MEDICAL SCIENCE MONITOR

CLINICAL RESEARCH

e-ISSN 1643-3750
© Med Sci Monit, 2018; 24: 791-796
DOI: 10.12659/MSM.906417

Received: 2017.07.28
Accepted: 2017.08.10
Published: 2018.02.07

Diagnostic Value of T1 Slope in Degenerative Cervical Spondylotic Myelopathy

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
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Source of support: This study received funding from the Project for Scientific Research, Education Department, Hubei Province (B2016027), and from the Medical and Health Research Project of Yichang (A15301-34)

Background: To explore the diagnostic value of sagittal measurement of thoracic inlet parameters for degenerative cervical spondylotic myelopathy (DCSM).

Material/Methods: Sixty patients with DCSM (study group) and the same number of normal subjects (control group) were initially enrolled in the study. All data from X-ray in the standing position and computed tomography (CT) in the supine position were collected and carefully analyzed. Cervical sagittal parameters, including C2–C7 angle, C2–C7 sagittal vertical axis (C2–C7 SVA), T1 slope, thoracic inlet angle (TIA), and neck tilt (NT), were measured at the lateral radiographs by using standard X-rays and CT. Univariate analysis and multivariate logistic regression analysis were carried out to explore the diagnostic value of cervical sagittal parameters for the DCSM.

Results: All the enrolled patients in the study and control groups completed the follow-up, and the mean follow-up periods were 35.8 months in the study group and 36.3 months in the control group. The DCSM group had smaller T1 slope and TIA when compared with that of the control group (18.14±2.67° *vs.* 24.16±3.7°, p=0.00; 66.42±12.36° *vs.* 70.42±10.21°, p=0.01). Logistic regression analysis and receiver operating characteristic (ROC) curve revealed that preoperative T1 slope of less than 18.5° had significant diagnostic value for the incidence of DCSM (p<0.05).

Conclusions: Patients with sagittal imbalance of thoracic inlet parameters have higher risk of DCSM, while T1 slope of less than 18.5° showed significant diagnostic value for the incidence of DCSM.

MeSH Keywords: **Cervical Rib Syndrome • Logistic Models • Uterine Cervical Diseases**

Full-text PDF: https://www.medscimonit.com/abstract/index/idArt/906417

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Background

Degenerative cervical spondylotic myelopathy (DCSM) has been defined as a chronic degenerative process caused by compression of the spinal cord by surrounding bony or ligamentous structures. The incidence of cervical spine degenerative disease has been rising owing to the increasing aging population. Diagnosing DCSM has traditionally relied on presence of clinical symptoms, including clumsy hands, paralysis of the lower extremities, gait disturbances, urinary/bowel incontinence and severe neurological dysfunction disturbances, urinary/bowel incontinence, and severe neurological dysfunction [1,2]. Magnetic resonance imaging (MRI) is the most widely used method for the diagnosis of DCSM, as it can reveal morphological changes and degree of compression of the cervical spinal cord, as well as provide pathological information through T2-weighted (T2W) imaging.

Keeping sagittal balance of the physiologic upright spine is vital to preventing spine degeneration, as it can minimize energy expenditure by maintaining alignment. Several published articles discussed the relationship between pelvic incidence (PI) and degenerative lumbar disease, and they confirmed that such constant parameter in each individual was associated with orientation parameters of the lumbar spine or the thoracic spine, such as thoracic kyphosis or lumbar lordosis (LL) [3–7]. Another newly published study was carried out to determine the incidence and risk factors of adjacent segment disease (ASD) after transforaminal inter-body fusion (TLIF) for degenerative lumbar disease, and they revealed that preoperative pelvic tilt (PT) of more than 22.58 was a significant risk factor of the incidence of ASD after TLIF (P=0.02; odds ratio: 5.1, 95% CI: 1.62–9.03) [8].

However, there has been no published clinical research on the relationship between the thoracic inlet parameters and degenerative cervical disease. We carried out the present study to explore the relation between degenerative cervical spondylopathy and thoracic inlet parameters, including TIA, T1 slope, and NT, by using logistic regression analysis and receiver operating characteristic (ROC).

Material and Methods

Patients selected for the study

The study was approved by the Institutional Review Board of the University of China, Three Gorges. All methods used in the research were performed in accordance with the relevant guidelines and regulations.

We identified 60 patients diagnosed with DCSM (study group) and the same number of normal subjects (control group) from August 2012 to July 2017. All the enrolled subjects had detailed imaging data, including cervical CT radiographs and standard plain radiographs; none had previous history of cervical surgery; age ranged from 40 to 60 years old; and none had spinal stenosis or cervical spondylolisthesis. We excluded those with scoliosis more severe than 15° and those with malignant tumors or cervical tuberculosis. The follow-up period was from enrolment to the final follow-up.

