Prognostic Importance of Spinopelvic Parameters in the Assessment of Conservative Treatment in Patients with Spondylolisthesis

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Study Design: This was a prospective, two-group comparative study.

Purpose: The present study aimed to determine the importance of the spinopelvic parameters in the causation and progression of spondylolisthesis.

Overview of Literature: Spondylolisthesis is slippage of one vertebra over the vertebra below. Since the discovery of pelvic incidence (PI) in 1998 in addition to documentation of other parameters in spinopelvic balance, slippage in spondylolisthesis has been attributed to these parameters. Many studies on the Caucasian population have implicated high PI as a causative factor of spondylolisthesis. To the best of our knowledge, no study has described the role of these parameters in the progression of spondylolisthesis.

Methods: The study was conducted in Jawaharlal Institute of Postgraduate Medical Education and Research, Puducherry, India. Seventy-nine patients with spondylolisthesis consented to participate in the study. All patients were advised to undergo conservative treatment and were regularly followed up according to the protocol. Seventy-five asymptomatic volunteers were recruited as a control group. Of the total of 79 patients, 54 were followed up for 6 months, during which 46 improved, eight showed no improvement, and 25 were lost to follow-up. Sagittal spinopelvic parameters were measured by a single observer using the Surgimap spine software ver. 2.1.2 (Nemaris, New York, NY, USA). Parameters measured were PI, pelvic tilt (PT), sacral slope (SS), thoracic kyphosis, and lumbar lordosis. The results from patients and controls were compared using appropriate statistical methods.

Results: The normal and spondylolisthesis groups significantly differed with respect to PI, SS, and PT ($p<0.001$). There were no significant differences in the measured spinopelvic parameters between patients with high- and low-grade spondylolisthesis or between those whose condition improved and those whose condition worsened.

Conclusions: PI, the most important of all spinopelvic parameters, is responsible for the slip in spondylolisthesis, but not for its progression.

Keywords: Spondylolisthesis; Sagittal balance; Conservative treatment

Introduction

Humans are the only primates capable of maintaining an upright, totally vertical, bipedal posture. Unlike the spine of other primates, the human spine has successive opposing curves that allow the trunk to assume an erect position. Although all primates can walk bipedally, only *Homo sapiens* can do so for a long period. This is mainly
because of the lumbar lordotic curvature. The adoption of an upright vertical posture by humans resulted in a broad, vertical pelvis and the characteristic curves of the spine [1-5].

Sagittal balance and spinopelvic organization are crucial for the diagnosis and treatment of lumbago and degenerative spine disease. Even the genesis of spinal deformities has been linked to the three dimensional spatial orientation of the spine and pelvis [3,6].

For the treatment of many spinal deformities, analysis of the morphology of the spine in the sagittal plane is essential. The morphology of the spine can be assessed with the aid of whole spine standing sagittal radiographs, in which the beam is centered on the 12th thoracic vertebra and the radiograph is taken during inspiration. The patient stands up naturally, looking horizontally, with the hands resting on a vertical support or with the fingertips on both cheeks or clavicles, the upper limbs relaxed, and the elbows half-bent [7-9].

The pelvis and spine as a whole in the sagittal plane can be considered a linear linking chain that connects the head with the pelvis. The shape and orientation of each segment are closely interrelated with one another and influence one another to maintain a stable posture with minimum energy expenditure. Changes at one level will affect other levels. The morphology and spatial orientation of the spine and pelvis can be described by a few radiographic parameters that can be classified as spinal and pelvis parameters which are measured in degrees. The pelvic parameters are pelvic incidence (PI), sacral slope (SS), and pelvic tilt (PT). The spinal parameters are lumbar lordosis (LL) and thoracic kyphosis (TK) [8,10-12].

