ABSTRACT • Purpose: Sagittal parameters do not have the same fluctuation and accuracy during adult spinal deformity (ASD) surgery follow-up. The relationship between sagittal radiographic parameters and health related quality of life (HRQoL) scores is well known in ASD. Sagittal vertical axis (SVA) and pelvic tilt (PT) are commonly used. Global tilt (GT) was recently added as an angle for the assessment of the global spinopelvic alignment. HRQoL scores and sagittal radiographic parameters’ fluctuations during the postoperative period have not been yet described. This study aimed to evaluate the fluctuations of HRQoL scores and radiographic sagittal parameters during the postoperative follow-up in ASD patients. METHODS: This is a multicenter, retrospective study of consecutive operated ASD patients included prospectively with a minimum follow-up of 2 years. Preoperative, 6 months, 1 year and 2 years postoperative data were analyzed. Pearson correlation analysis was performed and accuracy of all parameters was determined by the measurement of statistical fluctuation within the sample; \( p < 0.05 \) was considered significant. RESULTS: A total of 91 patients were included. All parameters improved at 6M post-op (\( p < 0.05 \)) and no parameter changed between 1Y and 2Y post-op. GT (GT6M = 18.57, GT1Y = 20.46, \( p = 0.024 \)), SF-36 PCS (PCS6M = 39.13, PCS1Y = 41.54, \( p = 0.002 \)) and ODI (ODI6M = 34.43, ODI1Y = 30.08, \( p = 0.009 \)) significantly changed between 6M and 1Y. No significant difference was found concerning SVA (SVA6M = 7.12, SVA1Y = 12.15), SVA fluctuation (SVA6M = 147.86%, SVA1Y = 83.76%, SVA2Y = 71.77%) was larger than GT (GT6M = 18.76%, GT1Y = 17.27%, GT2Y = 17.45%), PT (PT6M = 24.32%, PT1Y = 23.38%, PT2Y = 22.80%), SF-36 PCS (PCS6M = 4.74%, PCS1Y = 4.81%, PCS2Y = 5.10%) and ODI (ODI6M = 11.47%, ODI1Y = 13.11%, ODI2Y = 14.41%). Conclusions: GT was the only radiographic parameter that significantly changed between 6 months and 1 year. Its changes were parallel to HRQoL score modifications. All sagittal parameters did not have the same accuracy and precision for ASD surgery follow-up. Despite the large difference in the mean value of SVA at 6 months and 1 year, it is not a good parameter for follow-up because of its large fluctuations. GT has the highest precision and should be used for this purpose.

Keywords: adult spinal deformity; fluctuations; health related quality of life scores; sagittal parameters

REFERENCES

1. Kingdom Hospital, Riyadh, Saudi Arabia. 2. Bordeaux Pellegrin Hospital, Bordeaux, France. 3. Acibadem Maslak Hospital, Istanbul, Turkey. 4. Hospital Universitario Val Hebron, Barcelona, Spain. 5. Ankara Acibadem Spine Center, Ankara, Turkey. 6. Hospital Universitario La Paz, Madrid, Spain. 7. Spine Center, Shulthess Klinik, Zurich, Switzerland.

*Corresponding author: Anouar Bourghli, MD.

e-mail: anouar.bourghli@gmail.com
INTRODUCTION

Patients presenting an adult spinal deformity (ASD) may suffer from pain and disability that may require either a conservative treatment or a more aggressive surgical treatment [1-3]. Surgery seems to improve health related quality of life (HRQoL) scores at two years, when compared with the conservative management [4]; and older patients with greater inability before surgery show a better postoperative recovery when compared to less disabled patients [5].

Furthermore, sagittal radiographic parameters are strongly correlated to the clinical symptoms [6-10]. Yet, simultaneous study of HRQoL scores and sagittal radiographic parameters fluctuations over a 2-year period following surgery has not been done.

The first aim of our study is to analyze, in an ASD group of patients that underwent surgery, the postoperative fluctuations of HRQoL scores and sagittal radiographic parameters (PT: pelvic tilt, SVA: sagittal vertical axis [11-13], GT: global tilt [14,15]), at the following time intervals: 6 months, 1 year and 2 years. The second aim is to define which radiological parameter is best adapted for the postoperative follow-up.

MATERIALS AND METHODS

This study is a retrospective review of a prospective, multicenter adult spinal deformity database (6 sites) of the European Spine Study Group (ESSG). Inclusion criteria are: spinal deformity defined by a Cobb angle > 20°, thoracic kyphosis > 60°, SVA > 5 cm, PT > 25° and a minimum follow-up of two years.

Full-body radiographic analysis was performed using Surgimap (Nemaris, Inc.), a validated software. Spino-pelvic radiographic parameters included sagittal vertical axis (SVA : distance between the C7-plumb line and posterior superior margin of S1), global tilt (GT: 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), and pelvic tilt (PT: angle between the vertical and the line through the midpoint of the sacral plate to femoral head axis).