Radiographical assessment

All included subjects underwent radiographical assessment during the study. C2–C7 Cobb angle and sagittal vertical axis of C2–C7 (C2–C7 SVA) were the parameters, measured by lateral radiographs. The sagittal measurement of thoracic inlet parameters was carried out using cervical CT (Brilliance CT 64-channel scanner; Philips Electronics Amsterdam, Netherlands), while the thoracic inlet parameters included TIA, NT, and T1 slope. Two independent spine surgeons performed the measurement by using Centrieity Enterprise Web V3.0 (General Electric, USA). The slice thickness and the interval spacing was 2.5 mm for the cervical CT scanning.

The C2–C7 Cobb angle is mainly formed when the horizontal line of the C2 lower endplate and the horizontal line of the C7 lower endplate intersect (Figure 1). C2–C7 sagittal vertical axis (C2–C7 SVA) was usually defined as the distance between a plumb line dropped from the posterior superior corner of C7 and the center of C2, which was defined as the anterior deviation. T1 slope is the angle formed by drawing a line along the superior endplate of T1 and horizontal reference line at the median sagittal cervical vertebra from the CT radiographs (Figure 1). Two independent lines come from the upper sternum and form the neck tilt angle: one is the vertical line and the other is the line to the center of the T1UEP (Figure 1). The TIA is formed when the T1 vertical line of the upper endplate (from the center of the T-1 upper endplate) meets with the line formed between the upper end of the manubrium and the center of the T-1 upper endplate (Figure 1).

Other clinical characteristics were also recorded in the study, including body mass index (BMI), patient age, sex, and smoking history.

Statistical analysis

Data are presented as mean ± standard deviations. Statistical analysis was performed using SPSS 21.0 J for Windows. The χ^2 and *t* tests were performed for the

comparison of DCSM and control groups (univariate analysis). A P value of less than 0.05 was considered statistically significant. We performed logistic regression analysis of selected

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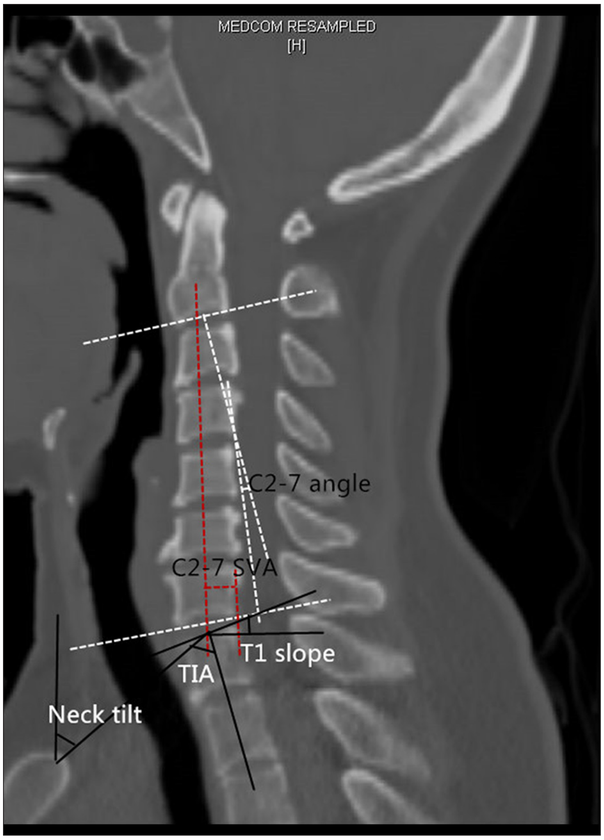

Figure 1. Parameters of the cervical parameters on CT scan (T1 slope, TIA, neck tilt, C2–C7 angle, C2–C7 SVA); CT indicates computed tomography, TIA indicates thoracic inlet angle, C2–C7 SVA indicates sagittal vertical axis. CT means computed tomography.

significant variables (P<0.05) from the univariate analysis. The area under the receiver operating characteristic curve (ROC) is the concordant index (c-index), which was used to identify which radiographic measurements were most effective in predicting DCSM. Pearson correlation test was used to evaluate the correlation strength between the T1 slope and C2–C7 angle in the DCSM and control groups.

Results

Basic characteristics of enrolled patients

All of the enrolled 120 subjects, divided into study and control groups, finished the follow-up. The main characteristics of the enrolled patients – mean age, sex, follow-up period, and BMI – showed no significant differences between the 2 groups (p>0.05) (Table 1). The incidence of DCSM was found in specific segments of the cervical vertebra, shown in Table 1.

