Global tilt: a single parameter incorporating spinal and pelvic sagittal parameters and least affected by patient positioning

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Abstract

Purpose Regarding the close interaction between the spinal alignment and the pelvis orientation, no parameter is routinely used to describe and to evaluate the global spinal-pelvic balance, taking into account simultaneously the spinal part and the pelvic part of the global alignment. We described the global tilt (GT) that could analyze malalignment considering the spine and the pelvis simultaneously. From a geometrical point of view, the global tilt is the sum of the pelvic tilt (PT) and the C7 vertical tilt (angular value of sagittal vertical axis). The aim of this study is to evaluate the global tilt with comparison to PT and sagittal vertical axis (SVA), with the hypothesis that GT would be the least sensitive to positional changes.

Methods A cohort of 22 patients with sagittal malalignment was identified from a multicentric database of adult spinal deformities (ASD). Inclusion criteria were age ≥ 30 years, SVA > 40 mm and/or PT ≥ 20°. All patients had full spine EOS radiographs in positions 1 and 2 (P1 and P2), in which the patient was asked to stand and put his hands on his shoulders without any effort (P1), or to make an effort to be as straight as possible (P2). PT, SVA and GT were measured in both positions and changes between P1 and P2 were calculated and compared using Student’s t test with significance level at \( p < 0.05 \).

Results No significant changes were observed for GT; SVA and PT were significantly influenced by patient positioning. SVA decreased and PT increased for all cases in P2 whereas the changes in GT were in either direction. The average increase in PT was 7.1° (±5.4) or 30.8 % (±24.9); decrease in SVA was 45.1 mm (±25.6) or 60.0 % (±44.2) while the change in GT was 4.4° (±3.3) or 12.6 % (±9.3).

Discussion GT appears to be less affected by the patient’s position compared to SVA and PT. This seems logical because GT contains both spinal alignment and pelvic compensation; it is not affected by their changes in opposing directions.

Conclusion GT appears to be the most reliable single sagittal plane parameter in ASD. It is the least affected by patient position and incorporates both the pelvic and the spinal alignment within one measure.

Keywords Global tilt · Spinal-pelvic balance · Spinal malalignment · Adult spinal deformity

Introduction

While spinal balance is obviously a dynamic concept, our assessment of this so-called “balance” is performed on full spine X-rays that are static and not dynamic exams. This interesting observation and critic is argued by Jean Dubousset, who thinks that sagittal balance or imbalance...
should rather be called spinal alignment or malalignment in the sagittal plane [1]. X-rays will give us an idea of the patient’s alignment at a given moment, mainly depending on the patient’s position during that exam. Therefore, spinal balance is probably assessed partially and our evaluation regarding deformities consequences remain limited.

The compensation mechanisms involved in adult spinal deformity (ASD) are commonly assessed through two main parameters: the sagittal vertical axis (SVA), reflecting the spine behavior and the pelvic tilt (PT), reflecting the pelvis behavior. Other parameters can also be used such as the C7 tilt [2] (or the T1 tilt) for the spine, and the sacral slope for the pelvis [3].

These dynamic parameters will become static on the X-rays and their measurement (angles or distances) will depend on the patient’s standing position when the X-ray beam reaches the patient. This position can be natural or following protocols, such as putting both hands on the shoulders or clavicles. When the aforementioned parameters are measured in the different positions, an important discrepancy occurs for the same patient with parameters being modified in opposite directions. Therefore, the global balance evaluation can be difficult and can lead to direct consequences for the future management. What is the real global alignment of a negative SVA associated to an increased PT (Fig. 1) or a positive SVA associated to a normal PT (Fig. 2)?

To answer these questions and try to overcome the effect of the patient’s position on our measurements, we described a spinopelvic parameter taking into account the spinal behavior (reflected by the SVA) and the pelvic behavior (reflected by the PT) and named it the global tilt. The global tilt (GT) is the angle formed by the intersection of two lines, the first line is drawn from the center of C7 to the center of the sacral endplate and the second line is drawn from the center of the femoral heads to the center of the sacral endplate. The GT seems interesting as it could overcome the alternate changes of the SVA and the PT making global sagittal balance easier to understand. To assess these considerations we will try to answer a question: which parameter between SVA, PT and GT is less affected by patient positioning?

