ABSTRACT

Objective: There has been an increasing recognition in the literature of the importance of ensuring a correct sagittal and pelvic balance after a surgical procedure in lumbar spine. Recent studies clearly demonstrated a correlation between pelvic balance and surgical outcomes. As the degenerative deformity gradually progresses there is evidence of corresponding alterations in spinopelvic parameters. Therefore, the aim of this work was to study the influence of spinopelvic balance in clinical and functional outcomes after surgery for degenerative spondylolisthesis. Methods: Retrospective study with 29 subjects (20 females/9 males) with DS submitted to lumbar decompression and fusion between 2006 and 2010. Mean age 65.45 (± 8.15) years old. Mean follow-up 2,1 years. Clinical, functional and radiological evaluation. VAS, Satisfaction, Oswesty disability Index (ODI). Spinopelvic parameters: Pelvic Incidence, Sacral Slope, Pelvic Tilt and Lumbar Lordosis. Two study groups: Group A (n=14) no improvement in pelvic tilt postoperatively (increased or unchanged); Group B (n=15) improvement in pelvic tilt postoperatively (decreased). Statistical analysis with SPSS19®. Results: The surgery is beneficial in reducing pain and improving quality of life. Patients in Group B (improved spinopelvic balance) have the best clinical and functional results (p<0.05) and also greater pelvic incidence values compared with group A. Conclusion: This study confirms the importance of spinopelvic balance in surgical planning: restoring the original spinopelvic balance seems to produce better outcomes.

Keywords: Spondylolisthesis; Postural balance; Spinal fusion; Lumbar vertebrae/injuries; Lumbar vertebrae/radiography.
INTRODUCTION

The impact of sagittal alignment on the treatment of spinal pathology has taken on increasing importance in the monitoring of such patients. The non-recognition of an imbalance in this plane may have a negative impact on the residual pain and quality of life. The spine is comprised of varying kyphotic and lordotic curves, which, in conjunction with the pelvis and lower limbs, allow for the harmonious and balanced distribution of forces by the human skeleton. Changing this balance through pathological processes or aging results in deformity and adaptive changes in the spine, pelvis, and lower limbs.  

The pelvic incidence (PI) angle describes the relationship between the sacrum and femoral heads. It is a morphological parameter that is constant for each individual starting at skeletal maturity and determines the capacity of the pelvis to rotate about the femoral heads along the hip axis. Two other parameters are directly related to the PI: pelvic tilt (PT) which varies with the rotation of the pelvis, i.e., the PT increases when the pelvis rotates posteriorly (in retroversion), and the PT decreases with the anteversion of the pelvis. The sacral slope (SS) is defined by the orientation of the S1 platform in the horizontal plane. These last two parameters are positional and dependent on the pelvic incidence, so that PI = SS + PT. Thus for a constant PI, if the PT increases the SS decreases and vice versa.  

From a pathophysiological viewpoint, the spine undergoes degenerative changes with age. In the context of degenerative spondylolthesis, the change in sagittal balance relates to postural and structural factors. The degeneration and slipping of intervertebral discs result in the loss of lumbar lordosis and the subsequent straightening of this segment. Similarly, the antaiga posture of the trunk in anterior flexion leads to the reduction of lumbar lordosis. The center of gravity (C7 plumb line) moves anteriorly and to compensate for this imbalance, the patient’s pelvis promotes retroversion, that is, the pelvis rotates posteriorly and inferiorly on the femoral heads causing a decrease in SS and an increase in PT, resulting in the verticalization of the sacrum. (Figure 1) This mechanism is broader or more ample the larger the PI, since it is this latter value which determines the pelvis’s ability to rotate.  

Thus, sagittal imbalance (C7 plumb line) is rarely observed in patients with degenerative spondylolthesis because they compensate for the changes described.  

Barrey et al. and Morel et al. demonstrated that patients with degenerative spondylolthesis have a significantly elevated PI angle compared to the population that is asymptomatic and without deformity, and is considered a possible risk factor for the disease. With the onset of the disease and its progression, a decrease in the SS and loss of lumbar lordosis are observed. Therefore, the PT is increased in these patients as a sign of pelvic retroversion.  