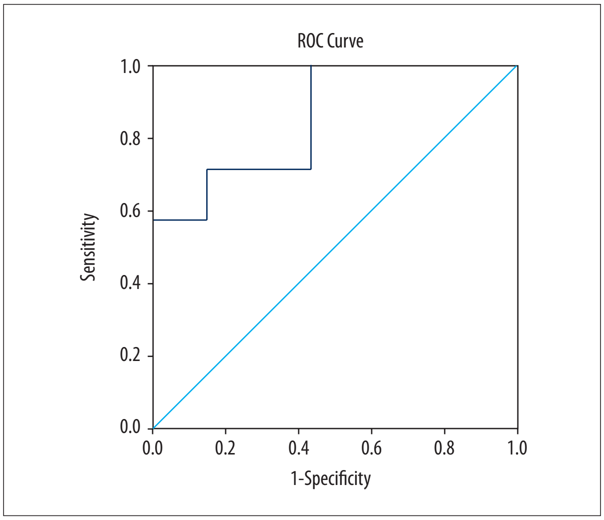

Figure 2. Logistic regression and ROC analysis. Logistic regression and ROC analysis revealed a cut-off value for T1 slope of 18.5. The area under the curve (AUC) was 0.857. AUC indicates under area under the curve, ROC indicates receiver operating characteristic.

Results of the univariate analysis

The mean T1 slope was 18.14±2.67° in the DCSM group and the mean T1 slope was 24.16±3.7° in the control group, with significant differences detected between the 2 group (p=0.00). The DCSM also had larger TIA when compared with the control group (66.42±12.36° *vs.* 70.42±10.21°, p=0.01). For the other results, no significant differences were found (C2–C7 angle, 9.18±2.11 *vs.* 9.55±1.44, p=0.62; C2–C7 SVA, 20.33±8.09 *vs.* 19.99±2.01, p=0.39; neck tilt, 46.33±4.05 *vs.* 47.44±5.01, p=0.28) (Table 2).

Results of multivariate logistic regression

Multiple logistic regression analysis was carried out to assess the relative impact of variables on the incidence of DCSM. The significant variables from the results of univariate analysis were T1 slope and TIA (Table 3). Logistic regression analysis and ROC curve confirmed that a T1 slope of less than 18.5° had significantly diagnostic value for the incidence of DCSM, and the area under curve (AUC) was 0.857, which shows good predictive value for DCSM (Figure 2).

Results of Pearson correlation test

We carried out Pearson correlation analysis to explore the relationship between the T1 slope and C2–C7 Cobb angle by using SPSS 21.0. Significant correlations were found between the T1 slope and C2–C7 Cobb angle in the DCSM and control groups (r=8.12, p=0.00; r=91, p=00) (Figure 3).

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Table 1. Characteristics of enrolled subjects in the DCSM and control group.

Characteristics	DCS group (n=60)	Control group (n=60)	Value of χ^2 or t	P
Age of patients (years)				
Sex	53.1±3.6	52. 9±2.1	1.26	0.08
Male	20 (33.3%)	22 (36.7%)	0.21	0.58
Female	40 (66.6%)	38 (63.3%)	0.76	0.11
Follow-up (months)	42.3±7.6	43.2±3.1	0.54	0.20
BMI	25.1±3.5	24.8±3.6	0.10	0.61
Smoking history	5 (8.3%)	6 (10%)		

Table 2. Parameters at sagittal plane of cervical vertebra.

Characteristics	DCS group (n=60)	Control group (n=60)	Value of χ^2 or t	P
C2–C7 angle (°)	9.18±2.11	9.55±1.44	0.42	0.62
C2–C7 SVA (mm)	20.33±8.09	19.99±2.01	0.60	0.39
T1 slope (°)	18.14±2.67	24.16±3.7	13.81	0.00
TIA (°)	66.42±12.36	70.42±10.21	7.42	0.01
Neck tilt (°)	46.33±4.05	47.44±5.01	0.85	0.28

Table 3. Logistic regression analysis of risk factors for DCSM.

Risk factors	P	OR 95%CI
T1 slope	0.00	0.55 (0.44–0.66)
TIA	0.12	0.22 (0.18–0.25)

