

## Choosing Levels in Adult Scoliosis

*Indications to Extend Fusion to the Sacrum and Pelvis*



Sigurd Berven, MD  
Professor in Residence  
UC San Francisco



---

---

---

---

---

---

---

---

## Disclosures

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

---

---

---

---

---

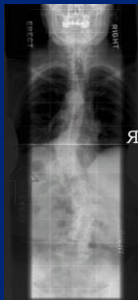
---

---

---

## Challenges in Adult Scoliosis Surgery

- Choosing Levels
- Junctional Complications
- When can we do less?
  - When should we do more?



---

---

---

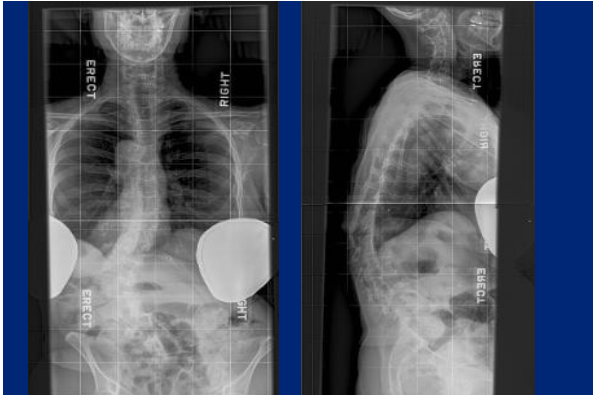
---

---

---

---

---



---

---

---

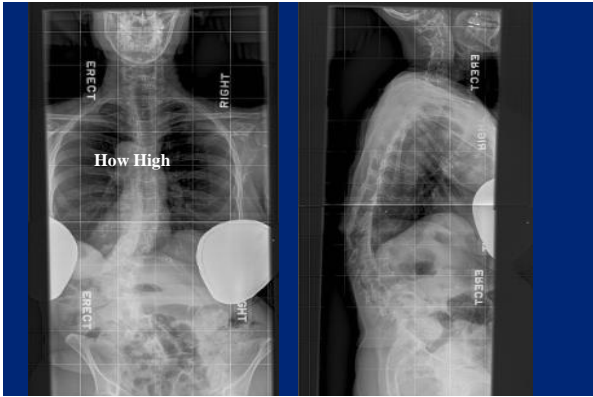
---

---

---

---

---



---

---

---

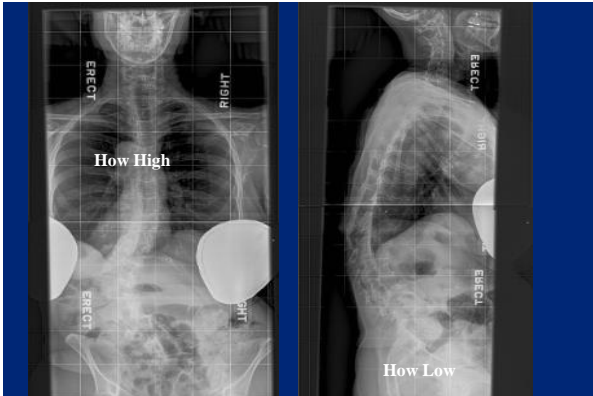
---

---

---

---

---



---

---

---

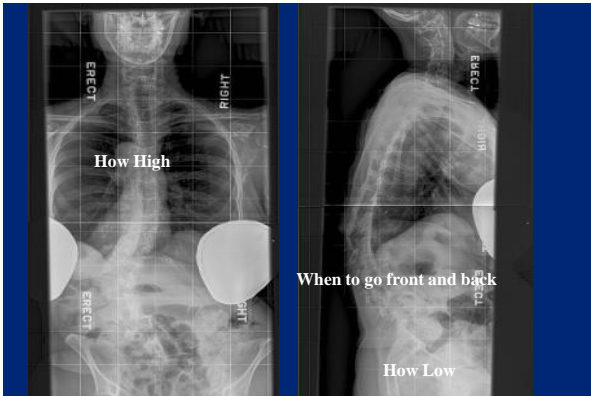
---

---

---

---

---



---

---

---

---

---


---

---

---

### Surgical Strategies

- Characterized by significant variability
- Outcomes studies required for an Evidence-based approach



---

---

---

---

---

---

---

---

### Overview

- The challenge of the lumbosacral junction:
  - Strain on S1 screws
  - Solid arthrodesis at L5-S1
- Biomechanics of the Pivot Point
- Techniques and Limitations

---

---

---

---

---

---

---

---

## Hazards of the Junctions

- Thoracolumbar
- Lumbosacral
- Cervicothoracic



---

---

---

---

---

---

---

---

## The Lumbosacral Junction

Two modes of failure:

- 1) Symptomatic degeneration below a long fusion to L4 or L5
- 2) Nonunion or Malunion at L5-S1

---

---

---

---

---

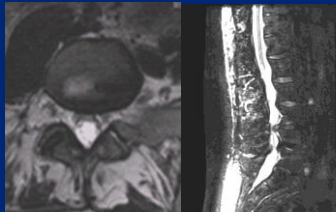
---

---

---

## Preoperative Assessment

- Localization of Pain on Physical Exam
- Advanced Imaging- MRI or CT
- Dynamic Imaging
- Provocative testing
  - Facet Block
  - Discography



---

---

---

---

---

---

---

---

## The Case to Fuse to L5

- Better Function
- Less complications
- Good Survival of the L5-S1 motion segment
- Revision considerations
- Leaving options open for new technologies in the future

---

---

---

---

---

---

---

---

### Does the lower instrumented vertebra have an effect on lumbar mobility, subjective perception of trunk flexibility, and quality of life in patients with idiopathic scoliosis treated by spinal fusion?

Sanchez-Raya J, Bago J, Peliss E, Cuatrecasas A, Villanueva C

J Spinal Disord Tech, 2012 Dec;25(8):437-42

- The loss of range of motion resulting from spinal fusion might lead to low back pain, trunk rigidity, and a negative impact on quality of life. Nonetheless, these outcomes have not been conclusively demonstrated because lumbar mobility and LIV have not been correlated with validated outcome instruments.
- **METHODS:**
- Forty-one patients (mean age, 27 y) with idiopathic scoliosis treated by spinal fusion (mean time since surgery, 135 mo) were included. Patients were assigned to 3 groups according to LIV level: group 1 (fusion to T12, L1, or L2) 14 patients; group 2 (fusion to L3) 13 patients, and group 3 (fusion to L4, L5, or S1) 14 patients. At midterm follow-up, patients completed the Scoliosis Research Society (SRS)-22 Questionnaire and Quality of Life Profile for Spine Deformities to evaluate perceived TF, and rated LBPI with a numerical scale. Lumbar mobility was assessed using a dual digital inclinometer.
- **RESULTS:**
- Group 3 (fusion to L4, L5, or S1) showed statistically significant differences relative to the other groups, with less lumbar mobility and poorer scores for the SRS subtotal ( $P = 0.003$ ) and SRS pain scale ( $P = 0.01$ ). Nevertheless, LBPI and TF were similar in the 3 groups. TF correlated with SRS-22 subtotal ( $r = -0.38$ ,  $P = 0.01$ ) and pain scale ( $r = -0.42$ ,  $P = 0.007$ ) scores, and with LBPI ( $r = 0.43$ ,  $P = 0.005$ ).
- **CONCLUSIONS:**
- LIV correlated moderately with lumbar mobility, health-related quality of life (SRS-22), and spinal pain (SRS-22 pain subscale), but not with intensity of pain in the lumbar area or perceived TF.

