63rd Southern Neurosurgical Society
Annual Meeting

Management of Degenerative Scoliosis

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Disclosures

- Medtronic- Consultant, royalties
- Depuy- Consultant
- Biomet- Consultant
- AO- Fellowship support, Grant support
- NIH- Grant support
- Department of Defense- Grant support
- NACTN- Grant support

Aging Population

- Over the next 25 years, the number of people >65 yrs/old will increase by 125% in the United States
- >70 million individuals

Age (y)	Population (in millions)		
	1990	2000	2030
20-44	99.73	104.00	110.45
≥65	31.2	34.99	70.3
≥85	3.1	4.2	8.9

Mayo Clin Proc. 2003 78(8):1026-40.

Prevalence Adult Scoliosis

- Robin evaluated 554 subjects aged between 50 and 84 years and found some scoliosis was found in 70% of the subjects
- Schwab a scoliosis rate of 68% in an older adult population with an average age of 70.5 years

Spine. 1982 Jul-Aug;7(4):355-9.
Spine. 2005 May 1;30(9):1082-5.

Types of Adult Scoliosis

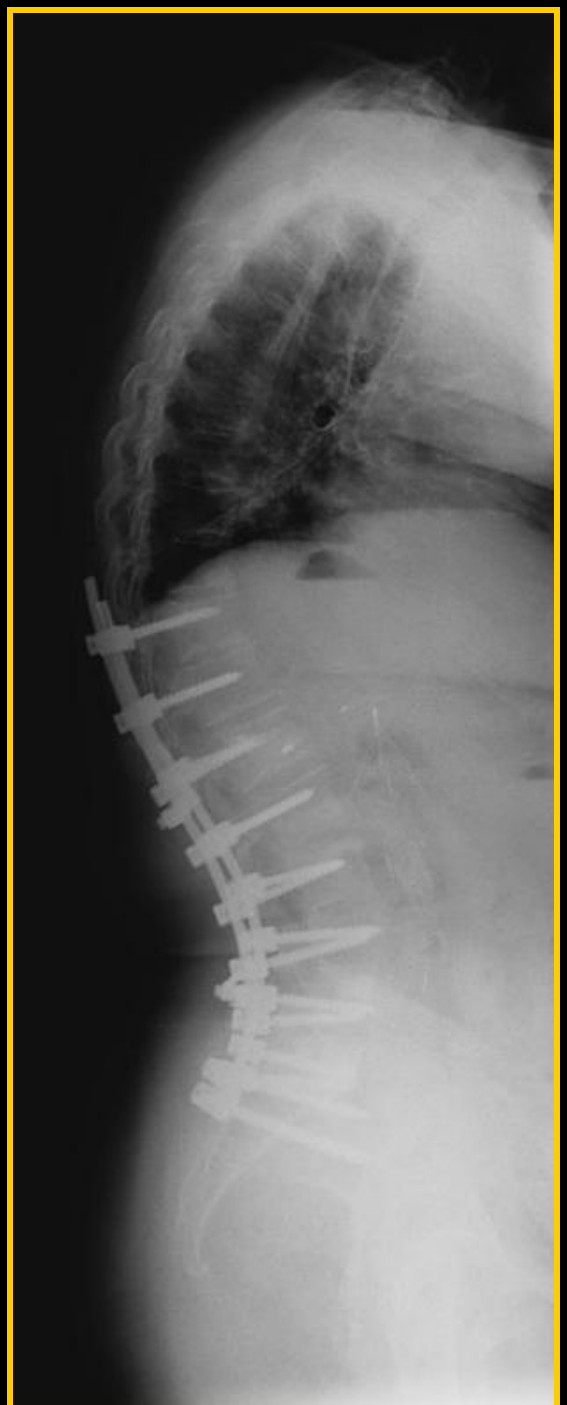
1. Adults with History of Adolescent Scoliosis
2. Older Adults with Degenerative “de novo” Scoliosis
    1. No Deformity Before 40 Years Old
    2. Consequence of disc degeneration
3. Iatrogenic Deformity
    - Mild or no deformity prior to destabilizing surgical intervention(s)

Degenerative Scoliosis:
Pathoanatomy

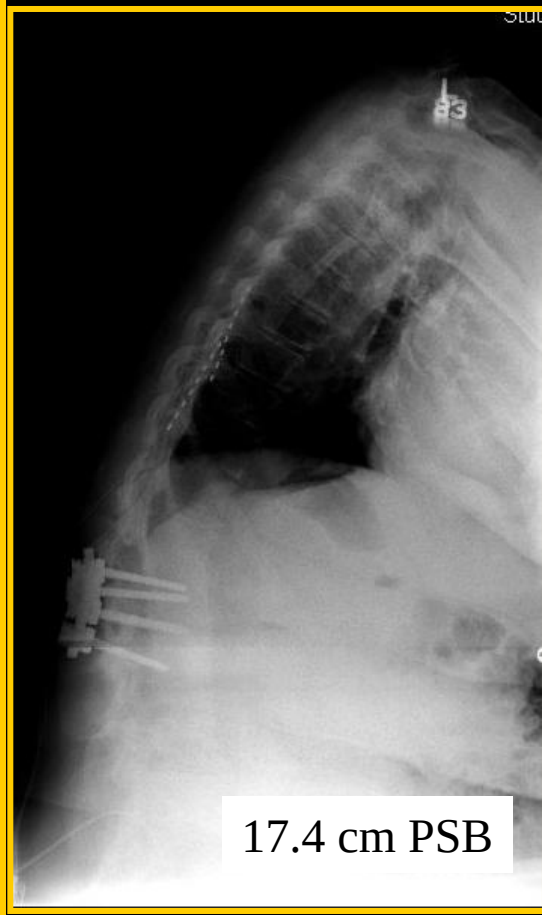
- Disc degeneration/collapse
- Facet arthrosis/hypertrophy
- Ligamentum hypertrophy
- Segmental instability:
  - Spondylolisthesis in 55%
  - Rotatory olisthesis in 13-34%
- Canal/foraminal stenosis common


74 y/o
28^0


L8S

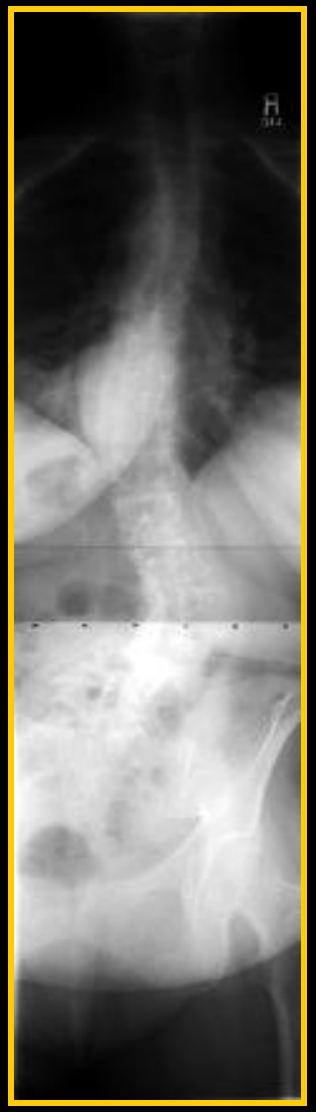


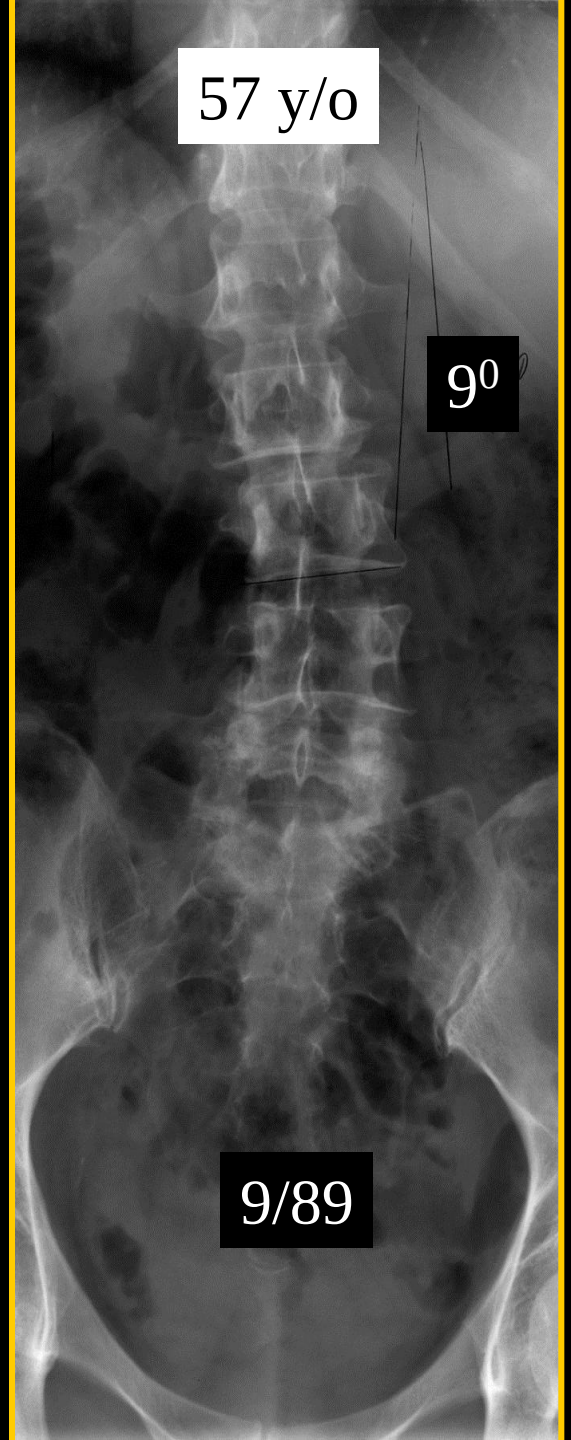
- The incidence of spinal deformity is almost certainly increasing
  - Aging population (more scoliosis)
  - Surgery resulting in iatrogenic deformity

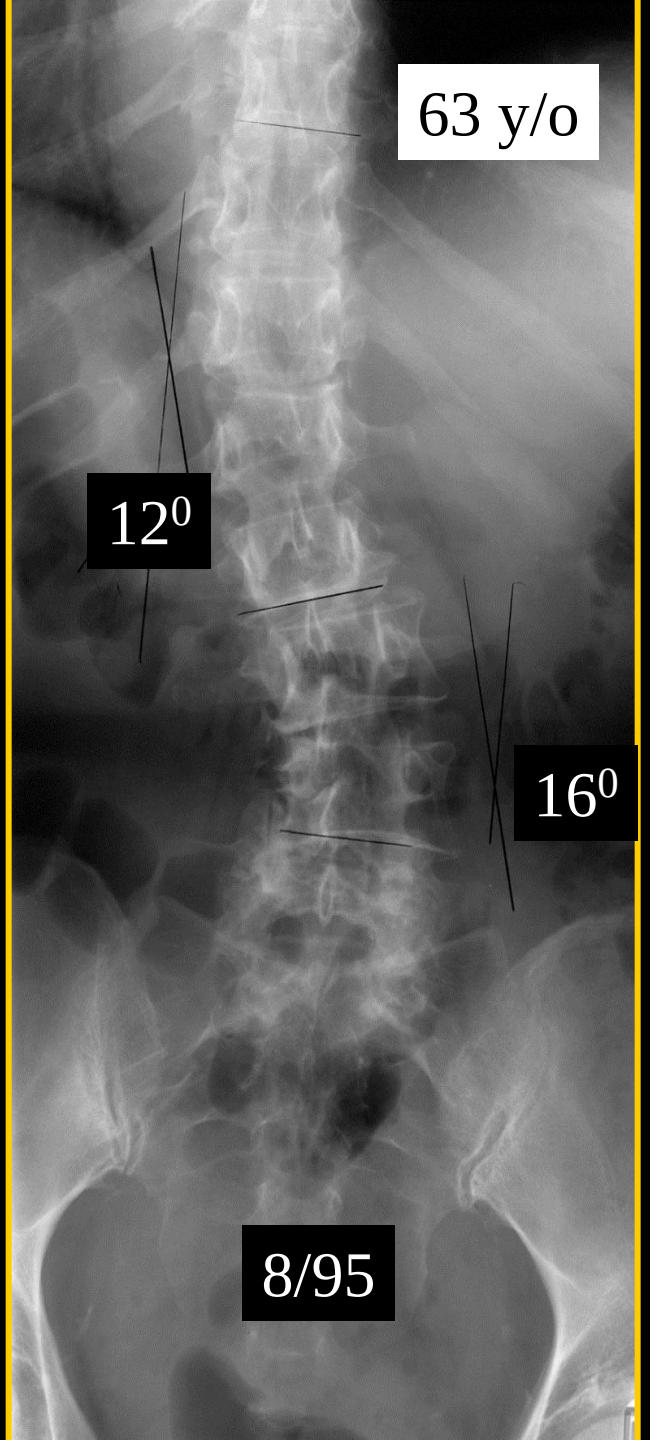


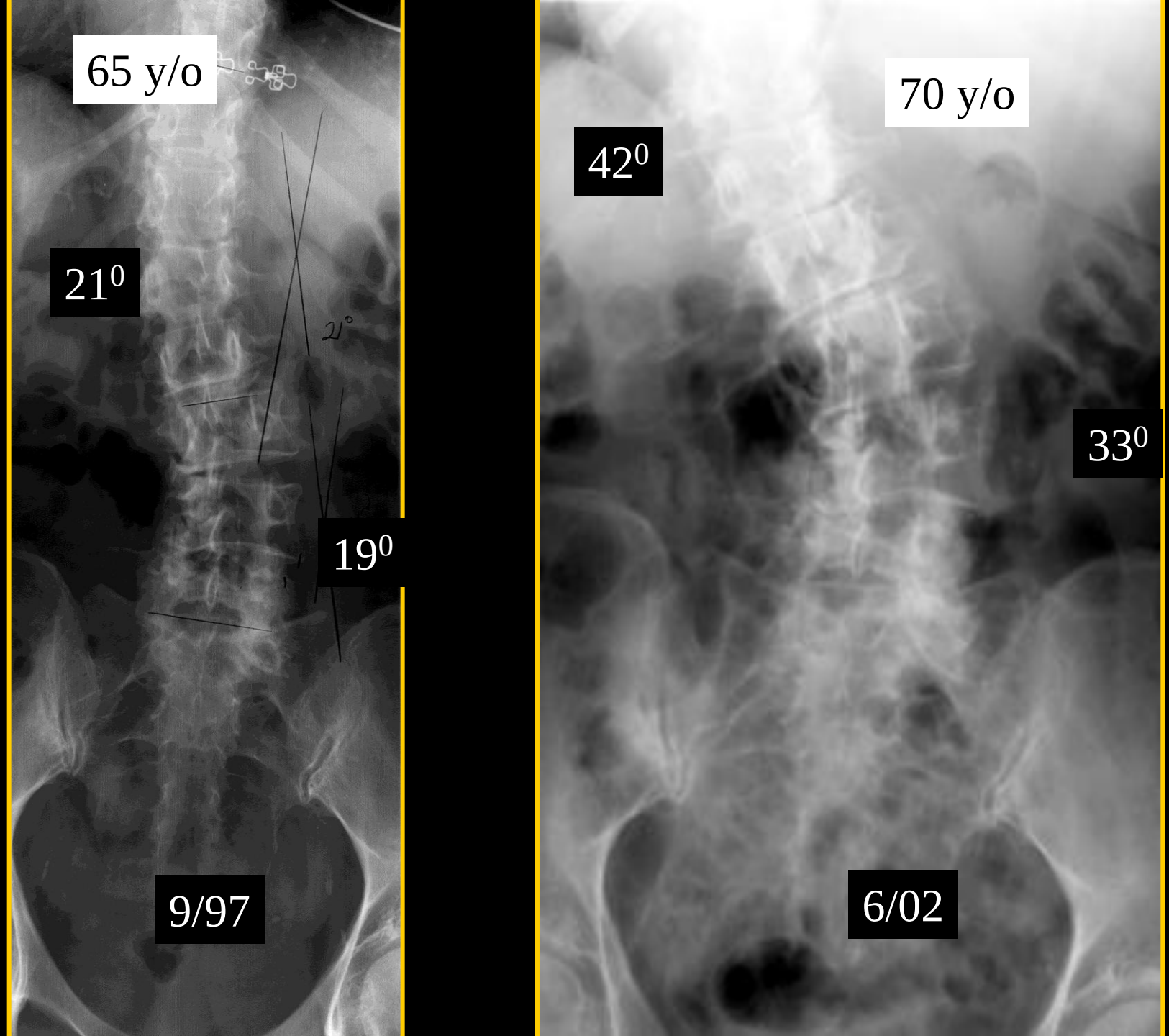
Natural History of Adult Scoliosis

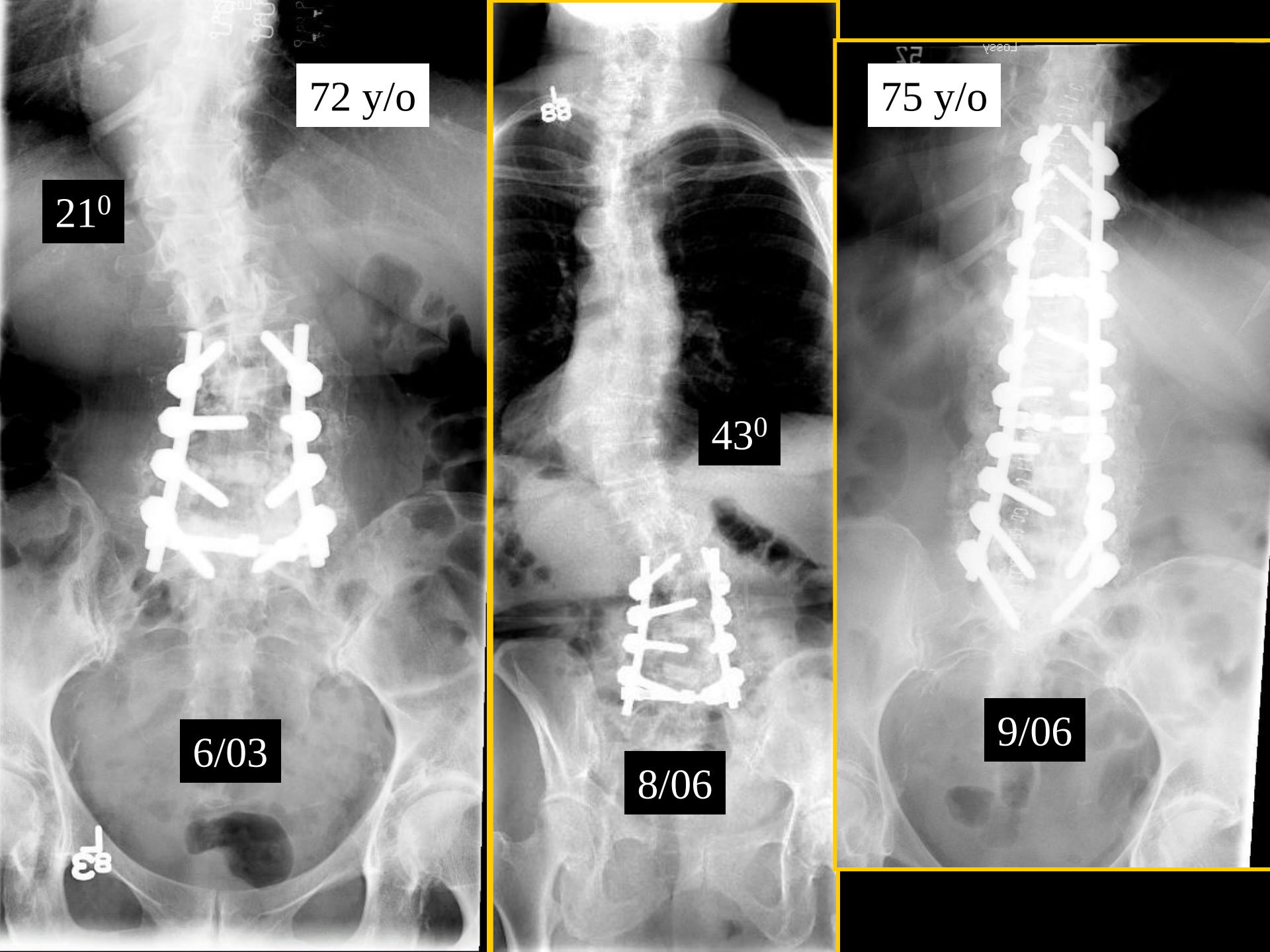
- Untreated AIS (>45^0) progresses 0.5 to 0.75^0 per year
- Greater magnitude curves are more likely to become symptomatic
- Degenerative adult curves may progress >3^0 per year
- Rapid decompensation may follow decompression for spinal stenosis

