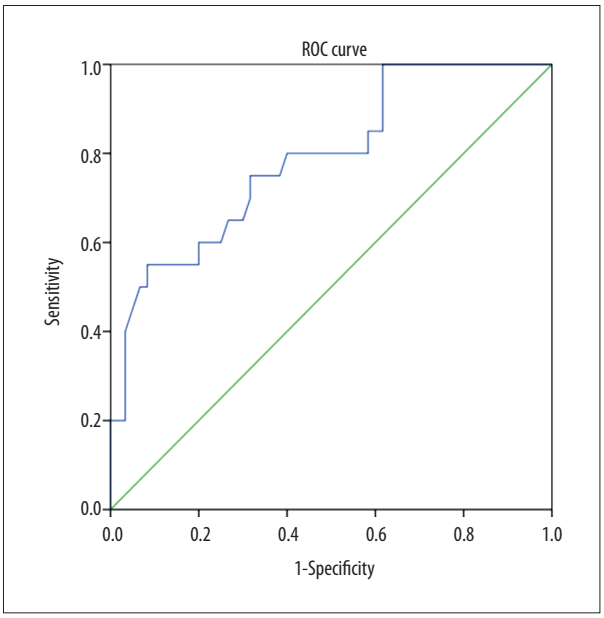

Figure 2. Logistic regression and ROC analysis. Logistic regression and ROC analysis revealed a cut-off value for PI of 43.2°, and the area under the curve (AUC) was 0.80. PI – pelvic incidence.

PI, SS, and PT were significantly correlated with LL, with correlation coefficients of 0.75_{PI}, $0.71_{SS,}$ and 0.69_{PT} ($p<0.05$) (Figure 3).

Discussion

The concept of PI was pioneered by Duval-Beaupere in 1992 [11], and it is an important anatomic parameter of the pelvic sagittal balance, together with PT and SS. Legaye [12] et al. showed that the value of PI was a constant anatomic pelvic variable specific to each individual and equal to the sum of PT and SS values. The orientation of the pelvis determines the position of the sacral endplate in the sagittal plane relative to the femoral head, and regression analysis confirmed that the pelvic parameters were closely related to the spinal parameters. The PI can also determine the orientation of the pelvis and lumbar lordosis, while a smaller PI corresponds to smaller lumbar lordosis and larger PI corresponds to a larger lumbar lordosis.

PI is not only associated with the spinal morphology, but is also a predictive value for degenerative spinal disease. A retrospective study of sagittal alignment investigated the role of pelvic anatomy and its effect on global balance of the trunk in developmental spondylolisthesis, and the results confirmed that patients with an larger PI appear to be at higher risk of spondylolisthesis, and an increased PI may be a factor predisposing to progression in developmental spondylolisthesis [13]. Another clinical study confirmed that PI was significant different in patients with high-grade spondylolisthesis versus those with low-grade spondylolisthesis, and it also had a significant correlation with the dislocation level in all patients [14]. The relationship between the PI and chronic low back pain was explored by enrolling 52 patients with chronic low back pain in a case-control study, showing that PI did not differ between the LBP and control groups, but a separate evaluation of each level revealed lumbar instability of L5–S1 segment was associated with lower PI [15]. The relationship between PI and spinal degenerative disease warrants further research.

MCs are bone marrow and vertebral endplates lesions on MRI, which have been proved to be associated with many factors.