Thus, the objectives of this study are: 1) to study the relationship between the pelvic parameters and clinical and functional results after spinal decompression and fusion; 2) to determine whether these parameters have predictive value for the postoperative result. If we seek to restore the original spino-pelvic balance, we hope to decrease the retroversion of the pelvis postoperatively, i.e., to decrease the PT.

MATERIAL AND METHODS

We developed a retrospective study evaluating 29 patients (9 men and 20 women) with a mean age of 65.54 years (51-81), who underwent decompression and posterior lumbar arthrodesis between 2006 and May 2010.  

Inclusion criteria were: 1) degenerative listhesis at only one level; 2) surgical treatment via a posterior approach (circumferential or posterolateral arthrodesis); 3) evidence of arthrodesis post-surgery in follow-up radiographs or computed tomography; 4) minimum of 18 months follow-up.  

Exclusion criteria were: 1) more than one level instrumented; 2) patients with a history of previous surgery to the lumbar spine; 3) patients with concomitant spinal deformities (scoliosis, tumor, or trauma).  

Symptoms lasting more than 24 months before the surgery. Level involved: L3-L4 in one patient; L4-L5 in 25 patients, and L5-S1 in three patients. Neurogenic claudication in 13 patients, lombosciatalgia in 13 patients, and only low back pain in three patients.  

Clinical and functional assessment

Clinical evaluation of pain consisted of the completion of the Visual Analogue Pain Score (VAS) and patients answered the Oswestry disability index (ODI) questionnaire regarding the impact of the disease on their quality of life.  

The functional and clinical results were evaluated by calculating the difference between the preoperative VAS and ODI with the results obtained in the final observation, and translated into a percentage, i.e. the change in the VAS (ΔVAS = preoperative VAS - current VAS) and change in the ODI (ΔODI = preoperative ODI - current ODI).  

Spino-pelvic parameters

Spino-pelvic parameters were measured on radiographs taken in the standing position with the knees extended. Long chassis view with lateral profile and exposure of the skull to the proximal femur. All measurements were performed by the same author (FD) and repeated twice.  

Pelvic parameters included in this study were: pelvic incidence (PI), the sacral slope (SS), and pelvic tilt (PT). Measurements were made according to the criteria of Duval-Beaupère and Robain. The vertebral parameters included were the lumbar and lordosis (LL) and the sacrum-C7 plumb line distance (SC7D).  

The pelvic incidence angle is defined as the angle between the line perpendicular to the S1 platform and the line that connects the midpoint of the S1 platform with the hip axis. (Figure 1 – β)  

The sacral slope is equivalent to the angle between the S1 platform and the horizontal plane. (Figure 1 – a)  

The pelvic tilt corresponds to the angle between the vertical plane and the line connecting the midpoint of the S1 platform with the hip axis. (Figure 1 – δ)  

Lumbar lordosis was measured according to the model proposed by Berthonnand by the two arches method. The most anterior point of the lumbar lordotic curvature (apex) was located and a horizontal line was drawn at this level. The distal arch forms an angle to the S1 platform and the proximal arch forms an angle with the line tangential to the upper edge of the vertebra, corresponding to the inflection point of the curve. The LL is the sum of the amplitude of the two arches. (Figure 2)  

The C7 plumb line is identified as a vertical line starting at C7 and should intersect the S1 platform. The horizontal distance between the end of the C7 plumb line and the S1 platform is the sacrum-C7 plumb line distance (SC7D).
According to the preoperative size of the pelvic tilt angle, the participant's lumbar curvature averaged 62.4° (± 14.2°), the average pelvic angle was 21.6° (± 7.3°), the current mean pelvic tilt was 21.6° (± 5.4°), and the preoperative mean sacral apex was 40.8° (± 11.7°), and the current mean sacral apex was 39.7° (± 12.2°); the current mean lumbar lordosis was 60.4° (± 14.7°), and the current mean lordosis was 61.8° (± 15°).

**Comparison of the two groups**

The clinical and functional results of the two groups are summarized in Table 2. No statistically significant differences were found between the two groups for the preoperative VAS and ODI values. However, the difference was significant for the current VAS and ODI values and the changes in these scores. In Group A, the current mean VAS was 4.5, and in Group B it was 3.4, which corresponds to an improvement of 50.7% in group A and 62.7% in Group B (p < 0.05).

