Spinal Sagittal Alignment Among Patients with Degenerative Lumbar Canal Stenosis

Mehdi Khaleghi[1], Sina Abdollahzade[2], Sanaz Jamshidi[2], Nafiseh Rastgoo[2], Reza Rouhani[3], Tahereh Padegane[4], Morteza Faghih-Jouybari[1✉], Masoud Khadivi[1]

[1]Department of Neurosurgery, Shariati Hospital, Tehran University of Medical Sciences,Tehran, Iran
[2]Department of Neurosurgery, Rajayi Hospital, Qazvin University of Medical Sciences, Qazvin, Iran
[3]Department of Maxillofacial Surgery, Tehran University of Medical Sciences, Tehran, Iran
[4]Department of Neurosurgery, Zabol University of Medical Sciences, Zabol, Iran

Abstract

Background: Degenerative lumbar canal stenosis (DLS) is a common spinal pathology characterized by radicular pain and neurogenic claudication. Sagittal alignment and its indices have been affected in several spinal pathologies and may play a key role in surgical planning and outcome. In this case-control study, we aimed to assess sagittal alignment among patients with DLS compared to healthy individuals. **Materials and Methods:** Sixty patients DLS and 60 healthy volunteers were selected. Pelvic tilt (PT), sacral slope (SS), lumbar lordosis (LL), pelvic incidence (PI), thoracic kyphosis (TK), and sagittal vertical axis (SVA) were obtained in lateral standing X-ray radiographs. **Results:** Mean LL was lower in DLS patients (35.3±10.2) compared to normal controls (44.78±12.95), which was statistically significant (P <0.05). In contrast, there were no significant differences in PI, SVA, and SS between the groups. In patients with DLS, TK was lower, and PT was higher when compared to healthy individuals (P<0.05). **Conclusion:** Patients with DLS utilize decreased lordosis of the lumbar spine as a compensatory mechanism to decompress the thecal sac and spinal roots and improve their symptoms. Consequently, these patients recruit compensatory adjustments such as thoracic hyperkyphosis and increased PT to maintain sagittal alignment.

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Keywords: Lumbar Stenosis; Pelvic Tilt; Sagittal Balance; Spinal Balance

Introduction

Spinal sagittal alignment has been shown to affect health-related quality of life in various spinal disorders [1-5]. It may have a role in the pathogenesis of spinal diseases and also may change secondary to them. A series of studies correlated the sagittal alignment with several lumbar degenerative diseases, such as degenerative spondylolisthesis, lumbar disc degeneration or lumbar disc herniation [1, 6-10]. Degenerative lumbar stenosis (DLS) is a common spinal pathology characterized by back pain, radicular leg pain, claudication, and disability with a significant social and economic burden [1].

Degenerative changes in the lumbar spine such as loss of disk height and hypertrophy of the facet joints and ligamentum flavum result

✉ **Correspondence to:**
Morteza Faghih-Jouybari MD Associate Professor of Neurosurgery Department of Neurosurgery, Shariati Hospital, Tehran University of Medical Sciences, Tehran, Iran
Telephone Number: +09884902350
Email Address: Sina21@gmail.com

in a decrease in lumbar lordosis and anterior sagittal imbalance [1].

Therefore, nearby structures activate compensatory mechanisms to counteract this imbalance, including thoracic hyperkyphosis and pelvic retroversion. These mechanisms tend to restore the upright posture at the expense of modifying spinopelvic parameters [11].

A thorough understanding of sagittal spinal alignment and spinopelvic relationship may elucidate predisposing factors for the development and progression of the degenerative process, as well as ongoing compensatory mechanisms in this group of patients. In the present study, we attempted to unveil the characteristics of sagittal alignment in patients with DLS and its comparison with healthy controls.

Materials and Methods

Study Design
In this case-control study, we included 60 patients with DLS who were a candidate for laminectomy (with or without in situ fusion) from the outpatient clinic of Shariati hospital and 60 asymptomatic volunteers. The control group was selected to truly represent the normal values of the study population rather than relying on standard normal values as ethnical variation is well documented in spinopelvic data [12].

Inclusion criteria for the selection of patients were patients with consistent symptoms who were a candidate for decompressive laminectomy, age between 45 to 80 years old, no history of any type of spinal tumors and/or trauma, no history of spinal deformities (such as scoliosis, spondylolysis, and spondylolisthesis), no history of severe osteoarthritis, no history of spinal infection and/or surgery.

