Sagittal Alignment

Cervical Balance Should Be Considered in All Cervical Surgery

Sigurd Berven, M.D.
Professor in Residence
University of California
San Francisco

Disclosures

- Research/Institutional Support:
  - NIH, AO Spine, OREF AOA
- Consultancies/Scientific Advisory:
  - Medtronic, DePuy, Biomet, Stryker, Globus
- Ownership/Stock/Options:
  - Co-Align, Providence Medical, Simpirica
- Royalties:
  - Medtronic

Overview

- Sagittal Alignment in the Cervical Spine
- Radiographic Assessment of Cervical Alignment
- Impact of Cervical Alignment on Health Status
- Correlations of Cervical Alignment and Lumbopelvic Parameters
  - Chain of Correlation
- Redefining Goals of Surgical Strategies
Resolved

• Cervical Kyphosis is strongly associated with health status and neck disability

• Restoration of alignment in the cervical spine is an important goal of all cervical surgeries

Clinical Equipose

• Variability in operative strategies are clear evidence of the absence of an evidence based approach

Right and Wrong
6 months post op
Cervical Radiographical Alignment

Comprehensive Assessment Techniques and Potential Importance in Cervical Myelopathy

Christopher F. Azzen, MD; Benjamin H. Grossel, MD; Justin J. Schonen, MD; Frank J. Schmack, MS

Influence of Spinal Deformity on Management and Outcome of Cervical Spondylotic Myelopathy

Define Measurements of Cervical Alignment

Cervical Alignment has important implications regarding Cervical Pathology including Myelopathy and overall HRQoL

Cervical alignment is directly correlated with thoracolumbosacral alignment and T1 slope

Measuring Cervical Alignment

- Cobb Method
  – C1 or C2 to C7

- Harrison Posterior Angle Method

- Jackson Physiologic Stress Lines

Measuring Cervical Lordosis

- Cobb Method

- Jackson Method
**Harrison Tangent Method**

- Most accurate method to depict what is happening segmentally within the cervical spine

**Cervical Spine Mobility**

- Most mobile region of the spinal column
Asymmetry of Segmental Lordosis

<table>
<thead>
<tr>
<th>Level</th>
<th>Angle (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1-C2</td>
<td>2.1 ± 0.9</td>
</tr>
<tr>
<td>C2-C3</td>
<td>-3.2 ± 7.0</td>
</tr>
<tr>
<td>C3-C4</td>
<td>3.9 ± 3.2</td>
</tr>
<tr>
<td>C4-C5</td>
<td>-1.5 ± 3.0</td>
</tr>
<tr>
<td>C5-C6</td>
<td>-0.6 ± 4.4</td>
</tr>
<tr>
<td>C6-C7</td>
<td>-1.1 ± 5.1</td>
</tr>
<tr>
<td>C7-T1</td>
<td>-1.5 ± 4.3</td>
</tr>
<tr>
<td>Total (C1-T1)</td>
<td>-1.9</td>
</tr>
</tbody>
</table>

Values presented as mean ± SDs, and the negative signs indicate kyphosis in the segmental plane.
*Adapted from Horikawa et al.*

Does the sagittal alignment of the cervical spine have an impact on disk degeneration? Minimum 10-year follow-up of asymptomatic volunteers

Eijiro Okada · Mariya Matsumoto · Daijiro Iwaihara · Kazuhiko Chiha · Yoshiki Toyama · Hirokazu Fujisawa · Tatsuhiko Motoshima · Yajir Nejikawa · Takeshi Hachimoto · Jim Okawa · Masahiko Watanabe · Takeshi Takahata

• Disc Degeneration is associated with a loss of segmental lordosis in the cervical spine
Cervical Sagittal Vertical Axis

- Sagittal translation of the c-spine

Scoliosis Research Society—Schwab Adult Spinal Deformity Classification

A Validation Study

Final Curve Types

- Thoracic only
- Thoracic/Thoracolumbar
- Cervicothoracic/lumbar
- Monoradiographic
- Bilateral
- Gross or Cobb > 10°
- No Gross Coronal Deformity (non coronal curves ≤ 10°)

