Global Alignment and Proportion (GAP) Score Better Correlates to HRQoL Scores and Better Predicts Mechanical Complications Compared to SRS-Schwab Sagittal Modifiers

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Background: Sagittal Plane Analysis

• SRS-Schwab Classification – Sagittal Modifiers
  – Have been used as alignment targets but addressing these
  – do not always prevent mechanical complications
    • Mechanical complication rate 31.7%
    • 52.6% of them revised!

• Disadvantages of Schwab Parameters
  – Based on HRQoL parameters, not mechanical complications
  – Do not include
    • Anteversion
    • Negative Malalignment
    • Shape and distribution of lumbar lordosis
  – Considering the whole spectrum of PI
    • when used as an absolute numeric value
    • in conjunction with previously reported
      • population-based average thresholds
    • Schwab criteria may be insufficient or misleading in quantifying
      • Normoverversion of pelvis (PT)
      • Spinopelvic mismatch (PI-LL)

• There is a need for a new look into the ‘ideal’ sagittal plane

• Spinal curvatures and alignment must be viewed in light of each other
  – Chain of correlations
    • PI influences SS
    • SS influences LL
    • LL influences TK
    • TK influences CL

• Pelvic incidence
  – is a (relatively) constant morphological parameter
  – that describes the ‘pelvic size’ for any given person

• PI = A signature

• All sagittal plane parameters
  – Should be evaluated proportional to PI
  – rather than absolute numeric
  – to assess disproportion compared with the calculated ideal
Global Alignment & Proportion: GAP Score
- New Method of Analyzing Sagittal Plane
- Offers individualized sagittal plane analysis
  - Instead of population norms & mean values
- Uses PI-based proportional radiographic parameters
  - Instead of absolute numerical values
- Denotes “normal” and “pathologic”
  - standing sagittal alignment and shape
  - as a single score for every magnitude of pelvic incidence.

Radiographic parameters
- **RPV**: Relative Pelvic Version (Measured-Ideal SS)
- **RLL**: Relative Lumbar Lordosis (Measured-Ideal LL)
- **LDI**: Lordosis Distribution Index (L4-S1 / L1 – S1)
- **RSA**: Relative Spinopelvic Alignment (Measured-Ideal GT)
- **Age Factor**
The GAP score, calculated by adding the scores for relative pelvic version, relative lumbar lordosis, lordosis distribution index, relative spinopelvic alignment, and the age factor, ranged from 0 to 13 points.

A GAP score of 0 to 2 was categorized as indicating a proportioned spinopelvic state; 3 to 6, as moderately disproportioned; and ≥7, as severely disproportioned.
Aim

- To compare GAP Score and Schwab modifiers
  - in prediction of mechanical complications and
  - Correlations to HRQoL Scores

Methods

- From the ESSG database
  - ≥4 levels posterior fusion
  - ≥2 years follow up
  - 222 patients (168F, 54M)
  - Mean age
    - 52.2 ± 19.3 (range 18-84)
  - Mean follow-up:
    - 28.8 ± 8.2 (24-62) months

- Mechanical Complications
  - PJK / PJF
  - DJK
  - Rod breakage
  - Implant related complications
    - Screw
      - loosening, fracture, pull out
    - Interbody, hook or set screw
      - pull out

- Correlations between Schwab modifiers and GAP Score with
  - ODI, COMI, SRS-22 and SF-36
  - Pearson’s Partial Correlation Coefficient

- The distribution of Schwab modifiers and GAP categories in patients
  - with / without mechanical complications
  - compared using McNemar-Bowker test

- Uni- & Multivariate logistic regression analysis
  - To compare prediction ability for mechanical complications
Results

• GAP Score had better
  – partial correlation coefficients
  – to HRQoL scores

• when compared to
  – PT, PI-LL and SVA (p<0.01)
Results

- In 122 patients that did not have:
  - mechanical complications
  - the distribution of Schwab modifiers
  - and GAP categories were similar (p>0.05).

- In 100 patients that had:
  - mechanical complications
  - GAP had a better prediction
  - with an increasing trend of complications
  - as the category worsens (p<0.001)

<table>
<thead>
<tr>
<th>122 Patients – Mechanical Complications ABSENT</th>
<th>100 Patients – Mechanical Complication PRESENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schwab</td>
<td>PI LL</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Categories</td>
<td>n (%)</td>
</tr>
<tr>
<td>0</td>
<td>77 (63.1%)</td>
</tr>
<tr>
<td>+</td>
<td>36 (29.5%)</td>
</tr>
<tr>
<td>++</td>
<td>9 (7.4%)</td>
</tr>
</tbody>
</table>
## Prediction of Mechanical Complications

