Evaluation of spinopelvic parameters in lumbar prolapsed intervertebral disc

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Abstract

Background: Sacro‑pelvic morphology and orientation are usually described in terms of pelvic incidence (PI), pelvic tilt (PT), and sacral slope (SS). Orientation and morphology of pelvis can affect degenerative changes in the lumbar spine. Thus, here we investigated the relationships between various sagittal spinopelvic parameters and the degree of disc degeneration in young adults. Material and Methods: A hospital-based cross-sectional study with a total of 60 cases was done. Patients presenting with back or leg pain having prolapsed disc on magnetic resonance imaging (MRI) were included in the study. A standing X‑ray of LS spine from dorso‑lumbar junction to mid‑thigh was taken. Various spinopelvic parameters were assessed from the scannogram using the software. Results: The mean age was 39.27 years. L5S1 was the most common level. Mean SS, PT, PI, and LL were 37.78°, 13.52°, 51.33°, and 41.01°. Disc pathologies at L1L2, L2L3, and L4L5 level showed a positive correlation with PT, PI, and LL. Disc pathology at the L5S1 level shows a positive correlation with PT and LL. A statistically significant correlation between SS and degenerative spondylolisthesis at L4L5 was found from data with \( P = 0.023 \). Discussion: An increase in SS statistically significantly increases the chance of development of degenerative spondylolisthesis at L4L5. An increase in PT, PI, and LL will cause an increase in disc pathology at L1L2. An increase in SS, PT, PI, and LL will cause an increase in disc pathology at L2L3. An increase in SS, PT, PI, and LL will cause an increase in disc pathology at L4L5. An increase in PT and LL will cause an increase in disc pathology at L5S1. Conclusion: Standing lateral view radiograph from dorso‑lumbar junction to the mid‑thigh is as good as standing whole spine radiograph for measurement of spinopelvic parameters. Degenerative spondylolisthesis at L4L5 has a statistically significant correlation with an increase in SS.

Key words: Lumbar disc herniation; pelvic incidence; pelvic tilt; sacral slope; spinopelvic parameters

Introduction

The human lumbar spine consists of five lumbar vertebrae articulating with each other at intervertebral discs anteriorly and facets joints posteriorly. Intervertebral disc functions physiologically as a shock absorber of the spine and helps to maintain the lordotic curve of lumbar spine. The functional and clinical importance of lumbar lordosis is being recognized increasingly.[1-3] Loss of normal lordotic alignment may induce pathologic changes in the spine from load-bearing and accelerate degeneration of the functional motion units.[3] The lumbar spine rests on the first sacral vertebra which is an integral part of the pelvis. The lumbar spine and pelvis are biomechanically connected, pathology of one affecting other, and vice-versa. Orientation and morphology of pelvis can, therefore, affect degenerative changes in the lumbar spine due to altered biomechanical forces.

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Sacropelvic morphology refers to the anatomy (shape) specific to each individual. On the contrary, sacropelvic orientation depends on the position of the individual in space and is best measured from standing lateral radiographs with the hips and knees extended [Figure 1]. Sacro-pelvic morphology and orientation are usually described in terms of pelvic incidence (PI), pelvic tilt (PT), and sacral slope (SS). The PI is a morphological parameter describing the sacro-pelvis, which is specific and constant for each individual. This parameter introduced by Duval-Beaupère et al. is defined as the angle between the line perpendicular to the upper sacral endplate and the line joining the middle of the upper sacral endplate and the hip axis [Figure 2]. The mean value of PI in the Indian population as given by Singh et al. is 48.52 ± 8.99. In contrast to the PI, the PT and SS measure the orientation of the Sacro-pelvis in the sagittal plane. SS is defined as the angle between the sacral endplate and the horizontal reference line (HRL) [Figure 2], whereas PT is defined as the angle between the vertical reference line (VRL) and the line joining the middle of the sacral endplate and the hip axis [Figure 2]. The mean values of SS and PT in the Indian population are 39.14 ± 7.05 and 9.30 ± 7.16, respectively. PI represents the arithmetic sum of the PT and SS (PI = PT + SS).