**Materials and methods**

A cohort of patients presenting sagittal malalignment was identified from a multicentric database of adult spinal deformities (ASD). Inclusion criteria were age >30 years, SVA > 40 mm and/or PT > 20°. All patients had full spine EOS radiographs [4] in 2 different positions that we called position 1 (P1) and position 2 (P2). For P1, the patient was asked to stand and put his hands on his shoulders without putting any effort to make himself straight (natural position). For P2, the patient was asked to make an effort to be as straight as possible (compensated position) (Fig. 3).

The following spinal and pelvic radiographic parameters were measured in both positions:

- **Sagittal vertical axis (SVA)** distance, in mm, between C7 plumb line and posterior superior corner on the top margin of S1.
• Pelvic tilt (PT) angle between the vertical axis and the line through the midpoint of the sacral endplate to femoral heads axis.

• Global tilt (GT) (Fig. 4) angle formed by the intersection of two lines, the first line is drawn from the center of C7 to the center of the sacral endplate and the second line is drawn from the center of the femoral heads to the center of the sacral endplate. From a geometrical point of view, GT equals the sum of PT and C7 vertical tilt (C7VT); the C7VT is the angle between the vertical axis and a line drawn from the center of C7 to the center of the sacral endplate. This angle corresponds to the C7 tilt (also named spinal tilt) minus 90°. A value inferior to 0° indicates that the center of C7 vertebral body is behind the center of the upper sacral endplate, whereas for values greater than 0°, the center of C7 vertebral body is in front of the center of the upper sacral endplate. C7VT is somewhat the angular version of the SVA.

Fig. 2 Male radiography with positive SVA over 5 cm associated to a normal PT.

Fig. 3 Illustration of the 2 positions P1 (right side) and P2 (left side).
Changes between P1 and P2 were calculated and compared using Student’s *t* test with significance level at *p* < 0.05.

Results

22 patients (17 women and 5 men) were included in this series; mean age was 66.2 years (range 44–79).

The average increase in PT was 7.1° (±5.4) or 30.8 % (±24.9); decrease in SVA was 45.1 mm (±25.6) or 60.0 % (±44.2) while the change in GT was 4.4° (±3.3) or 12.6 % (±9.3). Changes between P1 and P2 were statically significant for SVA and PT but not for GT (Table 1; Fig. 5).

In comparison to P1 (spontaneous position without any compensation effort), P2 (compensated position) showed in all patients decreasing of the SVA, and increasing of the PT. The changes in GT were either decreasing or increasing depending on the patients (Fig. 6).

Discussion

Sagittal balance understanding became, in the last decade, of most importance as imbalance correlates directly with disability and pain [5, 6]. The interaction existing between the spine and the pelvis is a major key point in spinal deformities analysis. When imbalance occurs, compensatory mechanisms are involved to restore a compensated balance. Compensation begins at the spine level with spinal curves modifications. If this compensation is not sufficient, the pelvis tilts, increasing the PT value. At last when all compensatory mechanisms are overcome, the lower extremities can help restoring a horizontal gaze by the mean of knees flexion [7]. Many parameters have been described for the spinal balance or pelvic compensatory mechanisms evaluation [8–11]. Recently, “second generation” parameters dealing with sagittal malalignment appeared willing to consider globally sagittal malalignment and its compensatory mechanism. Boissière et al. described the lumbar lordosis index (LLI) that demonstrated to be the most correlated parameter with sagittal malalignment in adult scoliosis [12]. But no parameter is actually commonly used for the assessment of the global spinopelvic alignment, taking into account simultaneously the two parts (spinal and pelvic) of this issue. In this study, we introduced a new parameter that corresponds to such criteria, the GT. It enables a global evaluation of the spinopelvic complex balance.

The GT appears to be least affected by patient positioning in this study than SVA and PT. Using a parameter combining spinal and pelvic alignment annihilates simultaneous changes of the spinal and pelvic balance. The assessment of the spinopelvic alignment becomes easier. A patient with a normal PT associated to an SVA above 5 cm has a non-compensated sagittal imbalance, and a patient with a high pelvic tilt associated to a normal SVA has a compensated sagittal balance. Both of these patients might need a surgical correction, but the analysis could be quite difficult with the use of the different parameters. Using the GT enables us to decrease the number of parameters used, and to evaluate by a simple measurement, the global spinopelvic alignment. In this study, we did not notice GT-significant change regardless patient position. This result illustrates GT interest as patient positioning influences directly other parameters’ measurement (such as SVA and PT), which can induce errors for surgical planning and management. The little difference observed (not

![Image](https://example.com/image.png)