<table>
<thead>
<tr>
<th>Performance of the models</th>
<th>Model I with GAP score</th>
<th>Model II with PI-LL</th>
<th>Model III with PT</th>
<th>Model IV with SVA</th>
<th>Model IV with PI-LL, PT, SVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significance of the model</td>
<td>.000</td>
<td>.000</td>
<td>.000</td>
<td>.000</td>
<td>.000</td>
</tr>
<tr>
<td>Nagelkerke $R^2$</td>
<td>.597</td>
<td>.108</td>
<td>.248</td>
<td>.122</td>
<td>.329</td>
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<tr>
<td>Discrimination</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAC</td>
<td>79.7</td>
<td>64</td>
<td>68.9</td>
<td>62.8</td>
<td>70.4</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>62</td>
<td>29.9</td>
<td>73</td>
<td>41.5</td>
<td>52.1</td>
</tr>
<tr>
<td>Specificity</td>
<td>94.3</td>
<td>92.6</td>
<td>65.6</td>
<td>81.9</td>
<td>86.7</td>
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<tr>
<td>PPV</td>
<td>89.9</td>
<td>76.3</td>
<td>63.5</td>
<td>67.2</td>
<td>77.8</td>
</tr>
<tr>
<td>NPV</td>
<td>75.2</td>
<td>61.4</td>
<td>74.8</td>
<td>60.9</td>
<td>66.9</td>
</tr>
</tbody>
</table>

PAC; Percentage Accuracy in Classification; PPV; Positive Predictive Value, NPV; Negative Predictive Value
<table>
<thead>
<tr>
<th>Pelvic Incidence</th>
<th>Age Factor</th>
<th>PI(=79^\circ)</th>
<th>GAP Score</th>
<th>1</th>
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</thead>
<tbody>
<tr>
<td>Age</td>
<td>61</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Pelvic Proportion</td>
<td>Aligned</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sacral Slope</td>
<td>49</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Ideal Sacral Slope</td>
<td>55.61</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Pelvic Proportion</td>
<td>Aligned</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L1-S1 Lordosis</td>
<td>66</td>
<td></td>
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<td></td>
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<tr>
<td>Ideal Lordosis</td>
<td>77.98</td>
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<tr>
<td>Lordosis Proportion</td>
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<tr>
<td>L4-S1 Lordosis</td>
<td>42</td>
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<td>Lordosis Proportion</td>
<td>Aligned</td>
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<tr>
<td>Global Tilt</td>
<td>26</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Ideal Global Tilt</td>
<td>22.92</td>
<td></td>
<td></td>
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<tr>
<td>Spino-Pelvic Proportion</td>
<td>Aligned</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Age Adjustment:
- PT ‘++’ = 30
- PI-LL ‘++’ = 13
- SVA ‘0’ = -2.3 cm
- PT under
- PI-LL under
- SVA over

No Mechanical complications
<table>
<thead>
<tr>
<th>Pelvic Incidence</th>
<th>GAP Score</th>
<th>Severe Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age 26</td>
<td>13</td>
<td>Severe Disproportion</td>
</tr>
<tr>
<td>Age Factor 60</td>
<td>1</td>
<td>Relative Pelvic Version -15.3</td>
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<tr>
<td>Sacral Slope 9</td>
<td></td>
<td>Relative Lumbar Lordosis -28.1</td>
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<tr>
<td>Ideal Sacral Slope 24.34</td>
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<td>Lordosis Distribution Index 118%</td>
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<tr>
<td>Pelvic Proportion</td>
<td>Severe Retroversion 3</td>
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<tr>
<td>L1-S1 Lordosis 17</td>
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<td>Relative Sagittal Alignment 20.52</td>
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<tr>
<td>Ideal Lordosis 45.12</td>
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<td>Spino-Pelvic Proportion Severe Positive Alignment 3</td>
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<tr>
<td>Lordosis Proportion</td>
<td>Severe Hypolordosis 3</td>
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<tr>
<td>L4-S1 Lordosis 20</td>
<td></td>
<td>Global Tilt 18</td>
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<tr>
<td>Lordosis Distribution Proportion</td>
<td>Hyperlordotic Maldistribution 3</td>
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<tr>
<td>Spino-Lumbar Tilt 18</td>
<td></td>
<td>Ideal Global Tilt -2.52</td>
</tr>
<tr>
<td>Global Tilt 18</td>
<td></td>
<td>Relative Sagittal Alignment 20.52</td>
</tr>
<tr>
<td>Spino-Pelvic Proportion</td>
<td>Severe Positive Alignment 3</td>
<td></td>
</tr>
</tbody>
</table>

**Age Adjustment**
- PT ‘0’ = 19
- PI-LL ‘++’ = 24
- SVA ‘+’ = 5.4 cm

**Rod Breakage**

**Pre-op** 6w 2y PJK & Rod Breakage
Conclusion

• GAP score
  – is a new PI-based proportional method of analyzing
  – the individualized sagittal plane

• GAP score
  – compared to Schwab modifiers, which uses average absolute value thresholds
  – better correlates to HRQoL scores and
  – better predicts mechanical complications

• Preoperative planning & setting surgical goals in the sagittal plane
  – on the basis of the proportional indices reflected by the GAP score
  – may decrease the rate of mechanical complications.
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