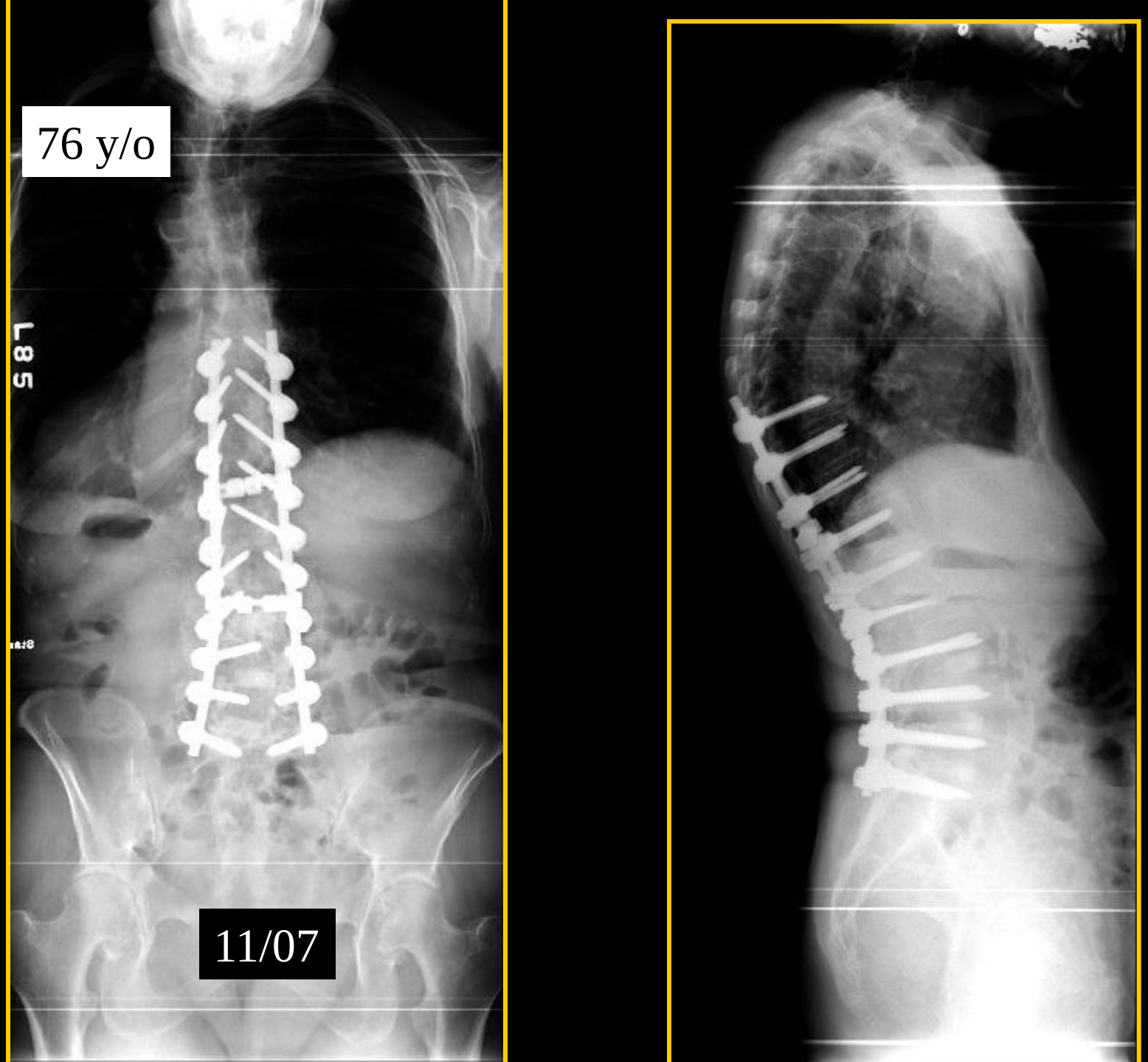



57 y/o
9^0
9/89


63 y/o
12^0
16^0
8/95


65 y/o
21°
21⁰
19⁰
9/97
70 y/o
42⁰
33⁰
6/02


72 y/o
21^0
6/03
43^0
8/06
75 y/o
9/06


76 y/o
L8 S
11/07

Impact of Adult Scoliosis?

- Adult scoliosis patients had significantly lower SF-36 scores when compared to the age matched norms
- Mean age 63 y/o

Table 3. SF-36 Scores for Maimonides Population *Vs.* General U.S. Population With Comorbid Conditions

SF-36 Variable	Mean Maimonides Score	General U.S. Score	*P* Value
PF	49.56	66.32	$P < 0.001$
RP	31.40	46.71	$P < 0.01$
BP	34.29	59.34	$P < 0.001$
GH	58.14	58.45	NS
VT	41.82	52.29	$P < 0.01$
SF	52.06	81.48	$P < 0.001$
RE	51.76	70.90	$P < 0.001$
MH	64.14	74.93	$P < 0.001$

PF = Physical Functioning scale; RP = Role Physical scale; BP = Bodily Pain scale; GH = General Health scale; VT = Vitality scale; SF = Social Functioning scale; RE = Role Emotional scale; MH = Mental Health scale; NS = not significant.
N = 49; age >55 = 32; age <55 = 17.

Schwab F et al. Adult Scoliosis: A Health Assessment Analysis by SF-36. Spine 2003

Incidence of Neurological Compression

- Symptomatic progression of AIS has neurologic compression in 31%
- Adult degenerative scoliosis has radiographic evidence neurological compression in up to 90%
  - Kostuik JP in Bridwell & DeWald 1997
  - Grubb SA Spine 1988

Prevalence, Severity, and Impact of Foraminal and Canal Stenosis Among Adults With Degenerative Scoliosis

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BACKGROUND: Management approaches for adult scoliosis are primarily based on adults with idiopathic scoliosis and extrapolated to adults with degenerative scoliosis. However, the often substantially, but poorly defined, greater degenerative changes present in degenerative scoliosis impact the management of these patients.

OBJECTIVE: To assess the prevalence, severity, and impact of canal and foraminal stenosis in adults with degenerative scoliosis seeking operative treatment.

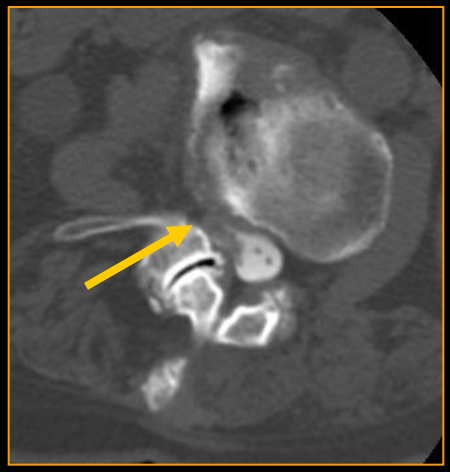
METHODS: A prospectively collected database of adult patients with deformity was reviewed for consecutive patients with degenerative scoliosis seeking surgical treatment, without prior corrective surgery. Patients completed the Oswestry Disability Index, SF-12, Scoliosis Research Society 22 questionnaire, and a pain numeric rating scale (0-10). Based on MRI or CT myelogram, the central canal and foraminae from T6 to S1 were graded for stenosis (normal or minimal/mild/moderate/severe).

RESULTS: Thirty-six patients were included (mean age, 68.9 years; range, 51-85). The mean leg pain numeric rating scale was 6.5, and the mean Oswestry Disability Index score was 53.2. At least 1 level of severe foraminal stenosis was identified in 97% of patients; 83% had maximum foraminal stenosis in the curve concavity. All but 1 patient reported significant radicular pain, including 78% with discrete and 19% with multiple radiculopathies. Of those with discrete radiculopathies, 76% had pain corresponding to areas of the most severe foraminal stenosis, and 24% had pain corresponding to areas of moderate stenosis.

CONCLUSION: Significant foraminal stenosis was prevalent in patients with degenerative scoliosis, and the distribution of leg pain corresponded to levels of moderate or severe foraminal stenosis. Failure to address symptomatic foraminal stenosis when surgically treating adult degenerative scoliosis may negatively impact clinical outcomes.

KEY WORDS: Adult degenerative scoliosis, Adult idiopathic scoliosis, Adult scoliosis, Central stenosis, Foramen, Foraminal stenosis, Radiculopathy, Pain, Spine, Stenosis, Surgery

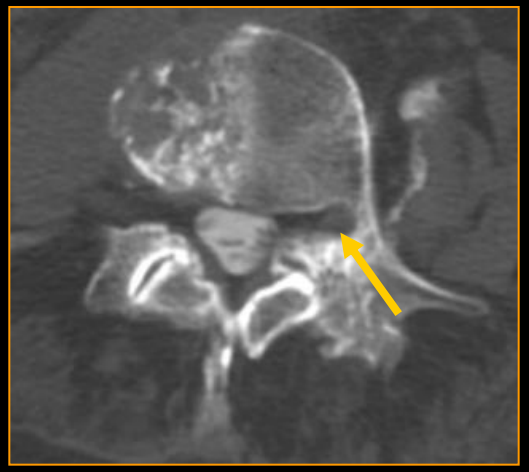
CT-myelogram



- Mod R L2-3 foraminal stenosis

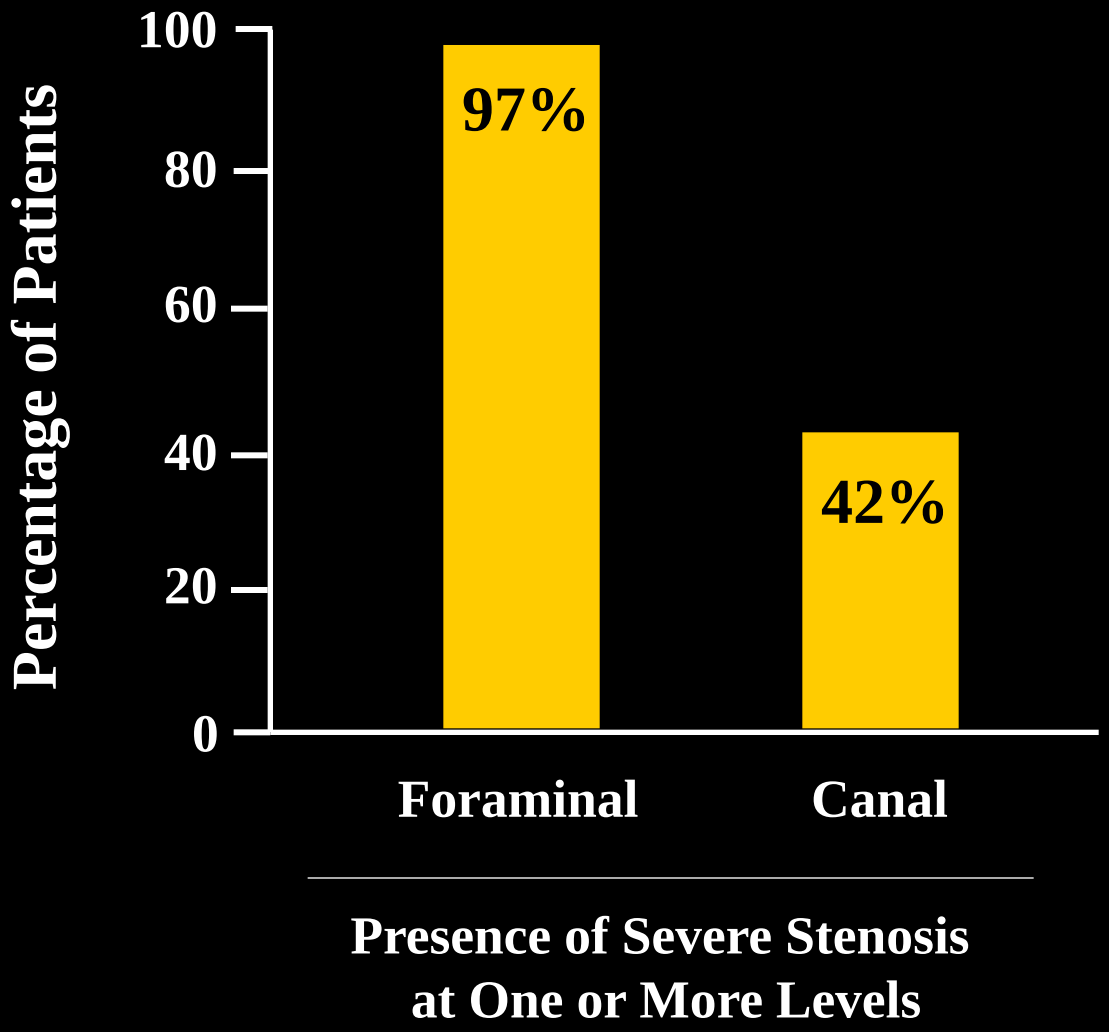
- Mod L3-4 canal stenosis

- Mod R L3-4 foraminal stenosis



- Mod L L4-5 foraminal stenosis

Prevalence of Stenosis in Adult Degenerative Scoliosis (n=37)



Fu *et al* (unpublished data)

Neurological Symptoms/Deficits in Adults with Scoliosis

Neurological symptoms and deficits in adults with scoliosis who present to a surgical clinic: incidence and association with the choice of operative versus nonoperative management

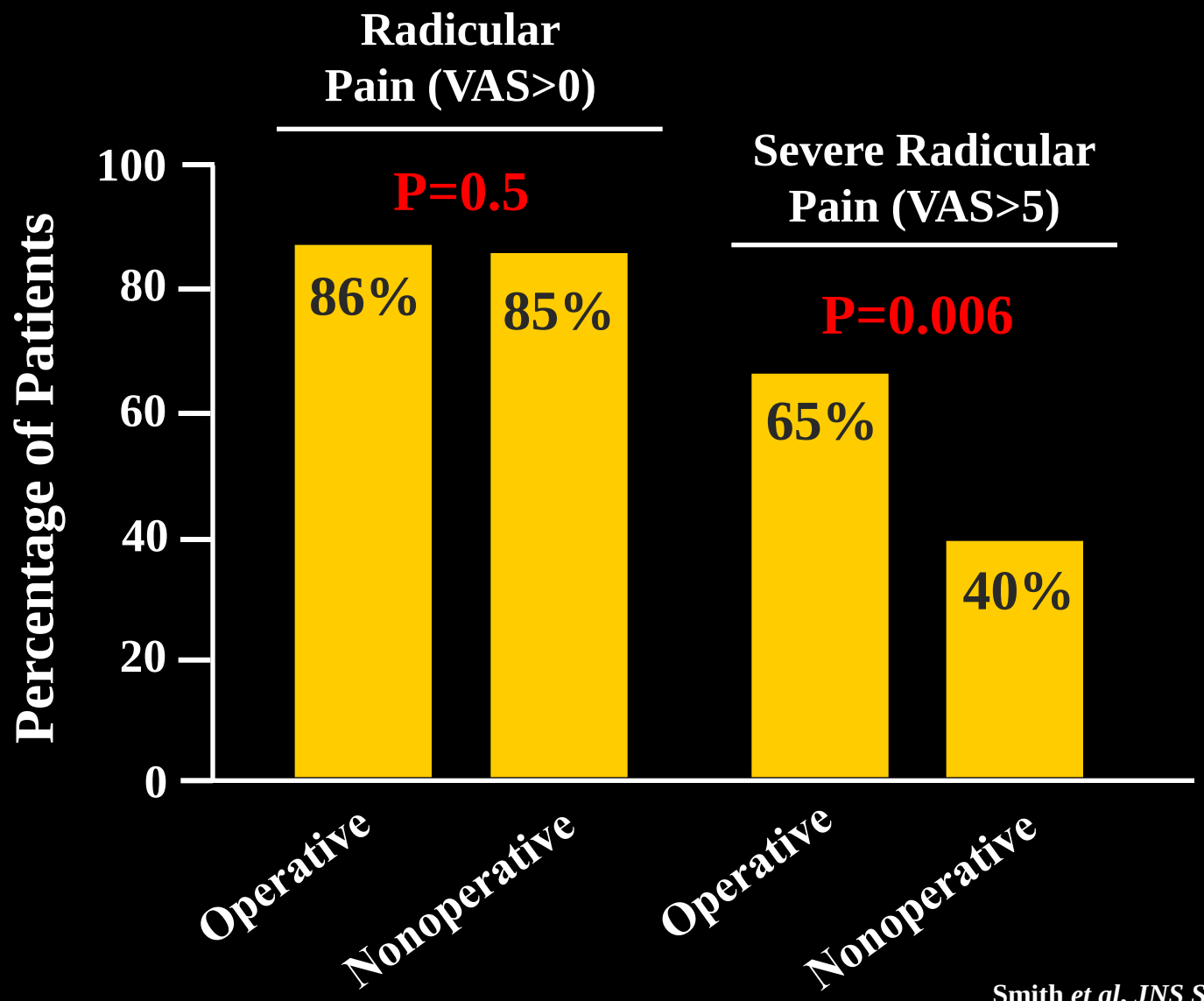
Clinical article

Justin S. Smith, M.D., Ph.D., Kai-Ming Fu, M.D., Ph.D., Peter Urban, R.N., and Christopher I. Shaffrey, M.D.