Spondylolisthesis is a sagittal plane deformity resulting in slipping of one vertebra over the one below. It has been proposed that a higher PI correlates with a higher incidence of spondylolisthesis. Studies have shown differences in the normative values of spinopelvic parameters in different populations and ethnic groups [6,9-13]. A correlation between spinopelvic parameters and the incidence of spondylolisthesis has not been reported in the Indian ethnic population. We started our study with the hypothesis that patients with spondylolisthesis have a higher PI. We aimed to confirm the hypothesis in our subset of patients. We also aimed to determine if these parameters were significantly different in patients with low-grade and high-grade listhesis and also to determine the response to conservative treatment.

### Materials and Methods

#### 1. Study design

This was a prospective, two-group comparative study.

#### 2. Study participants

The study enrolled 75 asymptomatic (control) volunteers and 79 patients with spondylolisthesis attending the orthopedic outpatient department. All controls and patients were aged >18 years. The study was conducted in Jawaharlal Institute of Postgraduate Medical Education and Research after obtaining approval from the institutional review board and ethics committee of Jawaharlal Institute of Postgraduate Medical Education and Research (JIPMER-PGRMC/140/2013). The study was conducted over a period of 2 years.

The control group comprised 75 asymptomatic volunteers without any complaints of low back, hip, or knee pain and no contraindication for radiographic exposure (Table 1). The spondylolisthesis group comprised 79 patients (five males and 74 females; mean age, 43 years) with developmental or degenerative spondylolisthesis accord-

| Gender | Normal | Listhesis |
|--------|--------|-----------|
| Male   | 21 (28.0) | 5 (6.3) |
| Female | 54 (72.0) | 74 (93.7) |
| Total  | 75 (100.0) | 79 (100.0) |

Values are presented as number (%).

Fig. 1. (A, B) Gender distribution in spondylolisthesis patients and controls. We included the spondylolisthesis patients as they presented. We had more female patients than male patients.
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3. Procedure

At their initial visit, patients with spondylolisthesis had a standing sagittal, lateral radiograph, and the functional score was assessed by modified Oswestry questionnaire that had been converted into the patient's vernacular language. The patients were given a trial of conservative treatment according to the hospital's standard physiotherapy protocol and evaluated every 6 weeks. The functional score was assessed with the aid of the Oswestry questionnaire at 6 weeks, 3 months, and 6 months. At the end of 6 months, patients who improved were followed up with the same protocol; those who worsened a repeat radiograph was taken for comparison and were advised to have surgery [15]. The spinopelvic parameters measured were PI, SS, PT, TK, and LL [4,5].

4. Radiographic protocol

One standing lateral radiograph of the spine was obtained from each subject in a standardized fashion, with the patient standing up naturally, looking horizontally, with the hands resting on a vertical support, the upper limbs relaxed, and the elbows half-bent. Three cassettes of size 35.56×43.18 cm (14×17 inches) were used for each subject. The cassettes were placed on a vertical platform and the subject stood in front of the platform in the standard position. The subject was at a distance of 2 m from the radiographic source, and a single X-ray was taken centering around D12. The radiograph included film from C7 to the femoral heads for calculating the parameters. The parameters were calculated with the use of free Surgimap spine software ver. 2.1.2 (Nemaris, New York, NY, USA). Surgimap, a Nemaris innovation, is a stand-alone, freeware application [16,17].

5. Physiotherapy protocol

The hospital's standardized physiotherapy protocol was tailored according to the patient's functional and clinical status.

6. Statistical analysis

Descriptive and inferential statistical analysis was performed. Continuous measurements are presented as mean±standard deviation (min–max), and categorical measurements are presented as numbers (percentage). All data with p<0.05 were considered to indicate statistical significance. Student t-test (two-tailed, independent) was used to determine the significance of differences in study parameters on a continuous scale between the two groups (intergroup analysis) for metric parameters, and Student t-test (two-tailed, dependent) was used to determine the significance of differences in study parameters on a continuous scale within each group. The chi-square test and Fisher's exact test were used to determine the significance of differences in study parameters on a categorical scale between two or more groups.