Regarding the functional score, the current mean ODI value was 80.7% for Group A and 78.1% for Group B. This improvement in score was 55.9% in group A and 70.2% in Group B (p < 0.05).

The values for the spino-pelvic parameters are summarized in Table 3. Comparing the preoperative results for each spino-pelvic parameter with the current did not comprise statistically significant differences except for the PT in both groups. In the comparison between Groups A and B, differences between the pelvic incidence values and also in respect to the current PT values stood out. There were no differences in the other parameters measured.

Statistical correlations using Pearson’s coefficient were performed between the clinical and functional results and the spino-pelvic parameters. Group A showed a negative relationship between the change in VAS and the current PT value. Similarly, a positive relationship was found in Group A when comparing changes in the ODI with the pelvic incidence value. No statistical relationship calculated using Pearson’s coefficient was found in Group B between the clinical and functional results and the spino-pelvic parameters. (Table 4)

**Results**

Fourteen patients were included in Group A and fifteen were included in Group B. Demographic data were summarized in Table 1.

**General statistics**

From the global point of view, the surgery was beneficial for patients, translating into decreased pain and improved quality of life. The preoperative mean VAS in the total sample was 9.1 (± 0.8), with the current being 3.9 (± 1.2) which is an improvement in mean VAS of 58.9%. Similarly, the preoperative mean ODI was 79.4% (± 5.6), with a significant improvement in the last follow-up visit, a current mean ODI of 29.2% (± 10.9), which is a 63.3% improvement in ODI.

**Table 1.** Epidemiological and preoperative data.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group A (n=14)</th>
<th>Group B (n=15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (M:F)</td>
<td>6:8</td>
<td>3:12</td>
</tr>
<tr>
<td>Average age</td>
<td>63.4 ± 9.6</td>
<td>673 ± 6.3</td>
</tr>
<tr>
<td>Level affected</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L3-L4</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>L4-L5</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>L5-S1</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

**Table 2.** Clinical and functional comparison between the two groups according to whether or not the PT improved (Values shown correspond to the means with standard deviation).

<table>
<thead>
<tr>
<th>Group</th>
<th>VAS Improvement (%)</th>
<th>ODI Improvement (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-op</td>
<td>Current</td>
</tr>
<tr>
<td>A (n=14)</td>
<td>9.1 ±0.8</td>
<td>4.5 ±1.1</td>
</tr>
<tr>
<td>B (n=15)</td>
<td>9.1 ±0.8</td>
<td>3.4 ±1.1</td>
</tr>
<tr>
<td>p†</td>
<td>ns</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

† Differences between group A and group B calculated with Mann-Whitney U-test.
* p < 0.05 – Statistically significant differences between the current values and the preoperative values calculated with Wilcoxon’s rank sum test.

**Table 3.** Comparison of pelvic parameters between the two groups according to the postoperative PT.

<table>
<thead>
<tr>
<th>Variable VR*</th>
<th>Pelvic tilt (*) (12-18°)</th>
<th>Sacral slope (*) (36-42°)</th>
<th>Lumbar lordosis (*) (48-55°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (n=14)</td>
<td>175 ± 7.3</td>
<td>24.4 ± 5.3</td>
<td>37.9 ± 12.2</td>
</tr>
<tr>
<td>B (n=15)</td>
<td>25.5 ± 4.9</td>
<td>18.9 ± 4.2</td>
<td>43.6 ± 10.8</td>
</tr>
<tr>
<td>p†</td>
<td>&lt;0.01</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

* Average reference values of several studies published in asymptomatic individuals without deformity.
† p < 0.05 – Statistically significant differences between the current levels and the preoperative values calculated with Wilcoxon’s rank sum test.