Department of Neurosurgery, University of Virginia, Charlottesville, Virginia

J Neurosurg Spine 9:326–331, 2008

Neurological Symptoms/Deficits in Adults with Scoliosis (n=204)



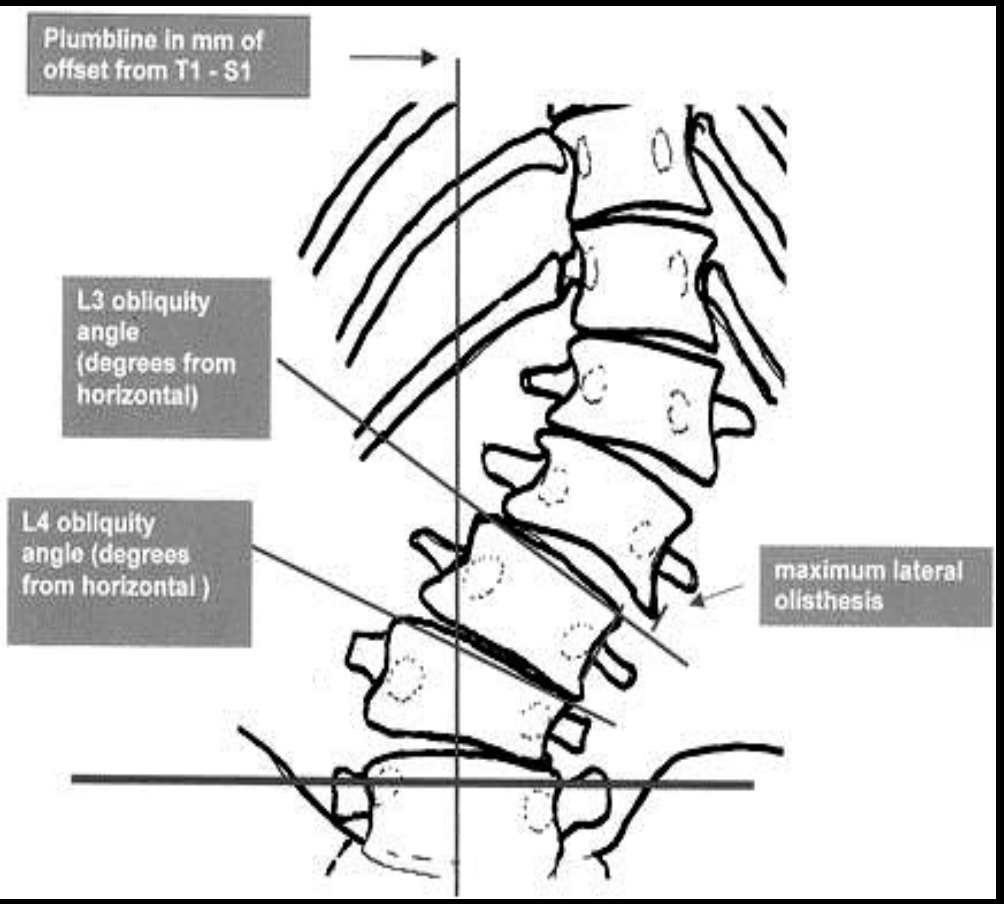
Smith *et al*, *JNS Spine* 9:326-331, 2008.

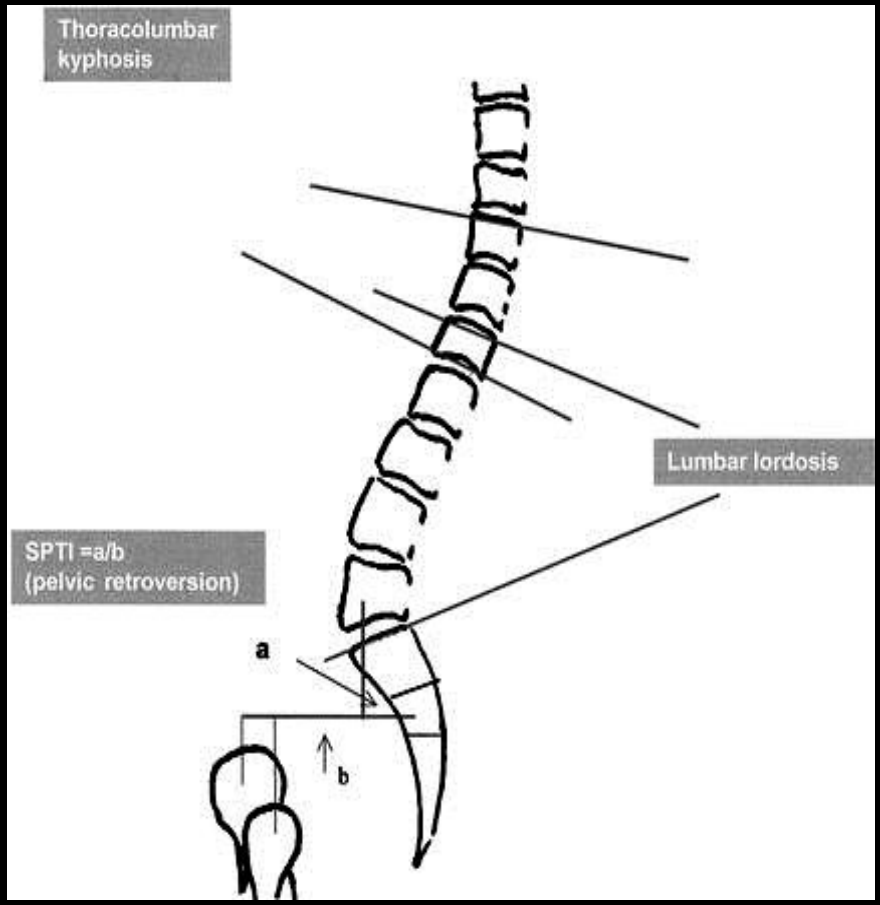
Radiographic Factors = Pain

- A correlation of radiographic parameters and pain in adult scoliosis
- Significant radiographic parameters are:
  - Endplate obliquity of L3 and L4
  - Lateral olisthesis between lumbar vertebrae
  - Thoracolumbar kyphosis
  - Loss of lumbar lordosis
- Cobb angle and age did not correlate with symptoms