Sagittal Modifiers

- Minimally 10°
- ≤ 10°
- ≥ 10°
- ≥ 15°
- Global Assessment
- ≥ 20°
- ≥ 25°
- ≥ 30°
- ≥ 35°

LL: Lordosis
PI: Pelvic Incidence
SVA: Sagittal Vertical Axis
PT: Pelvic Tilt
Traditional measures of sagittal balance focused upon the thoracolumbar unit
Consideration of the Cranial center of mass as the goal of optimal sagittal alignment
Cervicothoracic deformity is an important component of sagittal imbalance

Cranial Centre of Mass (CCOM)

- Goal of balanced spine
- CCOM alignment with COG
  - Head over Femoral Heads

<table>
<thead>
<tr>
<th></th>
<th>20- to 40-Yr-Old (Mean ± SD)</th>
<th>60- to 80-Yr-Old (Mean ± SD)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCOM (mm)</td>
<td>9.0 ± 31.6</td>
<td>41.2 ± 33.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>C2 (mm)</td>
<td>-2.7 ± 32.7</td>
<td>32.1 ± 33.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>C7 (mm)</td>
<td>-16.4 ± 31.5</td>
<td>10.6 ± 27.8</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
Extending the Scope of Vision

• “E-hole over A-hole”
Dr. Nunley’s Patient

The Impact of Standing Regional Cervical Sagittal Alignment on Outcomes in Posterior Cervical Fusion Surgery

- Study Purpose
  - Evaluate relationship between sagittal alignment of cervical spine and patient-reported HRQOL scores following multi-level posterior cervical fusion
  - Identify radiographic parameters in cervical spine most predictive of postoperative disability
MATERIALS AND METHODS

• Retrospective analysis (2006 – 2010)

• Clinical Outcomes
  – NDI
  – SF-36 PCS
  – VAS

• Radiographic Outcomes
  – C2-C7 Lordosis
  – C2-C7 SVA
  – T1 Slope
  – T1 Slope – C2-C7 Lordosis

Patient Demographics

• 113 patients (M=61, F=52)
• Mean age: 59 ± 12 years
• Most common indications for long segment cervical fusion:
  – Cervical stenosis (n = 65)
  – Myelopathy (n = 38)
  – Deformity (n = 14)
  – Degenerative disc (n = 13)
• Mean number of levels fused: 5.6 ± 1.9
• Average follow-up time: 187 ± 108 days

Cervical Measurements
Measurement of cervical SVA

- C2-C7 SVA
  - Distance between plumb line dropped from centroid of C2 and C7

Significant Correlations: Radiographic Measures and HRQOL Scores

<table>
<thead>
<tr>
<th>Radiographic Measure</th>
<th>HRQOL Score</th>
<th>No. Cases</th>
<th>Pearson's Correlation Coefficient</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1-C7 SVA</td>
<td>NDI</td>
<td>108</td>
<td>0.1863</td>
<td>0.0535</td>
</tr>
<tr>
<td>C1-C7 SVA</td>
<td>PCS</td>
<td>58</td>
<td>-0.4097</td>
<td>0.0014*</td>
</tr>
<tr>
<td>C2-C7 SVA</td>
<td>NDI</td>
<td>108</td>
<td>0.2015</td>
<td>0.0365*</td>
</tr>
<tr>
<td>C2-C7 SVA</td>
<td>PCS</td>
<td>58</td>
<td>-0.4262</td>
<td>0.0009*</td>
</tr>
<tr>
<td>CGH-C7 SVA</td>
<td>NDI</td>
<td>108</td>
<td>0.1873</td>
<td>0.0522</td>
</tr>
<tr>
<td>CGH-C7 SVA</td>
<td>PCS</td>
<td>58</td>
<td>-0.3613</td>
<td>0.0053*</td>
</tr>
</tbody>
</table>

Correlation between C2-C7 SVA and NDI Scores

[Graph showing correlation between C2-C7 SVA (mm) and NDI scores]
Determinants of Cervical Lordosis

- Chain of Correlation
  - T1 Tilt
  - Lumbosacral parameters
  - Thoracic Kyphosis

Factors determining cervical spine sagittal balance in asymptomatic adults: correlation with spinopelvic balance and thoracic inlet alignment

Sang-Hun Lee, MD, PhD*; Eun-Seek Son, MD, PhD*; Eun-Min Seo, MD, PhD,*; Kyung Seo Suk, MD, PhD*; Ki-Tack Kim, MD, PhD*
Goals for Restoring Cervical Lordosis

The influence of thoracic inlet alignment on the craniocervical sagittal balance in asymptomatic adults.

