High Grade Spondylolisthesis: Defining the Value of Deformity Reduction

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Disclosures

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  – Medtronic

Adult Spinal Deformity
Adult Spinal Deformity

Defining Adult Spinal Deformity

Adult spinal deformity encompasses spinal disorders that involve a malalignment:

- Global
- Regional
- Segmental level
Defining Adult Spinal Deformity

Adult spinal deformity encompasses spinal disorders that involve a malalignment:

Global
Regional
Segmental level
Evolution of Sagittal Alignment

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
Causes of Sagittal Malalignment

- Congenital anomaly
- Ankylosing spondylitis
- Iatrogenic:
  - Flatback Syndrome
  - Kyphotic Decompensation Syndrome
- Post-traumatic
- Infectious
- Neoplastic
- Osteoporotic Compression Fx
- Dysplastic Spondylolisthesis

Classification*

I) Dysplastic
II) Isthmic
  a) Lytic-fatigue fracture
  b) Elongated, intact pars
  c) Acute Fracture
III) Degenerative
IV) Traumatic
V) Pathologic
    - OI, Albers-Schoenber, disease, arthrogryposis, tumor

*Wiltse LL, Newman PH, MacNab I. CORR 117, 1975
Classification System

- Taxonomy for grouping similar conditions
  - Pathogenesis
  - Natural History
  - Risk for Progression

- Guide for decision-making regarding non-operative and operative care

Classification

- Limitations of the Wiltse Classification:
  - Based upon a mixture of morphologic and etiologic criteria
  - Imprecise in identifying forms
  - Incomplete recognition of acquired forms
Classification of Marchetti and Bartolozzi

<table>
<thead>
<tr>
<th>Developmental</th>
<th>Acquired</th>
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<tbody>
<tr>
<td>High Dysplastic</td>
<td>Traumatic</td>
</tr>
<tr>
<td>With Lysis</td>
<td>Acute Fracture</td>
</tr>
<tr>
<td>With Elongation</td>
<td>Stress Fracture</td>
</tr>
<tr>
<td>Low Dysplastic</td>
<td>Post-surgery</td>
</tr>
<tr>
<td>With Lysis</td>
<td>Direct surgery</td>
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<tr>
<td>With elongation</td>
<td>Indirect surgery</td>
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<tr>
<td>Acquired</td>
<td>Pathologic</td>
</tr>
<tr>
<td>Traumatic</td>
<td>Local Pathology</td>
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<tr>
<td>Acute Fracture</td>
<td>Systemic Pathology</td>
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<tr>
<td>Stress Fracture</td>
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<tr>
<td>Post-surgery</td>
<td>Primary</td>
</tr>
<tr>
<td>Direct surgery</td>
<td>Secondary</td>
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</table>

Developmental Spondylolisthesis

- Characterized by a congenital abnormality of the posterior elements, bony hook, facet joints, pars, or morphology of the lumbosacral spine that predisposes to the development of an isthmic spondylolysis or an olisthesis
- Encompasses the majority of spondylolisthesis in children and adolescents
Morphology of Dysplastic Spondylolisthesis

• Pelvic Incidence
  – A high pelvic incidence may be a dysplasia that predisposes to the development of spondylolysis and progressive olisthesis
Sacral Slope=  78 degrees
Pelvic Tilt=  38 degrees
Pelvic Incidence=  116 degrees
Mechanisms of Spondylolisthesis
Pelvic Parameters and Olisthesis

• Pelvic Dysplasia
  – High PI, High SS

• Nutcracker mechanism
  – Low PI, Low SS

Spondylolisthesis Classification
SDSG

- Type 1: PI=45° (nutcracker)
- Type 2: PI 45 to 90°
- Type 3: PI=60°
- Type 4: Balanced Pelvis
- Type 5: Balanced spine
- Type 6: Unbalanced spine

Spondylolisthesis Classification

- Low grade
  1. Low PI
  2. Normal PI
  3. High PI
- High grade
  4. Balanced Pelvis
  5. Retroverted
  6. Unbalanced spine
Global sagittal alignment and health-related quality of life in lumbosacral spondylolisthesis

Addi Harroun - Hubert Labelle - Julie Joces - Jean-Marc Mac-Thiong

- In high-grade spondylolisthesis, an increasing positive sagittal alignment was related to a poorer SRS-22 total score.