The HRQoL scores included Oswestry disability index (ODI) and Short Form 36 (SF36) mental and physical component summary (MCS and PCS).

Every parameter in this study was assessed preoperatively, at 6 months, 1 year and 2 years after the index surgery.

The number of patients included to calculate the differences in fluctuations between each follow-up period was comparable for the different measured parameters. Lack of data for either the radiological parameters or the HRQoL scores at different follow-ups was not significant.

Pearson correlation analysis (linear regression) between the radiological parameters and the HRQoL scores was performed. Crossed tables were generated and either Fisher’s tests or Pearson’s Chi² tests were used to compare the distributions of the demographic (age, sex) and clinical variables (BMI, rate of previous surgeries). Matched t-tests were used to assess the differences between the mean values of the different parameters at different follow-up periods.

For each distribution, we calculated a mean value (m), a standard deviation (σ), and a number of patients (n).

For each variable, margin of error was set at 5%, and we evaluated the confidence interval that would include the estimated mean for the population (M) where M = m ± h and h = tα σ /√n-1 where tα = 1.96.

### TABLE II. CORRELATION ANALYSIS BETWEEN SAGITTAL PARAMETERS & HRQoL

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pre-op</th>
<th>6 months</th>
<th>Pre-op</th>
<th>6 months</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GT</strong></td>
<td>R</td>
<td>0.418**</td>
<td>-0.296*</td>
<td>0.257</td>
</tr>
<tr>
<td>p-value</td>
<td>0.001</td>
<td>0.031</td>
<td>0.064</td>
<td>0.016</td>
</tr>
<tr>
<td>N</td>
<td>55</td>
<td>53</td>
<td>53</td>
<td>54</td>
</tr>
<tr>
<td><strong>PT</strong></td>
<td>R</td>
<td>0.329**</td>
<td>-0.243</td>
<td>-0.238</td>
</tr>
<tr>
<td>p-value</td>
<td>0.007</td>
<td>0.057</td>
<td>0.062</td>
<td>0.119</td>
</tr>
<tr>
<td>N</td>
<td>66</td>
<td>62</td>
<td>62</td>
<td>65</td>
</tr>
<tr>
<td><strong>SVA</strong></td>
<td>R</td>
<td>0.259*</td>
<td>0.052</td>
<td>-0.324*</td>
</tr>
<tr>
<td>p-value</td>
<td>0.048</td>
<td>0.707</td>
<td>0.017</td>
<td>0.153</td>
</tr>
<tr>
<td>N</td>
<td>59</td>
<td>54</td>
<td>54</td>
<td>59</td>
</tr>
</tbody>
</table>

ODI: Oswestry disability index  
MCS: mental component score  
PCS: physical component score  
R: Pearson’s ‘r’  
N: number of patients
The number of patients \( n \) required in a sample to obtain a specific accuracy \( h' \) for a variable with a known standard deviation \( \sigma_e \) for a specific sample is
\[
 n = \left( \frac{t_\alpha \sigma_e}{h'} \right)^2 + 1.
\]

**RESULTS**

Ninety-one patients met the inclusion criteria. It was confirmed that for the demographic data, BMI and percentage of previous spinal surgeries, all the distributions of the measured parameters were identical \((p > 0.3)\).

**GT, PT, SVA and HRQoL scores at baseline, 6 months, 1 year and 2 years follow-up**

The values of sagittal parameters and HRQoL scores in the preoperative period (G1), six months (G2), one year (G3), and two years (G4) after the surgery are summarized in Table I.

For all the variables, there is a significant difference between the preoperative and the 6-month follow-up values \((p < 0.05)\).

Correlation values are summarized in Table II with R and \( p \) values. The improvement of the radiological parameters GT, PT and SVA (decrease of the values) is correlated to the improvement of all HRQoL scores except SF-36 MCS, the latter only showed significant improvement between the preoperative values and the 2-year follow-up values. GT increased mildly but significantly between the 6-month and the 1-year follow-up periods, but the SF-36 PCS and ODI scores continued to improve (Figure 1).

For all measured radiological parameters and quality of life scores, there is no significant difference between the 1-year and the 2-year follow-up periods \((p > 0.05)\). Figure 1 shows that the GT and SVA decrease significantly after the surgical management, and they increase again between the 6-month and 1-year periods with a statistical significance only for GT. In addition, we can notice in Table I that SVA has a bigger standard deviation compared to GT at all the follow-up periods.