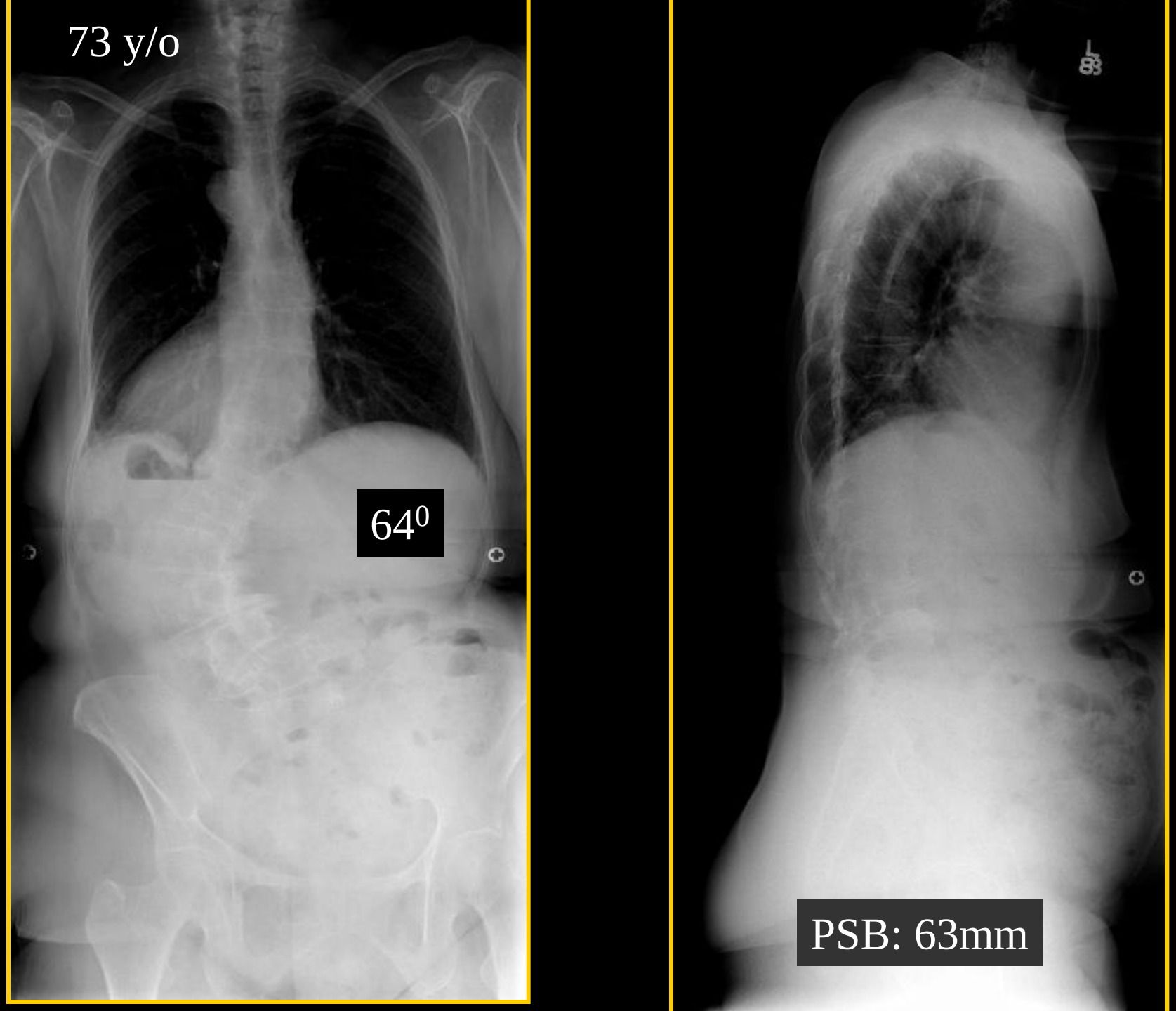
Schwab FB. Spine 2002

Radiographic Measurements

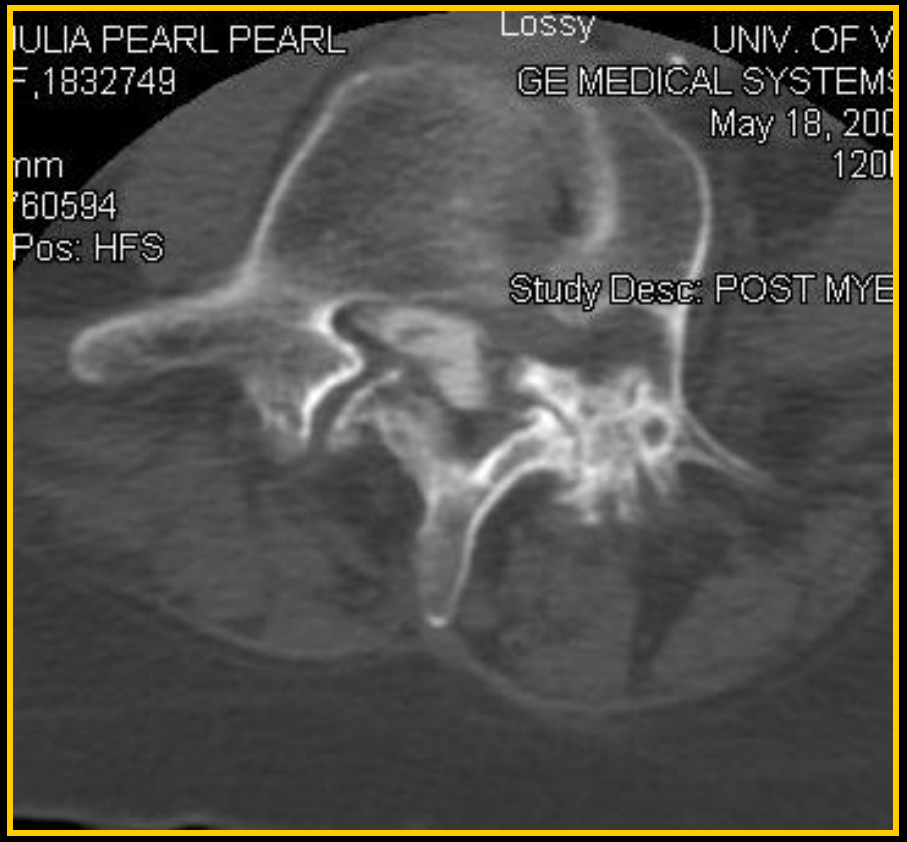


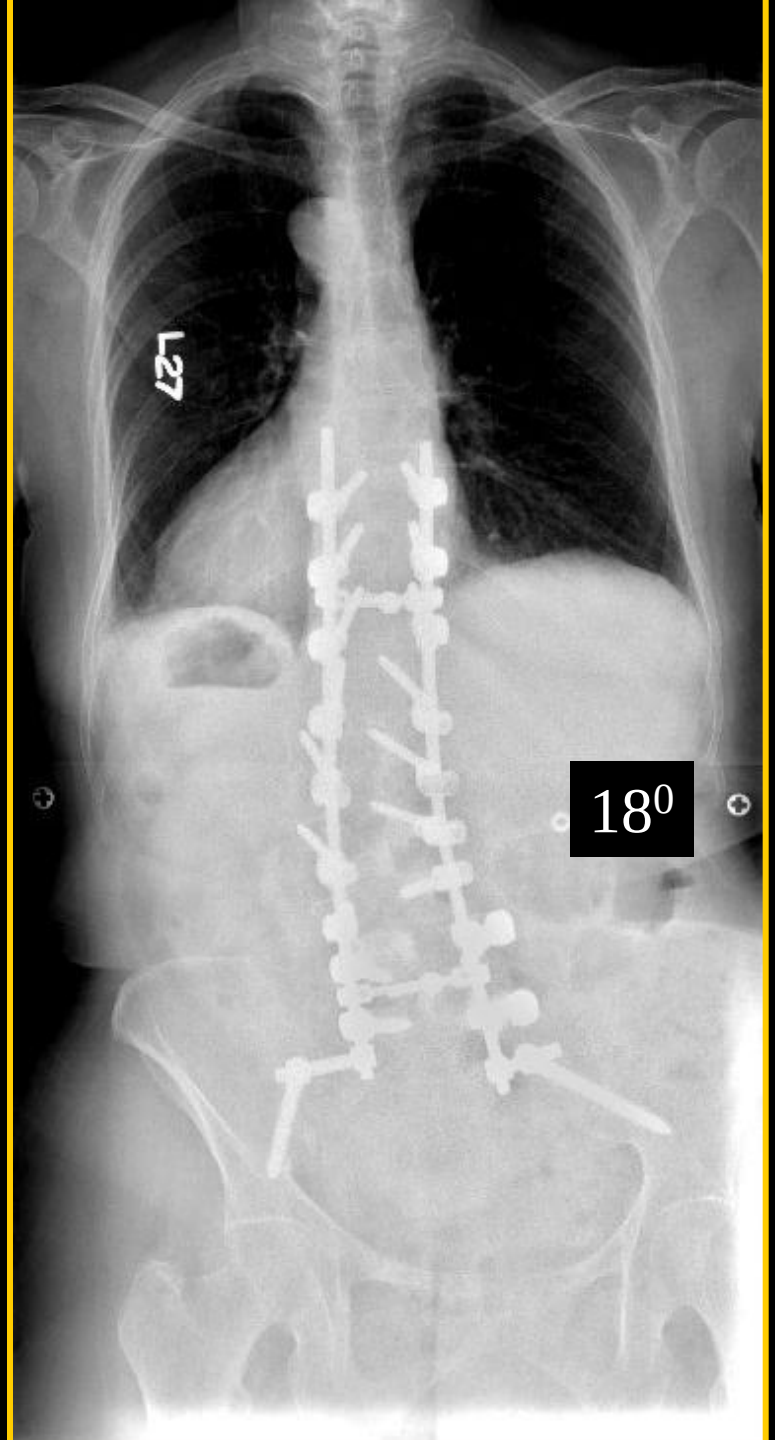


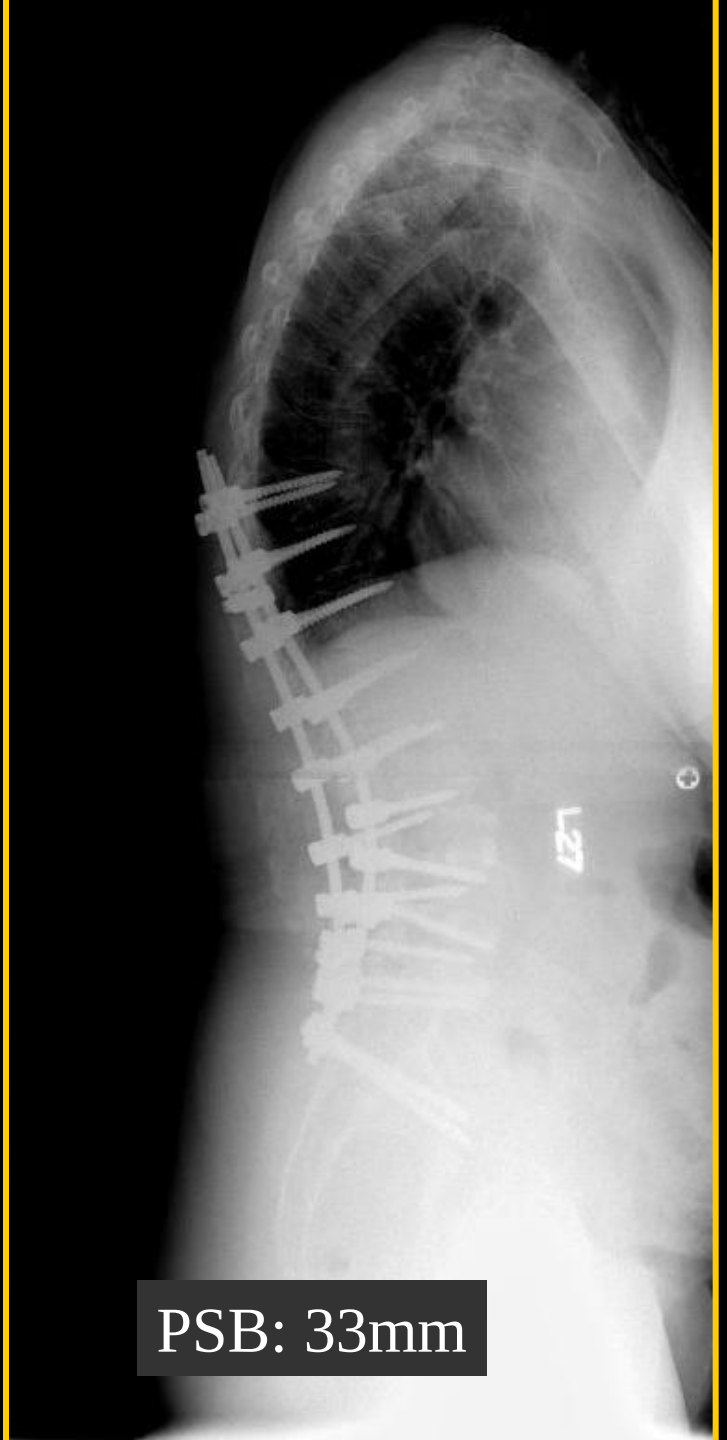
Schwab FB et al. SPINE 2002;27:387-392


73 y/o
64^{0}
PSB: 63mm


PEARL
UNIV. OF
GE MEDICAL SYSTEM
May 18, 20
120
Study Desc: POST MYE


ULIA PEARL PEARL
F,1832749
nm
760594
Pos: HFS
Lossy
UNIV. OF V
GE MEDICAL SYSTEMS
May 18, 200
120
Study Desc: POST MYE


L27
18^0


L27
PSB: 33mm

Loss of Global Alignment

Glassman, Bridwell, Dimar, Horton, Berven, Schwab. SPINE 2005

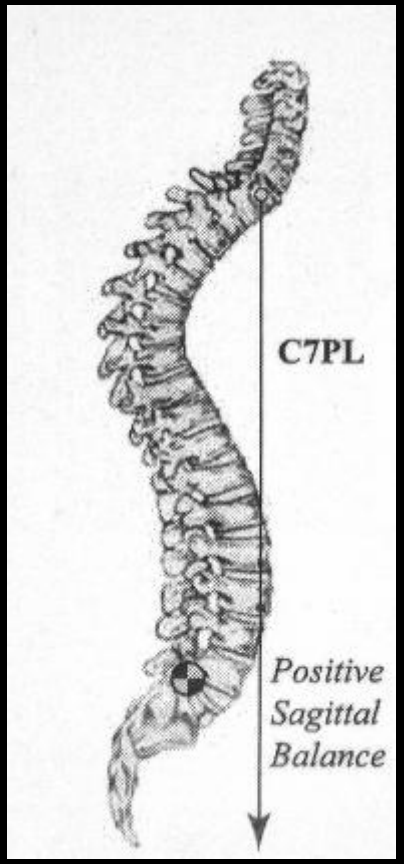
- Plumbline Shift Anteriorly

=> Increasing disability

SF-12, SRS-29, ODI ($p<0.001$)

=> Lumbar kyphosis marked disability

SRS-29, ODI ($p<0.05$)



SPINE Volume 30, Number 6, pp 682–688
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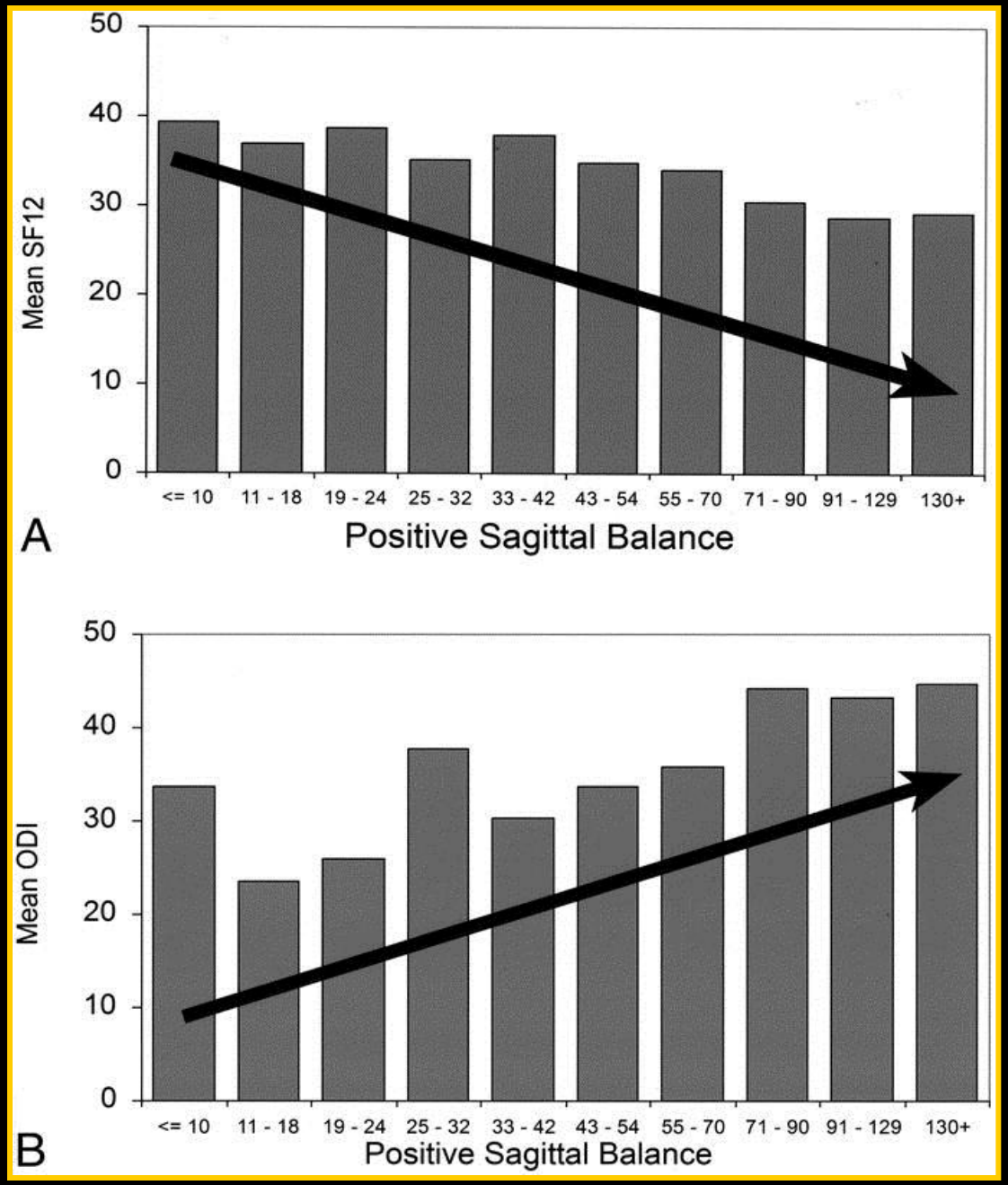
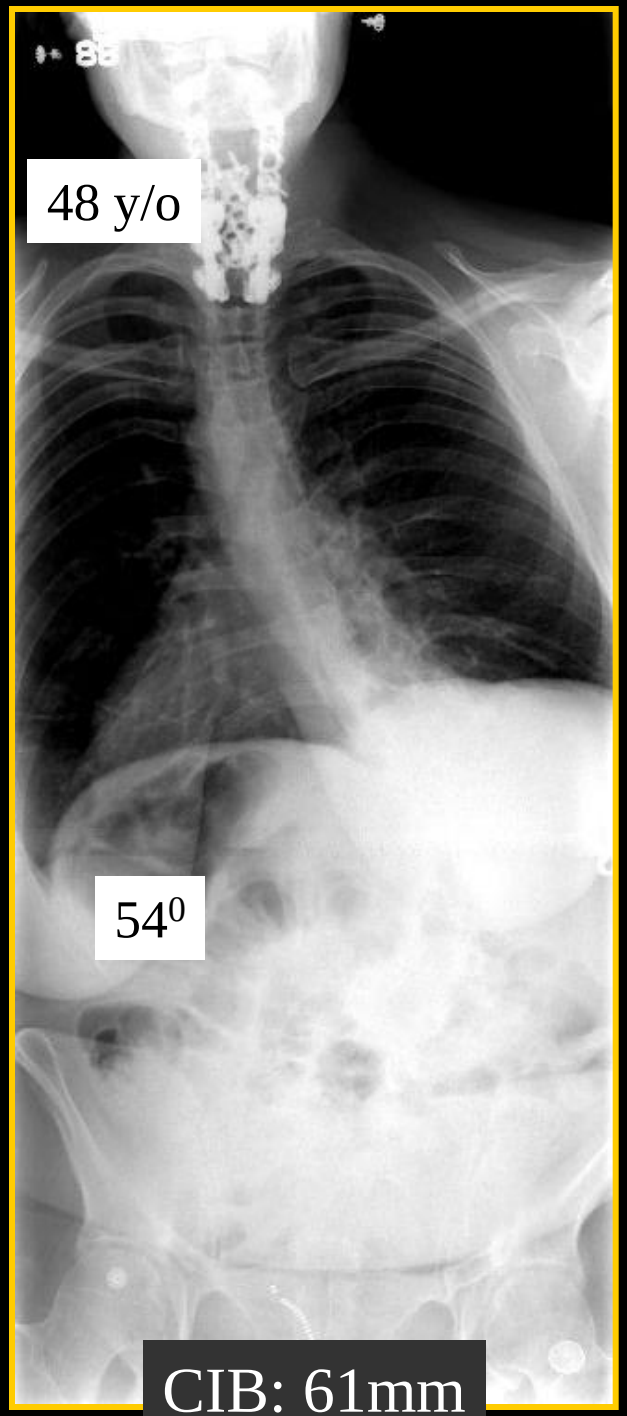
Correlation of Radiographic Parameters and Clinical Symptoms in Adult Scoliosis

Steven D. Glassman, MD,* Sigurd Berven, MD,† Keith Bridwell, MD,‡ William Horton, MD,§ and John R. Dimar, MD*

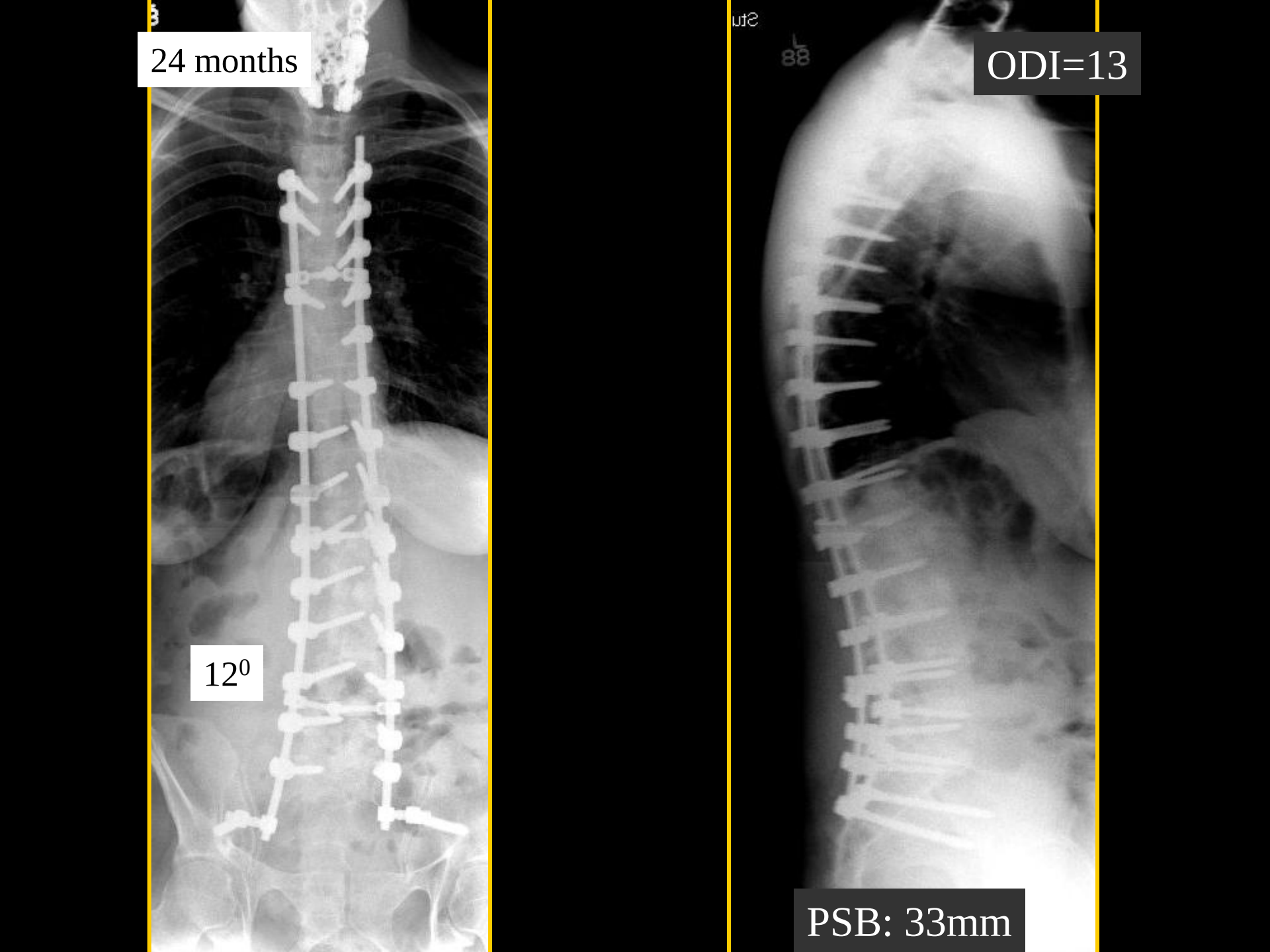
- This study correlates radiographic measures of deformity with scores on the SF-12, SRS-29, and ODI profiles
- 298 patients studied include 172 with no prior surgery and 126 who had undergone prior spine fusion
- Positive sagittal balance was the most reliable predictor of clinical symptoms in both patient groups



Glassman SD. Spine 2005

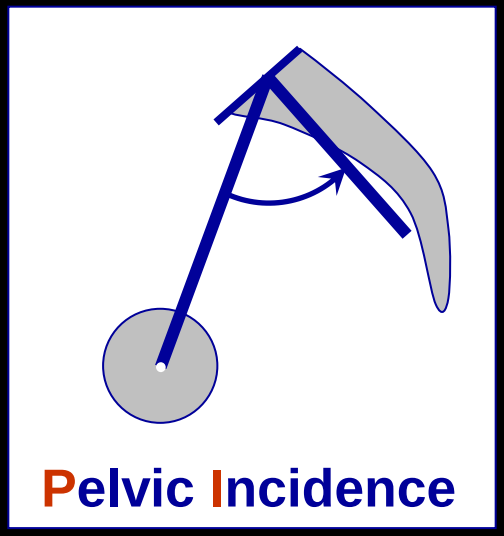

48 y/o
54^0
CIB: 61mm


ODI=72
PSB: 154mm

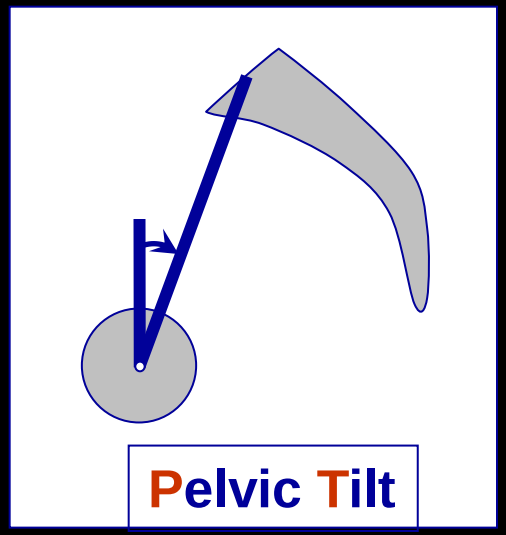

24 months
12⁰
ODI=13
PSB: 33mm

Pelvic Parameters

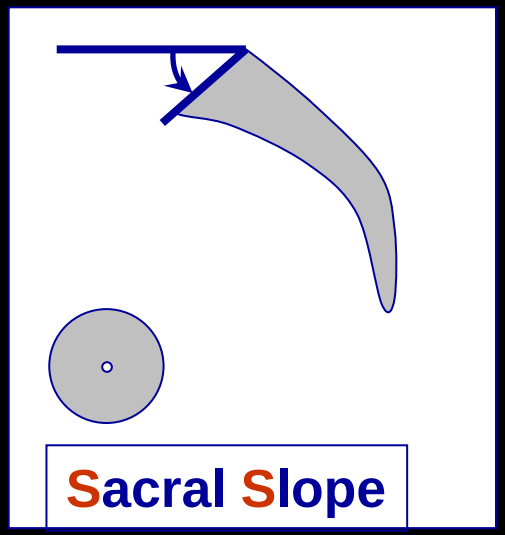
Duval Beaupere, Vidal, Roussouly, Farcy ...