- Correlation with global sagittal imbalance is highest in patients with high grade olisthesis

Table 2: Correlation study between parameters of global sagittal alignment and SRS-22 total score

<table>
<thead>
<tr>
<th>Parameters</th>
<th>All patients</th>
<th>Low-grade</th>
<th>High-grade</th>
<th>Positive sagittal alignment w/prop (≤29)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1-S1 (&gt;45°)</td>
<td>0.23 0.027</td>
<td>0.000</td>
<td>0.05</td>
<td>0.087 0.001</td>
</tr>
<tr>
<td>C7-T1 (mm)</td>
<td>-0.19 0.112</td>
<td>0.024 0.000</td>
<td>-0.33</td>
<td>0.000 0.008</td>
</tr>
</tbody>
</table>

High Grade Spondylolisthesis and Lumbopelvic Parameters:

Defining the relationship between radiographic measurement and Health-related quality of life

Sigurd Berven, MD
Vedat Deviren, MD
Michael O'Brien, MD
Pierre Roussouly, MD
Hubert LaBelle, MD
Introduction

• There exists tremendous variability in the surgical strategies for management of high grade spondylolisthesis:
  – Reduction and restoration of spinopelvic radiographic parameters
    • Poussa et al, Spine 2006
    • Ruf et al, Spine 2006
• 27 pts with minimum 2 year f/r
  – 23 pain free
  – 4 with moderate pain
• 5 L5 palsies
  – 4 resolved
• Slip angle improved 36.6 to 7.6
• Sacral Inclination improved 43 to 47

• The relationship between restoration of normal lumbopelvic parameters clinical outcome has not been well-defined.
Methods: Sagittal Plane Parameters

- Incidence \( i \) (degree)
- Pelvic version \( v \) (degree)
- Sacral slope \( p \) (degree)
- Distance \( d \) (mm)
- Kyphosis (degree)
- Lordosis (degree)

Advantages of Surgical Reduction

- Improved arthrodesis
  - Biomechanics of segmental alignment
  - Improved bone surface area
- Improvement of sagittal alignment
  - Segmental
  - Global

Disadvantages of Surgical Reduction

- Compromise of neural elements
- Loss of fixation
Study Purpose

The purpose of this study is to define the relationship radiographic measures of spinopelvic balance and health-related quality of life in patients with spondylolisthesis.
Material and Methods

• Prospective observational study including enrollment from multiple centers

• Predictor variables:
  – Segmental measures (Slip angle, Meyerding Grade, sacral slope)
  – Regional measures (lumbar lordosis, thoracic kyphosis, pelvic tilt, pelvic incidence)
  – Global measures (C7 sagittal balance).

• Outcome Variables:
  – SRS-22
  – SF-12
  – Complications

– Spearman’s Rank Order Correlation was used to determine relationships between individual radiographic parameters and HRQL.
– Patients were then grouped into dichotomous deformity patterns including: High(III-V)/Low grade (I-II) by Meyerding Grade, kyphotic or lordotic at L5-S1, and high (>30 degrees) and low (<30 degrees) pelvic tilt.
  * Dichotomous variables were analyzed using Student’s t-test.
Results

• 37 adults (age 18-68) with spondylolisthesis had complete radiographic and clinical data.
• There is a moderate correlation between C7 sagittal balance and appearance (r=0.7), and activity (r=0.6) on the SRS-22 instrument.
• All other radiographic parameters had a low independent correlation with HRQL.

Results

• Grouping patients by lordotic or kyphotic slip angle at L5-S1, adults with a neutral or kyphotic angle at L5-S1 had significantly more pain (p=0.01), functional limitations (p=0.02), and mental health compromise (p=0.01) than patients with a lordotic slip angle.

Results

• Adults with a high pelvic tilt had significantly worse scores for appearance (0.05), pain (p=0.00), function (p=0.02), and physical component summary (0.05).
Results

• Adults with a high grade olisthesis (III, IV) had more limitations in physical role (p=0.04) and mental health (p=0.02) than those with a low grade olisthesis.

Conclusions

• This study demonstrates that global sagittal balance is the only individual radiographic parameter with a moderate correlation with health status.
• Grouping patients into deformity patterns, segmental kyphosis at L5-S1, olisthesis greater than grade III, and pelvic tilt greater than 30 degrees are significantly associated with a measurable compromise of health status.
• This data may support the role of deformity reduction in the management of spondylolisthesis in the adult.