Results

In the cohort of 75 asymptomatic volunteers, we found

Table 2. Oswestry questionnaire evaluation of the spondylolisthesis group during follow-up

| Follow-up | Min–max | Mean±standard deviation | Difference | t-value | p-value |
|-----------|---------|-------------------------|------------|---------|---------|
| Baseline  | 10.00–100.00 | 66.13±17.96 | -          | -       | -       |
| 1         | 28.00–90.00  | 61.87±15.59  | 3.933      | 2.761   | 0.008** |
| 2         | 0.00–84.00   | 59.36±17.81  | 6.640      | 3.219   | 0.002** |
| 3         | 0.00–88.00   | 53.47±21.17  | 10.000     | 2.891   | 0.007** |

Over the follow-up period, there was an improvement in the scores in the functional assessment calculated using the Oswestry questionnaire. Majority of the patients improved. Of the 54 patients, 46 improved clinically.

**p<0.01.
the following values of spinopelvic parameters: PI 47.85°, PT 13.03°, SS 34.84°, LL 54.68°, and TK 24.03°. A total of 79 spondylolisthesis patients were followed. Over the follow-up period, majority of patients improved in the functional assessment that was performed using the Oswestry questionnaire (Table 2, Fig. 2). Among the 79 patients, four have 2 level listhesis, so the total listhesis levels were 83. Of the 79 patients with listhesis included in the study, 25 were lost to follow-up and 54 were followed for 6 months; 46 of these patients improved and eight were advised to undergo surgery (Table 3). Repeat X-rays were taken in these eight patients for comparison (Table 4).

The most common level of listhesis was L5–S1, followed by L4–L5, and the least common was L3–L4 (Table 5, Fig. 3). The most common grade of listhesis was grade 2, followed by grades 1, 3, 4, and 5 (Table 6, Fig. 4). Table 7 compares the spinopelvic parameters between the controls and spondylolisthesis patients. Table 8 compares the spinopelvic parameter according to grade of slip in spondylolisthesis patients. Table 9 compares the spinopelvic according to the outcome in spondylolisthesis patients. Table 10 shows the values of patients with spondylolisthesis in our study in comparison with those determined in other studies [18-21].

**Discussion**

Roussoly et al. [1] observed four types of spinopelvic alignment in the normal population. Types 1 and 2 are associated with low SS (<35°) and low PI. Type 3 is a well balanced spine with SS from 35°–45°. Type 4 is a curved spine (SS>45°). The mechanical stresses acting on the spinal column in each of the four spine groups are not the same (Fig. 5). The force acting on the lumbar spine, also called the contact force (CF) is the sum of forward forces (gravity, abdominal pressure) and the force of the posterior spinal muscles. The CF is distributed between the intervertebral discs in front and the facet joints behind. In the curved spine, the CF acts on the posterior elements, and in flat back, CF acts mostly on the discs. The CF act-

**Table 3.** Follow-up findings in the spondylolisthesis group

| Finding             | No. of patients (%) |
|---------------------|---------------------|
| Improved            | 46 (59.4)           |
| Advised surgery     | 8 (8.9)             |
| Lost to follow-up   | 25 (31.6)           |
| Total               | 79 (100.0)          |