---

---

---

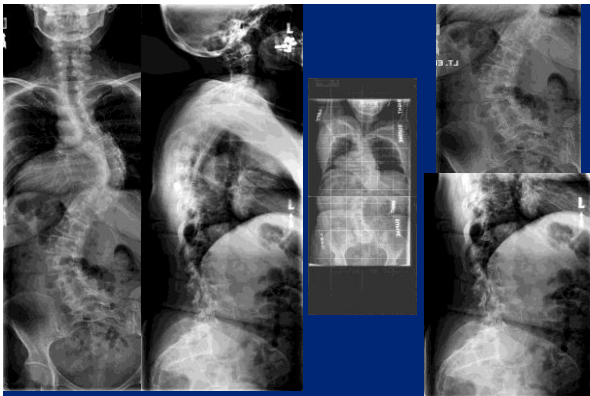
---

---

---

---

---



---

---

---

---

---

---

---

---



---

---

---

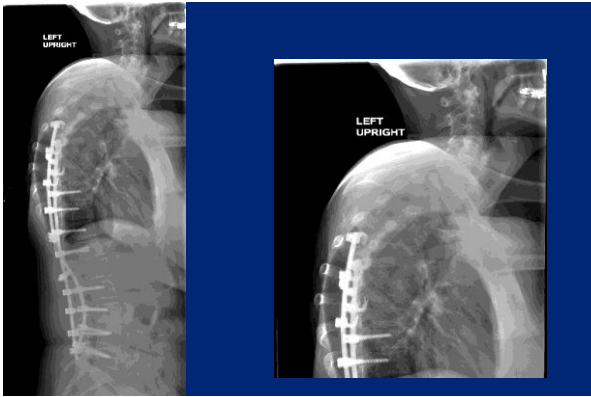
---

---

---

---

---



---

---

---

---

---

---

---

---



---

---

---

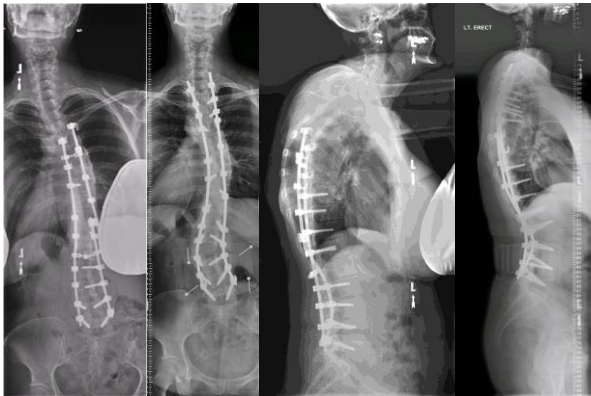
---

---

---

---

---




---

---

---

---

---


---

---

---

## The slippery slope of extending fusion to the sacrum

- Anterior column support
- Role of iliac fixation




---

---

---

---

---

---

---

---

SPINE Volume 29, Number 18, pp 1996-2005  
©2004, Lippincott Williams & Wilkins, Inc.

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

Charles C. Edwards II, MD, Keith H. Bridwell, MD, Alpesh Patel, MD,  
Anthony S. Rinella, MD, Annette Berra, BA, and Lawrence G. Lenke, MD



## Fusion to L5 vs. S1

---

---

---

---

---

---

---

---



## L5 vs S1 Paradox



Thoracolumbar deformity arthrodesis to L5 in adults: the fate of the L5-S1 disc.

- Edwards, Bridwell, et al. Spine 2003 Sep 15;28(18):2122-31.

- 61% developed advanced disc degeneration at L5-S1
  - Associated with loss of sagittal balance, need for revision surgery and lower scores of SRS-24
- 18% loss of fixation at L5

Higher incidence of complications in patients fused to S1  
Edwards, Bridwell et al, SRS 2003

---

---

---

---

---

---

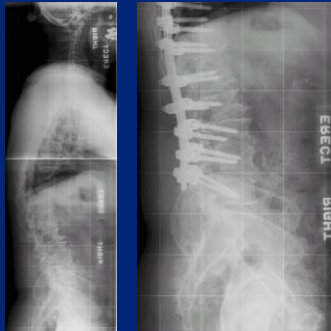
---

---

---

---

## Failure of Fixation at L5




---

---

---

---

---

---

---

---

---

---

The selection of L5 versus S1 in long fusions for adult idiopathic scoliosis.

Swamy, Berven, Bradford.

Neurosurg Clin N Am 2007 Apr;18(2):281-8.

### Purpose

Determine long-term radiographic and clinical outcome of long (>T12) fusions to L5

---

---

---

---

---

---

---

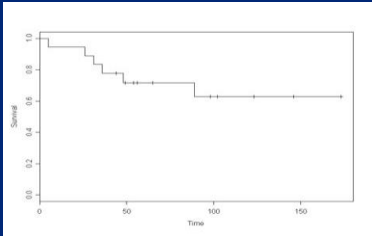
---

---

---



## Survivorship Analysis



5 year: 75%  
10 year: 70%

*If include pts  
considering  
revision*

5 year: 70%  
10 year: 65%

Overall: 50% at  
latest FU

The selection of L5 versus S1 in long fusions for adult idiopathic scoliosis.  
Swamy, Berven, Bradford. Neurosurg Clin N Am 2007 Apr;18(2):281-8.

---

---

---

---

---

---

---

---

---

---

## Conclusions

- Primary long fusions to L5 associated with
  - 25% revision rate at 5 years
  - 30% revision rate at 10 years
- Fusion to L5 is most reliable in patients with good sagittal balance and bone quality

---

---

---

---

---

---

---

---

---

---

## Indications to Extend Fusion to the Sacrum

- Symptomatic degenerative changes at L5-S1
  - Spondylolisthesis at L5-S1
  - Stenosis requiring decompression at L5-S1
- Significant sagittal plane realignment
- Osteoporosis
- Fixed obliquity of the L5-S1 motion segment
  - Trunk translation

---

---

---

---

---

---

---

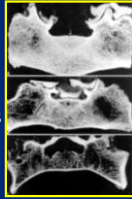
---

---

---

## Sacral Fixation Considerations

- Sacrum is a poor fixation point due to the large cancellous component
- Bicortical or tricortical fixation needed
- Sacrum exposed to large cantilever forces
- Fixation to the sacrum eliminates most important sagittal compensatory mech.
- Fixation to the sacrum alters gait




---

---

---

---

---

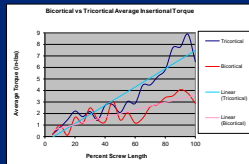
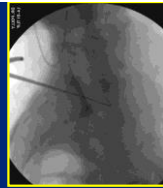
---

---

---

## Pedicle Fixation in the Sacrum

- S1 pedicle screw is the strongest fixation point
  - unicortical fixation
  - bicortical fixation
  - tricortical fixation
- S2 pedicle screw
  - short
  - weak bone



Polly, Kukilo, et al

---

---

---

---

---

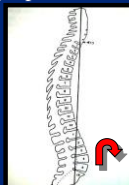
---

---

---

## Limitations of Long Fusion to the Sacrum

- Cantilever forces for long segment constructs becomes critical when sacral fusion extends to L3 or higher
  - Shono, et al. Spine 1998
  - Cunningham, et al. Spine, 2003
- Clinical correlation with a high incidence of symptomatic pseudarthroses in long fusions to S1
  - Kostuik 1983, 40% pseudarthrosis
  - Boachie 1991, 41% pseudarthrosis
  - Delvin 1991, 33% pseudarthrosis
  - Lenke 2004, 23% pseudarthrosis
  - Balderston 1986, 28% good result




---

---

---

---

---

---

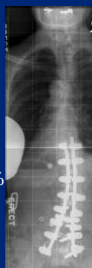
---

---

### Biomechanical Comparison of Iliac Screws Versus Interbody Femoral Ring Allograft on Lumbosacral Kinematics and Sacral Screw Strain

Bryan W. Cunningham, MSc,\* John C. Soffer, DO,\* Nianbin Hu, MD,\* Seok Woo Kim, MD,\* Keith H. Bridwell, MD,† and Paul C. McAfee, MD\*

- Cantilever forces for long segment constructs becomes critical when sacral fusion extends to L3 or higher
  - Anterior interbody decrease S1 screw strain 30-40 %
  - S2 fixation decreases S1 screw strain by 15%
  - Iliac fixation decreases S1 screw strain by 50 to 300 %



---

---

---

---

---

---

---

---

### Limitations of Long Fusion to the Sacrum

- Can be critical
  - S1
  - C
- Clinical presentation



tic



---

---

---

---

---

---

---

---

McCord DH et al  
Spine 1992

- 66 bovine specimens/10 instrumentation techniques
- Established pivot point at the lumbosacral joint at the intersection of the middle osteoligamentous column (sagittal plane) and the lumbosacral intervertebral disc (transverse plane)

---

---

---

---

---

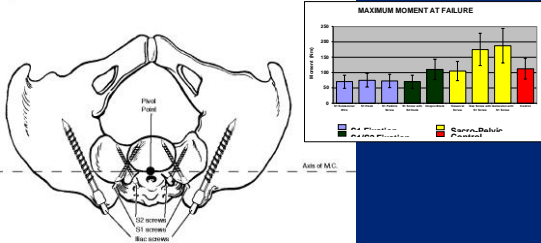
---

---

---

## Reducing Strain on Sacral Screws in Long Fusions to the Sacrum

Fig. 1




---

---

---

---

---

---

---

---

---

---

---

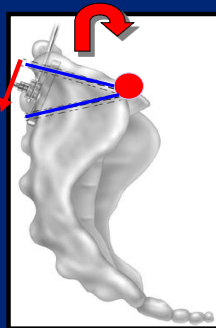
---

## S2 SCREW

- “Biomechanical comparison of lumbosacral fixation Techniques in a calf spine model”

Spine 2002, Lebowhl et al

- S2 screw extends fixation distal to the pivot point thus extending lever arm and providing additional support
- However, the S2 screw does not extend anterior to the pivot point and thus not as good as iliac screw fixation




