THE SPINE BONE IS CONNECTED TO THE HIP BONE:
THE IMPORTANCE OF SAGITTAL BALANCE IN THE MANAGEMENT OF THE ADULT SPINE

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DISCLOSURES

• Editorial Board: Spine Deformity, Global Spine Journal, Clinical Orthopedics and Related Research

• Board membership: AOA

• Royalties: Nuvasive

• Speaker’s fees: Depuy
• 69 yo healthy WF
• Dx with scoli in 20’s
• No Rx
• Noticed decreased mobility, increased fatigue, difficulty standing upright
• c/o “I keep getting slower”
• No pain
• Still swims and walks regularly
- Scoli 40
- PI 60
- LL 25
- SVA 10 cm
• Walks with short stride
• No pelvic rotation
• Very inefficient
WHAT SHOULD BE ADDRESSED FIRST?

- No hip or knee pain
- Nearly ankylosed
- Outcomes with stiff joints less ideal than painful joints

- No back pain
- Difficulty standing upright
- Surgical correction of spinal deformity
  - Risks of surgery
  - Persistent pain
  - Neurologic
67 yo WF presented to “famous spine doctor” in LA, who cares for “all the celebrities”

c/o groin pain > back pain

Scoliosis

Spinal stenosis
• 67 yo WF presented to “famous spine doctor” in LA, who cares for “all the celebrities”
• c/o groin pain > back pain
OVERVIEW

• Sagittal balance
  • Importance in achieving optimal patient outcomes in spine surgery
• Effect of hip disease on spinal conditions and vice versa
WHAT SHOULD BE ADDRESSED FIRST?
ANKYLOSING SPONDYLITIS
ANKYLOSING SPONDYLITIS
Impact of coexistent lumbar spine disorders on clinical outcomes and physician charges associated with total hip arthroplasty

- Prather et al, TSJ. 2012
- Retrospective review, single institution
- 3206 patients THA 1996-2008
  - 566 (18%) seen in spine
    - 59% F
    - 65.6 yo with lumbar and hip ds v 58.5 yo hip disease only
  - THA only: Greater improvement in HHS, UCLA and pain scores (p=0.0001)
  - THA and lumbar: avg $2668 more in charges per episode
  - Episode avg’d sig longer if both diagnoses (2166 v 1598 d, p<0.001)
LUMBAR SPINE DISEASE NEGATIVELY AFFECTS OUTCOMES AFTER TOTAL HIP ARTHROPLASTY

- Medicare sample 2005-12 (Pearldiver)
- Increased rates of dislocation, revision, fracture and infection if lumbar spondylosis, ankylosing spondylitis, HNP, DDD, spondylo
- RR 1.49 (1.16 to 1.93)
SAGITTAL IMBALANCE

- Forward lean, inability to stand upright
- Achievement of sagittal balance → outcomes

Glassman, 2004

Figure 3. Deterioration in ODI score was noted as the region of maximal kyphosis progressed from high thoracic to lumbar spine.
SAGITTAL BALANCE

- Lumbar fusion 15 years ago
- Mixed satisfaction
- Came back for junctional kyphosis
- Dx: flatback, PJK
- Underwent PSO, prox extension of fusion
- Very pleased with second operation
SAGITTAL BALANCE

- Lumbar fusion 15 years ago
- Mixed satisfaction
- Came back for junctional kyphosis
- Dx: flatback, PJK
- Very pleased with second operation
- “Did you get a face lift?”
RADIOGRAPHIC EVALUATION

- Scoliosis
- Sagittal balance
- Neurologic compression
- Instability
- Relationship of spine to pelvis
  - Pelvic incidence: fixed
  - Pelvic tilt
  - Sacral slope
A Clinical Impact Classification of Scoliosis in the Adult

Frank Schwab, MD,* Jean-Pierre Farcy, MD,* Keith Bridwell, MD,† Sigurd Berven, MD,‡ Steven Glassman, MD,§ John Harrast, MS,‖ and William Horton, MD¶

- **Significant**
  - Spondylolisthesis
  - Lateral Subluxation
  - Lumbar lordosis
  - Thoracolumbar alignment
  - Sagittal Alignment (SVA)
- **Not significant**
  - Coronal Cobb
  - Age
  - Adolescent vs. de-novo scoliosis