PI: 40-65°
Morphologic Parameter



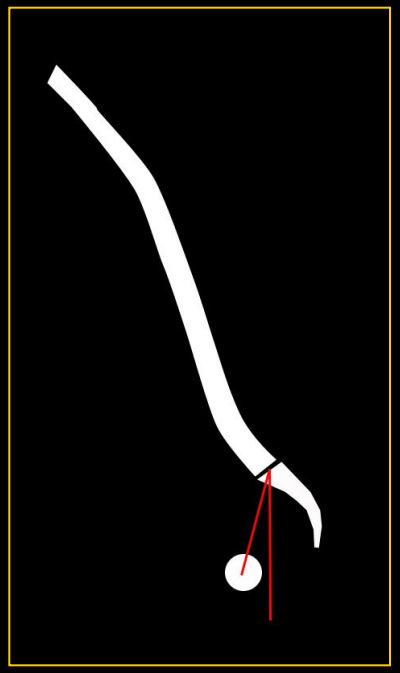
PT: 10-25°
Compensatory Parameter



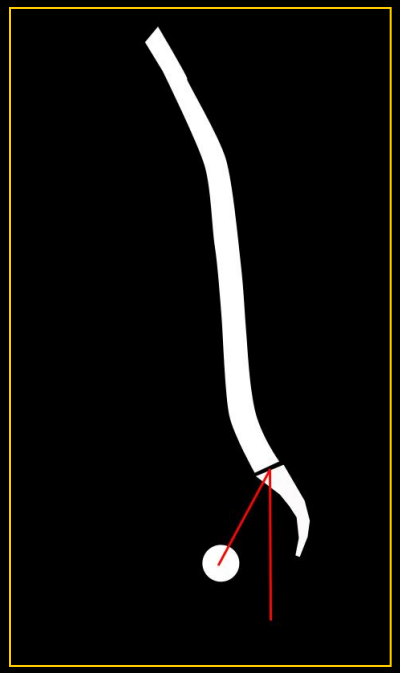
SS: 30-50°
Compensatory Parameter

PI = PT + SS

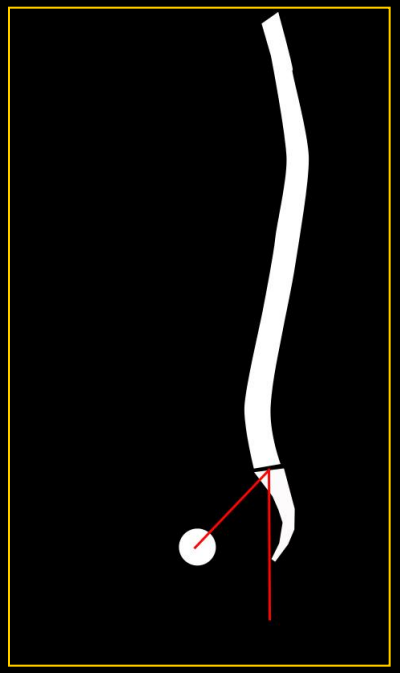
Same structural deformity … different compensation



Large SVA, No PT



Moderate SVA / PT



No SVA, Large PT

Pelvis = base of the spine, regulator of the standing posture …. “Pelvic Vertebra”

SPINE Volume 34, Number 17, pp E599–E606
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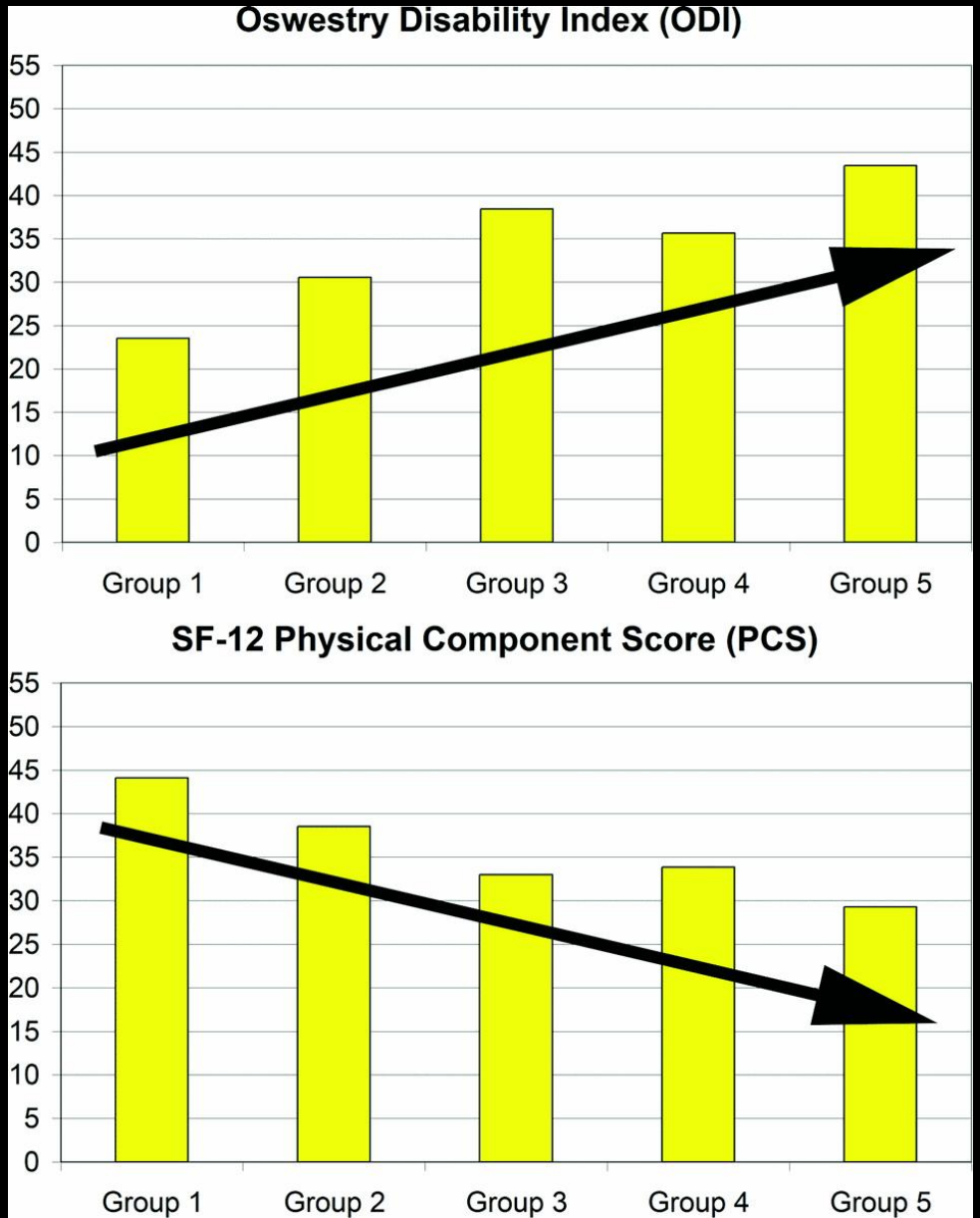
Pelvic Tilt and Truncal Inclination

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

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

- Prospective study was carried out on 125 adult patients with spinal deformity (mean age: 57 years)
- Correlation analysis between radiographic spinopelvic parameters and HRQOL measures was performed

Pelvic Tilt versus HQRL



Classification Guidelines

Classification of Adult Deformity

Curve Type (Cobb angle)

Type

T: Thoracic only – with lumbar curve <30°

L: TL/Lumbar only – with thoracic curve <30°

D: Double curve pattern – at least one T and one TL/L curve, with both curves at least 30°

S: Sagittal deformity – applies to deformities with <30° coronal Cobb angle, and any of the following modifiers:

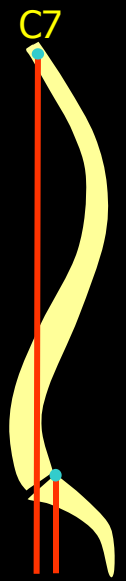
-B or C
-M or H
-P or VP

3 Modifiers

PI-LL	Pelvic Tilt	Global Balance
A: small <10°	L: PT <20°	N: SVA <4cm
B: moderate 10-20°	M: PT 20-30°	P: SVA 4-9.5cm
C: marked >20°	H: PT >30°	VP: SVA >9.5cm

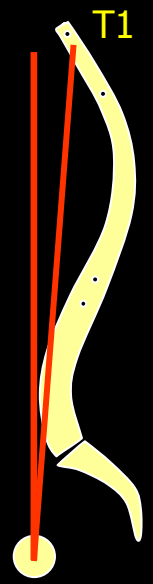
Example: Type L (45°) B,M,VP

Alignment Objectives



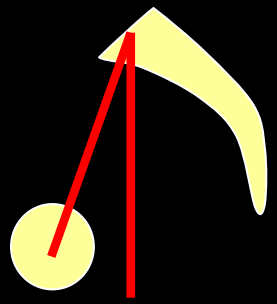
SVA

<5cm



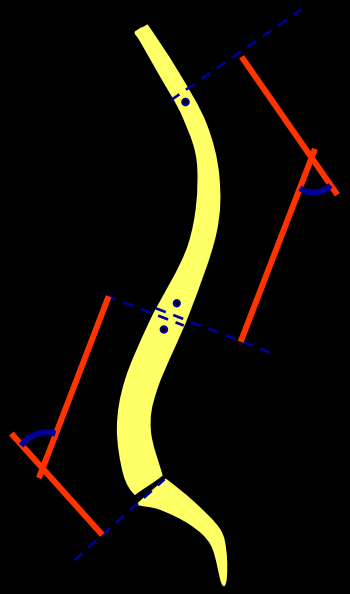
T1 Tilt

<0^0



PT

<25^0



Proportional:

LL=PI +/- 9^0

SPINE Volume 34, Number 20, pp 2171–2178
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Does Treatment (Nonoperative and Operative) Improve the Two-Year Quality of Life in Patients With Adult Symptomatic Lumbar Scoliosis

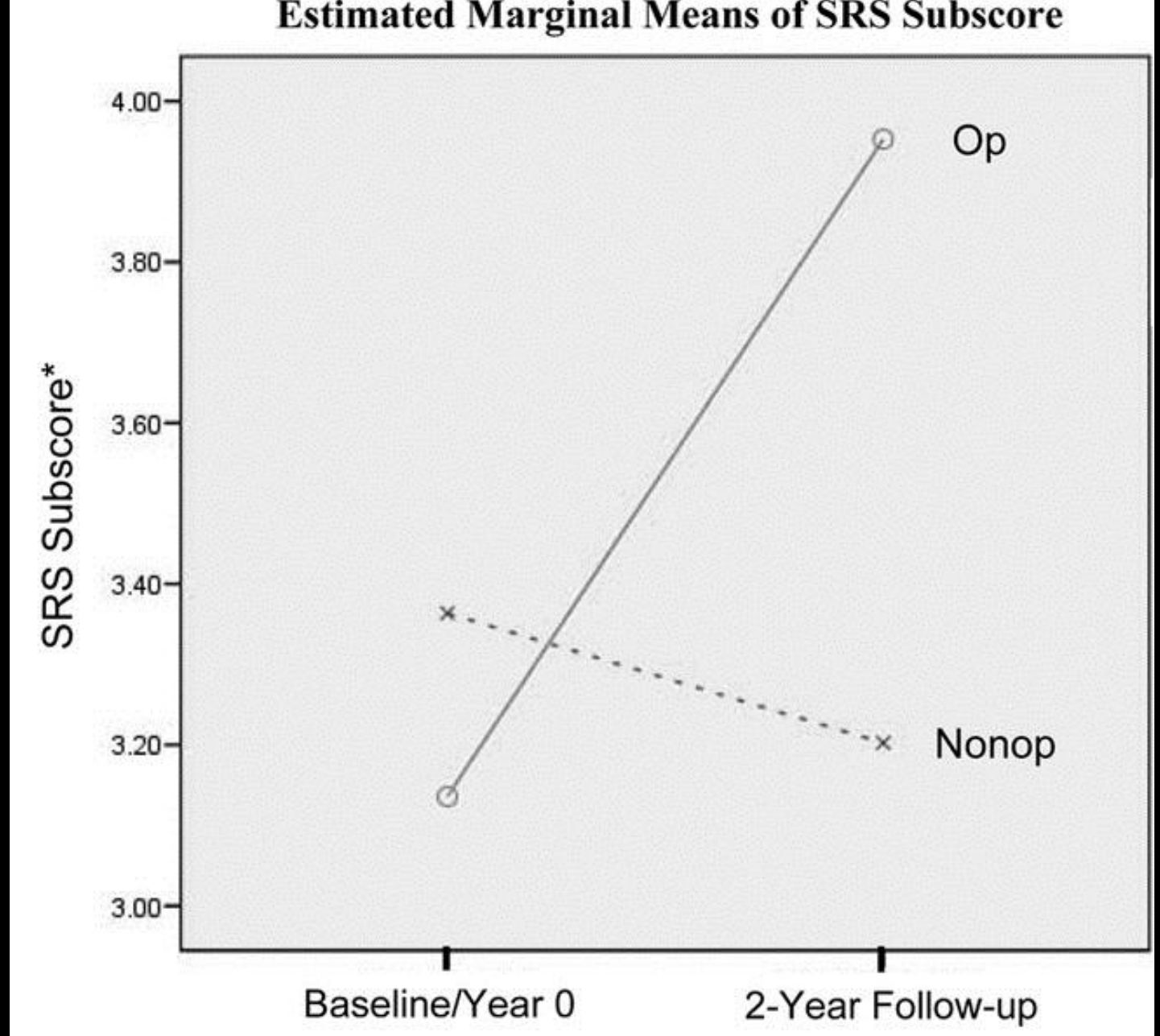
A Prospective Multicenter Evidence-Based Medicine Study

Keith H. Bridwell, MD,* Steven Glassman, MD,† William Horton, MD,‡
Christopher Shaffrey, MD,§ Frank Schwab, MD,¶ Lukas P. Zebala, MD,* Lawrence G. Lenke, MD,*
Joan F. Hilton, ScD,‖ Michael Shainline, MS, MBA,** Christine Baldus, RN, MHS,*
and David Wootten, PhD††

- Compared results of adult symptomatic lumbar scoliosis patients treated nonoperatively and operatively
- 160 consecutively enrolled patients (ages 40–80 years) with baseline and 2-year follow-up data from 5 centers

Does Treatment (Nonoperative and Operative) Improve the Two-Year Quality of Life in Patients With Adult Symptomatic Lumbar Scoliosis

- Lumbar scoliosis without prior surgical treatment
  Cobb angle of $\geq$30° (mean: 54°)
- ODI score of $\geq$20 (mean: 33), Scoliosis Research Society (SRS-22) domain scores of 4 or less in pain, function, and self-image (mean: 3.2)
- 2 cohorts were propensity matched for Cobb angle, SRS scores, ODI scores, and NRS back and leg pain scores at baseline


Estimated Marginal Means of SRS Subscore
SRS Subscore*
4.00
3.80
3.60
3.40
3.20
3.00
Op
Nonop
Baseline/Year 0
2-Year Follow-up
------ ADO Nonoperative group; n=75 patients with ASLS
ADO Operative group; n=85 patients with ASLS

SPINE Volume 35, Number 5, pp 578–582

The Costs and Benefits of Nonoperative Management for Adult Scoliosis

Steven D. Glassman, MD,*† Leah Y. Carreon, MD, MSc,† Christopher I. Shaffrey, MD,‡ David W. Polly, MD,§ Stephen L. Ondra, MD,¶ Sigurd H. Berven, MD,‖ and Keith H. Bridwell, MD**

- Study cohort of 123 patients with a mean age of 53.3 (18–79) years
- Nonoperative interventions included medication, exercise therapy, physical therapy, chiropractic treatment, and injections
- Narcotic medication was used by 16 patients in year 1 and 32 patients in year 2

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- Total cost over the 2-year observation period averaged $9704 in the low symptom patients, $11,116 in the mid symptom, and $14,022 in the high symptom patients
- There was no significant change in any of the HRQOL outcome parameters in any symptom group at 2-years