Figure 2. Calculation of lumbar lordosis. α-proximal arch. β-distal arch. Arrow – tangent to the most anterior point of the lumbar spine (Apex).
Table 4. Pearson’s correlation. * p < 0.05.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Group A (n=14)</th>
<th>Group B (n=15)</th>
<th>∆VAS</th>
<th>∆ODI</th>
<th>∆VAS</th>
<th>∆ODI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sacral slope</td>
<td>Pre-op ns</td>
<td>Current ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Lumbar lordosis</td>
<td>Pre-op ns</td>
<td>Current ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Pelvic tilt</td>
<td>Pre-op ns</td>
<td>Current -0.86*</td>
<td>-0.79*</td>
<td>ns</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>Pelvic incidence</td>
<td>ns</td>
<td>0.82*</td>
<td>ns</td>
<td>ns</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**DISCUSSION**

The compensatory pelvic tilt observed in degenerative spondylolisthesis makes the sagittal imbalance a rarity in patients with this type of spine pathology. Minor changes such as those found in the spine-pelvic parameters may be responsible for postoperative residual pain and even for the decomposition of the adjacent level. Lazennec et al. found a relationship between post-fusion pain and pelvic parameters, with the postoperative pain being associated with an elevated PT. Le Huc and Roussouly have even suggested that in the case of surgery, the original spine-pelvic balance should be reestablished or the spine would be permanently fused in retroversion, with consequences in postoperative pain.

Several published studies have demonstrated various relationships between pain perceived by patients (VAS) and imaging parameters to other clinical entities. In the case of vertebral deformities, the work of Glassman et al. also allowed for the establishment of a relationship between quality of life (ODI) and imaging parameters.

In this study, patients with a decreased PT (group B) showed better results in the variables measured. Assuming that changes in pelvic tilt may influence clinical and functional outcomes, we may say with our study that there is a clear relationship between the surgical restoration of the original spine-pelvic balance and the improved pain and quality of life of patients.

The statistical correlations made within the group with no decrease in PT (group A) found a negative relationship between the current PT value and the improvement in VAS and ODI, which allows us to affirm that, even in this group, the patients with the worst outcomes are those who have higher PT.

The analysis of the pelvic incidence angle found values that were clearly higher (p < 0.05) in group B than in group A. Assuming the hypothesis that the larger this angle, the greater the ability to compensate for changes in the spine-pelvic balance, we can deduce that the group B patients better offset the changes they have undergone, and therefore more easily restore the original values. The same is supported by the positive correlation between the improvement of the ODI with the PI value, i.e., the greater the PI angle, the greater the improvement in the quality of life after surgery.

In terms of spine-pelvic parameters, major sagittal imbalance is defined by loss of lordosis, anterior deviation of the C7 plumb line and retroversion of the pelvis with verticalization of the sacrum (increased PT). In this study sample, we observed elevated current global PT values compared to reference values. However, no individual showed changes consistent with major sagittal imbalance when measuring the distance from the sacrum to the end of the C7 plumb line, supporting the theory of a greater ability to compensate for changes in spine-pelvic balance.

Currently, the literature places greater emphasis on the role of morphology and spine-pelvic positioning in the study of sagittal balance. This study demonstrates that pelvic positioning – here represented by the PT – is related to the quality of life of patients and cannot be ignored in the preoperative planning of a patient. Surgery should aim to restore the original PT to restore spine-pelvic balance.

Although lumbar lordosis has also been related to the improvement of clinical and functional results in other studies, this relationship was not proven in this study. Kim et al. reported that after lumbar fusion there is a relationship between the spines that remained hypolordotic and more pain and a reduced quality of life. The same authors suggest that in these cases the patients benefit from increased intraoperative lumbar lordosis during the fusion. By comparing their results with those of our study, we found differences in the values of lumbar lordosis (preoperative mean LL of 42.9° and current mean LL of 47.8°) that differ significantly from those we encountered: a preoperative mean LL of 60.40° (+ 14.69) and a current mean LL of 61.82° (+ 15).

Despite the apparent importance to the outcome of patients, studies poring over the impact of sagittal and spine-pelvic balance on the surgical results of degenerative spondylolisthesis are scarce. Limitations of this study include those inherent in the retrospective design used together with the small sample size. Thus, these results should be interpreted cautiously.

**CONCLUSION**

The variation of the pelvic tilt and pelvic incidence proved to be determining factors in the outcome after the surgical treatment of degenerative spondylolisthesis.

Currently, the emphasis on sagittal balance appears to have reached consensus and shown evidence that it is too important to be ignored. This study is in line with a multifactorial approach in lumbar surgery for the treatment of this pathology: besides correcting the deformity, the surgeon should be aware of the characteristics and morphology of the spine, while seeking to restore the original balance of each patient.

All authors declare no potential conflict of interest concerning this article.

**REFERENCES**