**Statistically significant:** SRS-22, ODI, SF-12/36

Slides courtesy of Virginie Lafage and Frank Schwab
SRS-SCHWAB CLASSIFICATION 2012

3 Sagittal Modifiers

**Pl minus LL**
- 0: within 10°
- +: moderate 10-20°
- ++: marked >20°

**Global alignment**
- 0: SVA < 4cm
- +: SVA 4 to 9.5cm
- ++: SVA > 9.5cm

**Pelvic Tilt**
- 0: PT<20°
- +: PT 20-30°
- ++: PT>30°
• #1 most important parameter

• Correlation with
  – SRS (appearance, activity, total)
  – ODI (Walk, stand)
  – SF12 (PCS)

• r-values
  – $0.42 < r < 0.482$
  – $p < 0.000$
SVA AND T1SPI

- Second most important parameter
- Correlation with
  - SRS (appearance, activity, total)
  - ODI
  - SF12 (PCS)
- r-values
  - $0.40 < r < 0.46$
    - $(p<0.0001)$
- T1 tilt had greater correlation with HRQOL compared to SVA.
PELVIC TILT

- Third most important parameter

- Correlation with
  - SRS (appearance, activity, total)
  - ODI (Walk, stand)
  - SF12 (PCS)

- Correlations with HRQOL
  - $0.37 < r < 0.41$
  - $p < 0.000$
EXAMPLE OF CLASSIFICATION

Double curve Type D
PI-LL = 3° Grade 0
PT = 24° Grade +
SVA = -4.5cm Grade 0

Type D, PT +
EXAMPLE OF CLASSIFICATION

Thoracic curve Type T
PI-LL = 51° Grade ++
PT = 50° Grade ++
SVA = 13cm Grade ++

Type T, PI-LL++, PT ++, SVA ++
IMPACT OF CHANGE IN CLASSIFICATION GRADE ON HRQOL

<table>
<thead>
<tr>
<th>Change in PT grade</th>
<th>ODI</th>
<th>PCS</th>
<th>SRS Activity</th>
<th>SRS Pain</th>
<th>SRS Appearance</th>
<th>SRS Mental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chi Square</td>
<td>0.002</td>
<td>0.085</td>
<td>0.005</td>
<td>0.32</td>
<td>&lt;0.001</td>
<td>0.779</td>
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</table>

Change in PT grade does impact the likelihood of reaching MCID

<table>
<thead>
<tr>
<th>Change in SVAT grade</th>
<th>ODI</th>
<th>PCS</th>
<th>SRS Activity</th>
<th>SRS Pain</th>
<th>SRS Appearance</th>
<th>SRS Mental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chi Square</td>
<td>0.001</td>
<td>0.122</td>
<td>0.001</td>
<td>0.063</td>
<td>&lt;0.001</td>
<td>0.624</td>
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</table>

Change in SVA grade does impact the likelihood of reaching MCID

<table>
<thead>
<tr>
<th>Change in PI-LL grade</th>
<th>ODI</th>
<th>PCS</th>
<th>SRS Activity</th>
<th>SRS Pain</th>
<th>SRS Appearance</th>
<th>SRS Mental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chi Square</td>
<td>0.011</td>
<td>0.037</td>
<td>&lt;0.001</td>
<td>0.006</td>
<td>&lt;0.001</td>
<td>0.035</td>
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</table>

Change in PI-LL grade does impact the likelihood of reaching MCID
HOW TO ACHIEVE SPINAL BALANCE?

Jean Dubousset

- Dynamic measure
- Alignment = static measure

- Better understanding of neurologic concerns: Parkinson’s, MS, aging
  - Not yet quantified

Deviation from Stable Zone =>
Increased Muscle/energy use
SAGITTAL BALANCE

• Is sagittal imbalance
  • structural → osteotomies
  • secondary → decompression
SAGITTAL BALANCE

- Is sagittal imbalance
  - structural ➔ osteotomies
  - secondary ➔ decompression
SAGITTAL BALANCE

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SAGITTAL BALANCE

- Is sagittal imbalance
  - structural → osteotomies
  - secondary → decompression
CAUSES OF INABILITY TO STAND UPRIGHT: NOT EVERYONE NEEDS A PSO