---

---

---

---

---

---

---

---

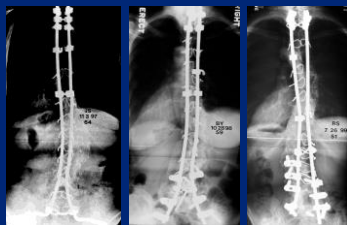
---

---

---

---

## Long Fusion To The Sacrum in Adult Spinal Deformity: Luque Galveston vs. Iliac Screws vs. Sacral Screws



Emami et al:Spine 2003  
UCSF Spinal Disorders Service




---

---

---

---

---

---

---

---

---

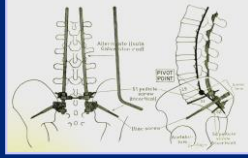
---

---

---

## Iliac Bolt Fixation

- Bolt or screw is passed into the ilium at the PSIS
- Bolt or screw is affixed directly to the spine construct
- Effective in high demand construct
- Failure rate half of traditional Galveston




---

---

---

---

---

---

---

---

---

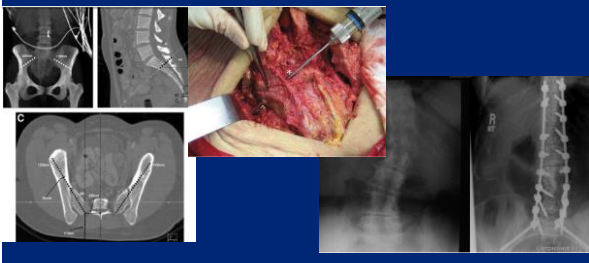
---

SPINE Volume 34, Number 5, pp 436-440  
©2009, Lippincott Williams & Wilkins

### Low Profile Pelvic Fixation

Anatomic Parameters for Sacral Alar-Iliac Fixation *Versus*  
Traditional Iliac Fixation

Tai-Li Chang, MD,\*† Paul D. Sponseller, MD,\* Khaled M. Kebaish, MD,\*  
and Elliot K. Fishman, MD†




---

---

---

---

---

---

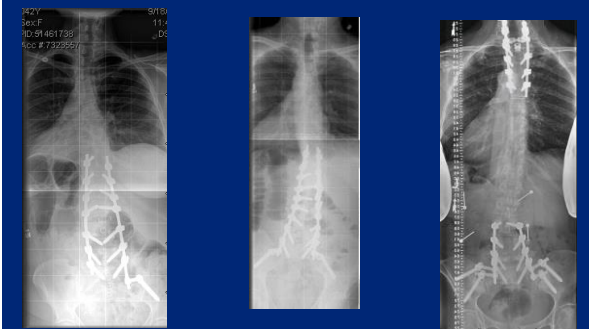
---

---

---

---

## How Many Iliac Screws?




---

---

---

---

---

---

---

---

---

---

## Study Aims and Design

### Goals

Pelvic versus Sacral + ALIF

Unilateral iliac versus bilateral iliac

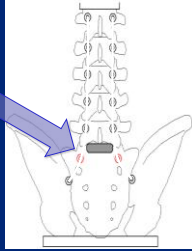
### Methods

Seven cadavers instrumented up to L1

Multi-axial bending with pure moment

S1 screws modified with strain gauges for pullout force

L1-S1, uni-ilic, bi-ilic... with and without ALIF at L5/S1




---

---

---

---

---

---

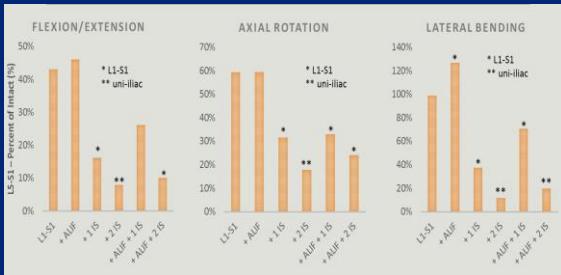
---

---

---

---

## Multi-axial bending




---

---

---

---

---

---

---

---

---

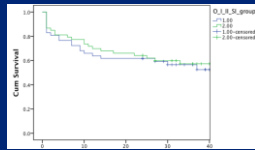
---

Unilateral versus bilateral iliac screws for spinopelvic fixation: are two screws better than one?

*Neurosurg Focus* 36 (5):E10, 2014

RAJIV SINGAL, M.D., Ph.D.,<sup>1</sup> DARRYL LAC, M.D.,<sup>1</sup> RISHU WADHWA, M.D.,<sup>1</sup> HAI LE, B.S.,<sup>2</sup> MOHIB KHANJAN, M.D.,<sup>3</sup> SIGRID BEAVEN, M.D.,<sup>4</sup> DEAN CHOO, M.D.,<sup>5</sup> AND PRAVEEN V. MUMMANENI, M.D.<sup>1</sup>

- 100 patients with long fusions from thoracic spine to the sacrum
  - 53 patients with 2 iliac screws
  - 47 patients with 1 iliac screws




---

---

---

---

---

---

---

---

---

---

## Limitations of Iliac Fixation

- Higher incidence of perioperative complications
  - Wound infection
    - Abdul-Jabbar A, et al.
- Higher incidence of need for revision surgery
  - Screw removal
    - Emami A, et al.

---

---

---

---

---

---

---

---

## Evidence-based approach to the use of Iliac Fixation

- Extension of fixation to ilium in:
  - Compromised anterior column support at L5-S1
    - TLIF at L5-S1
  - Revision fixation to the sacrum in a long construct
    - Above L3
  - Compromised sacral fixation
  - Incomplete correction of sagittal and coronal balance
  - Pelvic obliquity/Long thoracolumbar (c-shaped) deformity corrected with cantilever maneuver
  - Ankylosing Spondylitis

---

---

---

---

---

---

---

---

## Conclusions

- Fixation at the lumbosacral junction is challenging and important for stable reconstructions in deformity
- High strain on the sacral screws may lead to screw loosening and nonunion
- Pelvic fixation reduces strain on the sacral screws
- Role of biologics and new technologies in limiting need for iliac fixation requires further investigation

---

---

---

---

---

---

---

---



UCSF Center for Outcomes Research

---

---

---

---

---

---

---

---



# Spino-Pelvic Parameters: How Do They Affect My Decision to Extend a Fusion to the Sacrum/Pelvis

Han Jo Kim MD  
Frank J. Schwab, MD  
Bassel G. Diebo, MD  
Virginie Lafage, PhD

Hospital for Special Surgery  
New York, NY



---

---

---

---

---

---

---

---

## Disclosures

- Consultant
  - K2M, Biomet, Medtronic
- Speaker Bureau (not present, within last 36 months)
  - Depuy, Stryker
- Board Membership
  - ASJ, HSS Journal

---

---

---

---

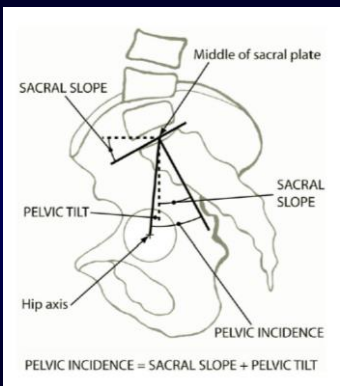
---

---

---

---

## SPINOPELVIC PARAMETERS



---

---

---

---

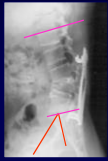
---

---

---

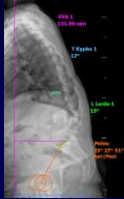
---

## Setting Surgical Goals



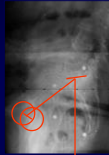
Regional  
Loss of lordosis  
Versus PI

PI-LL < 10°



Global  
SVA

SVA < 5cm



Compensatory  
Pelvic tilt

PT < 20-25°

---

---

---

---

---

---

---

---

---

---

## Literature Review

SPINE Volume 28, Number 18, pp 1996-2003  
©2009, Lippincott Williams & Wilkins, Inc.

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

Charles C. Edwards II, MD, Keith H. Bridwell, MD, Alpesh Patel, MD,  
Anthony S. Rinella, MD, Annette Berra, BA, and Lawrence G. Lenke, MD

- 34 consecutive adult deformity patients fused from the thoracic spine to L5
- Subsequent L5-S1 DDD developed in 66% of patients after long adult fusions to L5

---

---

---

---

---

---

---

---

---

---

## Literature Review

SPINE Volume 32, Number 24, pp 2771-2776  
©2007, Lippincott Williams & Wilkins, Inc.