In a static standing position, the way SS and PT balance themselves refers to the concept of acro-pelvic balance. Patients with high PI and SS would increase the shear stresses at the lumbosacral junction, causing more tension on L5/S1 articulations, i.e., intervertebral disc anteriorly and facets joints posteriorly. This increased stress, in theory, will increase disc degeneration and prolapse at this level [Figure 3].

Figure 1: Lateral view lumbo-sacral spine with hip joints overlapped and extended. (patient in standing position)

Figure 2: Measurement of PI, SS, PT, and LL
In normal individuals, studies have shown that the sacropelvic morphology determines the sacro-pelvic orientation, which in turn greatly influences the shape and orientation of the spine, especially the lumbar lordosis.\(^\text{[6,7]}\) This results in an open linear chain linking the head to the pelvis where the shape and orientation of each successive anatomical segment are closely related and influence the adjacent segment\(^\text{[6-8]}\) to maintain the center of gravity over the femoral heads. Hence, any change in SS will affect LL. The normal physiological orientation of the lumbar spine is that of lordosis which ranges between 40° and 60°. Change in lumbar lordosis outside of normal range affects load transmission along the lumbar spine and hence leads to accelerated disc degeneration. Recently, Keorochana et al.\(^\text{[3]}\) reported that sagittal spinopelvic alignment may alter spinal load and mobility, thereby possibly influencing segmental degeneration; moreover, alterations in sagittal spinopelvic alignment may lead to kinematic changes that influence load bearing and the distribution of disc degeneration at each level. Consequently, the analysis of sagittal balance recently seems to be essential in the management of lumbar degenerative pathologies.\(^\text{[9]}\)

Nevertheless, the relationship between sagittal balance and the degree of disc degeneration has not been extensively explored. Thus, here we investigated the relationships between various sagittal spinopelvic parameters and the degree of disc degeneration in young adults. LL is measured as an angle between lines along the superior endplate of the L1 vertebra and the inferior endplate of the L5 vertebra [Figure 2]. The mean value of LL in the Indian population is 58.78 ± 9.51.\(^\text{[5]}\)

**Material and Methods**

Our study was a hospital-based cross-sectional study done in the Department of Radiodiagnosis, GMCH, Udaipur from November 2017 to April 2020. A total of 60 cases were included in the study. All outdoor patients of age between 18 and 50 years with chronic prolapsed intervertebral disc visiting the Department of Radiodiagnosis, GMCH, Udaipur were recruited to participate in the study. All patients were evaluated clinically and radiologically with X-ray and MRI. Inclusion criteria were individual of 18–50 years age group having back or leg pain without any history of other spinal disease or deformity, having prolapsed intervertebral disc on MRI. Criteria for exclusion were Patients not consenting for the study, patients with a history of trauma, pregnant females, patients with scoliotic deviation, and patients with congenital anomalies, post-polio residual paralysis, and neuromuscular dystrophy. Institutional Ethical Committee approval and prior informed consent were taken from all patients.

Patients presenting with back or leg pain having prolapsed disc on MRI were included in the study. A standing X-ray of L5 spine from dorso-lumbar junction to mid-thigh was taken. Each patient was asked to stand in his or her own neutral standing position. The knees were kept straight. The arms were placed over the chest in such a way as to remove arms from the field of view [Figure 4]. Various spinopelvic parameters were assessed from the scannogram using software (Digimizer Image Analysis Software, Version 5.4.4; © 2005-2020 MedCalc Software Ltd).

**Results**

Our study population comprised young adults in the age group between 20 years to 50 years. The mean age was 39.27 years with a standard deviation of ± 8.93. The maximum number of patients was in the age group between 41 and 50 years. Females comprised of major sex group among the study population. There were 37 female patients making 61.7% of the total group as compared to 23 male patients making 38.3% of the total population. Patients with two levels of disc pathologies were major group comprising of 58.3% of cases. LSS1 was the most common level followed by L4 L5 in cases with a single level of disc pathologies.
L4L5 + L5S1 were the most commonly involved levels in cases with two-level involvement however L4L5 was the most common level involved in combination with other levels in cases with two-level involvement. Diffuse disc bulge was the commonest type of disc pathology comprising 31 (51.7%) cases. Disc protrusion was the second commonest type with 20 (33.3%) cases.