### TABLE I  SAGITTAL PARAMETERS AND HRQoL FOR ALL TIME INTERVALS

<table>
<thead>
<tr>
<th></th>
<th>G1 Baseline</th>
<th>G2 6-month FU</th>
<th>G3 1-year FU</th>
<th>G4 2-year FU</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td></td>
</tr>
<tr>
<td>SVA (mm)</td>
<td>30.91</td>
<td>57.57</td>
<td>7.12</td>
<td>46.80</td>
<td></td>
</tr>
<tr>
<td>Global Tilt (Deg)</td>
<td>24.26</td>
<td>17.46</td>
<td>18.57</td>
<td>14.25</td>
<td></td>
</tr>
<tr>
<td>Pelvic Tilt (Deg)</td>
<td>21.36</td>
<td>11.19</td>
<td>19.26</td>
<td>10.33</td>
<td></td>
</tr>
<tr>
<td>ODI score</td>
<td>41.06</td>
<td>21.41</td>
<td>34.80</td>
<td>19.20</td>
<td></td>
</tr>
<tr>
<td>SF36v2 PCS score</td>
<td>35.06</td>
<td>9.26</td>
<td>38.93</td>
<td>9.09</td>
<td></td>
</tr>
<tr>
<td>SF36v2 MCS score</td>
<td>43.39</td>
<td>10.97</td>
<td>45.16</td>
<td>12.53</td>
<td></td>
</tr>
</tbody>
</table>

**FU**: follow-up

**SVA**: sagittal vertical axis

**Deg**: degree

**ODI**: Oswestry disability index

**SF-36 PCS**: short form-36 physical component score

**SF-36 MCS**: short form-36 mental component score

**SD**: standard deviation

**GT**: global score

**PT**: pelvic tilt

**SVA**: sagittal vertical axis

### HEALTH RELATED QUALITY OF LIFE (HRQoL) SCORES FOR ALL TIME INTERVALS

<table>
<thead>
<tr>
<th></th>
<th>ODI 1 year</th>
<th>MCS 1 year</th>
<th>PCS 1 year</th>
<th>ODI 2 years</th>
<th>MCS 2 years</th>
<th>PCS 2 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R</td>
<td>p-value</td>
<td>R</td>
<td>p-value</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>GT 1 year</td>
<td>0.417**</td>
<td>0.001</td>
<td>0.35</td>
<td>0.004</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>PT 1 year</td>
<td>0.257*</td>
<td>0.033</td>
<td>0.06</td>
<td>0.135</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>SVA 1 year</td>
<td>0.275*</td>
<td>0.029</td>
<td>0.062</td>
<td>0.011</td>
<td>N</td>
<td></td>
</tr>
</tbody>
</table>

**correlation significant at 0.01**

**correlation significant at 0.05**

**GT**: global score

**PT**: pelvic tilt

**SVA**: sagittal vertical axis

A. BOURGHLI et al. – Fluctuations in Adult Spinal Deformity

Lebanese Medical Journal 2018 • Volume 66 (4) 199
Assessment of the heterogeneity in the cohorts

Figure 2 illustrates the mean values and standard deviations for SVA, PT, GT, SF-36 PCS, SF-36 MCS and ODI at 6 months, 1 year and 2 years postoperatively. Mean values for sagittal vertical axis are smaller when compared to all other parameters at all follow-up periods, whereas standard deviations are always higher. We calculated the confidence intervals including the estimated mean value of the population for each parameter, at 6 months (Figure 3), one year (Figure 4), and two years (Figure 5) of follow-up. Accuracy rates are noted in Table III. Confidence intervals for SVA are higher therefore less

Figure 1. Plots illustrating the preoperative and follow-up mean health-related quality of life scores and sagittal parameters. (a) GT: global tilt  PT: pelvic tilt  (b) SVA: sagittal vertical axis  (c) ODI: Oswestry disability index  SF-36 PCS & SF-36 MCS: short form-36 physical and mental component scores
accurate (SVA6 months = 147.86%; SVA1 year = 83.76%; SVA2 years = 71.77%) compared to GT (GT6 months = 18.76%; GT1 year = 17.27%; GT2 years = 17.45%), PT (PT6 months = 24.32%; PT1 year = 23.38%; PT2 years = 22.80%), SF-36 PCS (PCS6 months = 4.74%; PCS1 year = 4.81%; PCS2 years = 5.10%) and ODI (ODI6 months = 11.47%; ODI1 year = 13.11%; ODI2 years = 14.41%) in all the follow-up periods.

SF-36 PCS has the best accuracy and GT and PT are at 20%. Yet, the GT is always more accurate than the PT. Table IV shows that the number of required patients in the cohort for the SVA to get an equivalent accuracy as GT and PT would be very important (n6 months = 4150, n1 year = 1394, n2 years = 975).