### Thoracolumbar Deformity Arthrodesis Stopping at L5

Fate of the L5-S1 Disc, Minimum 5-Year Follow-up

Craig A. Kuhns, MD,\* Keith H. Bridwell, MD,† Lawrence G. Lenke, MD,†  
Courtney Amor, BS,† Ronald A. Lehman, MD,‡ Jacob M. Buchowski, MD,†  
Charles Edwards, II, MD,§ and Baldus Christine, RN†

- High percentage of patients subsequently degenerated the L5-S1 disc
- With degeneration of the L5-S1 disc, sagittal balance was frequently lost
- Prevalence of breakdown of the L5-S1 disc much greater in the "long" fusions (T4-L5) vs. the "short" fusions (T10-L5)

---

---

---

---

---

---

---

---

---

---

## Literature Review

Kim YJ, Bridwell KH, Lenke LG, Cho K, Edwards II C, Rinella AS: Pseudarthrosis in adult spinal deformity following multisegmental instrumentation and arthrodesis. J Bone Joint Surg 2006;88(4):721-728

- A clinical and radiographic assessment of 232 adults
- Factors found to be significantly associated were preop thoracolumbar kyphosis of  $>20^\circ$ , age of  $>55$  years, arthrodesis to S1 compared to L5
- Patients with a pseudarthrosis had lower total outcome scores on SRS questionnaire
- Prevalence of pseudarthrosis following long arthrodesis was 17%. Close to 30% for fusions to sacrum.

---

---

---

---

---

---

---

---

## Literature Review

Islam NC, Wood KB, Transfeldt EE, Winter RB, Denis F, Lonstein JE, Ogilvie JW. Extension of fusions to the pelvis in idiopathic scoliosis. Spine 2001;26(2):166-173.

- 41 patients (40 female; 1 male)
- 39 of 41 had combined anteroposterior fusion extension
- Pseudarthrosis rate was 37% (15/41)
- With sacral fixation only, the rate was 53% (8/15), with iliac fixation only 42% (3/7) and with both iliac and sacral fixation 21% (4/19;  $p<0.05$ )

---

---

---

---

---

---

---

---

## Literature Review

Enami A, Deviren V, Berven S, Smith JA, Hu SS, Bradford DS. Outcome and complications of long fusions to the sacrum in adult spinal deformity. Spine 2002;27:776-686.

- 54 consecutive patients who underwent elective combined anterior and posterior surgical reconstruction for acute spine deformity were studied
- Attention to sagittal balance is critical
- Luque-Galveston fixation technique has an unacceptably high rate of pseudarthrosis. Currently, the authors are using bicortical and triangulated sacral screws with anterior interbody support
- They recommend using iliac fixation, although there is a higher rate of painful implants, requiring removal

---

---

---

---

---

---

---

---

## Literature Review

McCord DH, Cunningham BW, Shono Y, Myers JJ, McAfee PC. Biomechanical analysis of lumbosacral fixation. Spine 1992;17(8S):S235-243

Long fixation points in the ilium that extend anterior to the axis of rotation of L5-S1 provide the most stable fixation of the lumbosacral joint.

---

---

---

---

---

---

---

---

## Literature Review

Cunningham BW, Lewis SJ, Long J, Dmitriev AE, Linville DA, Bridwell KH. Biomechanical evaluation of lumbosacral reconstruction techniques for spondylo-listhesis: An *in vitro* porcine model. Spine 2002;27(21):2321-2327

In a spondylolisthesis model, both the iliac screws and the interbody cages at the lumbo-sacral junction protected the S1 screws, but the iliac screws were far more valuable.

---

---

---

---

---

---

---

---

## Factors that Dictate my Decision to Fuse to Sacrum/Ilium

- Age
  - Bone quality
  - Degenerative changes in disc, foramen, canal
- Deformity
  - Large SVA
  - Large Coronal Decompensation
  - Large Curve Magnitude
  - Rigid vs. Flexible Deformity
  - Presence of L5/S1 Spondylolisthesis
  - Laminectomy Defects at L5/S1

---

---

---

---

---

---

---

---

## Factors that Dictate my Decision to Fuse to Sacrum/Ilium

- Age
  - Bone quality
  - Degenerative changes in disc, foramen, canal
- Deformity
  - **Large SVA**
  - Large Coronal Decompensation
  - Large Curve Magnitude
  - Rigid vs. Flexible Deformity
  - Presence of L5/S1 Spondylolisthesis
  - Laminectomy Defects at L5/S1
- **Spino-Pelvic Parameters**
  - **High PT**
  - **High PI**

---

---

---

---

---

---

---

---

## High PT

- PT will be very difficult to correct without fusion to S1 and Iliac Fixation in Adult Spinal Deformity

---

---

---

---

---

---

---

---

## High PI

- “Guillotine Effect” of Fusion to L5 on L5/S1 Disc Space
  - High shear stresses

---

---

---

---

---

---

---

---

Substantial sagittal imbalance, back pain, inability to ambulate



PT 36  
LL 20  
PI 55  
SVA 20cm



---

---

---

---

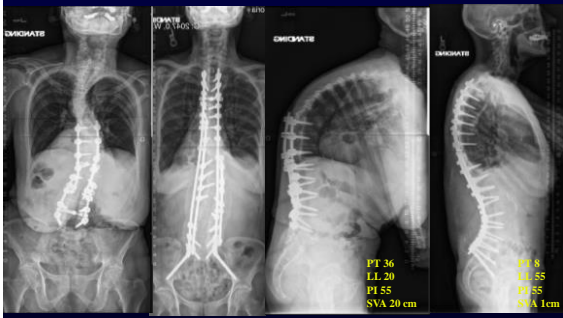
---

---

---

---

### Cantilever to “Dial In” Pelvic Anteversion



---

---

---

---

---

---

---

---

### Case

- 79M with bilateral leg and back pain
  - 10% back, 90% leg pain
    - 50% Left, 50% Right
  - Exacerbated by standing/walking
  - Improved with sitting, lying down (some positions)
  - No bowel/bladder symptoms
  - Subjective weakness/numbness when ambulating
  - Failed PT/Injections

---

---

---

---

---

---

---

---

## Exam

- Marked Positive Sagittal Balance
- Can only stand for a short period of time
- Static Motor Exam intact
- Sensory exam normal

---

---

---

---

---

---

---

---



---

---

---

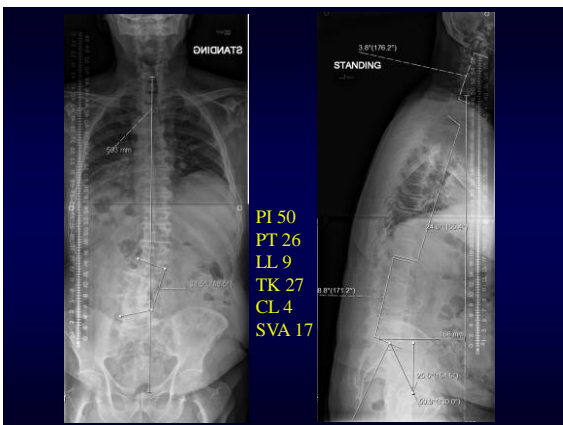
---

---

---

---

---



---

---

---

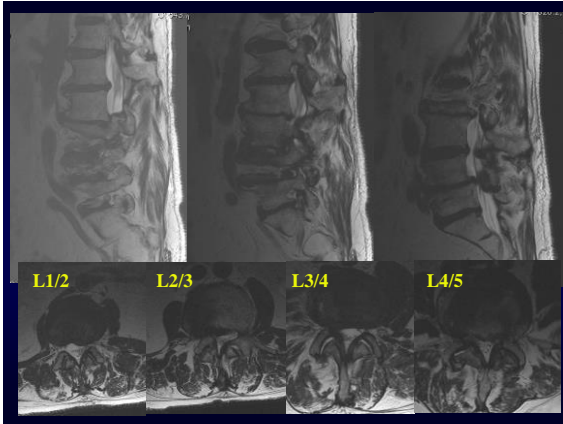
---

---

---

---

---




---

---

---

---

---

---

---

---




---

---

---

---

---

---

---

---

## Questions

- Osteotomy? Can you do PCOs? Or will this need a PSO?
  - If PSO, what level?
  - If PCO, what level(s)?
- Is an Interbody necessary?
  - Lateral? Transforaminal? Anterior?
- Choice for UIV? Lower or Upper Thoracic?
- Iliac Fixation?
- Will you need Biologics?

---

---

---

---

---

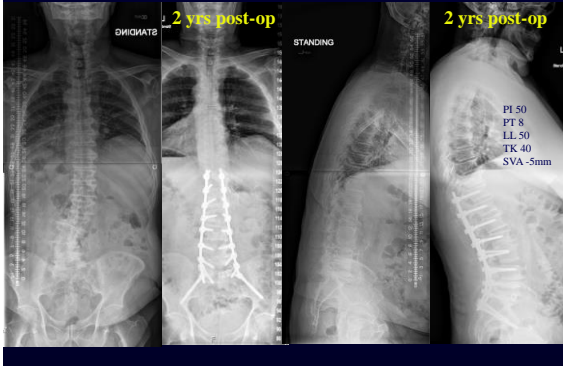
---

---

---



PSF T11-Ilium, PCO L1-L5, TLIF L5/S1



---

---

---

---

---

---

---

---

Do We Always Have To  
Go To The Sacrum? Are  
There Select  
Circumstances Where  
We'd Be Better Off  
Stopping At L5?