**Fig. 4** Global tilt geometrical method of calculation

**Table 1** Radiographic parameters in both positions

<table>
<thead>
<tr>
<th>Measurement</th>
<th>P1</th>
<th>P2</th>
<th>Diff</th>
<th>Diff (%)</th>
<th><em>p</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>SVA (mm)</td>
<td>96.9 (±65.2)</td>
<td>52.6 (±59.2)</td>
<td>45.1 (±25.6)</td>
<td>60.0 (±44.1)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>PT (°)</td>
<td>25.7 (±8.5)</td>
<td>32.5 (±10.3)</td>
<td>7.1 (±5.4)</td>
<td>30.8 (±24.9)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>GT (°)</td>
<td>38.4 (±14.5)</td>
<td>37.9 (±16.0)</td>
<td>4.4 (±3.3)</td>
<td>12.6 (±9.3)</td>
<td>NS</td>
</tr>
</tbody>
</table>

*Diff = P1 − P2*

Diff (%) = (*P1 − P2)/P1 × 100

Mean and standard deviation, *p* values for the comparison between P1 and P2 are also reported

NS not significant
significant) by GT modifications can be explained by measurement error or by the knee flexion change between P1 and P2. Indeed knee flexion is not involved in GT and knee flexion modifications can impact spinal and pelvic balance.

With regard to other previously described parameters in the literature, global tilt is, actually, a modified version of the spinopelvic angle (SPA) described by Roussouly [13]. SPA corresponds to the angle drawn between two lines; the first line joins the center of C7 to the center of S1 endplate, and the second line joins the center of the sacral endplate to the center of the femoral heads. From a geometrical point of view, this angle corresponds to the following formula:

$$SPA = 180 - GT.$$ 

GT and SPA are indeed supplementary angles. Thus, the SPA also evaluates the global spinopelvic alignment as it takes into account the pelvic tilt and the spinal tilt. One main advantage of the GT over the SPA is its easy and quick calculation. Indeed, it corresponds to the sum of the PT and the C7VT. For normal balanced subjects, the GT approaches the value of the PT as the C7VT approaches 0. If sagittal imbalance occurs the GT will raise due to retroversion of the pelvis (raise of PT) and/or spinal malalignment (raise of C7VT). Another advantage of the GT is that its value as an angle would not be very high like SPA (all GT values were below 70° in our series), which makes the understanding and assessment of the alignment much easier. Also compared to the GT, SPA was not evaluated on a cohort of spinal deformity patients, and compared to other parameters.

Recently, reference values for GT were described in elderly volunteers [14]. In this study, GT appears to be age related (15.4° ± 8.7 for patients between 50 and 59 years old and 30.8° ± 14.8 after 80 years old) and sex related (26° for females and 18.8° for males), with a high correlation with PT ($r = 0.914$) and SVA ($r = 0.751$). A GT cutoff value of 33.7° was proposed by the authors, for an ODI score $\geq 40$. These results emphasize the fact that the interpretation of GT values, like other sagittal parameters, should be made according to the general context of spinal deformity patients.

Another parameter recently described in the literature, and assessing the spinopelvic alignment is the T1 pelvic angle (TPA) [15–17]. The latter is defined as the angle between the line from the femoral head axis to the centroid of T1 and the line from the femoral head axis to the middle of the S1 endplate. The TPA is the sum of the T1 spino-pelvic inclination (T1 SPI) and the pelvic tilt. Compared to the GT, the TPA is less easy to calculate as the T1 SPI is not routinely used, and it may also be less accurate as both parameters that form this angle rely on the femoral head axis, which may increase the error margin during the measurement given the fact that femoral heads are not...
always seen properly on the X-rays. Also TPA was not assessed in two different standing positions to evaluate its modification and degree of relative stability depending on the patient’s sagittal dynamics.

Global tilt could be applied, in future studies, on a larger group of deformities patient, and its correlation to the lack of lumbar lordosis [18] should be compared to other spine or pelvic parameters, before and after corrective surgeries.

Conclusion

Normal sagittal alignment is the result of a close interaction between multiple parameters including the spine, the pelvis and the lower extremities. Global tilt is a parameter for the evaluation of the global spinopelvic alignment. It appears in this study less affected by patient positioning than the other parameters, SVA and PT, decreasing somehow the static effect due to the standard full spine X-ray, thus improving our analysis of the global alignment of our patients, with a direct impact on their surgical management.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no potential conflict of interest.

References