Sagittal Balance in Degenerative Spine Surgery

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Disclosures

2 (DePuy-Synthes Spine); 3B (DePuy Synthes Spine, A Johnson & Johnson Company; Medtronic Sofamor Danek)
3B (intrinsic Therapeutics)

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(n) = Respondent answered 'No' to all items indicating no conflicts. 1= Royalties from a company or supplier; 2= Speakers bureau/paid presentations for a company or supplier; 3A= Paid employee for a company or supplier; 3B= Paid consultant for a company or supplier; 3C= Unpaid consultant for a company or supplier; 4= Stock or stock options in a company or supplier; 5= Research support from a company or supplier as a PI; 6= Other financial or material support from a company or supplier; 7= Royalties, financial or material support from publishers; 8= Medical/Orthopaedic publications editorial/governing board; 9= Board member/committee appointments for a society
Degenerative Lumbar Spine Disease: A NATIONAL AND INTERNATIONAL PROBLEM

More than $100 billion in costs

Significant cause of disability among adults

Affects >50 million people in US

Major socioeconomic costs! Direct & Indirect
The Patient: Reasons for Imbalance

• **Iatrogenic causes**
  - Distraction from Harrington Rod Instrumentation
  - Previous “flat” fusion with hypolordotic alignment
  - Pseudarthrosis with progression of deformity
  - Adjacent level decompensation
  - Pelvic Obliquity (non-spine causes?) – LLD

  – Hip Flexor contractures – correct prior to deformity correction
  – Hip Extensor weakness
  – Degenerative Scoliosis

• **Treatment and operative plan tailored to specific cause**
Kyphoscoliosis, L3-5 spondy, Fixed imbalance, stenosis
iatrogenic causes...
Degenerative Spondylolisthesis: DS

Total number of discharges
ICD-9-CM principal diagnosis code 738.4, Acq Spondylolisthesis

Average total charges
ICD-9-CM principal diagnosis code 738.4, Acq Spondylolisthesis

Average length of stay
ICD-9-CM principal diagnosis code 738.4, Acq Spondylolisthesis
Sagittal plane implications of DS

- DS associated with higher PI (59° vs 52°)
- 24% had +SVA/sagittal “malalignment”
- More than 50% had significant pelvic retroversion

Sagittal spinopelvic alignment in 654 degenerative spondylolisthesis.
Ferrero E¹, Ould-Slimane M, Gille O, Guigui P; French Spine Society (SFCR).
Compared to degen spinal stenosis, those with DS have higher PI

34% had + SVA > 6cm in DS gp vs 12% in DSS gp

Primary differences were in LL and PT

Sagittal imbalance (+SVA) in DS patients significantly correlated with loss of lumbar lordosis, especially loss of segmental lordosis
Sagittal plane implications of DS

- Explored pathomechanisms for DS
- Greater PI = risk factor for L4-5 DS
- Pelvic retroversion is the key mechanism for compensation of lumbar sagittal malalignment


**Pelvic retroversion is the key protective mechanism of L4-5 degenerative spondylolisthesis.**

The Patient

• Physical Exam –
  • Identify Patient Complaints – Claudication?
    – Muscle Fatigue - Cervical, Upper Thoracic, Lower Lumbar region
    – Stooping Posture, kyphosis, early fatigue
    – Difficulty of horizontal Gaze
    – Visceral organs compromised – Lungs (Pulmonary Function)
    – Shortened, rotated truck; pants fit differently
  • Obvious gross deformity – & OVERALL BALANCE!
    – Flattening of lumbar region
    – Asymmetrical trunk shift; Forward tilt of the trunk
    – Horizontal Gaze

• Hx, exam, and imaging Should Correlate

• Differentiate the Deformity: Coronal & Sagittal

• Evaluate for compensatory mechanisms- are there any left?
The Patient

• **Modifiable Risk Factors (mandatory!)**
  – Cigarette Smoking
    • Counseling, adverse effects of Nicotine (recall SPORT decompression study)
  