Case following Courtesy of Dr. Keith H. Bridwell MD

---

---

---

---

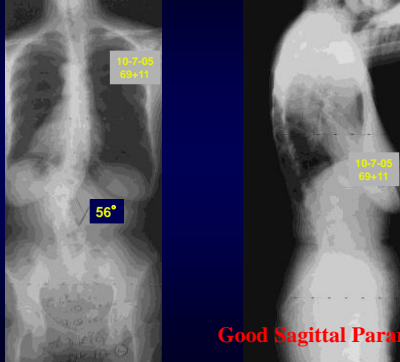
---

---

---

---

Frail Almost 70-Year-Old Female. Bilateral Leg  
Pain And Weakness, Left Greater Than Right.



Good Sagittal Parameters!

---

---

---

---

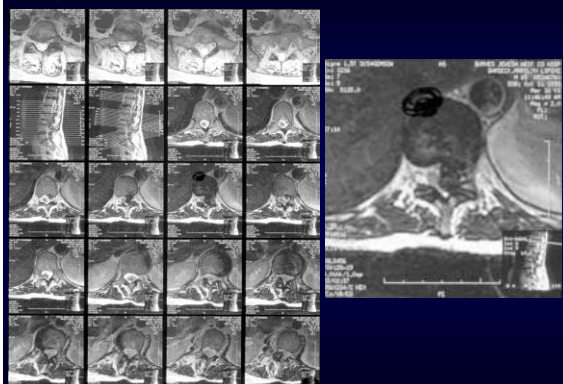
---

---

---

---

### Large Calcified Disc Herniation at T11-T12 on the Left Side



---

---

---

---

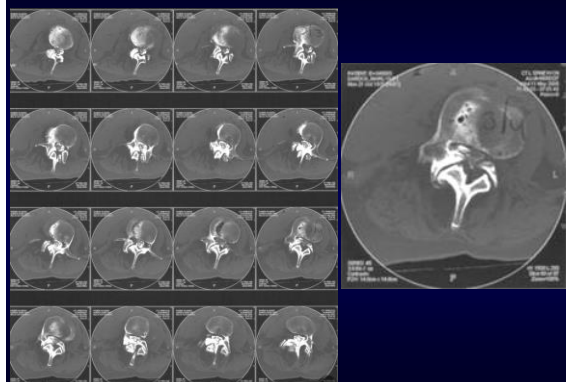
---

---

---

---

### Stenosis at L3-L4



---

---

---

---

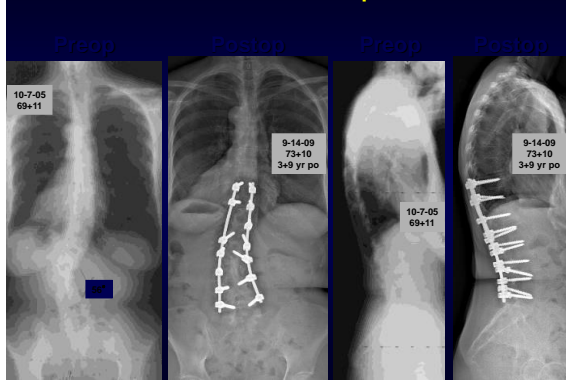
---

---

---

---

### 4 Year Follow-up



---

---

---

---

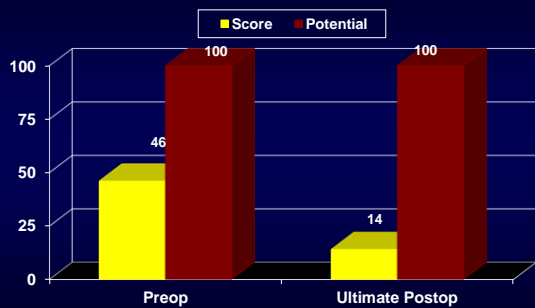
---

---

---

---

## Oswestry Scores



---

---

---

---

---

---

---

---

## Balance Risks/Benefits

- Large PI-LL mismatch
- Large PT
- Large PI (natural anatomy)

---

---

---

---

---

---

---

---

## Balance Risks/Benefits

- Large PI-LL mismatch
- Large PT
- Large PI (natural anatomy)
- **Need fusions to Sacrum/Ilium**
- **Pseudo Risk**

---

---

---

---

---

---

---

---




---

---

---

---

---

---

---

---

**DISCLOSURES**

- Consultant: Stryker Spine
- Editorial Board: JSMT
- Off-label use of BMP

Cleveland Clinic

---

---

---

---

---

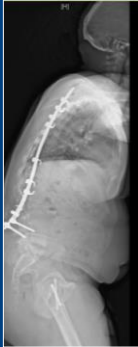
---

---

---

**OUTLINE**

- **Approach**
  - Anterior
  - Posterior
- **Interbody Support**
  - ALIF/PLIF/TLIF/OLIF
  - Advantages/Disadvantages
  - Is it necessary ???
- **Graft Options**
  - Bone vs. PEEK vs. Metal
  - BMP



Cleveland Clinic

---

---

---

---

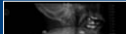
---

---

---

---

# GOALS OF SURGERY



SPINE Volume 31, Number 20, pp 2329-2336  
©2009, Lippincott Williams & Wilkins, Inc.

**Pseudarthrosis in Long Adult Spinal Deformity Instrumentation and Fusion to the Sacrum: Prevalence and Risk Factor Analysis of 144 Cases**

Yongjung J. Kim, MD,\* Keith H. Bridwell, MD,\* Lawrence G. Lenka, MD,\* Seungchul Rhim, MD,† and Gene Cheh, MD\*



Up to 25% pseudarthrosis rate at L5-S1



---

---

---

---

---

---

---

---

# ANTERIOR APPROACH

## • Advantages

- Access to disc space
- Large structural graft
- Lordosis

## • Disadvantages

- Unfamiliar and separate approach
- Complications



---

---

---

---

---

---

---

---

# POSTERIOR APPROACH

## • Advantages

- Provides interbody support
- Single approach/procedure

## • Disadvantages

- Inferior disc "prep"
- Graft extrusion
- Nerve root irritation
- Fusion ???



---

---

---

---

---

---

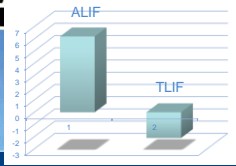
---

---

### Anterior lumbar interbody fusion in comparison with transforaminal lumbar interbody fusion: implications for the restoration of foraminal height, local disc angle, lumbar lordosis, and sagittal balance

PATRICK C. HSIEH, M.D., TYLER R. KOSKI, M.D., BRIAN A. O'SHAUGHNESSY, M.D., PATRICK SUGRUE, M.D., SEAN SALEHI, M.D., STEPHEN ONDRA, M.D., AND JOHN C. LIU, M.D.

- Retrospective **BETTER WAY** Lumbar Lordosis
- 32 ALIF vs. 25 TLIF
- **Foraminal Height**
  - 18.5% vs. -0.4% ( $p<0.01$ )
- **Segmental Lordosis**
  - 8.3 vs. -0.1° ( $p<0.01$ )
- **Regional Lordosis**
  - 6.2° vs. -2.1° ( $p<0.01$ )



J Neurosurg Spine 2007;7:379-386.

---

---

---

---

---

---

---

---

### Transforaminal Versus Anterior Lumbar Interbody Fusion in Long Deformity Constructs

A Matched Cohort Analysis

Ian G. Dorward, MD,\* Lawrence G. Lenke, MD,† Keith H. Bridwell, MD,† Patrick T. O'Leary, MD,† Geoffrey E. Stoker, BS,† Joshua M. Pahys, MD,† Matthew M. Kang, MD,† Brenda A. Sides, MA,† and Linda A. Koester, BS†

- Retrospective
- ALIF vs. TLIF in ASD
- 42 pts in each group
- **Segmental lordosis**
  - -6.9° vs. -2.6° ( $p<0.0001$ )
- **Regional lordosis**
  - -11.5° vs. 7.9° ( $p=0.29$ )



Spine 2013;38:E755-E762.

---

---

---

---

---

---

---

---

### Transforaminal Versus Anterior Lumbar Interbody Fusion in Long Deformity Constructs

A Matched Cohort Analysis

Ian G. Dorward, MD,\* Lawrence G. Lenke, MD,† Keith H. Bridwell, MD,† Patrick T. O'Leary, MD,† Geoffrey E. Stoker, BS,† Joshua M. Pahys, MD,† Matthew M. Kang, MD,† Brenda A. Sides, MA,† and Linda A. Koester, BS†



NO DIFFERENCE IN RATE OF PSEUDARTHROSIS



Spine 2013;38:E755-E762.