IMPROVEMENT OF BACK PAIN WITH OPERATIVE AND NONOPERATIVE TREATMENT IN ADULTS WITH SCOLIOSIS

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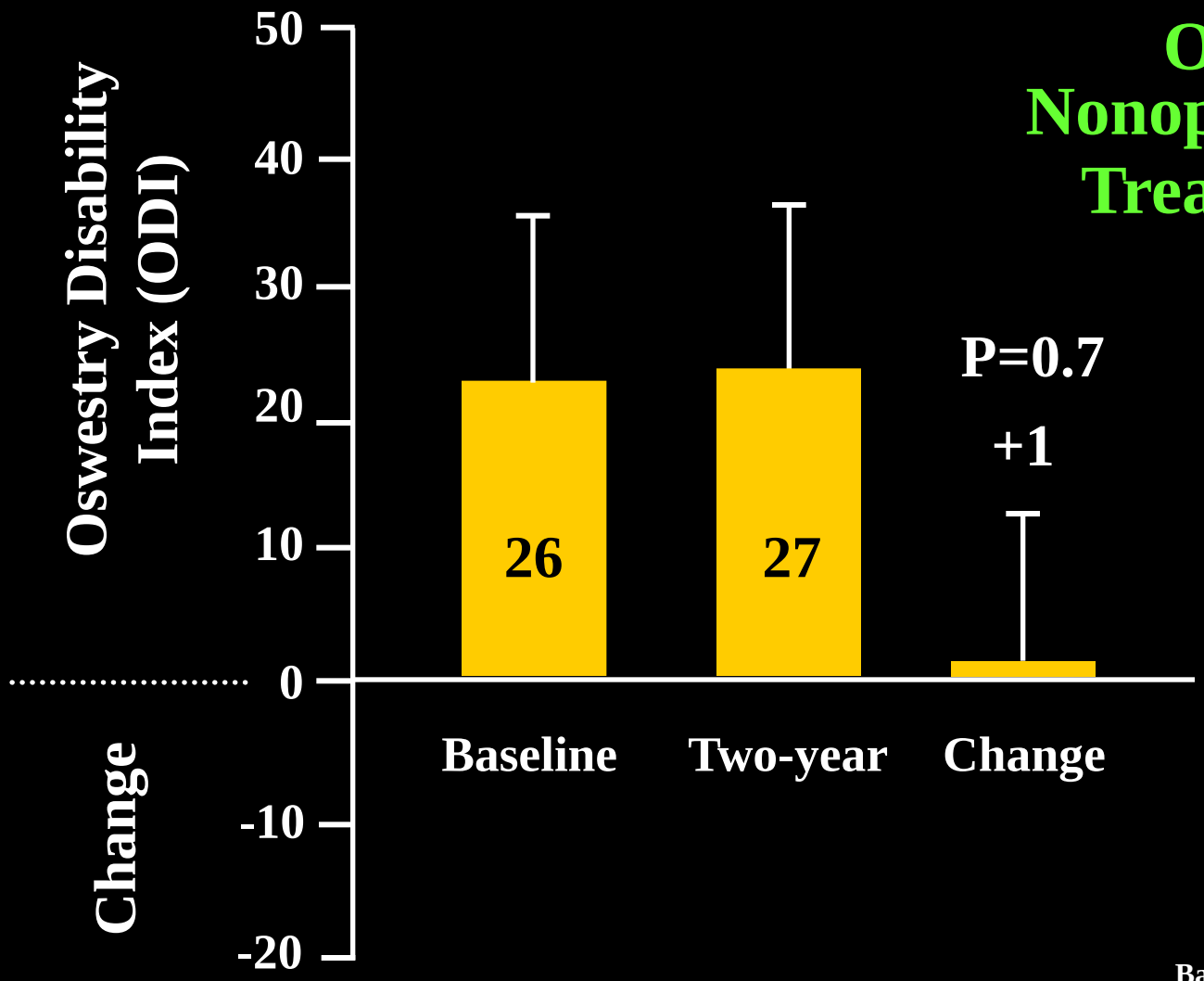
Spine Center for Orthopaedic and Neurosurgical Care, New York, New York

- 317 scoliosis patients with back pain, 147 (46%) had surgery and 170 patients (54%) non-op care
- At 2-year follow-up operatively treated patients had a lower NRS score for back pain ($P<0.001$) and ODI ($P<0.001$) and higher SRS-22 ($P<0.001$) than non-operative

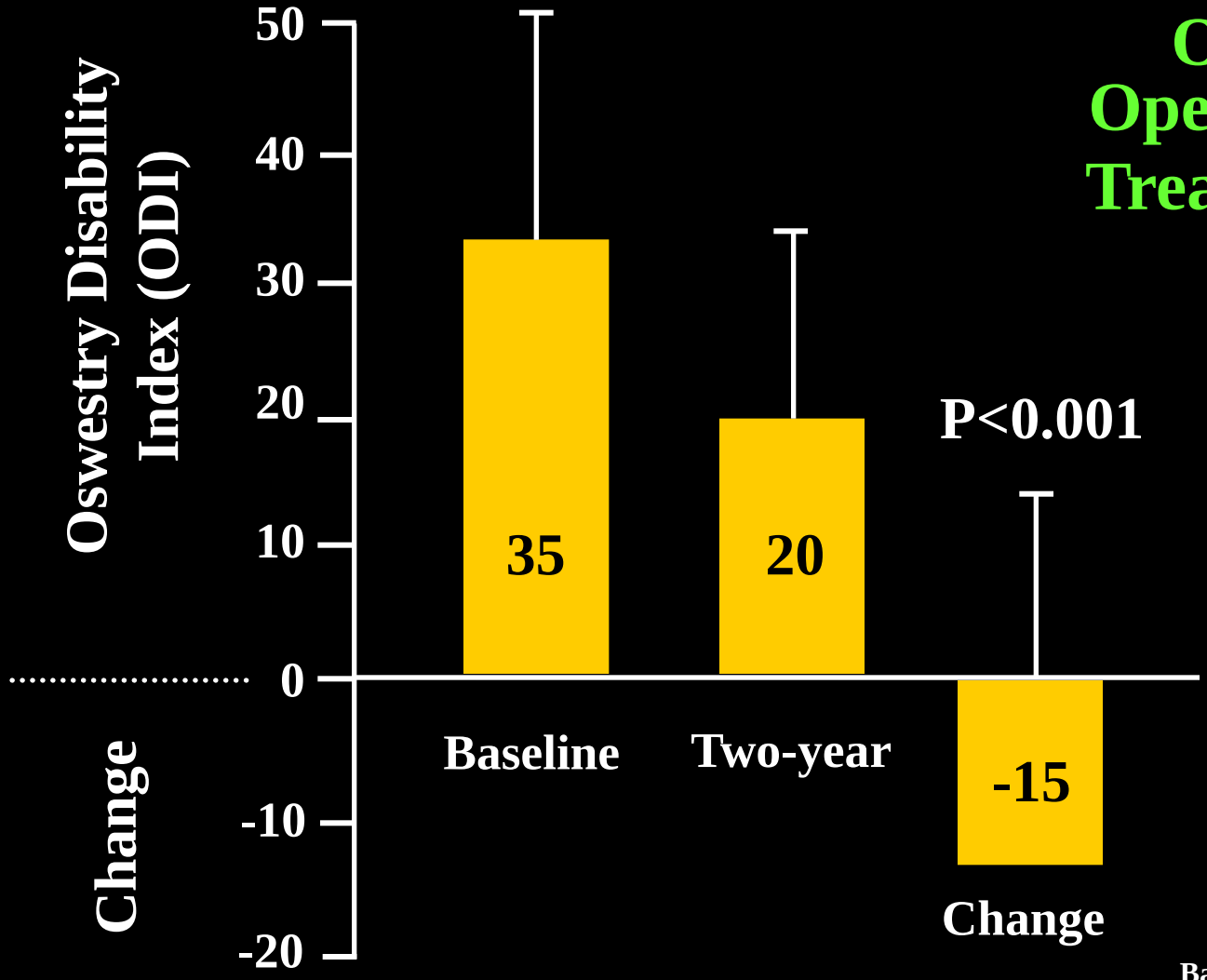
Neurosurgery 65:86–94, 2009 DOI: 10.1227/01.NEU.0000347005.35282.6C www.neurosurgery-online.com

Disability in Adults with Scoliosis: Nonoperative Treatment (n=170)



Bars indicate standard deviation.

Disability in Adults with Scoliosis: Operative Treatment (n=147)



Bars indicate standard deviation.

Operative *Versus* Nonoperative Treatment of Leg Pain in Adults With Scoliosis

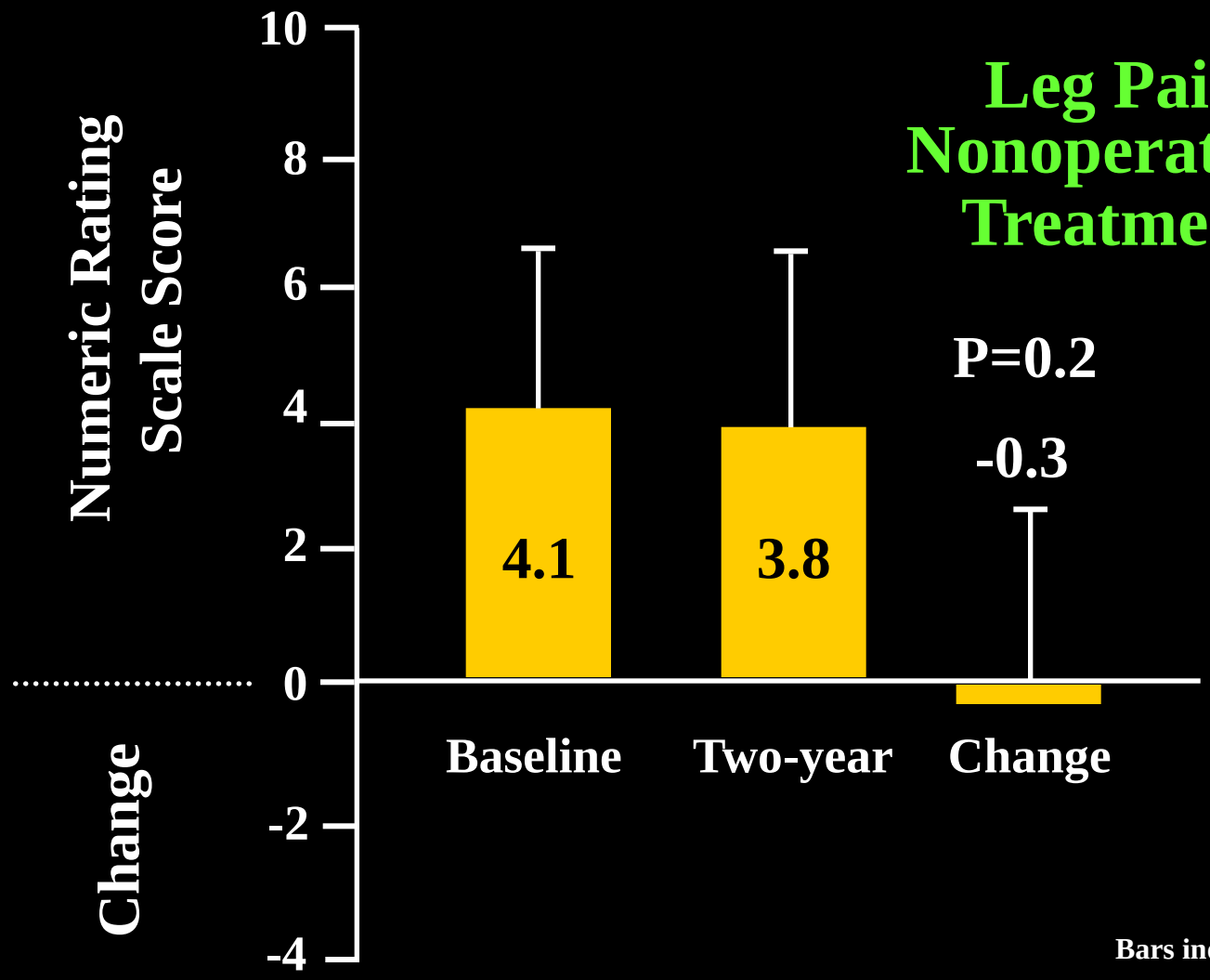
A Retrospective Review of a Prospective Multicenter Database With Two-Year Follow-up

Justin S. Smith, MD, PhD,*† Christopher I. Shaffrey, MD,*† Sigurd Berven, MD,‡ Steven Glassman, MD,§ Christopher Hamill, MD,¶ William Horton, MD,‖ Stephen Ondra, MD,** Frank Schwab, MD,†† Michael Shainline, MS,§§ Kai-Ming G. Fu, MD, PhD,* Keith Bridwell, MD,¶¶ and the Spinal Deformity Study Group

- 208 of 326 adults with scoliosis had leg pain at presentation (mean NRS score=4.7)
- 96 patients with leg pain (46%) were managed operatively and 112 were treated non-operatively
- 2-year follow-up, non-operative patients had no significant change in any outcome measure
- 2-year follow-up, operative patients had better mean NRS score for leg pain (5.4 *vs.* 2.2, $P < 0.001$) and ODI (41 *vs.* 24, $P < 0.001$)

SPINE Volume 34, Number 16, pp 1693–1698

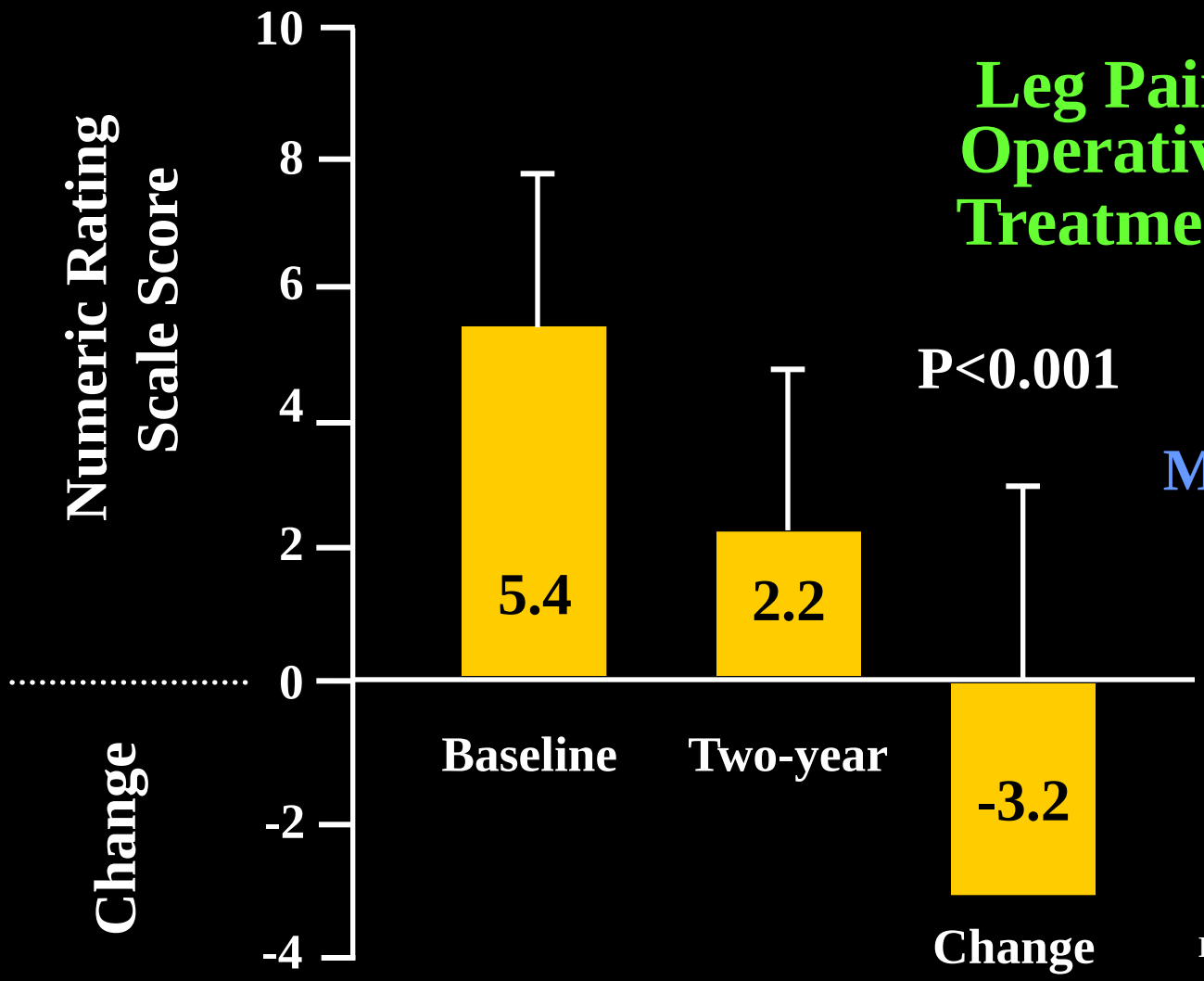
Leg Pain in Adults with Scoliosis: Nonoperative Treatment (n=112)



Bars indicate standard deviation.

Smith *et al*. *Spine* 34(16), 2009.

Leg Pain in Adults with Scoliosis: Operative Treatment (n=96)



Bars indicate standard deviation.

Smith *et al*. *Spine* 34(16), 2009.

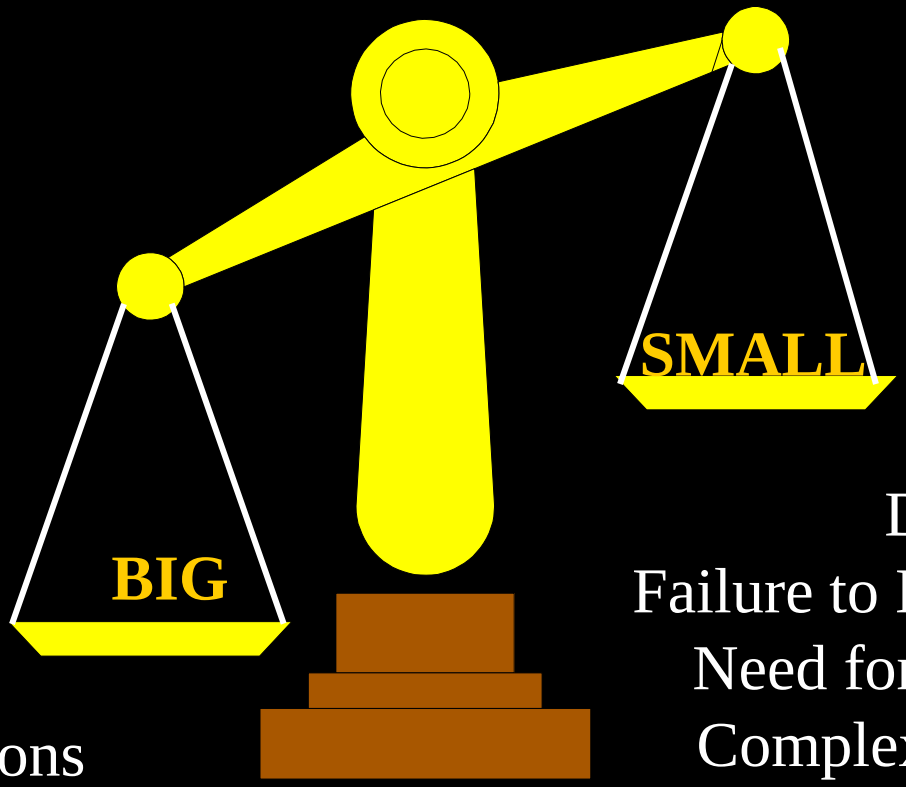
Indications for Older Adults

- Severe back pain
- Intractable radicular pain or neurogenic claudication
- Significant radiographic abnormalities
  - Documented significant curve progression
  - Progressive olisthesis
  - Severe coronal and/or sagittal imbalance

Surgical Approaches

- Simple decompression alone
- Decompression and focal fusion
- Extensive posterior instrumentation and fusion +/- TLIF or PLIF
- Anterior-posterior procedures
- Posterior osteotomy based procedures

How Big of an Operation?