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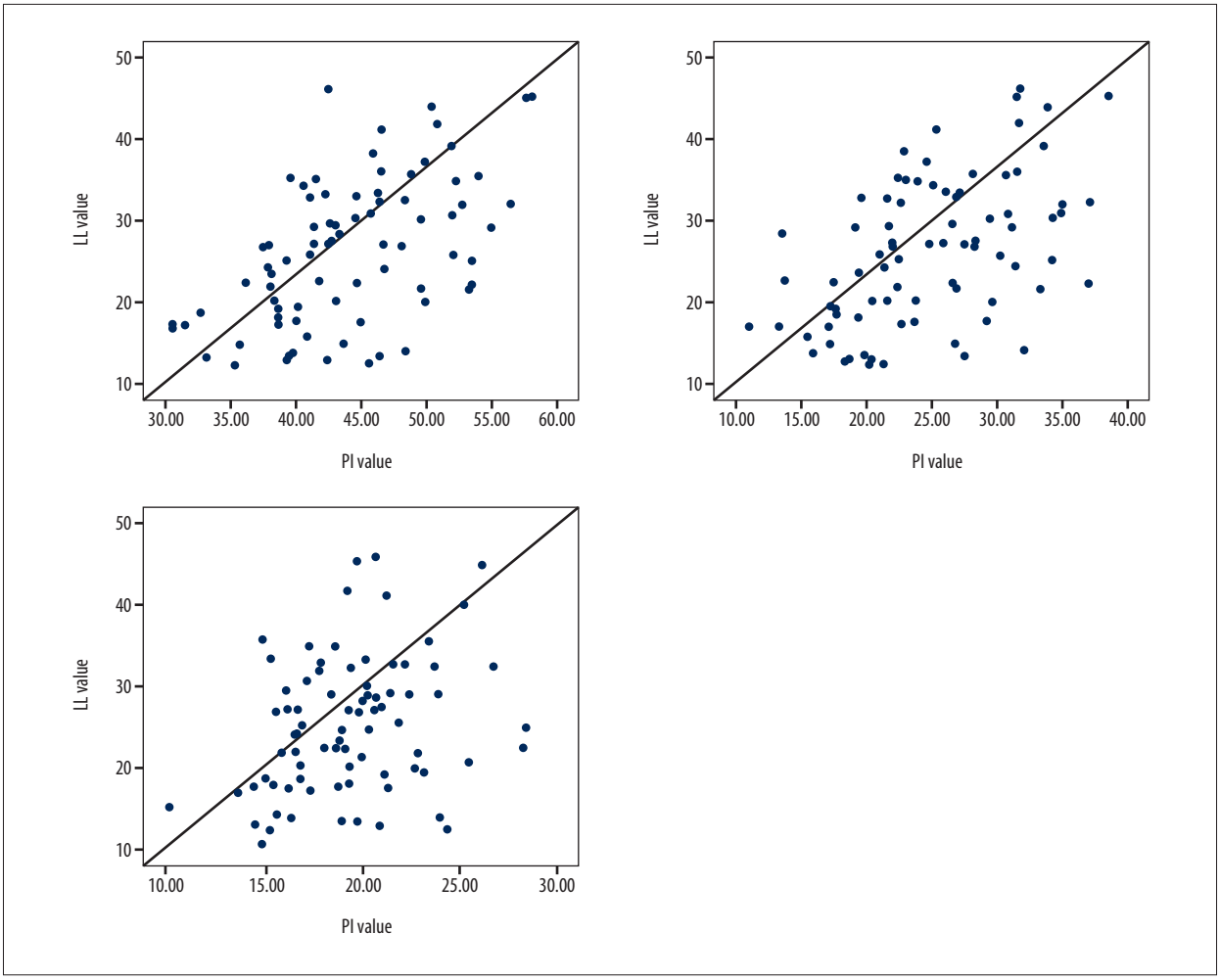

Figure 3. Pearson correlation analysis of the PI and LL, and SS and LL (A, PI *vs.* LL; B, SS *vs.* LL). PI, SS, and PT were significantly correlated with LL, with correlation coefficients of 0.75_{PI},$0.71_{SS,}$ and 0.69_{PT}. PI – pelvic incidence, SS – sacral slope, LL – lumbar lordosis.

A study [16] enrolled 2449 volunteers to explore the possible factors associated with MC, and the results confirmed that disc displacement and a higher disc degeneration score were associated with MC at the upper lumbar levels (L1/L2–L3/L4) ($p<.01$), while MC at the lowest 2 lumbar levels (L4/L5–L5/S1) were associated with the presence of Schmorl nodes, older patient age, disc degeneration or displacement, and historical lumbar injury. Research showed that cartilage and osseous endplate play an important role in biomechanics of the spine; the volume and shape of the disc is affected as the load on the spine increases, resulting in bending deformation of cartilage, the osseous endplate, and trabecular bone under the endplate [17–20]. MC may happen with the occurrence of these irreversible deformable injuries and microfracture of the cartilage, osseous endplate, and trabecular bone under the endplate [21–25]. Our results showed that PI is a risk factor for forecasting MC, and the LL was much smaller in the MC groups when compared with the control groups (normal subjects) ($p<0.05$). The correlation analysis confirmed a positive correlation between LL and PI ($r=0.75$; $p<0.05$), which indicates that smaller PI corresponds to smaller LL and larger weight bearing of the lumbar endplate, and MC increase as heavier weight bearing can lead to endplate denaturation. The endplate is particularly sensitive to the axial load, and excessive axial load can lead to bending deformation of the cartilage endplate, osseous endplate, and subplate trabecular bone, resulting in MC of the lumbar spine. The PI decreased as the MC level increased gradually, but no statistically significant difference in PI was detected between the different MC groups based on the ANOVA results, suggesting that PI has little effect on the MC shift once MC occur.

There are some deficiencies in the present study. First, this retrospective study may have had selection bias; secondly, the limited number of the patients may have caused selection bias; thirdly, more pathophysiological mechanisms need

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to be explained, as it is not surprising that some patients with the MC3 type had the least lumbar lordosis; and fourth, these whether patients already had a P-LL mismatch when younger is difficult to predict.

Conclusions

PI is a risk factor for MC, and smaller PI is associated with higher incidence of MC.

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