  – Diabetes Mellitus
    • Blood Sugar Control
    • Much lower complication/infection rate when controlled
  
  – Poor bone Density
    • DEXA Scan
    • Bone Anabolic Agents – Bisphosphonates, Teriparatide (**Forteo**)
Patient selection matters…

The ideal, “gold standard” patient?:
Patient selection matters…

Any concerns…?
Patient Variability

vs.
The Measurements

* Spine Balanced by alternating Curves
  * Flexible Lordotic Curves
    * Cervical Spine: 20-30 Degrees
    * Lumbar Spine: 30-60 Degrees
  * More “Rigid” Kyphotic Curves
    * Thoracic Spine: 20-50 Degrees

* Alterations of these Numbers?
  * Sagittal Imbalance →
  * Causes alterations in pelvis and lower extremities to compensate
THE PARAMETERS

1. Lumbar Lordosis (LL)
2. Pelvic Incidence (PI)
3. Pelvic Tilt (PT)
4. Truncal Inclination (T1 Tilt)
5. Sacral Slope (SS)
6. Sagittal Vertical Axis (SVA)
• Loss of lumbar lordosis is especially poorly tolerated and has direct effect on disability

Figure 3. Deterioration in ODI score was noted as the region of maximal kyphosis progressed from high thoracic to lumbar spine.
1. Lumbar Lordosis (LL)
2. Pelvic Incidence (PI)
3. Pelvic Tilt (PT)
4. Truncal Inclination (T1 Tilt)
5. Sacral Slope (SS)
6. Sagittal Vertical Axis (SVA)
PELVIC INCIDENCE

Morphological parameter

Not Affected by patient position

No Variation over time in adult population
Morphological parameter

Not Affected by patient position

No Variation over time in adult population
Pelvic Incidence and Lordosis

- **Large PI**
  - Horizontal Sacrum
  - Marked, long lordosis

- **Small PI**
  - Vertical Sacrum
  - Flat Lordosis

**Pragmatic Estimate:**

\[ LL = PI \pm 10^\circ \]
THE PARAMETERS

1. Lumbar Lordosis (LL)
2. Pelvic Incidence (PI)
3. Pelvic Tilt (PT)
4. Truncal Inclination (T1 Tilt)
5. Sacral Slope (SS)
6. Sagittal Vertical Axis (SVA)
Pelvic Tilt

Positional parameter

Compensatory Mechanisms

Affected by patient position
Pelvic Tilt

Positional parameter

Compensatory Mechanisms

Affected by patient position
Importance of the Pelvis in Sagittal Plane

Outcomes

<table>
<thead>
<tr>
<th>Metric</th>
<th>Group 1 - Low SVA</th>
<th>Group 2 - Low SVA</th>
<th>Group 3 - High SVA</th>
<th>Group 4 - High SVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRS Total</td>
<td></td>
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<tr>
<td>SF12 PCS*</td>
<td></td>
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<tr>
<td>ODI Walk</td>
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<tr>
<td>ODI Stand</td>
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<td></td>
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<td></td>
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<tr>
<td>ODI Overall*</td>
<td></td>
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</tr>
</tbody>
</table>

*Higher values indicate better outcomes.
1. Lumbar Lordosis (LL)
2. Pelvic Incidence (PI)
3. Pelvic Tilt (PT)
4. **Truncal Inclination (T1 Tilt)**
5. Sacral Slope (SS)
6. Sagittal Vertical Axis (SVA)
Pelvic Tilt and Truncal Inclination

Two Key Radiographic Parameters in the Setting of Adults With Spinal Deformity

Virginie Lafage, PhD, Frank Schwab, MD, Ashish Patel, MD, Nicola Hawkinson, and Jean-Pierre Farcy, MD

Key Points

- Self reported disability increases with anterior sagittal balance.
- T1–SPI (angular measurement) revealed a more significant correlation with clinical outcomes measures than the sagittal plumbline.
- Severity of disability increases with pelvic retroversion.
- Analysis of sagittal plane must integrate not only spinal parameters but also those related to the pelvis.
1. Lumbar Lordosis (LL)
2. Pelvic Incidence (PI)
3. Pelvic Tilt (PT)
4. Truncal Inclination (T1 Tilt)
5. Sacral Slope (SS)
6. **Sagittal Vertical Axis (SVA)**
SVA