The subjects with incomplete physical examinations and imaging were also excluded. On the other hand, the age- and sex-matched asymptomatic healthy volunteers were included as the control group.

DLS was diagnosed according to signs and symptoms of the disease and confirmed by magnetic resonance imaging (MRI) parameter (cross-sectional area of dural sac narrower than 100mm2) in all subjects of the case group [13].

Imaging and Clinical Measurements
Lateral standing X-ray radiographs of the thoracolumbosacral spine from all subjects of both groups were obtained with the following position: full flexion of elbows with fists resting on clavicles and full extension of knees and hip.

All images were analyzed, and spinopelvic parameters and sagittal balance parameters, including pelvic tilt (PT), sacral slope (SS), lumbar lordosis (LL), pelvic incidence (PI), thoracic kyphosis (TK), and sagittal vertical axis (SVA) were calculated by applying the online INFINITT PACS. Two attending spinal surgeons digitally measured the parameters under the maximum possible image magnification, and mean values were used for statistical comparisons between groups.

The PI was indicated as an angle between the vertical line of the plate of the sacrum and the line that connected the middle of the sacral plate to the middle of the center of the bilateral femoral head. The SS was determined as the angle between the plate of the sacrum and the horizontal plane. The PT was determined as the angle between a line that connected the middle of the sacral plate to the center of the bilateral femoral head and plumb line.

Likewise, the following relationship exists between these parameters:

$PI = SS + PT.$

The LL was determined as the Cobb angle between the upper level of L1 and S1; also, TK was determined as the Cobb angle between the upper level of the T1 and L1.

In addition, SVA was determined as the horizontal interval between the C7 plumb line and the posterior angle of the sacrum, and a positive content was calculated when the sacral posterior angel was located in the front line of the C7 plumb. Patients were stratified according to SVA, PI−LL mismatch, and PT using the SRS-Schwab classification [14] to the assessment of the severity of sagittal malalignment and compensatory mechanisms in the DLS group.

Table 1. Demographic Characteristics of the Patients with DLS and Normal Controls.

Variables	Case group (n=60)	Control group (n=60)	P-value*
Age (years), Mean±SD	61.22±9.35	60.97±8.9	0.881
Gender, n(%)			
Male	38(63.3)	39(65)	
Female	22(36.7)	21(35)	0.849
Body mass index (Kg/m2), Mean±SD	28.1±3.74	28.03±3.4	0.919

* Chi-square Test and Independent Samples Test were used. P < 0.05 was considered meaningful.

Ethical Considerations
The study protocol was approved by the Ethics Committee of Tehran University of Medical Sciences (IR.TUMS.MEDICINE. REC.1397.172). Written informed consent was obtained from all participants in both groups.

Statistical Analysis
Statistical analysis was performed using SPSS (version 18.0 for Windows; SPSS Inc., Chicago, IL). Data were presented as mean and standard deviation (SD), and 95% Confidence interval 95%(CI) was calculated. Parametric variables with normal distribution were analyzed using an independent t-test. Also, we applied the Mann-Whitney U test for the parametric variables without normal distribution. Proportions were analyzed using the Chi-square test. P < 0.05 was considered statistically significant.

Results

One hundred twenty subjects aged between 45 to 80 years old were included in this study. The mean age of subjects in the case and control group was 61.22±9.35 and 60.97±8.9 years, respectively. Other demographic findings are summarized in Table-1. No significant differences in the body mass index (P=0.919), age (P=0.881), and sex

(0.849) were noticed between the two groups. The sagittal balance parameters in both groups are shown in Table-2. The mean LL was lower in DLS patients (35.3±10.2°) than normal controls (44.78±12.95°), which was significant (95% CI: -12.47– -6.52, P=0.001). There was no significant difference in PI, SVA, and SS between the groups. Compared with normal people, TK was lower (32.62±12.6°), and PT (21.2±6.93°) was higher in patients with DLS.

Discussion

Patients with spinal disease may change their posture to relieve symptoms. DLS has been classically described as a condition with diminished space available for the neural and vascular elements in the lumbar spine secondary to osteophyte formation, disk protrusion, and facet and flavum hypertrophy [15, 16].
Symptoms have been attributed to relative hypoxia of the cauda equina and nerve roots secondary to circulatory disturbance and increased mechanical pressure[17]. Decreased LL leads to increases spinal canal diameter and alleviates pressure effect of ligamentum flavum on the thecal sac.
Takahashi *et al*. showed that epidural pressure in the lumbar spine decreased by flexion [18]. So decrease of LL, and forward inclination is

Table 2. Sagittal Balance Parameters Calculated On Standing Thoracolumbosacral X-Ray in the Patients with DLS and Normal Controls. Data Are Presented AS Mean±SD.