Case Examples
• 21yo male with high grade spondylolisthesis
• Bilateral L5 weakness
• + Phalen Dixon
Transition from Degenerative to Deformity
Figure 4a  Figure 4b  Figure 4c

Figure 5a  Figure 5b

<table>
<thead>
<tr>
<th></th>
<th>Pre-op</th>
<th>Post-op</th>
<th>Change</th>
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<tr>
<td>SVA</td>
<td>125</td>
<td>40</td>
<td>85</td>
</tr>
<tr>
<td>LL: L1-S1</td>
<td>50</td>
<td>78</td>
<td>28</td>
</tr>
<tr>
<td>TK: T5-L2</td>
<td>30</td>
<td>36</td>
<td>6</td>
</tr>
<tr>
<td>L5-S1</td>
<td>-6</td>
<td>-6</td>
<td>0</td>
</tr>
<tr>
<td>L3 slip Neut</td>
<td>12/40 (30%)</td>
<td>x</td>
<td>X</td>
</tr>
<tr>
<td>L3 slip Flex</td>
<td>14/40 (35%)</td>
<td>x</td>
<td>X</td>
</tr>
<tr>
<td>L3 slip Ext</td>
<td>12/40 (30%)</td>
<td>x</td>
<td>X</td>
</tr>
<tr>
<td>L3-4</td>
<td>14</td>
<td>40</td>
<td>26</td>
</tr>
<tr>
<td>PI</td>
<td>86</td>
<td>86</td>
<td>0</td>
</tr>
<tr>
<td>PT</td>
<td>34</td>
<td>20</td>
<td>-14</td>
</tr>
<tr>
<td>SS</td>
<td>53</td>
<td>67</td>
<td>14</td>
</tr>
<tr>
<td>PI - LL</td>
<td>36</td>
<td>8</td>
<td>28</td>
</tr>
</tbody>
</table>
Conclusions

• Lumbopelvic parameters have an important impact on the etiology of spondylolisthesis and on the health status of spondylolisthesis.

• The role of reduction in the operative management of spondylolisthesis improves HRQoL in patient with high gradeolisthesis and unbalanced spines.

• Reduction of lumbosacral kyphosis and improvement of global sagittal alignment are important goals of deformity correction.

UC San Francisco
Clinical Outcomes Research Program
Why I Don't Reduce Spondy

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Royalties - Medtronic, Saunders Elsevier

Isthmic Spondylolisthesis: Low Grade

Goals of surgical treatment:
1. Solid Fusion
2. Neural Decompression

most common Fusion techniques

- Uninstrumented Posterior insitu fusion
- Posterior Pedicle Screw instrumentation
- Posterior instrumentation with TLIF
- Stand-alone ALIF
- Anterior + Posterior
neural decompression-
2 distinct surgical techniques

- **Direct** neural decompression via posterior approach
  - Gill Laminectomy with decompression of L5 nerves under L5 pars interarticularis

- **Indirect** neural decompression via anterior approach
  - Distract neural foramen L5-S1 decompress L5 nerves in foramen

- There does not appear to be compelling evidence that one strategy is better than the other.

Reduction of the spondylolisthesis does not improve clinical outcome.

- No correlation between slip reduction in low-grade spondylolisthesis or change in neuroforaminal morphology and clinical outcome.

Hagenmaier, BMC Musculoskelet Disord 2013
High-Grade Spondylolisthesis

Goals
Solid Fusion
Neural Decompression

Reduction benefits?
Increase fusion rate
Decrease slip progression
Improve sagittal alignment
Restore posture and gait anomaly
Restore normal anatomy = pretty x-ray
Limit fusion length
**Reduction Risks**

- Increased Neurologic Deficits
- Increased Failure during reduction
- Increased OR Time
- Increased Blood Loss

**Increased Neurologic Deficits 15-30%**

25% Bradford  JBJS 1987
75% Lehmer  Spine 1994
25% Hu  Spine 1996

Instrumentation Failure 25%

**Nerve Stretch with Reduction**

- Strain 4% 1st 50% reduction
- Strain 10% 2nd half reduction
- Conduction loss with 6% strain
- Permanent damage with 12% strain

Petraco  Spine 1996
Avoid Reduction
- No complications
- No cosmetic dissatisfaction
  • Wiltse 1989
- Progression without instrumentation
  • Kumar 2000
- Circumferential fusion
  • Molinari 1999

Interbody Fusion
High-Grade Slip
• Dowel Strut Grafts
  – Anterior
  – Posterior
Dowel Fibular Strut

- Hanson, Spine 2002
  - 17 pts
  - Translation improved 1.4 grades
  - Slip angle improved 14°
  - No loss of correction
  - No Neuro deficits
- Smith, JBJS 1999
- Roca, Spine 1999
- Smith Bradford, Spine 2001
  - 9 pts
  - Excellent results
- Laursen, JOSD 1999
  - 10 pts
  - Kellogg-Speed
- Boachie, Spine 2002
  - 6 pts
  - Screw transfixation
  - Slip angle improved - not translation
  - SRS outcomes-good
- Slosar, The Spine Journal 2001
  - Threaded cage
**Dowel Fibular Strut**