**Table 4.** Comparison of grade and slip in the worsened patients at 6 months interval

| No. of slip | Level    | Initial Grade | % of slip | 6 months Grade | % of slip |
|-------------|----------|---------------|-----------|---------------|-----------|
| 1           | L4–L5    | 2             | 12        | 2             | 16        |
|             | L5–S1    | 3             | 60        | 5             | 102       |
| 2           | L4–L5    | 2             | 40        | 3             | 68        |
| 3           | L4–L5    | 2             | 22        | 2             | 26        |
| 4           | L5–S1    | 2             | 29        | 2             | 45        |
| 5           | L4–L5    | 2             | 32        | 2             | 36        |
|             | L5–S1    | 2             | 32        | 2             | 48        |
| 6           | L5–S1    | 2             | 44        | 3             | 58        |
| 7           | L5–S1    | 2             | 35        | 2             | 40        |
| 8           | L5–S1    | 2             | 43        | 4             | 82        |
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ing at each vertebral level can be split into two resultant vectors, one parallel to the end plate and the other perpendicular to it. In hypolordosis, the perpendicular vector force increases and the disc pressure increases. In the case of hyperlordosis when the vertebrae are tilted, the parallel vector has a role in increasing shear forces, resulting in anterolisthesis or retrolisthesis, depending on the tilt of the vertebrae. Hence, hypolordosis causes degenerative disk diseases, whereas hyperlordosis may cause posterior facet arthritis and listhesis [1].

In the type 1 spine, which is a combination of kyphosis and hyperextension area, there is an increased risk of degenerative changes in thoracolumbar kyphosis and a likelihood of spondylolisthesis in the lordotic lumbar segment. There is also a risk of spondylolysis in the hyperlordotic area. In the type 2 spine, which is flat back where the discs are parallel, the pressure is maximum. Hence, there is a risk of degeneration (Fig. 5). In types 3 and 4 spines, there is a risk of listhesis and posterior facet arthritis [1].

In our study, we found that the differences between spinopelvic parameters in patients with spondylolisthesis and asymptomatic controls were significant. As described

| Grade | No. of listhesis (%) |
|-------|----------------------|
| 1     | 31 (37.3)            |
| 2     | 38 (45.8)            |
| 3     | 10 (12.0)            |
| 4     | 3 (3.6)              |
| 5     | 1 (1.2)              |
| Total | 83 (100.0)           |

Most of the patients have a diagnosis of L5–S1, followed by L4–L5 and L3–L4.

Table 5. Spondylolisthesis levels

| Diagnosis | No. of listhesis (%) |
|-----------|----------------------|
| L5–S1     | 42 (50.6)            |
| L4–L5     | 38 (45.8)            |
| L3–L4     | 3 (3.6)              |
| Total     | 83 (100.0)           |

Fig. 3. Distribution of spondylolisthesis levels.

Fig. 4. Grade in the spondylolisthesis group. Most of the patients were grade 2, followed by grade 1 and then grades 3, 4, and 5.

Fig. 5. Distribution of resultant vectors (S, P) of CF for types 2, 3, and 4 spines according to the classification of Roussouly and Pinheiro-Franco. From Roussouly et al. Eur Spine J 2011;20 Suppl 5:609-18 [1]. CF, contact force.
by Roussouly and Pinheiro-Franco [1], the type 4 spine is associated with listhesis. The type 4 spine has high PI and high slope that is responsible for increased stress at the lumbosacral junction, and also greater force acting on posterior elements, resulting in listhesis. The same result was found in studies by Vialle et al. [18], Funao et al. [19], Schuller et al. [20], and Lim et al. [21] (Table 10). In their studies on patients with different types of listhesis, they found that high PI was associated with listhesis. However, some studies showed a correlation between slip degree and PI while others did not [18-21].

We found that high PI was associated with spondylolisthesis, but we could not find any association with the progression of spondylolisthesis. The patients were followed

| Table 7. Comparison of spinopelvic parameters between normal subjects and patients with spondylolisthesis |
| Parameter | Normal | Listhesis | p-value |
| PI | 47.85±13.34 | 65.32±11.79 | <0.001** |
| SS | 34.84±10.83 | 44.13±11.02 | <0.001** |
| PT | 13.03±7.72 | 21.30±7.42 | <0.001** |
| LL | 54.68±14.16 | 60.30±15.86 | 0.048* |
| TK | 24.03±9.59 | 25.49±12.47 | 0.713 |

Values are presented as mean±standard deviation. There is a significant difference in PI, SS, PT, and LL between asymptomatic and spondylolisthesis groups. Suggestive significance: 0.05<p-value<0.10.