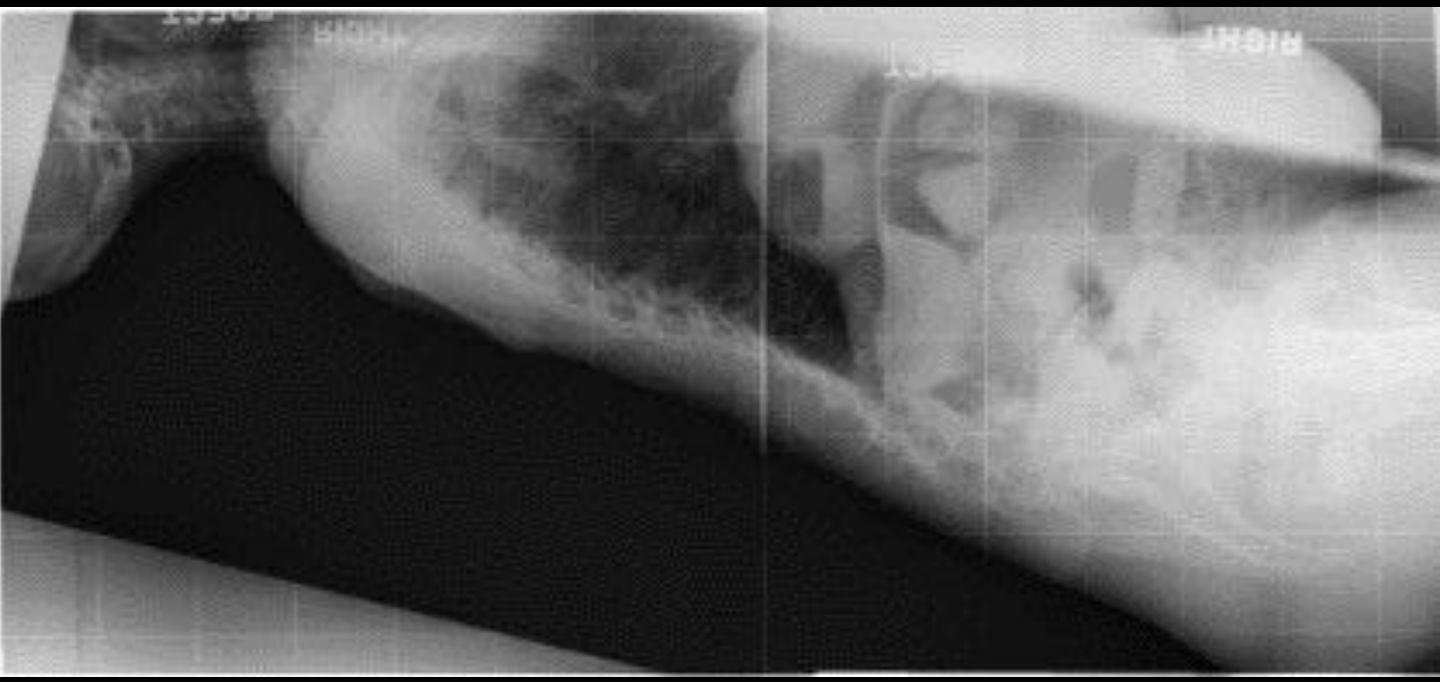
Durability
Failure to Improve Symptoms
Need for Further Surgery
Complexity of Revisions

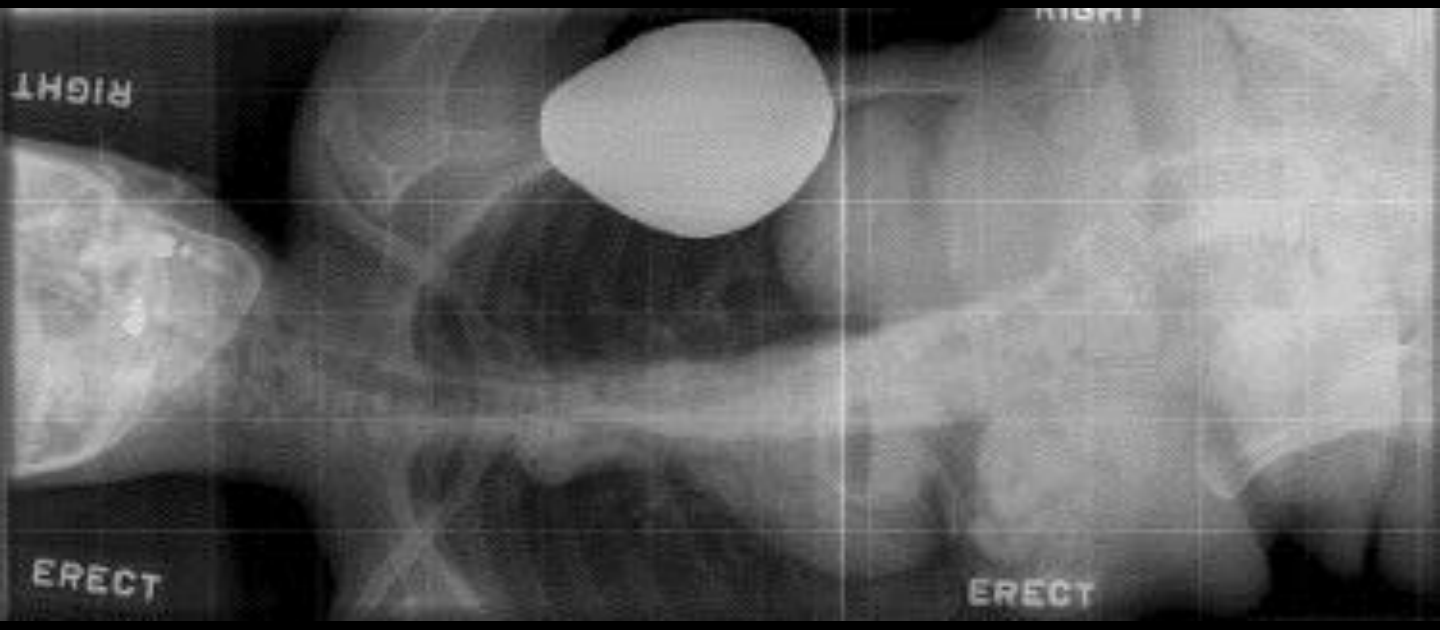
Complications
Length of Recovery
Cost
Functional Limitations

Limitations of Decompression Alone for Degenerative Scoliosis

- Decompression alone leads to high rates of curve progression
  - Benner et al: Spine 1979
  - Epstein, et al: Spine 1979

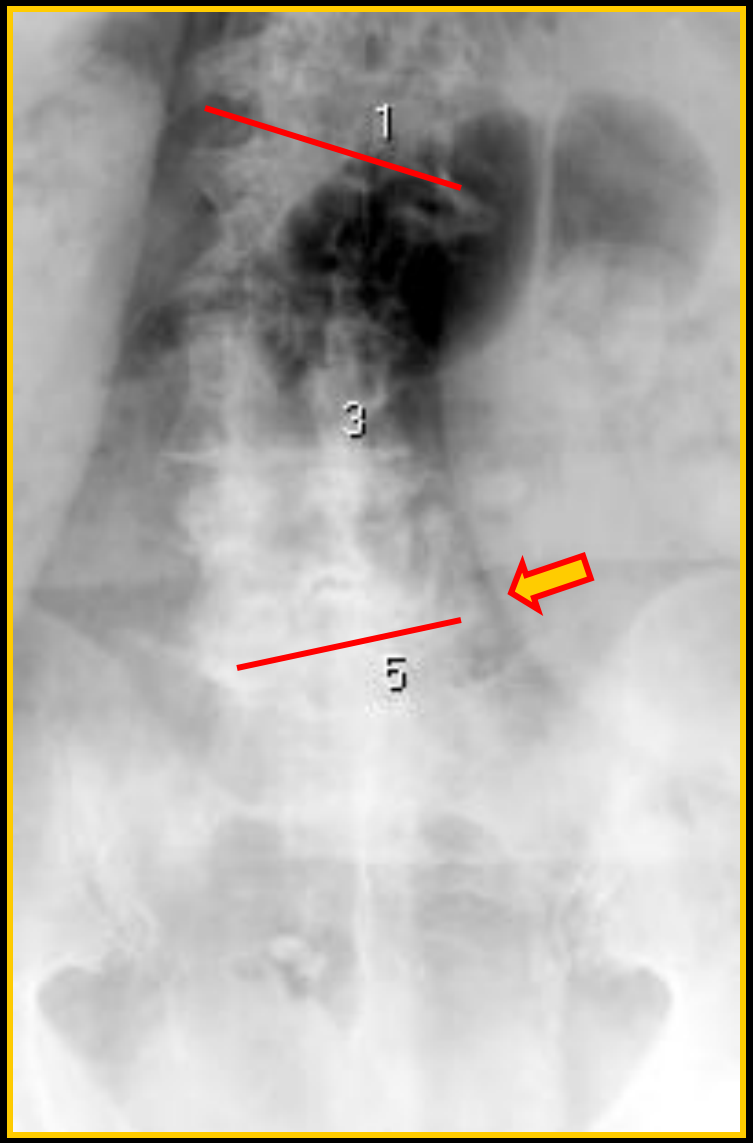
- Frazier DD, et al: Spine 1997
  - Preoperative scoliosis is associated with unfavorable outcome in decompressive surgeries


RIGHT


RIGHT
ERECT
ERECT

When Micro-decompression Considered?

- Low grade curves
- Radicular Sx
- Single level
- Maintained lordosis
- “Hyperstable” spines
- No spondylolisthesis or significant laterolisthesis

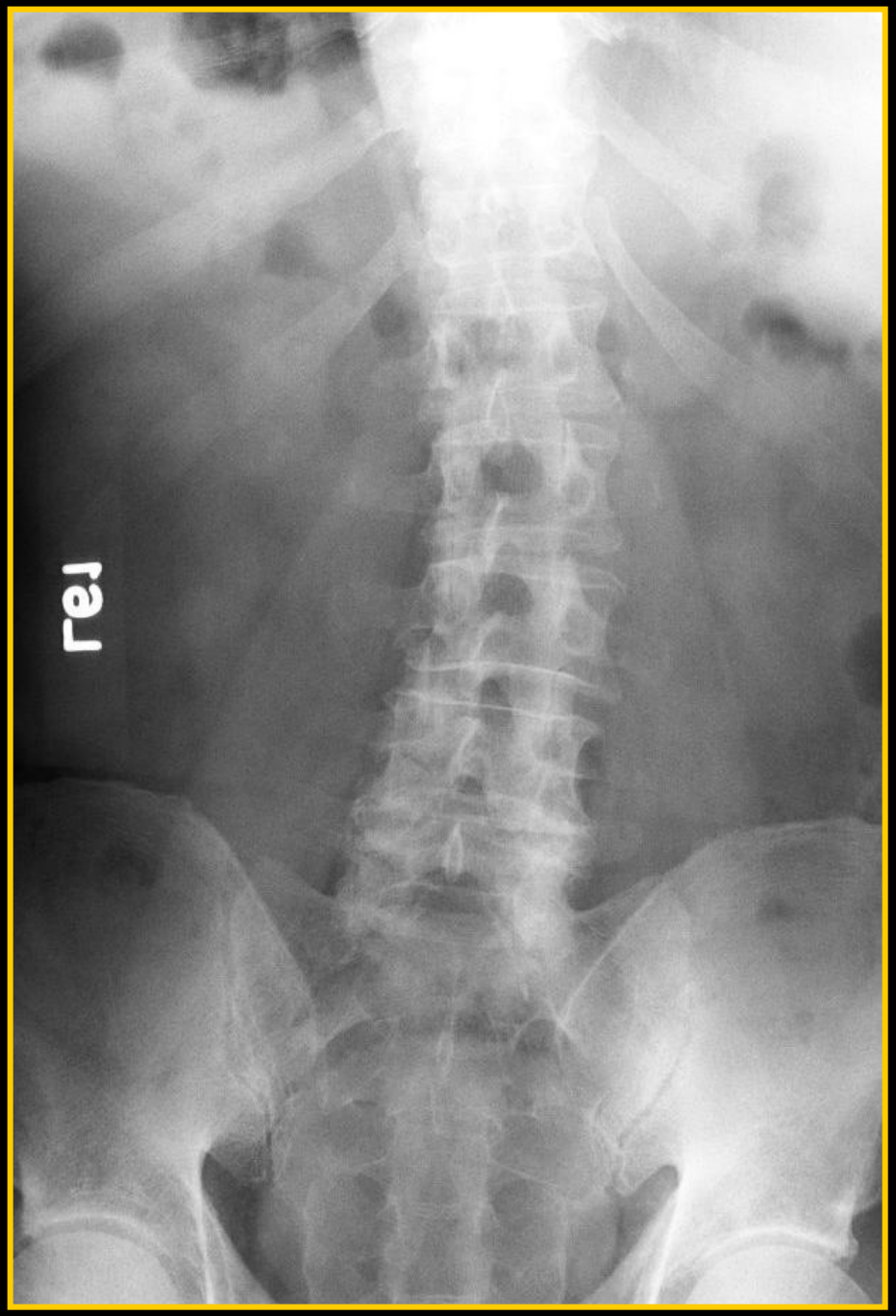


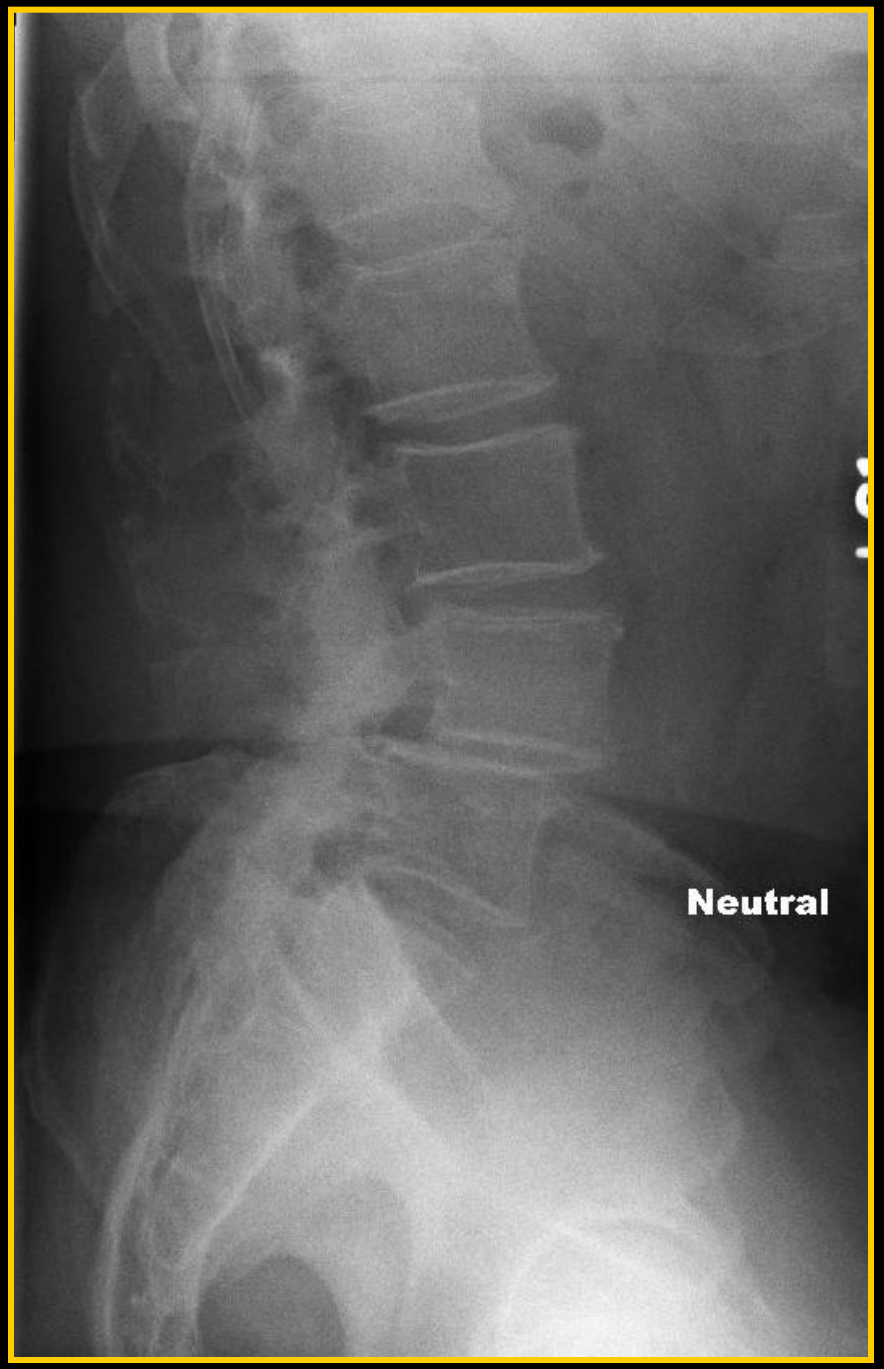
Degenerative Scoliosis – Focal Fusion

- **Less invasive**
- **Risk of junctional instability**
- **Risk adjacent stenosis**