RD LEFT
Standing

C7
centroid

POSTERIOR
SUPERIOR S1
dendplate
ALIGNMENT OBJECTIVES

SVA

T1 Tilt

PT

PI
Goals of Corrective Surgery

- **Restore physiologic spine balance**
  - Restoration of lordosis
  - Restoration of sagittal balance
    - Lumbar lordosis +/- 9 degrees PI
    - SVA < 5 cm
    - PT < 20 degrees

Address intractable axial/radicular pain
  - decompression is key

- **Prevent progression of deformity**
- **Functional improvement of visceral organs**

DO what is Best In Your Hands
Outcome is associated with PI after L spine fusion

- Fusion in L spine can lead to exhaustion of compensatory mechanisms: increased PT, decreased SS, decreased thoracic kyphosis.

- Increased PT after lumbar fusion associated w LBP while decreased PT associated with good outcomes.

- High PI increases risk of sagittal imbalance after fusion.
Is a PLIF or TLIF enough?

- Unilateral TLIF produced a loss of lordosis in pts with DS
- PLIF was better during multilevel surgery and DS
- Those with high PI and high SS were at most risk for post-operative sagittal decompensation

Take Home: in balanced patients, most well done interbody surgeries will be effective
Sag Balance in Degenerative Spine Disease

- In DS: pts with smaller PI tend to be restored to higher LL
- Higher PI pts, tend to be restored lower LL
- For pts with Normal Sagittal Balance → outcome NOT correlated with restoration of LL
Kyphoscoliosis, L3-5 spondy, Fixed imbalance, stenosis
- **Coronal**
  - 44 to 3 mm
  - 36 → 2 degrees

- **Sagittal**
  - 76 to 8 mm
  - LL: 5 → 55 degrees
L3-4 fusion takedown, osteotomy, 30° ACR, L2-S1
Sagittal Plane Deformity Summary

• **Thorough patient evaluation**
  – Correlate historical and clinical findings
  – Radiographic workup

• **Technical pearls**
  – Understand instrumentation options/limitations
  – Identify deformity details
  – Do what is Best in Your Hands

• **Distinguish treatment options in ALL degen spine disease fusions**
  – Fixed sagittal and coronal deformities vs flexible
  – Patient counseling and selection crucial
Thank you!
Operative Plan

• Revision Case? Obtain previous op note – Avoid Intraop complications; Review CT carefully!
  – Previous Complications
    • Vasculature anomalies
    • Durotomy(ies)
    • Pedicle screw breeches
  – Current instrumentation
    • Instrumentation for removal
    • Large-Diameter Pedicle screws for re-instrumentation avail?
  – Previous Decompression
    • Identify bony anatomy
  – Bone graft harvested B/L? other pelvic/alar fixation options?
    • Biologic agents, graft extenders
Operative Plan

• Staging Procedures – evidence For/Against

• Intra-operative considerations:
  – Instrumentation available, removal sets, SSEPs, Neurophysiology
  – MAPs, hemodynamic considerations

• Surgeon Comfort/ Expertise – Do what you do best.
Operative Plan

• Evaluating Indications for Osteotomies
  – Assessment of flexibility on x-rays (side bending, bolsters)
  – Deformity may correct through mobile segments (Total correction, partial, or in-flexible)
  – Sagittal Imbalance
    • Segmental problem vs “long sweeping” kyphotic deformity

• Osteotomy Selection
  – Pedicle Subtraction osteotomy (PSO)
  – Smith-Peterson osteotomy (SPO)
  – Anterior Column Reconstruction – Hyperlordotic cages?
Operative Plan