- Hip pathology/OA
- Kyphosis
  - Thoracic
  - Cervicothoracic
- Spinal stenosis
- Spondylolisthesis
- Back pain
  - Pseudoarthrosis
  - Instrumentation failure
  - Adjacent segment disease
  - Back pain
- Trunk muscle weakness
- Flatback
SAGITTAL BALANCE FOR DEGENERATIVE SPINE SURGEONS

- Avoidance of contributing to sagittal imbalance
  - Proper intraop positioning: hips extended NOT flexed
  - Avoid distracting in the lumbar spine
  - Restore disc height and segmental lordosis where indicated
- Segmental lordosis as foundation for future
  - May decrease ASD
- \(2/3\) of lordosis at L4-S1
MULTIPLE TIMES RE-OPERATED FOR ADJACENT SEGMENT DISEASE

2000

2005

2008
ADJACENT SEGMENT DISEASE
• Underwent PSO
• Resolved her leg symptoms
• Now taking less pain meds than she had in years
• Thinking about returning to work 6 m post op
SURGICAL OPTIONS FOR SPINAL REALIGNMENT

- Posteriorly based osteotomies
  - ± TLIF, PLIF
- Anterior interbody fusion
- Lateral interbody fusion
  - Anterior column release
- Combined ASF/PSF or LSF/PSF
- Pedicle subtraction osteotomy
- Vertebral column resection
- Extended VCR
  - Use of cage
SELECTION OF SURGICAL APPROACH

Severity of deformity
- Sagittal imbalance
- Coronal imbalance
- Combined deformities
- Shoulders, pelvis
- Co-existing hip, knee pathology

Flexibility of spine
- Prior surgery
- Disc height/flexibility
- Prior interbody fusion
- Need for decompression
- Should the pelvis be included?
- How proximal?
SELECTION OF SURGICAL APPROACH

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- Need for decompression
- Should the pelvis be included?
- How proximal?
- Risks of going for that home run
EFFECT OF AGING ON SAGITTAL BALANCE: LIFE IS A KYPHOSING EVENT

...and gravity will always win!
AGE-ADJUSTED ALIGNMENT THRESHOLDS

<table>
<thead>
<tr>
<th>AGE</th>
<th>PT</th>
<th>PI-LL</th>
<th>SVA</th>
</tr>
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<tbody>
<tr>
<td>&lt;35</td>
<td>11.0</td>
<td>-10.5</td>
<td>-30.5</td>
</tr>
<tr>
<td>35-44</td>
<td>15.4</td>
<td>-4.5</td>
<td>-5.5</td>
</tr>
<tr>
<td>45-54</td>
<td>18.8</td>
<td>0.5</td>
<td>15.1</td>
</tr>
<tr>
<td>55-64</td>
<td>22.0</td>
<td>5.8</td>
<td>35.8</td>
</tr>
<tr>
<td>65-74</td>
<td>25.1</td>
<td>10.5</td>
<td>54.5</td>
</tr>
<tr>
<td>&gt;75</td>
<td>28.8</td>
<td>17.0</td>
<td>79.3</td>
</tr>
</tbody>
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Lafage and Schwab, SRS 2015
SPINOPELVIC BALANCE

- Increasing recognition of relevance of pelvic incidence
- Aging decreases hip flexibility, trunk strength, lumbopelvic flexibility
- $\text{LL} = \text{PI} \pm 10^\circ$
- $\text{TK}+\text{PI}+\text{LL} \leq 45^\circ$
MILD TO MODERATE IMBALANCE: POSTERIOR

- Intraoperative positioning
  - Hips full extension
- Decompression if indicated
- Posteriorly based osteotomies
- Interbody fusion if indicated
- Necessitates flexible disc
- Can gain ~10-20 degrees of lordosis
MILD TO MODERATE IMBALANCE: POSTERIOR
POSTERIORLY BASED INTERBODY FUSIONS

- Multilevel degenerative spondylosis with spinal stenosis
- PI 54, LL 25
- Decompression fusion with lordotic TLIF’s and wide facetectomies
- LL improved to 43
MILD TO MODERATE IMBALANCE: ANTERIOR

- Short segment only
- May require formal decompression as well if severe stenosis
  - Inadequate indirect decompression
SMITH-PETERSEN OSTEOTOMIES