Chain of Correlation

Pelvic Incidence: LL  as  TIA: CL

Concept CT “Incidence” - T1 slope
Subjacent Alignment

- Cervical Alignment depends on subjacent alignment
- Pelvic retroversion and lumbar hyperlordosis in primary cervical deformity
- Cervical correction results in improvement in normalization of compensatory parameters

How Much Lordosis is Needed?
Regional Parameters

- CL = +45 degrees
- C2 SVA = 85 mm

Global Parameters

- C2 SVA = -89 mm
- C7 SVA = -104 mm
- CGH SVA = -46 mm
- CL = +45 degrees
- LL = -64 degrees
- TK = 94 degrees
- PT = 0 degrees
Regional Parameters

- CL = -27 degrees
- C2 SVA = 36 mm

Global Parameters

- C2 SVA = -4 mm
- CGH SVA = -10 mm
- C7 SVA = -24 mm
- CL = -27 degrees
- TK = 65 degrees
- LL = -67 degrees
- PT = 12 degrees
Conclusions

Sagittal deformity has an important and measurable impact on Health-related Quality of Life

Measurement of Pelvic and Craniocervical parameters are important for accurate assessment of deformity

Goals for deformity correction are:
  - SVA<4cm
cSVA<4cm
  - Match PI and LL
  - Match TIA and C2-C7 lordosis

Thank You

UCSF Center for Outcomes Research
Chain of Balance

Interrelationship between regions of the spine in which the role of the pelvic vertebra is to adopt a posture that conserves muscular energy.

Cone of Economy

Minimum muscular energy is required to maintain balance between the heavy cephalic vertebrae (the head) and the polygon of support (both feet).
Sagittal Balance

*Cone of economy*

- Muscle demand
- Fatigue
- Pain/Disability
- Loss of forward gaze
- Loss of head over pelvis

Jean Dubousset

Sagittal Malalignment

- **Clinical Presentation**
  - Imbalance
  - Difficulty with horizontal gaze
  - Early fatigue
  - Intractable pain

Correlation of Radiographic Parameters with HRQOL


- Multicenter database with >1200 pts with adult spinal deformity
- Predictor variables:
  - Curve magnitude
  - Curve location
  - Trunk shift
  - Global sagittal balance
  - Global coronal balance
- Outcome variable:
  - SF-36
  - SRS-22
Correlation of Radiographic Parameters and Clinical Symptoms in Adult Scoliosis

Chouman, MD; Sigal Baran, MD; Kerth Buwell, MD; William Horton, MD; and John B. Doros, MD.

Correlation of HRQoL with Global Sagittal Balance

Pelvic Tilt = 43
Sacral Slope = 10
• The pelvic incidence is the primary determinant of the sagittal balance of the spine
• Chain of interdependence between the pelvic incidence and other spinal parameters
Spontaneous improvement of cervical alignment after correction of global sagittal balance following pedicle subtraction osteotomy

Presented at the 2012 Joint Spine Section Meeting

Clinical article

JUSTIN S. SMITH, M.D., PH.D.,’ CHRISTOPHER L. SHAPIRO, M.D.,’ VIRGINIE LAFAGE, PH.D.,’ BENJAMIN BOUTONNE, M.D.,’ FRANK SCHWARZ, M.D.,’ RICHARD HOYT, M.D.,’ ROBERT BART, M.D.,’ BRIAN O’SHAUGHNESSY, M.D.,’ SHAY ROSS, M.D.,’ SERENA S. HE, M.D.,’ VEDAT DENER, M.D.,’ CHRISTOPHER P. ASHTY, M.D.,’ AND INTERNATIONAL SPINE STUDY GROUP

J Neuroumg Spine 17:000–000, 2012