---

---

---

---

---

---

---

---

ORIGINAL ARTICLE

Anterior lumbar interbody fusion versus transforaminal lumbar interbody fusion – systematic review and meta-analysis

Kevin Phan, Ganesha K. Thayakaran & Ralph J. Mobbs

Department of Neurosurgery, Neuro Spine Clinic, Prince of Wales Private Hospital, New South Wales, Australia and NeuroSpine Surgery Research Group (NSURG), Sydney, Australia

- Systematic Review (12 Retrospective Studies)
  - 609 ALIFs, 631 TLIFs
- Fusion Rates
  - 88.6% vs. 91.9% (p=0.23)
- Disc height (2.71mm)
- Segmental lordosis (2.35deg)
- Lumbar lordosis (6.33deg)



Br J Neurosurg 2015;Early Online:1-7.

---

---

---

---

---

---

---

---

---

---

### INTERBODY GRAFT OPTIONS

- Provide structural support
  - Function is primarily mechanical
- Require “other” bone graft substitutes to achieve bony fusion
- Implant material is important
  - Limit subsidence and stress shielding
  - Bone integration




---

---

---

---

---

---

---

---

---

---

### INTERBODY GRAFT OPTIONS

- Femoral Ring Allograft
  - “Biological Cages”
  - Natural elasticity
  - Potential for incorporation
- PEEK
  - Elasticity less than cortical bone
  - No potential for incorporation
- Titanium
  - Elasticity is much greater than bone
  - Radiopaque




---

---

---

---

---

---

---

---

---

---

### Radiographic Analysis of PEEK Cage and FRA in Adult Spinal Deformity Fused to Sacrum

Zongmiao Wan, MD,\* Min Dai, MD,\* Jun Miao, MD,† Guoan Li, PhD,† and Kirkham B. Wood, MD†

- Retrospective review
- ALIF with PEEK (N=27) vs. RFA (N=14) at L5-S1
- X-ray evaluation
- Fusion Rates
  - 94.9% vs. 84.2% (p<0.05)
- Improved foraminal height and segmental lordosis with PEEK



J Spinal Disord Tech 2014;27:327-335.

---

---

---

---

---

---

---

---

---

---

### Comparison of fusion rates following transforaminal lumbar interbody fusion using polyetheretherketone cages or titanium cages with transpedicular instrumentation

Osamu Nemoto · Takashi Asanuma · Yoshiyuki Yato · Hideaki Imabayashi · Hiroki Yasuoka · Akira Fujikawa

- Retrospective
- Single level TLIF with local autograft
- Titanium (N=23) vs. PEEK (N=25)
- Fusion Rates
  - 100% vs. 75% at 2 years (p=0.016)
- Vertebral osteolysis was seen in 60% of PEEK non-unions



Eur Spine J 2014;23:2150-2155.

---

---

---

---

---

---

---

---

---

---

### INTERBODY GRAFT OPTIONS

- Expandable Cages
- “Surface Enhanced”
- Silicone Nitrate
- Tantalum
- 3D Printing
- Nanotechnology




---

---

---

---

---

---

---

---

---

---



## THE WORLD OF BIOLOGICS

Courtesy of Wellington K. Hsu, MD

---

---

---

---

---

---

---

---

### Improving the Clinical Evidence of Bone Graft Substitute Technology in Lumbar Spine Surgery

Wellington K. Hsu<sup>1</sup> M. S. Nickoli<sup>1</sup> J. C. Wang<sup>2</sup> J. R. Lieberman<sup>3</sup> H. S. An<sup>4</sup> S. T. Yoon<sup>5</sup>  
J. A. Youssef<sup>6</sup> D. S. Brodke<sup>7</sup> C. M. McCullough<sup>8</sup>

	# Studies	# Patients	# Fused	Rate (%)
ICBG	23	1389	1103	79%
Local Autograft	8	714	637	89%
Allograft alone	4	269	141	52%
BMA	2	40	34	85%
BMP - 2	3	213	201	94%
Ceramics	16	697	603	87%
DBM <sup>1</sup>	3	192	171	89%
PRP	4	209	154	74%

Cleveland Clinic

---

---

---

---

---

---

---

---

SPINE Volume 34, Number 20, pp 2205-2212  
©2009, Lippincott Williams & Wilkins

### Long Adult Spinal Deformity Fusion to the Sacrum Using rhBMP-2 *Versus* Autogenous Iliac Crest Bone Graft

Takashi Maeda, MD, PhD,\* Jacob M. Buchowski, MD, MS,† Yongjung J. Kim, MD,‡ Takuya Mishiro, MD, PhD,† and Keith H. Bridwell, MD†

- Retrospective Study
- ALIF in ASD
  - ICBG (N=32) vs. BMP (N=23)
- **Fusion Rates**
  - 71.9% vs. 95.7% (p=0.057)
- Follow-up
  - 4.9 vs. 2.7 years

Cleveland Clinic

Spine 2009;34:2205-2212.

---

---

---

---

---

---

---

---

# The Fate of L5-S1 With Low-Dose BMP-2 and Pelvic Fixation, With or Without Interbody Fusion, in Adult Deformity Surgery

Prokopis Annis, MD,\* Darrel S. Brodke, MD,\* William R. Spiker, MD,\* Michael D. Daubs, MD,† and Brandon D. Lawrence, MD\*

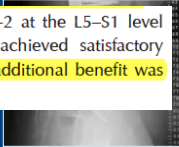
- Retrospective Case Series
- L5-S1 Interbody fusion vs. PLF

**Conclusion.** The use of low dose of BMP-2 at the L5-S1 level in combination with sacropelvic fixation achieved satisfactory fusion rates in adult deformity surgery. No additional benefit was encountered by adding an interbody cage.

- **Fusion Rates**
  - 97% vs. 96% (p=1.0)



Spine 2015;11:E634-E639.



---

---

---

---

---

---

---

---

## MY ALGORITHM AT L5-S1

- **ALIF**
  - Sagittal plane deformity (mostly from L4-L5 and/or L5-S1)
  - Adjacent segment pathology below a previous fusion (i.e. AIS)
- **TLIF**
  - De novo scoliosis with “tall” disc or spondy
  - Fractional curve
- **PLF alone**
  - De novo scoliosis with collapsed disc



---

---

---

---

---

---

---

---

## CASE EXAMPLE



Courtesy of Doug Orr, MD

---

---

---

---

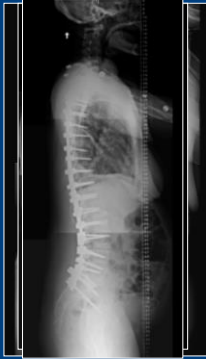
---

---

---

---

### CASE EXAMPLE



---

---

---

---

---

---

---

---

### CONCLUSIONS

- Historically high rate of pseudarthrosis at L5-S1
- Iliac Fixation, 360° , and Biologics have improved fusion rates
- ALIF improves disc height, segmental lordosis, and LL better than TLIF
- Likely no difference in fusion
- Still a lot of questions ???



---

---

---

---

---

---

---

---

### THANK YOU



---

---

---

---

---

---

---

---

## Sacroplevic Fixation Options, Techniques and Complications

Khaled M. Kebaish, M.D., FRCSC

*Professor of Orthopedic & Neurosurgery*

Department of Orthopedic Surgery

Johns Hopkins University

---

---

---

---

---

---

---

---

## DISCLOSURE

- Depuy Spine      Consultant, Royalty
- K2M                Consultant
- Orthofix          Consultant

---

---

---

---

---

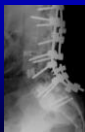
---

---

---

## WHY PELVIC FIXATION?

- S1 Pedicles capacious & short
- Sacrum bone is osteopenic
- Failure rate of S1 Screws  
Up to 44%
- Inadequate as the only means  
of fixation in long fusion



*Camp et al, Spine 1990*

---

---

---

---

---

---

---

---

## INDICATIONS FOR PELVIC FIXATION

### Expected significant biomechanical stresses

- Long fusions to the sacrum
- Definition: > 4 levels
- Osteoporosis

---

---

---

---

---

---

---

---

## Sacral Fracture



---

---

---

---

---

---

---

---



---

---

---

---

---

---

---

---

## Sacro-Pelvic Fixation Options

- Casting and bracing
- Sacral Sublaminar devices
  - Wires
  - Cables
  - Hooks
- Sacral pedicle screws
  - S1 pedicle screws
  - S2 Pedicle screws
- S1 Alar screws
- S1 and Alar screw blocks
- Dunn-McCarthy S-Rod
- Jackson intra-sacral rod
- Kostuik sacral bar
- Galveston technique
- Iliac Screws
- Sacral Alar Iliac screws (S2AI)

---

---

---

---

---

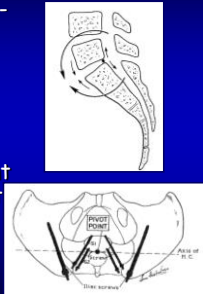
---

---

---

## LUMBO-SACRAL PIVOT POINT

- "Axis about which the lumbo-sacral region rotates"
- Middle of osteo-ligamentous column at L5-S1
- Implants ventral to this point provide an effective moment arm to resist flexion & improve fixation strength



McCord et al, Spine, 1992.