SS, PT, PI, and LL
Mean SS in the study population was 37.78° with a standard deviation of ± 9.34 [Table 1]. The median value of SS was 37.08° with a range of 13.11 to 58.39. Mean PT in the study population was 13.52° with a standard deviation of ± 5.84. The median value of PT was 12.64° with a range of 1.52 to 25.24. Mean PI in the study population was 51.33° with a standard deviation of ± 9.19. The median value of PI was 50.94° with a range of 30.44 to 71.62. Mean LL in the study population was 41.01° with a standard deviation of ± 14.52. The median value of SS was 42.46° with a range of 1.51–70.28. The sum of the mean of SS and PT (37.78 + 13.52 = 51.3) is equal to PI mean (51.33). So, the correlation between SS, PT, and PI that is PI = PT + SS stands true in the result of our study.

Correlation between SS, PT, and PI
Pearson correlation shows that SS, PT, and PI are linearly correlated. A change in the value of one will correspondingly change the other two linearly [Table 2 and Figures 5-7]. This linear correlation is statistically significant in all the cases with P < 0.05. SS had positive linear correlation with PI (Pearson correlation coefficient = 0.798) and negative linear correlation with PT (Pearson correlation coefficient = -0.303). Similarly, PT had a positive linear correlation with PI (Pearson correlation coefficient = 0.330) and a negative linear correlation with SS (Pearson correlation coefficient = -0.303). PI had positive linear correlation with both SS and PT.

Table 1: Values of SS, PT, PI, and LL in study population

|         | Mean±SD   | Median | Min-Max   |
|---------|-----------|--------|-----------|
| SS      | 37.78±9.34| 37.08  | 13.11-58.39|
| PT      | 13.52±5.84| 12.64  | 1.52-25.24 |
| PI      | 51.33±9.19| 50.94  | 30.44-71.62|
| LL      | 41.01±14.52| 42.46 | 1.51-70.28 |

Table 2: Pearson correlation (linear correlation) between SS, PT, and PI

|         | SS   | PT   | PI   |
|---------|------|------|------|
| SS      | 1    | -0.303* | 0.798** |
| P       | 0.019 | <0.001 |
| n       | 60   | 60   | 60   |
| PT      | -0.303* | 1    | 0.330** |
| P       | 0.010 |       |
| n       | 60   | 60   | 60   |
| PI      | 0.798** | 0.330** | 1    |
| P       | <0.001 | 0.010 |
| N       | 60   | 60   | 60   |

Figure 4: Position of patient for taking radiograph

Figure 5: Pearson correlation (linear correlation) between SS and PT
SS (Pearson correlation coefficient = 0.798) and PT (Pearson correlation coefficient = 0.330).

**Correlation between LL and SS, PT, and PI**
LL was found to be linearly correlated to SS and in turn to PI and this correlation was statistically significant with $P < 0.05$. No such statistically significant correlation was found between LL and PT [Table 3 and Figures 8-10].

**Correlation between Disc pathology at L1L2 and pelvic parameters (SS, PT, PI, and LL)**
In cases with L1L2 disc pathology, mean SS, PT, PI, and LL were 36.59 ± 8.23, 16.22 ± 5.06, 53.18 ± 7.10 and 41.07 ± 13.90, respectively [Figure 11]. Disc pathologies at L1L2 level showed positive monotonic correlation with PT, PI, and LL (Spearman’s rho correlation coefficient of 0.173, 0.083, and 0.016, respectively). These correlations however were not statistically significant [Table 4].

**Correlation between Disc pathology at L2L3 and pelvic parameters (SS, PT, PI, and LL)**
In cases with L2L3 disc pathology, mean SS, PT, PI, and LL were 39.42 ± 9.26, 13.86 ± 8.09, 53.36 ± 8.39 and 46.92 ± 13.89, respectively [Figure 12]. Disc pathologies at the L2L3 level showed positive monotonic correlation with SS, PT, PI, and LL (Spearman’s rho correlation coefficient of 0.031, 0.042, 0.074, and 0.136, respectively). These correlations however were not statistically significant [Table 4].