Discussion

Physiological curvature of the spine, including the normal cervical lordosis, thoracic kyphosis, and lumbar lordosis, has received increasing research attention as it has been proved to be associated with accelerated disc degeneration and low back pain (LBP). Many questions concerning the proper assessment of sagittal balance have been put forward in several published papers [9,10]. The thoracic inlet (TI) forms the cervicothoracic junction, which is a fixed bony circle composed of the structures of the first ribs on both sides, T-1 vertebral body, and the upper part of the sternum; while the TI consists of 3 important sagittal parameters: TIA, T1 slope, and neck tilt [11]. The TIA is formed where the T1 vertical line of the upper endplate (from the center of the T-1 upper endplate) meets with the line formed between the upper end of the manubrium and the center of the T-1 upper endplate. Several published papers confirmed that T1 slope and the other cervical parameters are highly correlated with cervical sagittal balance [12,13]. T1 slope is considered to be a variable usually influenced by aging, posture, and spinal degeneration. However, TIA is usually considered to be a constant, which does not change with increased thoracic kyphosis or any position change [14–19]. Several published papers confirmed that a lager T1 slope usually leads to larger TIA and TS, which results in a greater magnitude of cervical lordosis, just as a greater pelvic incidence corresponds to greater lumbar lordosis [20–23]. Our study showed that positive correlation was detected between T1 slope and C2–C7 Cobb angle, which was identical to the hypothesis described above. The physiological curvature of cervical vertebra becomes smaller (C2–C7 Cobb angle) as the degree of degeneration of the intervertebral disc increases, which decreases the TI parameters.

Increasing research attention has focussed on cervical spine sagittal balance because it is correlated with cervical degenerative disc diseases, spondylotic myelopathy, and clinical outcomes after fusion surgery [24,25]. T1 slope is the angle formed between the T1UEP and horizontal plane. Vedantam et al. [26] reported that the T1 slope has a significant relationship with thoracic kyphosis (TK). Knott et al. [27] was the first to use the "T1 sagittal angle" to predict the overall sagittal balance of the cervical spine, similar to the T1 slopes usually described in published papers. They confirmed that this parameter was correlated with SVA, but the potential influence on cervical spine sagittal balance remains unclear. T1 slope is also regarded as the only parameter showing significant correlation with both spinopelvic balance and TI alignment, which means it is an important parameter influencing TI alignment and spinopelvic balance [28–31]. The present study was carried out mainly to assess the diagnostic value of T1 slope in DCSM. Our study

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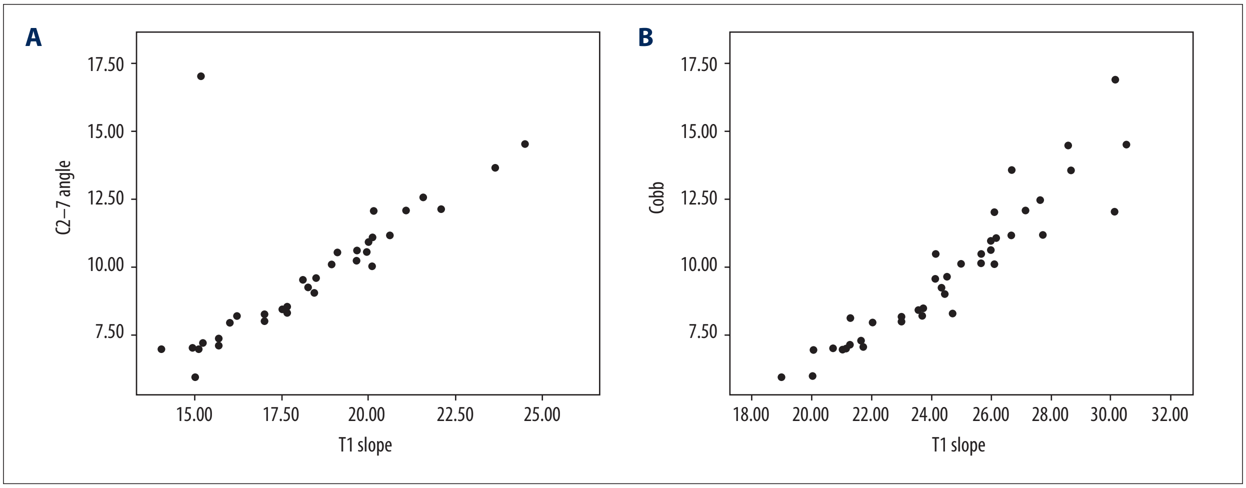

Figure 3. Statistically significant relationships were detected between T1 slope and C2–C7 angle in the DCSM (**A**) and control group (**B**), which is shown in the scatter plot.

showed that T1 slope less than 18.5° was an independent risk factor for DCSM, which means that cervical spine sagittal imbalance aggravates as the T1 slope becomes smaller, which may increase the incidence of DCSM.

Two groups of subjects were enrolled in the clinical research: the study group and the control group. We found no significant differences between the 2 groups in clinical characteristics, and no others factors influenced the imaging results in the 2 groups.

Some limitations may exist in the present study. First, its retrospective design may have induced section bias. Secondly, the duration of follow-up varied considerably because the enrolment period was so long. Thirdly, the results of univariate and multivariate analyses may be different from the real results because of the limited number of enrolled patients. Fourth, only Chinese subjects were included and the sample size was limited.

Conclusions

Patients with sagittal imbalance of thoracic inlet parameters have higher risk of DCSM, while T1 slope of less than 18.5° shows significant diagnostic value for DCSM.

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