| Table 8. Comparison of spinopelvic parameter according to grade in the spondylolisthesis group |
| Parameter | Grade 1, 2 | Grade 3, 4, 5 | p-value |
| Pelvic incidence | 65.35±12.04 | 65.15±10.88 | 0.957 |
| Sacral slope | 44.02±11.26 | 44.69±10.14 | 0.841 |
| Pelvic tilt | 21.48±7.34 | 20.38±8.05 | 0.628 |
| Lumbar lordosis | 61.52±15.46 | 54.15±17.06 | 0.127 |
| Thoracic kyphosis | 26.30±12.78 | 21.38±10.18 | 0.195 |

Values are presented as mean±standard deviation. There was no difference in spinopelvic parameters between patients with high-grade and low-grade spondylolisthesis.

| Table 9. Comparison of spinopelvic parameters according to outcome in the spondylolisthesis group |
| Variable | Surgery/no improvement | Improvement | p-value |
| Pelvic incidence | 64.00±8.02 | 63.59±12.83 | 0.929 |
| Sacral slope | 37.75±7.15 | 43.02±10.15 | 0.166 |
| Pelvic tilt | 25.38±6.65 | 20.74±7.76 | 0.118 |
| Lumbar lordosis | 51.63±9.02 | 60.41±14.48 | 0.104 |
| Thoracic kyphosis | 20.63±8.12 | 25.67±12.58 | 0.280 |

Values are presented as mean±standard deviation. There were no significant differences in spinopelvic parameters between the groups.

| Table 10. Comparison of spinopelvic parameters in spondylolisthesis patients among different ethnic groups |
| Spinopelvic parameter | India: present study | Japan: Funao et al. [19] | Korea: Lim et al. [21] | France: Schuller et al. [20] | France: Vialle et al. [18] |
| Total (N=79) | Male (n=5) | Female (n=74) | DS (N=50) | DS (N=50) | Isthmic listhesis (N=50) | DS | Developmental listhesis (N=244) |
| Pelvic incidence | 65.32 | 56.8 | 65.89 | 57.5 | 59 | 59 | 66.2 | 73.05 |
| Sacral slope | 44.13 | 38.6 | 44.5 | 34 | 34 | 38 | 42.3 | 46.57 |
| Pelvic tilt | 21.3 | 18.2 | 21.51 | 23.5 | 24 | 21 | 25.6 | 26.53 |
| Lumbar lordosis | 60.3 | 55.6 | 60.82 | 47.4 | 42 | 55 | - | 70.22 |
| Thoracic kyphosis | 25.49 | 31.4 | 25.09 | 37.2 | - | - | - | 23.09 |

DS, degenerative spondylolisthesis.
up for 6 months. Eight of the 54 patients followed had worsening of symptoms and were advised to have surgery; all eight of these patients in their repeat radiographs had progression of the slip.

There were no significant differences in any of the measured spinopelvic parameters between those with high-grade and low-grade spondylolisthesis (Table 8) or between patients who improved and those who worsened (Table 9). Thus, we could not attribute the progression of slip to spinopelvic parameters (PI) alone. The patients whose condition worsened had a high PI, two levels of spondylolisthesis, initially compromised spine (sagittal vertical axis >50 mm), and a large slip to start with or connective tissue disorders (one of the patients had Marfan’s syndrome). We found that PI was associated with the slip but not with its progression. More factors come into play for progression.