- More graduated correction, multi levels
- Include/correct pseudo levels
- Less EBL, neuro risk
- Cannot be performed at site of solid ASF
COMBINED ANTERIOR/POSTERIOR OSTEOTOMIES

- Major truncal imbalance
- Open/unfused disc spaces
- Interbody fusions may be indicated for large segmental corrections
CORONAL AND SAGITTAL IMBALANCE
72 YO WF, SEVERE LBP, LEANING TO RIGHT
Between stages
• 66 yo retired lawyer from S. Cal
• Prior
  • Lumbar decompression
  • Lumbar fusion L3-S1
  • lumbar interbody fusion L3-S1 (ALIF, XLIF)
• Unable to stand straight
• Desirous of PSO
ACR TECHNIQUE—ALL Release

Courtesy Behrooz Akbarnia, MD

Direct visualization and release of ALL, indirectly release the rest

Plate/screw fixation needed due to loss of ALL as tension
• Underwent anterior column release,
• Staged PSF, possible PSO
• Intraoperative measurement after SPO’s demonstrated sufficient lordosis
Anterior Column Realignment (ACR) for Focal Kyphotic Spinal Deformity Using a Lateral Transpsoas Approach and ALL Release

Behrooz A. Akharnia, MD,* † Gregory M. Mundis, Jr, MD,* Payam Moazzaz, MD,* Nima Kabirian, MD,* Ramin Bagheri, MD,* Robert K. Eastlack, MD,‡ and Jeff B. Pawelek, BS*
PEDICLE-SUBTRACTION (THOMASEN) OSTEOTOMIES

- Max reliable correction 30 deg
  - (up to 50 deg)
- Rapid, reliable fusion
- Neuro risk-work around neural elements
  - shortening
- Greater EBL
- Can avoid anterior (vascular) scar
- Best in presence of existing 360 fusion
  - High rate of pseudo if open disc spaces adj to PSO
PEDICLE-SUBTRACTION (THOMASEN) OSTEOTOMIES

• Perform more distally
  • Lower neuro risk
  • Better overall sagittal correction
  • More physiologic

• Requires 3 segments distal fixation
  • L3, L4 common level
  • One- or two-plane correction
  • Limited coronal correction
• 71 yo healthy male, avid road biker
• 2005 L3-S1 decompression
• 2006 L2-S1 decompression fusion
• 2011 Proximal extension to T11

• In 2011, we maintain his lordosis at 50°, but his PI measures 78°

• He continues to do well. He walks with a slight crouch, but even when I ask him, he doesn’t notice…

    ....good thing he’s a rider, not a walker
• Presented all options and pros and cons
• Sought second opinions
• Elected PSO with proximal extension
• Rode 84 mi with 8200 ft of climb as pre-birthday ride

• PI 71
• LL 75
• Pleased with progress
VERTEBRAL COLUMN RESECTION: INDICATIONS

• Hemivertebra
• Congenital kyphosis
• Thoracic deformity
• Cervicothoracic deformity
• Complex deformity
• Tumor
**SURGICAL TECHNIQUE OPTIONS**

**Anterior only**
- Segmental kyphosis

**Posterior only:**
- Short (≤3 levels) fusion
- ~5 deg per level
- Supplement by interbody

**ASF/PSF**
- Open disc spaces
  - Need for interbody fusion
  - More harmonious lordosis

**PSO**
- Circumferential fusion present
  - Can extend to proximal disc
- Sagittal > coronal correction desired
- 30-50 deg correction

**VCR**
- Severe kyphotic deformity
- Complex deformity
HIP AND SPINE DISEASE

- Sing et al, J Arthroplasty 2016 31(9 Suppl) 227-232
- Pearldiver study
- 18% of THA patients have lumbar disease
- 2% of THA patients have had prior fusion
- Higher rate of hip dislocation if >3 level fusion (2.4% v 7.5%, RR 7.5%)
- Higher rate of revision at 2 yrs if > 3 level fusion (3.4% v 7.8%, RR 2.26)
CONCLUSION

• Surgical outcomes for adult spinal deformity – and all spine surgery -- improved when pelvic and hip alignment considered

• Better understanding of how hip (and knee) pathology can further improve our results