---

---

---

---

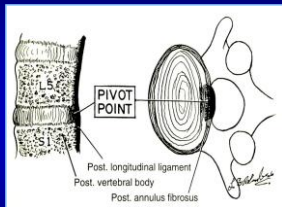
---

---

---

---

## LUMBO-SACRAL PIVOT POINT



McCord et al, Spine, 1992.

---

---

---

---

---

---

---

---

## GALVESTON TECHNIQUE

- Most commonly used in NM Spinal deformities
- Inexpensive
- Difficult to get the correct angle
- Loss of correction
- Windshield wiper effect



Broom MJ, et al, JBJS (A), 1989.  
Gao Y, et al, J Spinal Disord, 1991.  
Massley C, et al, Orthop Trans, 1986.

---

---

---

---

---

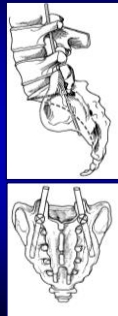
---

---

---

## Jackson Technique

- S1 pedicle screws
- Rod placed in S1 screw and into sacral ala
- Not crossing the SI joint
- Technically difficult
- Biomechanically weaker than iliac fixation



Jackson RP, et al, Spine, 1993.  
Leibwohl NH, Spine, 2002.

---

---

---

---

---

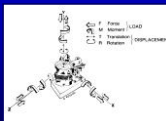
---

---

---

## Iliac Screws

- Commonly used
- Fixation with screws
- Implants easier to place
- Reduction in LS motion
- More Protective of S1 than IB cages



Cunningham BW, et al, Spine, 2002.

---

---

---

---

---

---

---

---

■ **Minimum 5-Year Analysis of L5-S1 Fusion Using SacroPelvic Fixation (Bilateral S1 and Iliac Screws) for Spinal Deformity**

Kuniyoshi Tsuchiya, MD, Keith H. Bridwell, MD, Timothy R. Kiklo, MD, Lawrence G. Lian, MD, and Christine Baldus, RN

- 67 patients ( 81 initial Cohort)
- 5 years Follow-up
- Iliac screws removed in 23 pts
- 7 broken screws
- Screws halos in 29 pts
- No SI joint arthritis

---

---

---

---

---

---

---

---

**Woojin et Al. paper 46, IMAST 2011**

- 67 of 190 patients
- Iliac screws
- Minimum 2 ys follow-up
- 34.3 % failure
- 11.9 Major failure

---

---

---

---

---

---

---

---

**S2 Alar -Iliac S2AI "SAI"**



---

---

---

---

---

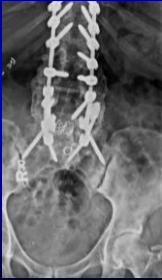
---

---

---



**Surgical Technique**  
How it all started?



---

---

---

---

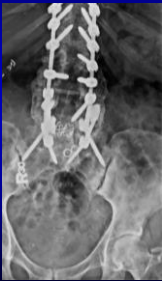
---

---

---

---

**Surgical Technique**  
How it all started?



---

---

---

---

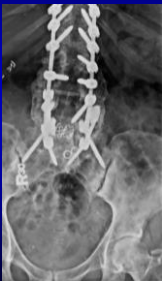
---

---

---

---

**Surgical Technique**  
How it all started?



---

---

---

---

---

---

---

---

## Surgical Technique How it all started?



---

---

---

---

---

---

---

---

## Surgical Technique S2AI

- Starting point:  
*Midway between S1 & S2 foramina*
- 2.5 mm drill from pelvic set
- Trajectory: 45° to floor  
20-30° caudal  
*"Varies w. pelvic obliquity & Sacral tilt"*  
*Aim for the AIIS*
- Confirm bony end point with a probe



---

---

---

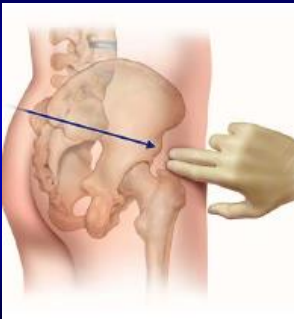
---

---

---

---

---



---

---

---

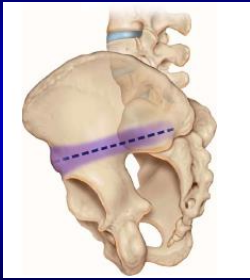
---

---

---

---

---



---

---

---

---

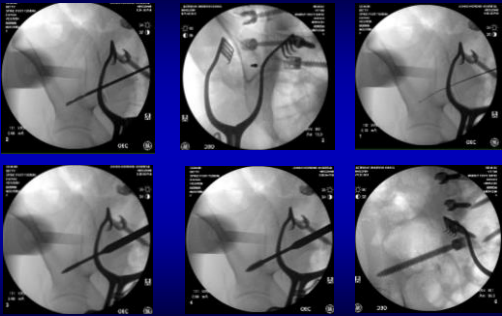
---

---

---

---

### Surgical Technique S2AI



---

---

---

---

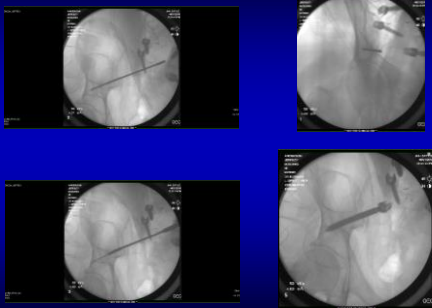
---

---

---

---

### Surgical Technique S2AI



---

---

---

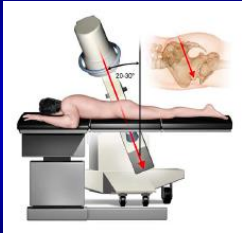
---

---

---

---

---



---

---

---

---

---

---

---

---



---

---

---

---

---

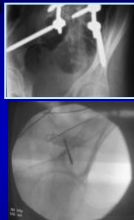
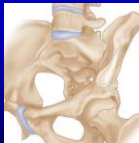
---

---

---

## Surgical Technique S2AI

- Screw path just above sciatic notch
- Fluoroscopy is helpful  
Iliac oblique, Tear drop



---

---

---

---

---

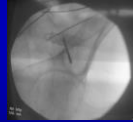
---

---

---

## Surgical Technique S2AI

- Screw path just above sciatic notch
- Fluoroscopy is helpful  
Iliac oblique, Tear drop
- Diameter 8-10 mm
- Length 80-100



---

---

---

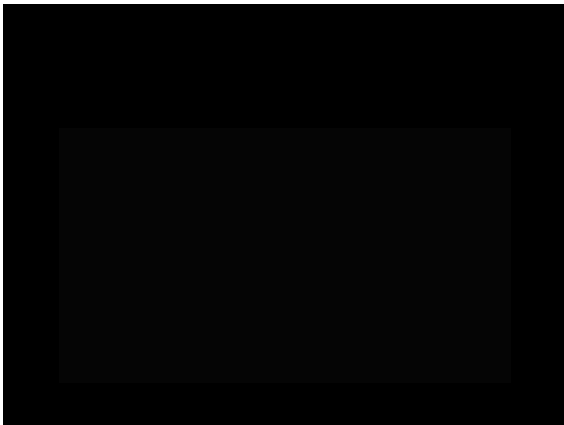
---

---

---

---

---



---

---

---

---

---

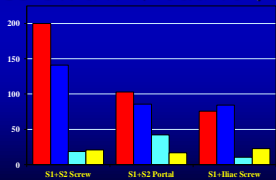
---

---

---

## Biomechanics

- Biomechanical properties equivalent to Iliac screws
- Stress-strain & load to failure



---

---

---

---

---

---

---

---

**Outcomes and Complications of Sacro-Pelvic Fixation Using S2 Alar-Iliac (S2AI) Fixation in Adult Deformity patients: A prospective Study with 2-Year Follow-Up**

Khaled Kebaish, MD  
 Mostafa El Dafrawy, M.D  
 Hamid Hassanzadeh, M.D  
 Philip Neubauer, M.D  
 Roosevelt Offoha, BS  
 Eric Tan, M.D  
 Paul Sponseller, MD

Department of Orthopaedic Surgery  
 Johns Hopkins University

---

---

---

---

---

---

---

---

---

---

**RESULTS**

- 146 patients were included
- 2 year clinical & radiographic F/U
- 2 patient were lost to follow up
- Average age: **59 ys (21-80)**
- 35% of patients had > one co-morbidity