DISCUSSION

Roussouly classified the human lumbar spine and pelvis in the sagittal plane [16], specifying four different types according to the shape and values of the different spinal and pelvic parameters; his study helped the spine surgeon to significantly increase his understanding of the sagittal alignment biomechanics and to link it to pathology (including deformity), therefore improving the surgical results as the final alignment to achieve was predefined by the classification. In addition, other studies from the same author [17,18] shed the light on the way to further understand the global spinal alignment with the introduction of new angles like the spinosacral angle and spinopelvic angle; these angles helped in clarifying the interrelation between the spine and pelvis with the different compensatory mechanisms put into play when a malalignment occurs.

The aforementioned angles formed probably the basis to the different angles that were recently described in the literature, like the TPA [19] and the global tilt. As the GT takes into account simultaneously the SVA and the PT, we decided in our study to compare it with these two parameters taken separately, to find out which one would
reveal less fluctuations in the postoperative period of ASD patients.

In ASD patients, many papers have shown the superiority of the surgical management, when compared to conservative treatment, with improvement of the radiological parameters and the HRQoL scores, with a globally maintained result at 2 years [4, 20-25]. Scheer et al. [5] suggested that recovery is even better for elderly people and with worse preoperative inability. In the latter paper, data between 6 weeks and 1 year postoperatively are not assessed, and no study has yet compared simultaneously the sagittal radiological parameters and the HRQoL scores at 6 months, 1 year and 2 years postoperatively to establish their respective fluctuations over time.

In our study, we found a significant difference between the preoperative data and the postoperative data at all the different follow-up periods, but no significant difference was found between the 1-year and the 2-year periods. Furthermore, the improvement of HRQoL scores at 6 months postoperatively was correlated to a significant decrease of the GT whereas the same scores’ improvement between 6 months and 1 year was associated to an increase of the GT. Same evolution was observed for PT and SVA but the differences were not statistically significant. Sagittal radiological parameters stop to vary at 1 year and quality of life scores also become stable.

GT showed a globally significant linear correlation at the different follow-up periods with the three different scores (even if the R value is less at 6 months), whereas SVA and PT did not show a correlation at 6 months, with ODI, MCS and PCS; this finding suggests that GT is probably the parameter that is less affected by postoperative fluctuations. GT was indeed always correlated with the ODI, and also with the MCS, but not with the PCS at 6 months and 2 years; but the correlation was nevertheless very close to significance (0.062 and 0.079), this finding is probably due to the size of the cohort, if it had been larger, significance would have probably been reached.

One limitation of this study is that we assessed globally the fluctuations of the different radiological and quality of life parameters in the group of ASD patients; it would be interesting to verify if these variations are observed according to different age groups, different ASD etiologies and even different past surgical histories.

Even if the SVA mean values are following the same variations of the GT at the different postoperative follow-

<table>
<thead>
<tr>
<th>TABLE IV</th>
<th>NUMBER OF PATIENTS NEEDED IN THE SAMPLE FOR A 20% SVA PRECISION (α = 0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6 months FU</td>
</tr>
<tr>
<td>Mean</td>
<td>7.12</td>
</tr>
<tr>
<td>Standard deviation in the SVA cohort</td>
<td>46.8</td>
</tr>
<tr>
<td>Number of patients in the sample in the SVA cohort</td>
<td>66</td>
</tr>
<tr>
<td>Number of patients needed for a 20% precision</td>
<td>4150</td>
</tr>
</tbody>
</table>

up periods, only the GT values are significantly different between the 6 months and one year intervals. We have demonstrated in our study that SVA has a greater heterogeneity compared to other radiological parameters and quality of life scores. A cohort of patients should represent the real population; we found that the confidence interval, where we have 95% of chances to find the SVA estimated mean value calculated according to our sample of patients, is large. We also found that the number of patients required to obtain the same accuracy for GT and PT would be very high.

In summary, GT is the most accurate sagittal parameter, as it is showing less postoperative fluctuations. It was actually shown in a previous study [15] that GT, when measured on a patient in two different positions, was less affected by the patient’s position compared to SVA and PT, which were showing changes in opposing directions, making their interpretation more difficult. This finding is explained by the fact that the GT takes into account simultaneously the SVA and PT, and also the fact that the SVA is a measurement of a distance and not of an angle, which makes it probably more sensitive to the patient’s position and height. The GT seems to be the best statistical parameter for the follow-up of the sagittal alignment after surgery for ASD patients.

CONCLUSION

In this study, we have analyzed, in an ASD group of patients that underwent surgery, the postoperative fluctuations of HRQoL scores and sagittal radiographic parameters at the following time intervals: 6 months, 1 year and 2 years. The mean values of PT, GT and SVA increased between the 6 months and the one year period, to remain stable after one year. However, only the GT was statistically correlated to the HRQoL scores. In fact, the GT has a better statistical accuracy compared to SVA that is showing a very important fluctuation in our study, which decreases the ability to detect changes over time. Therefore, GT may be used in the future to more accurately assess the postoperative sagittal alignment and its correlation with pain and disability of ASD patients.

REFERENCES