**Table 3: Pearson correlation (linear correlation) between LL and SS, PT, PI**

| Correlations | SS  | PT  | PI  |
|--------------|-----|-----|-----|
| LL Pearson correlation | 0.759** | 0.049 | 0.781** |
| $P$           | <0.001 | 0.712 | <0.001 |
| $n$           | 60   | 60   | 60   |

Figure 6: Pearson correlation (linear correlation) between SS and PI

Figure 7: Pearson correlation (linear correlation) between PT and PI

Figure 8: Pearson correlation (linear correlation) between LL and SS

Figure 9: Pearson correlation (linear correlation) between LL and PT
Correlation between disc pathology at L3L4 and pelvic parameters (SS, PT, PI, and LL)

In cases with L3L4 disc pathology, mean SS, PT, PI, and LL were 37.41 ± 6.21, 13.86 ± 7.56, 51.34 ± 5.39 and 42.09 ± 7.49, respectively [Figure 13]. Disc pathology at L3L4 level show positive monotonic correlation with LL (Spearman’s rho correlation coefficient of 0.027) only and shows a negative correlation with SS, PT, and PI (Spearman’s rho correlation coefficient of −0.035, −0.013, and −0.004, respectively). These correlations however were not statistically significant [Table 4].

Correlation between Disc pathology at L4L5 and pelvic parameters (SS, PT, PI, and LL)

In cases with L4L5 disc pathology, mean SS, PT, PI, and LL were 38.36 ± 9.43, 13.58 ± 5.77, 51.93 ± 9.69, and 41.92 ± 15.06, respectively [Figure 14]. Disc pathology at L4L5 level shows a positive monotonic correlation with SS, PT, PI, and LL (Spearman’s rho correlation coefficient of 0.106, 0.014, 0.086, and 0.106, respectively). These correlations however were not statistically significant [Table 4].

Correlation between Degenerative spondylolisthesis at L4L5 and SS, PT, PI, LL

A total of four (6.7%) cases had degenerative listhesis and all of them had it at the level of L4L5. A statistically significant correlation between SS and degenerative spondylolisthesis at L4L5 was found from data with \( P = 0.023 \) [Table 5]. This correlation was found to be a monotonic direct correlation with Spearman’s rho correlation coefficient of 0.293 [Table 6]. A similar trend is shown by PI (Spearman’s rho correlation coefficient of 0.177) and LL (Spearman’s rho correlation coefficient of 0.201) i.e., increase in PI and LL lordosis increase chance of development of degenerative spondylolisthesis at L4L5 but this increase was not found to be statistically significant for PI and LL.
Table 4: Spearman’s rank correlation coefficient (Spearman’s rho) between disc pathologies at various levels and SS, PT, PI, and LL.

| Disc level | SS   | PT   | PI   | LL   |
|------------|------|------|------|------|
| L1-L2      | 0.042| 0.173| 0.083| 0.016|
|            | P    | N    |      |      |
|            | 0.752| 0.186| 0.526| 0.903|
|            | 60   | 60   | 60   | 60   |
| L2-L3      | 0.031| 0.042| 0.074| 0.136|
|            | P    | N    |      |      |
|            | 0.813| 0.747| 0.576| 0.301|
|            | 60   | 60   | 60   | 60   |
| L3-L4      | -0.035| -0.013| -0.004| 0.027|
|            | P    | N    |      |      |
|            | 0.79 | 0.922| 0.979| 0.839|
|            | 60   | 60   | 60   | 60   |
| L4-L5      | 0.106| 0.014| 0.086| 0.106|
|            | P    | N    |      |      |
|            | 0.422| 0.913| 0.516| 0.422|
|            | 60   | 60   | 60   | 60   |
| L5-SI      | 0.003| 0.038| -0.04 | 0.003|
|            | P    | n    |      |      |
|            | 0.994| 0.775| 0.764| 0.982|
|            | 60   | 60   | 60   | 60   |