Variables	Case group (n=60)	Control group (n=60)	P-value**	95% Confidence interval
Pelvic incidence*	52.4±12.68	53.22±13.43	0.733	-0.13–6
Lumbar lordosis*	35.3±10.2	44.78±12.95	0.001	-12.47– -6.52
Pelvic tilt*	21.2±6.93	11.57±5.2	0.001	8.26 –11.35
Sacral slope*	37.22±12.32	42.22±13.91	0.063	-7.81 – -1.01
Thoracic kyphosis*	32.62±12.6	37.13±11.57	0.043	-7.44 – -1.27
Sagittal vertical axis (mm)	4.12±29.02	-1.37±18.06	0.217	-0.35 –11.96

 *The unit of measurement for all angles is the degree (º)

** Chi-square Test and Independent Samples Test were used. P < 0.05 was considered meaningful.

a compensatory mechanism to decompress neural structures and improve symptoms. In our study, LL was lower in DLS patients than controls, similar to previous studies [19, 20]. We assume that the main compensatory change in spinal alignment and spinal curves in other regions is adopted to maintain an upright posture.

Spinal column tends to maintain the axis of gravity near the sacrum and feet. Because LL is diminished in DLS patients, the center of gravity moves anteriorly, keeping standing posture energy desires high, leading to early fatigue. In response, the thoracic spine and pelvis change the sagittal alignment to address this issue. Thoracic hyperkyphosis and increase of PT pull the axis of gravity backward to maintain sagittal balance. In this study, TK was lower, and PT was higher significantly in the DLS patient than controls which could be considered as a compensatory reaction to the loss of LL.

A useful parameter for the assessment of total sagittal balance is SVA. It has been correlated with the quality of life in different kinds of spinal disorders [21-23]. According to Schwab classification [14], SVA less than 4.5 is considered normal.

In the current study, there was a trend toward a higher SVA in DLS patients than controls, but the difference was not significant, and it was within the normal range in both groups. It shows that in patients with DLS, a decrease of LL shifted the axis of gravity anteriorly, but compensatory changes in other parts of spine were effective and pulled back SVA within normal limits.

The PI is an anatomic parameter that represents the morphology of the pelvis. The value of PI is constant at the end of the bone growth and unaffected by the individual posture or position [24-26].

The PI determines pelvic orientation represented by the SS and PT, and the size of the LL [27]. Indeed, the PI plays a fundamental role in sagittal spinopelvic alignment [27-30]. A Low PI is accompanied by a low LL, which puts most of the axial load on the anterior part of the vertebral column and has been correlated to disc degeneration [31, 32].

Theoretically, high PI and high LL put the axial load on posterior elements and facet joints, leading to facet hypertrophy and resultant spinal stenosis. Nevertheless, our findings showed no significant difference in PI between DLS patients and healthy controls.

It may underscore other risk factors such as genetics, nutrition, and overuse/disuse in the pathogenesis of DLS. Compensatory mechanisms for maintaining sagittal balance differ in various kinds of spinal disorders.

They can involve all parts of the spine, pelvis, and lower extremities. Buckland *et al*. revealed that patients with lumbar stenosis tended to recruit increasing PT in the late stages of the disease [20]. Among our patients, 45% had severe SVA malalignment, while 10% had a severe increase of PT according to Schwab classification.

A comprehensive study with the measurement of sagittal parameters in the whole spine and lower extremities is mandatory to elucidate the pattern of compensatory mechanisms in DLS patients.

The limitations of this study were the lack of biomechanical analysis of patients to elucidate the precise role of sagittal balance in the pathogenesis of degenerative stenosis as well as the limited number of cases.

Conclusion

Patients with DLS tend to have a lower LL to decompress the thecal sac and spinal roots. Subsequently, these patients recruit compensatory mechanisms such as thoracic hyperkyphosis and increased PT to maintain sagittal alignment. There was no correlation between lumbar stenosis and PI in our patients, which underscores the importance of other factors such as genetics in the pathogenesis of DLS.

Conflicts of Interest

None

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