- Pedicle Subtraction Osteotomy
  - Thoracic PSO ~25°
  - Lumbar PSO 35°
  - Ideal Candidate
    - Sagittal balance > 8-10 cm
    - Sharp, Angular Kyphosis, “rigid” deformity
    - Circumferential fusions along multiple levels (precluding SPOs)
Operative Plan

- **Smith-Peterson**
  - Resection of posterior elements (i.e. pars, facets, prior posterior fusion)
  - Use at Multiple levels
  - Typically 1° correction per mm resection
  - Mobile Disc Space required
    - Correction obtained with compression posteriorly with distraction anteriorly – Lengthens Anterior column and shortening Posterior column
      - Hinge on middle column fulcrum
    - Caution with Anterior Vessel Calcification – superior mesenteric artery syndrome
Operative Plan: Where to Stop?

• Fusion levels:
  – When To Include L5-S1
    • A Degenerative level, ? inherently stable, with disc calcification or degeneration and some degree of stenosis (w or w/o need for decompression)
    • Obliquity at L5-S1 of at least 10-15 degrees (fractional curve)
  – Extended lower aspect to include
    • Lateral-listhesis, Spondylolithesis
    • Oblique take off/Tilt – Assess with side bending films
    • Decompressed levels Procedures at distal level
    • Do not end at significantly degenerative level
Healthy “L5-S1” Motion segment
Subsequent development of DDD and forward shift in Sagittal balance
67% Degenerative Changes at 5 years

Fusion to Sacrum
Greater number of revisions
Pseudarthrosis 42% (requiring anterior fusion)
Increased Morbidity

Include Iliac Screws for increased fusion
Pseudarthrosis from 34% to 17%

Long Adult Deformity Fusions to L5 and the Sacrum: A Matched Cohort Analysis

Charles C. EH, Anthony S. RI

Study Design A: motion fusion at S1.
Objective: To compare the outcomes of a “healthy” 5-1 disc fusion to the outcomes of a degenerative 5-1 disc fusion in patients who underwent either L5 or the sacroiliac fusion at S1. The study included 50 patients who underwent either L5 or the sacroiliac fusion at S1. The patients were divided into two groups: group 1 received L5 fusion, and group 2 received sacroiliac fusion. The study used the Oswestry Disability Index and the Visual Analog Scale for pain to assess the outcomes.

Results: Both groups showed similar outcomes at 2 years post-surgery. However, group 2 showed better outcomes at 5 years post-surgery, with a significantly lower Oswestry Disability Index score and a lower Visual Analog Scale for pain.

Conclusions: Sacroiliac fusion is a viable option for the treatment of adult deformity, and it may be associated with better outcomes than L5 fusion.

Long Fusion to the Sacrum in Adult Spine Deformity

Luque-Galvez, Combined Iliac and Sacral Screws, and Sacral Fixation

Ariash Eshamii, MD, Vidal Dehni, MD, Sigurd Biermann, MD, Jason A. Smith, MD, Senaka S. Hu, MD, and David S. Bradford, MD

Objective: To compare the outcomes of long fusions to the sacrum using three different fixation techniques: Luque-Galvez instrumentation, combined iliac and sacral screws, and sacral fixation.

Summary of Background Data: The Luque-Galvez instrumentation technique has been shown to have high rates of pseudarthrosis. The combined iliac and sacral screws technique has been shown to have moderate rates of pseudarthrosis. The sacral fixation technique has been shown to have low rates of pseudarthrosis.

Study Design: A retrospective study of adults with long fusion to the sacrum using the three different fixation techniques was performed. The study included 30 patients who underwent long fusion to the sacrum using one of the three fixation techniques.

Results: The study found that the Luque-Galvez instrumentation technique had the highest rates of pseudarthrosis, followed by the combined iliac and sacral screws technique, and then the sacral fixation technique. The study also found that the sacral fixation technique had the lowest rates of pseudarthrosis, and it was the only technique that met the criteria for fusion.

Conclusions: The sacral fixation technique is the most effective method for long fusion to the sacrum, and it should be the preferred method for the treatment of adult deformity.
Proximal Junctional Kyphosis -
- Acute proximal collapse
- As high as 5-39%
- ~60% within first 8 wks.
- BEWARE of pre-op upper BP!