---

---

---

---

---

---

---

---

---

---

**S2AI Fixation specific complications**

Screw Breakage	8 (5 pts)
Screw Misplacement	2
Minimal Screw loosening (<2mm) 13 patients	16 screws (6%)
<i>Reoperation</i>	4




---

---

---

---

---

---

---

---

---

---

## Sacropelvic Fixation Using the S2 Alar-Iliac (S2AI) Screw in Adult Deformity Surgery: A Prospective Study with Minimum 5-Year Follow-Up

Sophia A. Strike, MD; Hamid Hassanzadeh, MD;  
Floreana Naef, MD; John Carrino, MD;  
Paul D. Sponseller, MD; Richard Skolasky, ScD;  
Khaled M. Kebaish, MD

---

---

---

---

---

---

---

---

## S2AI FIXATION COMPLICATIONS

- 109 S2AI screws placed
  - Six broken screws (four patients)
- > 2 mm lucency: 20 screws
- No pseudoarthrosis at L5-S1
- No SI joint degeneration

---

---

---

---

---

---

---

---

## Effect on the SI Joint

- There was no evidence of SI joint fusion
- No significant change in joint space
- No significant SI joint area pain



Corlett EN, Bishop RP. Ergonomics 1976

---

---

---

---

---

---

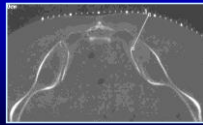
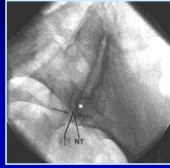
---

---

## Concerns of Fusion Across SI Joint

### Anatomic studies

- Minimal motion in pediatric cadavers
- No motion in adult cadavers
- 75% auto fused in adults over 50 years



Ashur MA, et al. CORR 1986.  
Kozlusk JP, et al. CORR 1986.  
White AA, et al. Surgery of Musculoskeletal System, 1999.

---

---

---

---

---

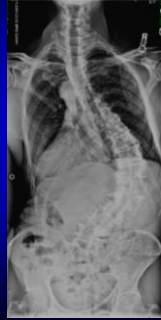
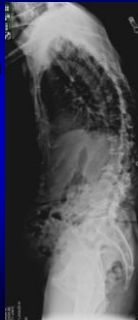
---

---

---

## Adult Scoliosis

- 71 YO M
- Retired Physician
- Severe Back Pain and Rt Buttock
- Used to be very active now Limited by his symptoms
- No Prior Rx



---

---

---

---

---

---

---

---



---

---

---

---

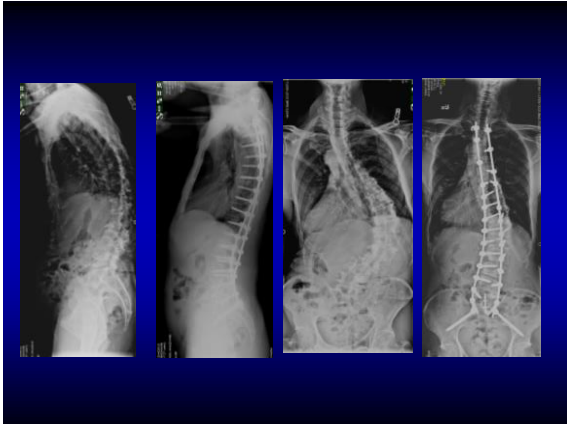
---

---

---

---





---

---

---

---

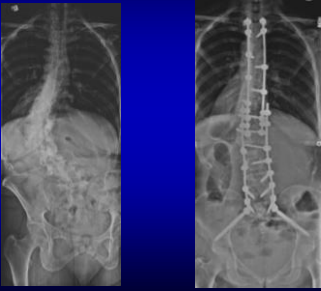
---

---

---

---

62 y.o. Female  
Degenerative on Idiopathic



---

---

---

---

---

---

---

---

Spondylolithesis



---

---

---

---

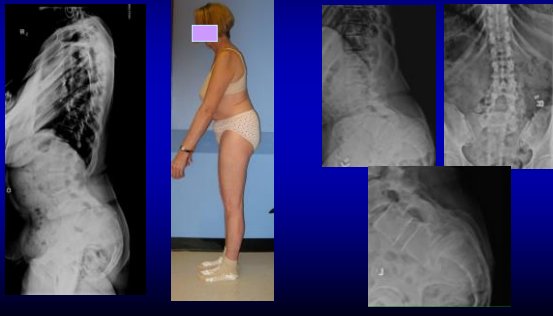
---

---

---

---

## Spondylolithesis



---

---

---

---

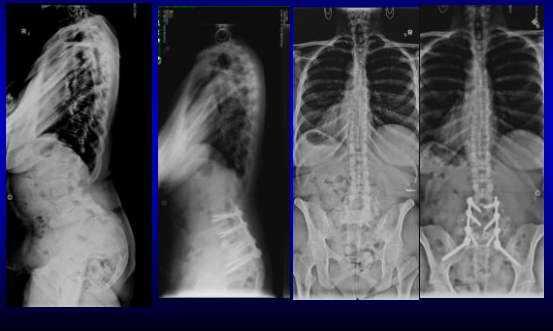
---

---

---

---

## Spondylolithesis



---

---

---

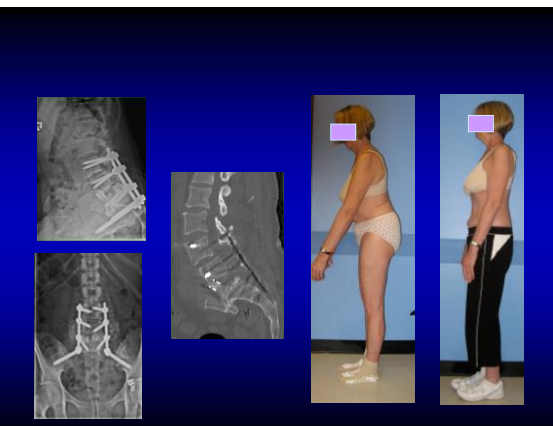
---

---

---

---

---



---

---

---

---

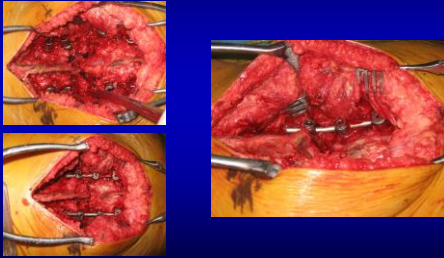
---

---

---

---

## Spondylolithesis



---

---

---

---

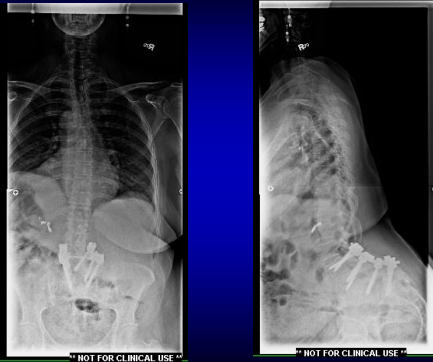
---

---

---

---

## Sacral Fracture



---

---

---

---

---

---

---

---



---

---

---

---

---

---

---

---



---

---

---

---

---

---

---

---



---

---

---

---

---

---

---

---



---

---

---

---

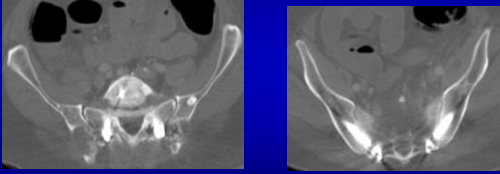
---

---

---

---

## Bone Graft Harvest!



---

---

---

---

---

---

---

---



---

---

---

---

---

---

---

---

## DISCUSSION

- Implant fractures were only seen with smaller diameter screws (7mm)
- Recommend using Larger screws (>8mm)
- Loosening > 2mm very rare
- Reoperation and removal are infrequent

---

---

---

---

---

---

---

---

## S2AI Technique

- Relatively easy and safe
- Minimal offset from the axis of spine
- Less prominent
- One rod no connectors
- Better control of the pelvis



---

---

---

---

---

---

---

---

## S2AI Technique

- Relatively easy and safe
- Minimal offset from the axis of spine
- Less prominent
- One rod no connectors
- Better control of the pelvis



▪ *EASIER TO PERFORM  
RECONSTRUCTIVE PROCEDURES AT  
THE LS JUNCTION*

---

---

---

---

---

---

---

---

## Conclusion

- Many techniques for PELVIC FIXATION
- High Rate of implant related problems
- S2 Alar Iliac (SAI) technique easy & safe
- Lower Complications
- Effective in distal LS corrective procedures
- No effect on the SI joint at 5 ys!
- Can be done through an MIS approach

---

---

---

---

---

---

---

---



---

---

---

---

---

---

---

---