- 25 pts, 1992-2002
  - Grade III-V (average 3)
  - 17 A + P: 8 Post only
  - F/U 39 mos (30-71)
  - EBL 692 (500-1500) no diff A+P vs P only
- Slip angle 35° post op
- 100% fusion: No increase
- No neuro deficits
- VAS 8.2 post op 3.4
- SRS outcome 94% satisfied

Reduction not required for good long-term outcome

- High-grade isthmic spondylolisthesis
- 35 patients
- In situ fusion-No Reduction
- 15 yrs old (9-25)
- Follow-up 29 yrs (23-35) Age 43 (37-51)
- Work, SF-36, EQ-5D, Zung, ODI, Million, VAS back and leg
- Good outcomes in Quality of Life, disability, pain, ability to work

Conclusions

- Complete reduction not supported in literature
- Partial reduction (slip angle) achieved with minimal complications
- Circumferential fusion with fibular strut
  - High fusion rate
  - Low complications
  - Good function and cosmesis
Pedicle Subtraction Osteotomy: Indications, Technique, Tips and Pearls

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University of Nevada School of Medicine
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Disclosures

• Consultant, Royalties Dupuy-Synthes Spine
• Received research grants from Stryker Spine

Outline

• Illustrative Cases
• Sagittal Balance
• Radiographic parameters
• Indications
• Technique
• Illustrative Cases
67 y/o female with h/o AIS, leg pain, LBP,
56 y/o female, multiple surgeries, hx Scoliosis
Pelvic Incidence and Tilt

PI = 47
PT = 38

Sagittal Balance and Symptoms
Glassman, Berven et al Spine 2005

- Curve type, location, magnitude
- Coronal and Sagittal balance
- SRS 22, ODI, SF-12
- Thoracolumbar curves worse function
- Positive Sagittal Balance > 5cm
  - Most important reliable radiographic predictor of health status
  - Worse pain, function, and self image

Sagittal Balance and Symptoms

- 752 pts
- 352 with positive sagittal imbalance
- Kyphosis poorly tolerated in lumbar region
- Health status deteriorated with progressive increase in positive sag balance over 5cm

Glassman, Bridwell et al Spine 2005
Sagittal Balance and Symptoms

- 5 year minimum follow-up of PSO’s
- Sagittal vertical axis < 8 cm at ultimate follow-up was significant for better SRS outcomes scores (P = 0.038).

Pelvic Parameters

- Incidence = Pelvic Tilt + Sacral Slope
- PI – constant
- PT, SS – positional, determined by PI

Berthonnaud et al E Spine J 2005

- 214 developmental spondylolisthesis; 180 controls
- Greater PI, SS, LL (p<0.01) vs controls
- PI, SS, LL correlate with slip severity

Spine 2004
Sagittal Balance and Pelvic Parameters

- Linear regression models demonstrated
- threshold radiographic spino-pelvic parameters for ODI ≥ 40 included:
  - PT ≥ 22° (normal 10-11°)
  - SVA ≥ 46 mm,
  - PI-LL ≥ 11°

Schwab et al Spine 2013

Surgical Goals

Radiographic

- SVA 5 – 8cm
- PT = < 25°
- LL = PI + 9-10°
Determining the amount of correction that is needed

- How much lumbar lordosis is necessary to achieve sagittal balance?
- Must consider pelvic incidence
- Many different formulas

• PI + LL + TK < or = 45°
Surgical Correction of Sagittal Imbalance

• Anterior
  – Restoration of disc height, Lordosis through ALIF’s lumbar spine
  – Anterior corpectomy

• Posterior
  – Osteotomies
    • Ponte/Smith-Petersen
    • Pedicle subtraction
    • Vertebral Column Resection (VCR)
      Costotransversectomy

Sagittal Balance Corrective Procedures

• ALIF (Anterior Lumbar Interbody Fusion)
  – Focal loss of lordosis (L4-L5, L5-S1 disc collapse)
  – Mild global/ focal sagittal imbalance
  – Gain 10° or > of correction each level

• Ponte/Smith Petersen
  – Schuermans/Thoracic Kyphosis
  – T-L Scoliosis Kyphosis
  – Disc spaces open
  – 5-10° per level

Sagittal Balance Corrective Procedures

• PSO (Pedicle Subtraction Osteotomy)
  – 30° to 40° correction
  – Global sagittal imbalance >10cm
  – Typically performed at Lumbar L2, L3, L4 level