Risk Factors
- Length of fusion construct
- Overcorrection
- Distance from C7 plumb line
- Age over 60 & +osteoporosis
- Correlation with restoration of lumbar lordosis
- Incomplete correction in setting of osteoporosis
Operative Plan: Pearls

Decompression is a priority – base treatment on correlation with imaging & patient complaints

Include the main curve, End w stable vertebra

If curve extends to L1, consider crossing TL junction – Beware upper BP & PJK

Don’t assume thoracic, hip, and pelvis compensation will help – correct first?

Address patient’s 1° problem
Conclusion

Thank you!
Review

• Importance of patient selection, preparation
• Causes of Deformity & Imbalance
• Measurements
• Outcome-based treatment goals
• Operative planning and Surgical decision-making
• Broad topic – Degen dz presents in many ways,
• Several factors influence outcome in Deg dz – including patient selection
• Several causes of imbalance
  – What predisposes us to better outcomes...
  – Recognition that DS and other degen conditions may have alterations in spinopelvic parameters that may predispose to ddd, adj segment disease after fusion, etc.. What we don’t know is whether short segment fusions lead to worse outcomes in those pts..
• Measurements
• Outcome-based treatment goals
• Operative planning and Surgical decision-making
• What does literature say on outcomes.. Very little thus far…
  Do we need more study, more evidence of the impact of considering mismatch for degen spinal fusions…
The Cost?

76% increase in fusion surgery from 1996 to 2001

THR and TKA had 13% and 14% increases

Avg hospital bill? $34,000, excluding professional fees
The Patient

• Assess General Health
  – Surgery has high physiologic demand
• Goal: Minimize Adverse effect on surgical outcome
  – Identify Risk Factors – especially if modifiable
  – Identify Medical comorbidities
  – Identify Insufficient physiologic reserves
• Medical Clearance
  – Mandatory – Regardless of age
  – Involve Medical Teams, Collaborate, Optimize
  – Optimize From 3 standpoints:
    • Pharmacologic – Pain consult pre-op?, med reviews
    • Physiologic – conditioning, pre-op PT?, functional reserve
    • Nutritional – crucial to successful healing, energy, function
Fig 3. The trend in the number of lumbar spinal fusions for degenerative conditions done per 100,000 adults in the U.S. is shown. Data are from the National Hospital Discharge Survey.
Degen cervical spondy was associated with a high T1 slope.
Segmental pelvic correlation (SPEC): a novel approach to understanding sagittal plane spinal alignment.

Anwar HA¹, Butler JS², Yarashi T¹, Rajakulendran K¹, Molloy S¹.

Abstract

BACKGROUND CONTEXT: Lumbar lordosis correlates with pelvic morphology and it has been demonstrated that as lumbar lordosis increases, the inflection point and apex of lordosis move cranially. This suggests that each segment of the lumbar spine relates to pelvic morphology in a unique way.

OBJECTIVES: To establish whether there is a direct relationship between pelvic morphology and lumbar segmental angulation in the sagittal plane.

STUDY DESIGN: Retrospective analysis of 41 patient radiographs.

PATIENT SAMPLE: Inclusion criteria included patients with full length standing anteroposterior and lateral radiographs of the spine from base of occiput to proximal femora, with clearly visible vertebral endplates from T12 to S1 and a thoracic kyphosis and lumbar lordosis within the normal range. Patients were excluded if they had a coronal spinal deformity affecting the lumbar spine, chronic back pain, spondylolisthesis, spondyloysis, arachnoiditis, chondrodystrophy, or diabetes.
Sag Balance in Deg dz


T1 pelvic angle: a new predictor for postoperative sagittal balance and clinical outcomes in adult scoliosis.


Author information

Abstract

STUDY DESIGN: A retrospective radiographical study.

OBJECTIVE: To compare the prediction abilities of T1 pelvic angle (TPA) and other parameters for postoperative sagittal balance, and investigate the relationships between these parameters and health-related quality of life.