Conclusions

Patients with spondylolisthesis had higher PI, SS, PT, and LL than control subjects. These differences were statistically significant. There were no statistically significant differences in the values of the measured radiographic parameters between patients with low-grade and those with high-grade spondylolisthesis. The progression of slip and the clinical and functional response to conservative treatment do not depend solely on spinopelvic parameters, which are poor predictors of the outcome in patients with spondylolisthesis.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

References

1. Roussouly P, Pinheiro-Franco JL. Biomechanical analysis of the spino-pelvic organization and adaptation in pathology. Eur Spine J 2011;20 Suppl 5:609-18.
2. Le Huec JC, Saddiki R, Franke J, Rigel J, Aunoble S. Equilibrium of the human body and the gravity line: the basics. Eur Spine J 2011;20 Suppl 5:558-63.
3. Le Huec JC, Aunoble S, Philippe L, Nicolas P. Pelvic parameters: origin and significance. Eur Spine J 2011;20 Suppl 5:564-71.
4. Roussouly P, Pinheiro-Franco JL. Sagittal parameters of the spine: biomechanical approach. Eur Spine J 2011;20 Suppl 5:578-85.
5. Heary RF, Madhavan K. The history of spinal deformity. Neurosurgery 2008;63(3 Suppl):5-15.
6. Le Huec JC, Roussouly P. Sagittal spino-pelvic balance is a crucial analysis for normal and degenerative spine. Eur Spine J 2011;20 Suppl 5:556-7.
7. Ferguson AB. The study and treatment of scoliosis. South Med J 1930;23:116-20.
8. Legaye J, Duval-Beaupère G. Sagittal plane alignment of the spine and gravity: a radiological and clinical evaluation. Acta Orthop Belg 2005;71:213-20.
9. Morvan G, Mathieu P, Vuillemin V, et al. Standardized way for imaging of the sagittal spinal balance. Eur Spine J 2011;20 Suppl 5:602-8.
10. Legaye J, Duval-Beaupère G, Hequet J, Marty C. Pelvic incidence: a fundamental pelvic parameter for three-dimensional regulation of spinal sagittal curves. Eur Spine J 1998;7:99-103.
11. Lafage V, Schwab F, Patel A, Hawkinson N, Farcy JP. Pelvic tilt and truncal inclination: two key radiographic parameters in the setting of adults with spinal deformity. Spine (Phila Pa 1976) 2009;34:E599-606.
12. Schwab F, Lafage V, Patel A, Farcy JP. Sagittal plane considerations and the pelvis in the adult patient. Spine (Phila Pa 1976) 2009;34:1828-33.
13. Chaleat-Valayer E, Mac-Thiong JM, Paquet J, Berthonnaud E, Siani F, Roussouly P. Sagittal spinopelvic alignment in chronic low back pain. Eur Spine J 2011;20 Suppl 5:634-40.
14. Lee JC, Shin BJ. Current concept on the classification and treatment of spondylolisthesis. J Korean Soc Spine Surg 2010;17:38-48.
15. Vincent JI, Macdermid JC, Grewal R, Sekar VP, Balachandran D. Translation of Oswestry disability index into Tamil with cross cultural adaptation and evaluation of reliability and validity. Open Orthop J 2014;8:11-9.
16. Akbar M, Terran J, Ames CP, Lafage V, Schwab F. Use of Surgimap Spine in sagittal plane analysis, osteotomy planning, and correction calculation. Neurosurg Clin N Am 2013;24:163-72.
17. Lafage R, Ferrero E, Henry JK, et al. Validation of a
new computer-assisted tool to measure spino-pelvic parameters. Spine J 2015;15:2493-502.
18. Vialle R, Ilharreborde B, Dauzac C, Lenoir T, Rillardon L, Guigui P. Is there a sagittal imbalance of the spine in isthmic spondylolisthesis?: a correlation study. Eur Spine J 2007;16:1641-9.
19. Funao H, Tsuji T, Hosogane N, et al. Comparative study of spinopelvic sagittal alignment between patients with and without degenerative spondylolisthesis. Eur Spine J 2012;21:2181-7.
20. Schuller S, Charles YP, Steib JP. Sagittal spinopelvic alignment and body mass index in patients with degenerative spondylolisthesis. Eur Spine J 2011;20:713-9.
21. Lim JK, Kim SM. Difference of sagittal spinopelvic alignments between degenerative spondylolisthesis and isthmic spondylolisthesis. J Korean Neurosurg Soc 2013;53:96-101.