Discussion

The adoption of vertical posture represents the main transformation in the evolution of humans. Spine and spinopelvic complex played a major role in vertical posture development and bipedalism. To achieve this marvellous feat, the human spine comprises of successive, opposing curves that allow the trunk to assume an erect position. The lumbar lordosis is unique and is not found in any other species. Pelvis also underwent tremendous modifications to alter posture to a vertical one. The pelvis attempts to couple lumbar lordosis with hip extension in the erect position with minimal expense of energy. However, some pelvis can accomplish this task better than others. Progressive knowledge has demonstrated that the shape of the pelvis and its relation to the SS influence dramatically the type of lumbar lordosis in a single individual. Due to the work of Duval-Beaupère et al.,[4,11,12] it became possible to define the pelvic geometry and the relation of this geometry with the position of the pelvis. Recently, some authors have highlighted the correlation between lumbar spine disc pathologies and degeneration with the spinopelvic organization.[13]

The key for it is the pelvic incidence (PI) angle. It is now crystal clear that the PI and the SS are important in determining the type of lumbar lordosis in a specific individual. The specific spinopelvic geometry will result in mechanical stress at the lumbar spine.

Any pattern of the degenerative spine is not a static entity. This is a result of dynamic forces acting on it because of its spatial orientation in space and resulting in biomechanical forces. There is a strong correlation in shape and positioning, and form and function, between the pelvis and the spine. The morphology of the pelvis is identified by PI, with consequences on the morphology of the spine. With time, depending on the individual morphology of a person, specific degenerative evolutions may occur. Sagittal parameters may be considered as predictive regarding the respective shape of the spine and pelvis. A better understanding of this relation may lead to improved diagnosis of degenerative spine diseases and a better strategy of treatment.

The mean age in our study falls in the young adult category. Age group was similar in the study by Endo et al.[14] with a mean age of 32.7 years. Although other studies by P. Rajnics et al.[15] and Barrey et al.[9] constituted a higher age group with a mean age of 47.70 ± 14.15 years and 49 ± 12 years, respectively. Sex distribution in our study was female dominant as was in the study by Barrey et al.,[9] while in a study by Endo et al.[14] males formed a majority group.

A statistically significant monotonic direct correlation of SS with degenerative spondylololisthesis at L4L5 was found in our study. A monotonic direct relationship is where an
increase in the independent variable causes an increase in the
dependent variable; never to remain constant or decrease,
i.e., our study signifies that an increase in SS statistically
significantly increases the chance of development of
degenerative spondylolisthesis at L4L5. A similar trend
is shown by PI and LL although it was not statistically
significant. Similar findings were reported by Wang et al.[16]
They reported that cases with single-level degenerative
spondylolisthesis have higher PI and SS than those
without degenerative spondylolisthesis. Ferrero et al.[17]
reported that patients with degenerative spondylolisthesis
had higher PI as compared to asymptomatic volunteers.
Similarly, Lai et al.[18] found that PI was associated with
degenerative spondylolisthesis and that among patients
with degenerative spondylolisthesis, SS has higher values
compared to a control group.

A statistically significant linear correlation was found
between SS, PI, and PT [Table 2]. In our study, increase in
SS linearly increased PI as PI is the mathematical sum of
SS and PT. On the contrary, an increase in SS decreased
PT because the pelvis has to compensate for increase SS to
maintain a straight posture of the body, and pelvis does
this by reducing its tilt, i.e., PT. Increase in PT linearly
increased PI as PI is mathematical sum of PT and SS. On
the contrary, an increase in PT decreased SS because the
spine has to compensate for increase PT to maintain a
straight posture of body and spine does this by reducing
SS i.e., SS.

LL showed a statistically significant linear correlation with
SS and PI. Any increase in SS will increase LL. This is on
expected lines to compensate for increased SS, the lumbar
spine will have to increase its curve to maintain an erect
standing posture.