• VCR (Vertebral Body Resection)
  – More severe Scoliosis/Kyphosis (thoracic)
  – Performed at apex of Kyphosis
  – Correction 50° or greater, limited by neurologic conditions
67 y/o female with h/o AIS, leg pain, LBP,
Calculation

• PI + LL + TK < or = 45°

• LL = 45° - TK - PI
• LL = 45° - 20 - 60

• LL=35° to achieve sagittal balance of 5cm
• Her LL is currently +15°, so she needs 50° of additional lordosis

L2 PSO, Multiple Ponte’s
T3 – Pelvis PSF
Pedicle Subtraction Osteotomy for the Treatment of Fixed Sagittal Imbalance

Surgical Technique

The original surgical article on which the surgical technique was presented was published in JBJS Vol. 85-A, pp. 216-221, March 2003.
56 y/o female, multiple surgeries
Pelvic Incidence and Tilt

PI = 47
PT = 38

Sagittal plane

PI = 47
PT = 18

Coronal Plane
Pelvic Tilt

Complications

• PSO
  – Neurologic: Permanent neurologic deficit, most at root level 3%. Buchowski et al Spine 2007
  – Proximal junctional kyphosis (PJK)
    • Compression fracture at upper inst level or level above
    • Development of kyphosis without fracture
      – Overcorrection
      – Osteoporosis

Thank you

Red Rock Mountains in Las Vegas
Vertebral Column Resection
Technical Tips for VCR

Khaled M. Kebaish, M.D., FRCSC
Department of Orthopedic Surgery
Johns Hopkins University

Disclosure

- Depuy Synthes Spine  Royalty
  Consultant
- K2M  Consultant
- Orthofix  Consultant

Treatment options In Rigid Adult Spinal deformity

Posterior:
- Wide ligaments release
- Ponte osteotomy
- PSOs
- Posterior VCR
Treatment options In **Rigid**
Adult Spinal deformity

Posterior:
- Wide ligaments release
- Ponte osteotomy
- PSOs
- Posterior VCR
Posterior Bone Resection Spectrum

Amount of bone resection

(Grade I) SPOs
(Grade II) PSO
(Grade III) Ext PSO
(Grade IV) PSO
(Grade V) VCR

Posterior Vertebral Column resection

Three column vertebral resection including adjacent disks through a posterior Approach

PVCR Technique

Exposure
Costotransversectomy
Screw Placement
PVCR Technique

Lat VB Access  VB Removal  Post VB Impaction  Discectomies

PVCR Technique

Compression/Closure  Final Correction

WHY posterior VCR??

- Severe Stiff Deformities
- Single approach
- Surgeons Familiarity
- Circumferential access to neural elements
WHY posterior VCR??

- More Correction
- More control during Correction
- Decreased Operative time??
- Less morbidity in patients with compromised PF

COMPLICATION PREVENTION

- Combined motor (MEP or DNEP) and SSEP for every case
- If monitoring is lost:
  - Raise MAPs >90
  - Ensure adequate hematocrit
  - Ease correction

COMPLICATION PREVENTION

Failure of Fixation

- Adequate number of fixation points above and below VCR
- Place temporary rods prior to vertebral resection
- En Mass fixation
COMPLICATION PREVENTION

Avoid overshortening of spinal column

- Possible kinking of vascular supply to cord, with lost MEPs
- Distract open osteotomy site and place larger cage
- Place Dural stitch above and below to unkink the dura

SCARRED DURA
- 60 year old female
- Hx of AIS
- 2 PSF with Harrington rods 40 years ago
- LBP and R more than L, groin and leg pain
- Worse with walking and standing
- Tried PT, Injections no relief
Discussion
Prerequisite for Doing PVCRs (Surgeon)

- Must be comfortable with:
  - Placement of instrumentation in severe curves
  - Lumbar & TL PSOs
  - Hemivertebra excision
  - PLIFs and TLIFs
  - Handling neural elements and scarred dura
Discussion
Prerequisite for Doing PVCRs (Surgeon)
- Before performing VCR for deformity, start with VCR's for:
  - Tumor
  - Infection
  - Trauma
  - Hemivertebra excision

Discussion
Prerequisite for Doing PVCRs (Patient)
- Patient must be able to tolerate surgery (i.e. be healthy enough)
- Adequate bone stock and anatomy to allow instrumentation placement
- Able to obtain SCM data (MEP)!!!
- Best for:
  - Severe angular deformity
  - Rigid deformity

THANK YOU