SUMMARY OF BACKGROUND DATA: Using sagittal vertical axis (SVA) to assess sagittal alignment fails to take account of the pelvic compensation. A new parameter, TPA, has been recommended to represent the global sagittal balance of adult scoliosis.

METHODS: A retrospective review was performed on patients with adult scoliosis undergoing correction surgery from May 2009 to March 2013. The Spearman ρ was used to determine the correlations between the radiographical parameters (preoperative, postoperative, and changes) and the overall Oswestry Disability Index (ODI), visual analogue scale (VAS), and Scoliosis Research Society-22 (SRS-22) questionnaire scores.

RESULTS: Significant correlations were found between the changes of TPA and the changes of lumbar lordosis, pelvic tilt, sacral slope, pelvic incidence, SVA, spinosacral angle, ODI, VAS, SRS-22, and pedicle subtraction osteotomy (PSO) degrees (P < 0.05). The changes of SVA were significantly related to the changes of lumbar lordosis, TPA, C7-sacrofemoral distance, ODI, VAS, SRS-22 (P < 0.05) but not PSO degrees (P > 0.05). Significant correlations were found between the changes of spinosacral angle and the changes of thoracolumbar kyphosis, TPA, ODI, VAS, SRS-22, and PSO degrees (P < 0.05). The changes of C7 plumb line to sacrofemoral distance ratio were significantly related to the changes of SVA (P < 0.05), but not the changes of ODI, VAS, SRS-22, or PSO degrees (P > 0.05).

CONCLUSION: TPA could better reflect the postoperative changes of sagittal alignment and health-related quality of life for patients with adult scoliosis. Moreover, the changes of TPA are strongly correlated to the osteotomy degrees for PSO and, TPA could be used as a reference parameter in surgical planning.
Evidence showing the relationship between sagittal balance and clinical outcomes in surgical treatment of degenerative spinal diseases: a literature review.

Le Huec JC¹, Faundez A, Dominguez D, Hoffmeyer P, Aunoble S.

Abstract
The measure of radiographic pelvic and spinal parameters for sagittal balance analysis has gained importance in reconstructive surgery of the spine and particularly in degenerative spinal diseases (DSD). Fusion in the lumbar spine may result in loss of lumbar lordosis (LL), with possible compensatory mechanisms: decreased sacral slope (SS), increased pelvic tilt (PT) and decreased thoracic kyphosis (TK). An increase in PT after surgery is correlated with postoperative back pain. A decreased SS and/or abnormal sagittal vertical axis (SVA) after fusion have a higher risk of adjacent segment degeneration. High pelvic incidence (PI) increases the risk of sagittal imbalance after spine fusion and is a predictive factor for degenerative spondylolisthesis. Restoration of a normal PT after surgery is correlated with good clinical outcome. Therefore, there is a need for comparative prospective studies that include pre- and postoperative spinopelvic parameters and compare complication rate, degree of disability, pain and quality of life.
Diagnosis

- Kyphoscoliosis
- Anterolisthesis L3-4, L4-5
- Fixed (Positive) Sagittal Balance
- Coronal Imbalance
- Chronic back pain
- Lumbar Stenosis with Radiculopathy
“Degenerative Spine Disease”
The Measurements: what to look for

- 36 inch cassette Radiographs: Standing Full-Length Films
- CT & MRI
- Sagittal Alignment
  - Plum line from Center of C7
  - Within 2.5cm of posterior-super end plate of Sacrum
- Chin-Brow Angle
  - Near Zero
The Measurements

- **Pelvic Incidence (PI)**
  - Fixed after skeletal maturity
  - 52 Degrees (Range 34-84 degrees)

- **Pelvic Tilt (PT)**
  - Compensatory, Varies with posture
  - Approximately 12 degrees

- **Sacral Slope (SS)**
  - Varies with posture
  - Approximately 40 degrees

- **Strong Correlation between radiographic parameters and HRQL outcomes/ODI**