### Table 5: Correlation between degenerative spondylolisthesis at L4L5 and SS, PT, PI, LL.

|                      | Degenerative spondylolisthesis L4L5 | Spondylolisthesis = No |
|----------------------|-------------------------------------|------------------------|
|                      | Mean±SD | Median (IQR) | Mean±SD | Median (IQR) | P         |
| SS                   | 47.97±7.13 | 45.51 (42.96-55.43) | 37.05±9.10 | 36.81 (30.54-43.21) | 0.023    |
| PT                   | 11.48±8.53 | 11.12 (3.52-19.79) | 13.67±5.69 | 12.82 (9.73-17.73) | 0.475    |
| PI                   | 59.20±11.20 | 59.47 (48.57-69.56) | 50.77±6.88 | 50.58 (45.56-57.40) | 0.076    |
| LL                   | 52.47±12.26 | 50.57 (42.02-64.81) | 40.20±14.41 | 41.29 (33.10-49.05) | 0.103    |

### Table 6: Spearman’s rank correlation coefficient (Spearman’s rho) between degenerative spondylolisthesis at L4L5 and SS, PT, PI, LL.

| Spearman’s rho | SS | PT | PI | LL |
|----------------|----|----|----|----|
| Spondylolisthesis | 0.293* | -0.073 | 0.177 | 0.201 |
| P               | 0.023 | 0.578 | 0.175 | 0.124 |
| n               | 60  | 60  | 60  | 60  |

Disc pathologies at the L1L2 level showed a positive
monotonic correlation with PT, PI, and LL [Figure 16]. It
implies that an increase in PT, PI, and LL will cause an
increase in disc pathology at L1L2 in a monotonic fashion,
i.e., disc pathology at L1L2 always increasing; never
remaining constant or decreasing with increase in PT, PI,
and LL.

Disc pathologies at L2L3 and L4L5 level showed positive
monotonic correlation with SS, PT, PI, and LL [Figures 17 and 18]. It implies that an increase in SS, PT, PI,
and LL will cause an increase in disc pathology at L2L3 and
L4L5 in a monotonic fashion.

Disc pathology at L3L4 level shows a positive
monotonic correlation with LL only and shows a negative correlation
with SS, PT, and PI [Figure 19].

Disc pathology at L5S1 level shows positive monotonic
correlation with PT and LL [Figure 20]. Disc pathology at L5S1
however showed negative monotonic correlation with PI. This
implies that with an increase in PI, disc pathology at L5S1
will always decrease; never remaining constant or increase.

A similar result was reported by Fei et al.[19] Khallaf,[20] and
Oh and Eun et al.[21]

In our study, we took radiographs in a neutral standing
position with knees straight and arms placed over the
chest in such a way as to remove arms from the field of
view. Imaging was acquired by using Digital Scannogram
in LATERAL view from dorso-lumbar junction to the
mid-thigh. Various spinopelvic parameters were measured from the scanogram by using computer software which required lines to be drawn manually on the DICOM file, but angles were measured automatically by software between lines drawn (Digimizer Image Analysis Software, Version 5.4.4; © 2005-2020 MedCalc Software Ltd). We measured SS, PT, PI, and LL independently. Mean values were - SS - 37.78°, PT - 13.52°, and PI - 51.33°. Now, as we know PI must be equal to the sum of SS and PT i.e., PI = SS + PT. So, 37.78 + 13.52 (SS + PT) gives 51.3 which is equal to mean PI we calculated 51.33. This proves that our radiography technique was fairly accurate. The technique of taking radiographs gave clear images which allowed us to clearly mark lines on computer software to calculate angles. This can be interpreted that our technique can be used as a standard technique to calculate spinopelvic parameters and whole spine radiographs are not a must-have to calculate these parameters (SS, PI, and PT). A similar observation was made in a study by Chung et al.[22] who concluded that spinopelvic and LL measurements on lateral lumbar radiographs were similar to those on lateral whole-spine radiographs and exhibited excellent reproducibility.

**Conclusion**

Disc herniation has multifactorial pathophysiology. Correlation of sacropelvic parameters with disc herniation in the young population is a new paradigm for research and should be explored further with prospective randomized controlled studies to validate results. Standing lateral view radiograph from dorso-lumbar junction to the mid-thigh is as good as standing whole spine radiograph for measurement of spinopelvic parameters.

**Declaration of patient consent**

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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**Conflicts of interest**

There are no conflicts of interest.

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