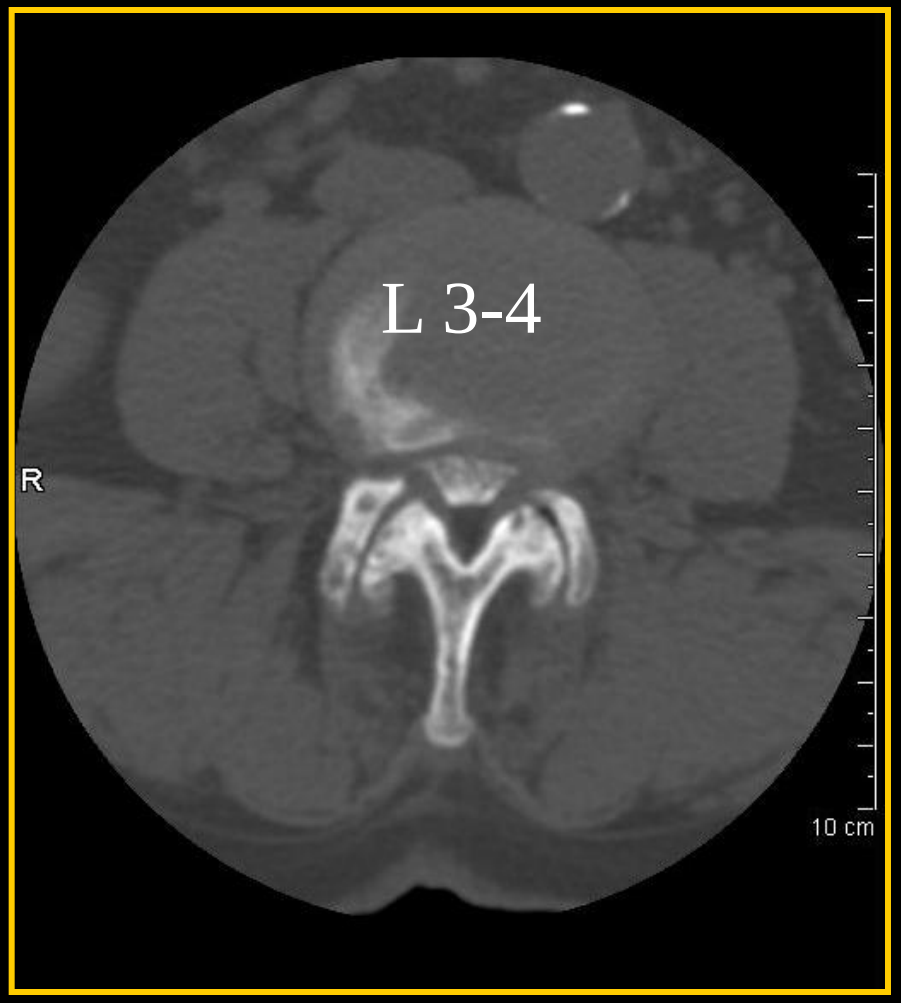
Limited Fusion Indications

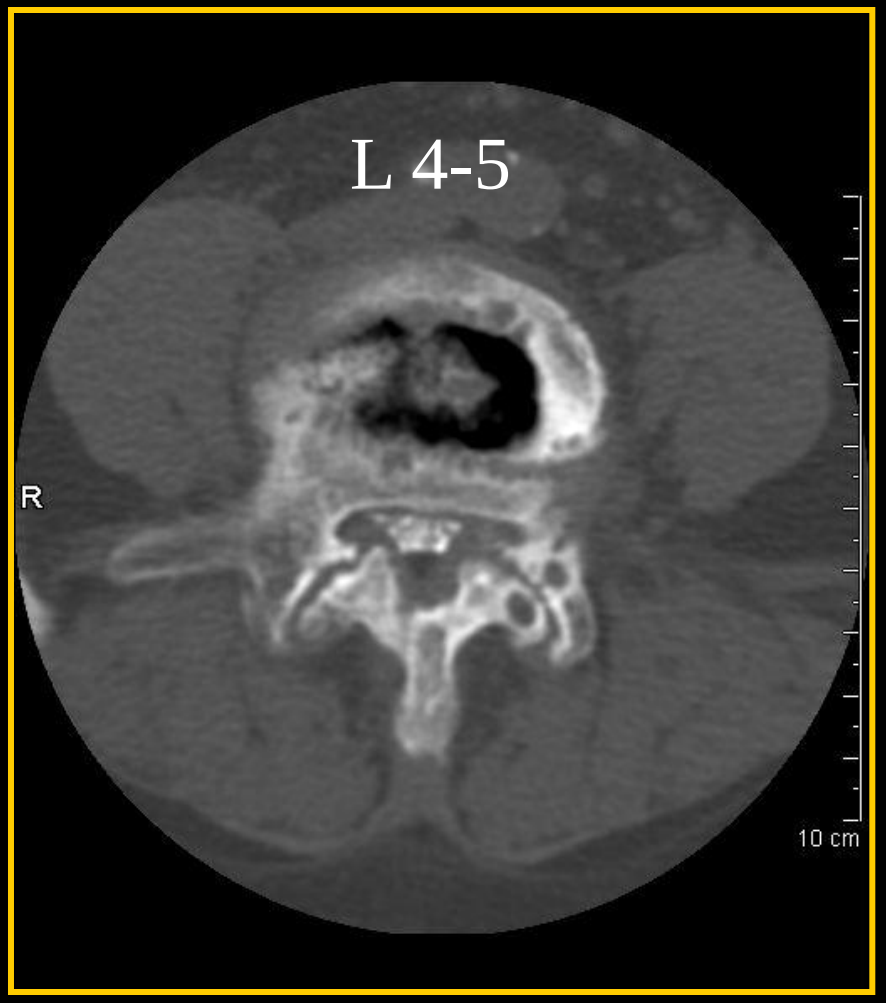
- Acceptable coronal and sagittal balance
- Expectation that the superior and inferior end vertebra will be within 10^0 of horizontal on completion of procedure
  - Do not leave substantial residual curve
  - Do not do not do laminectomy at end levels
- Realize that breakdown may eventually occur
  - Evaluate status of disc and facets

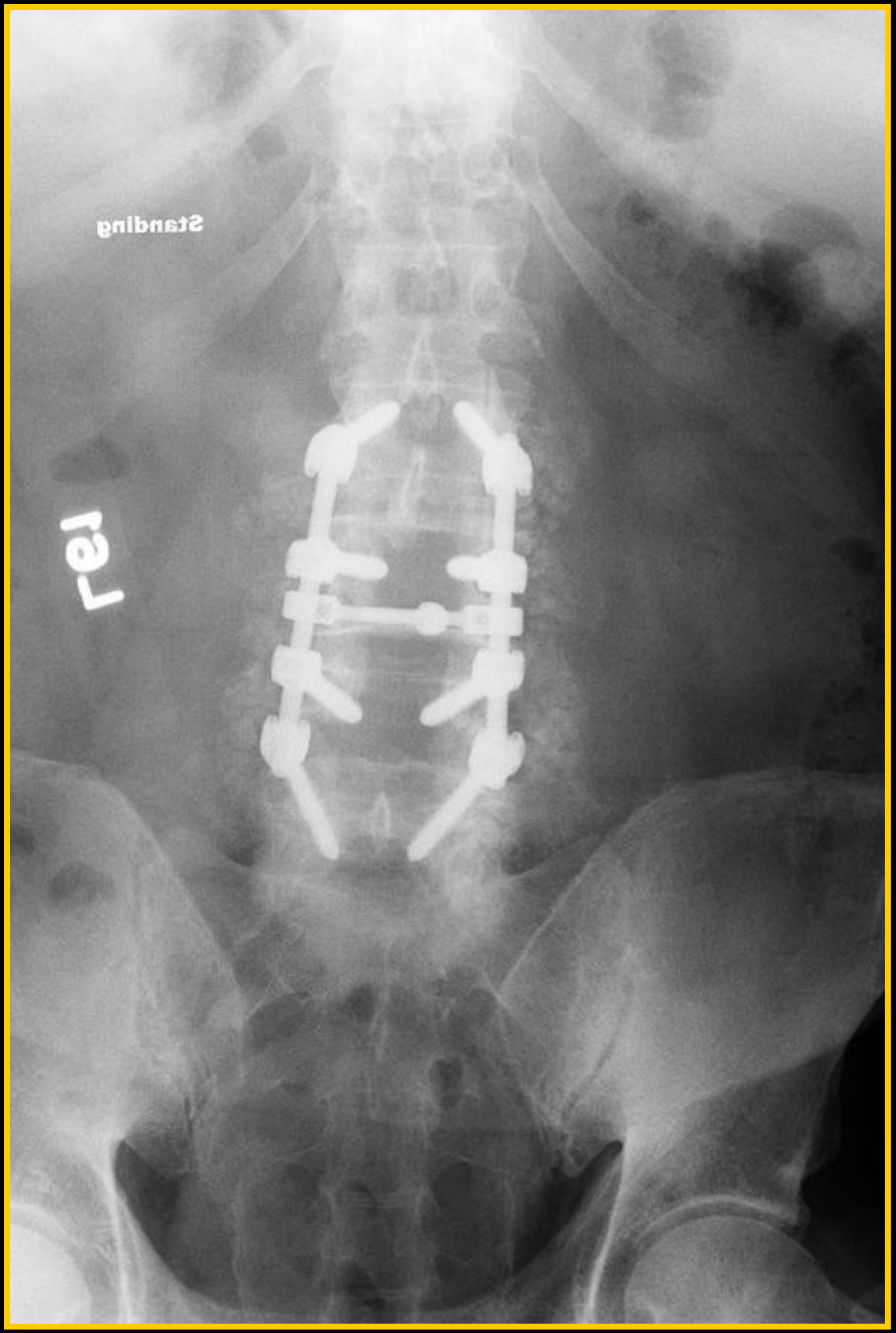


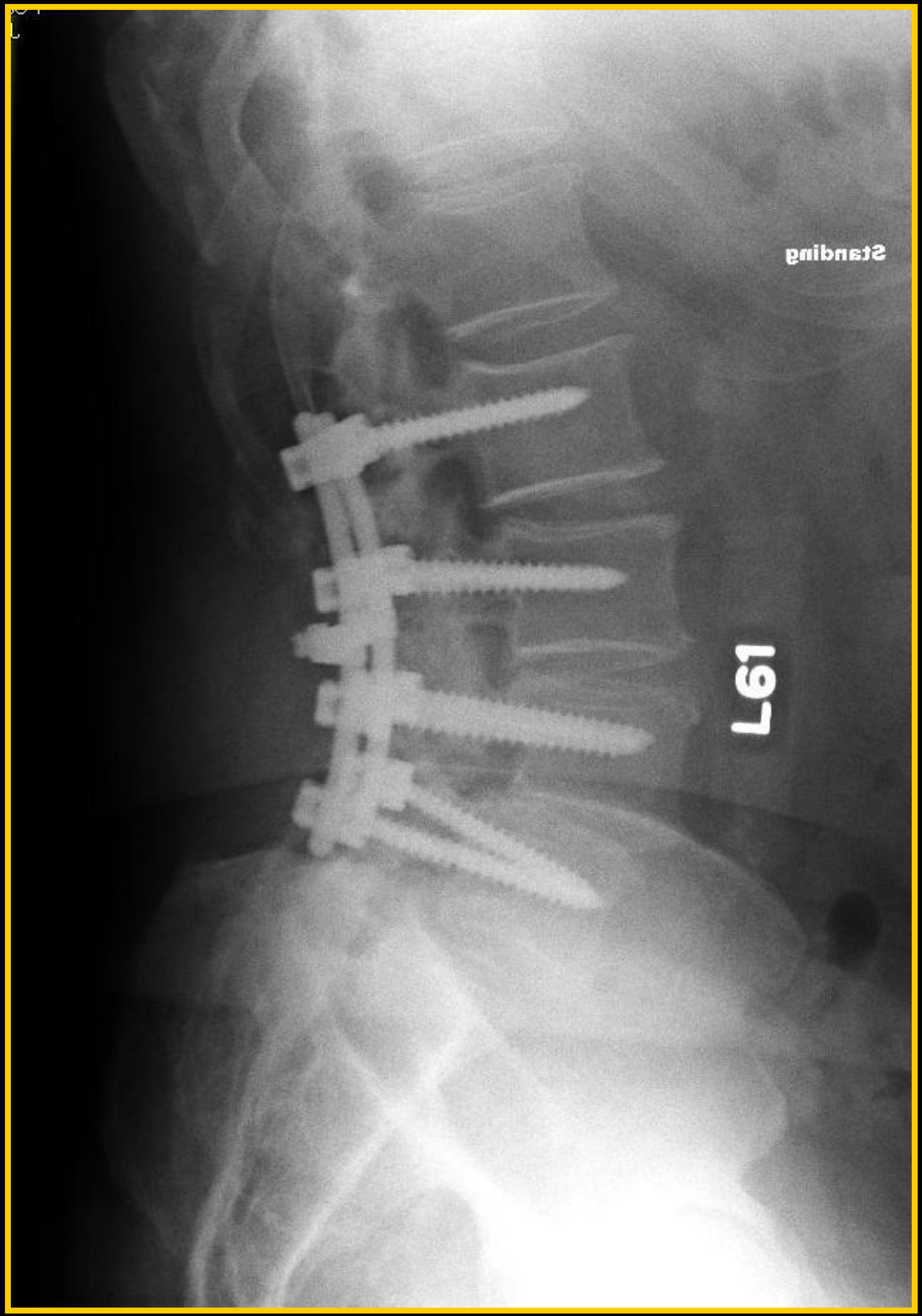

Neutral

*


L 3-4
R
10 cm

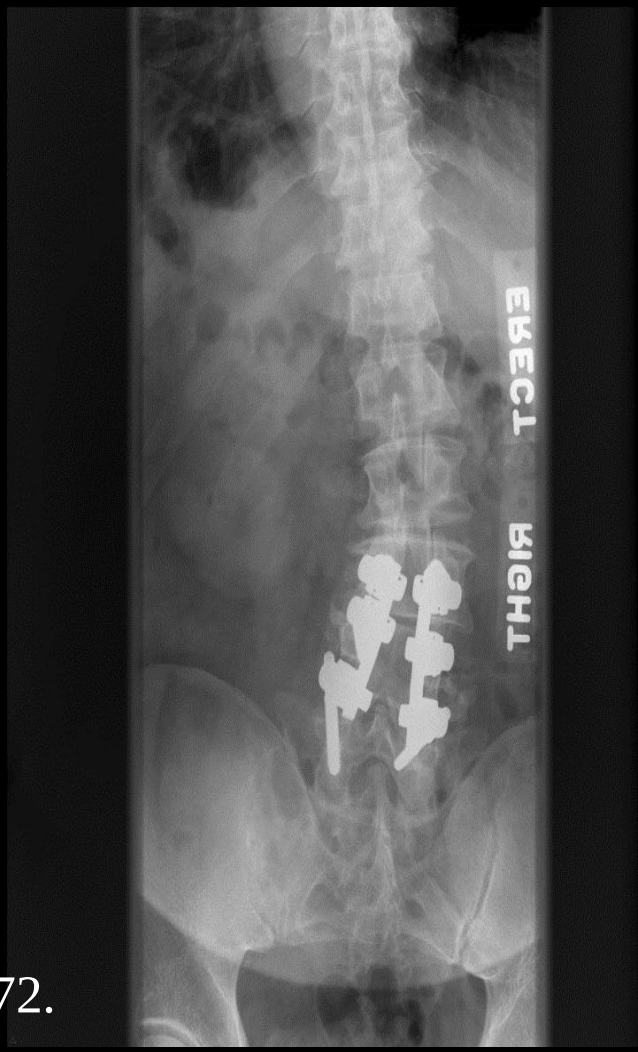

L 4-5
R
10 cm





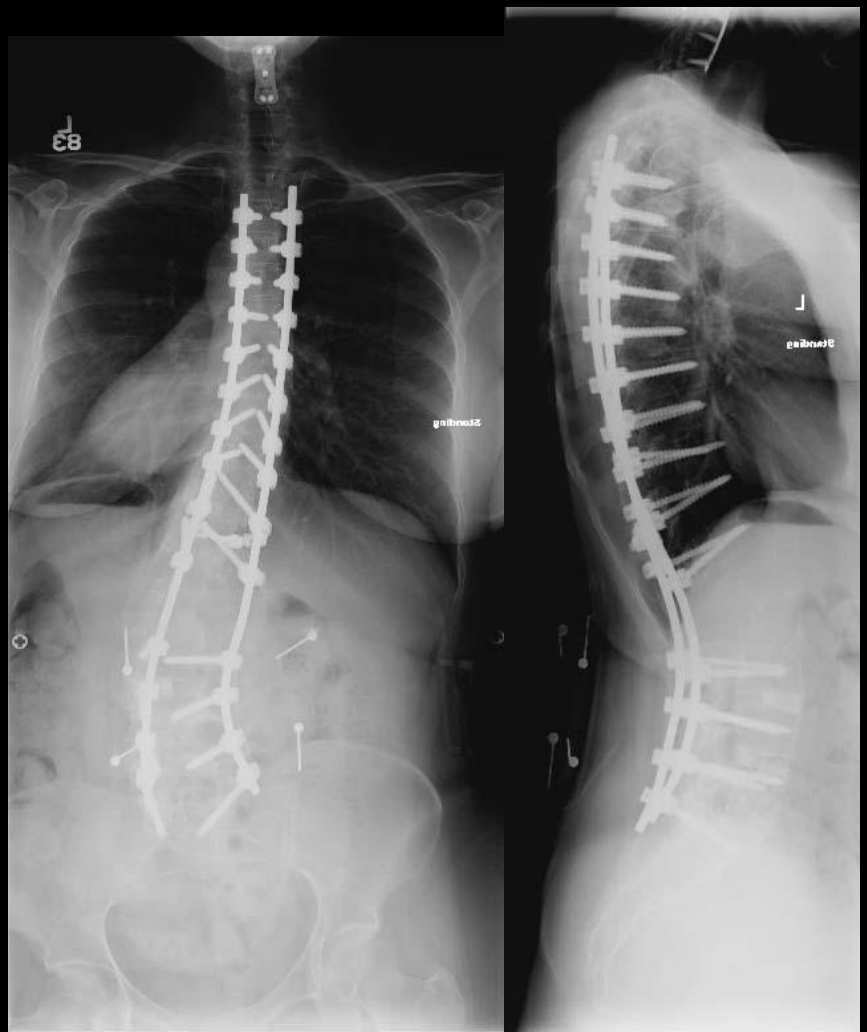
Limited Fusion

- Strategies and Outcomes
  - 3/18 patients with fusion that did not encompass the entire measured end vertebrae required extension of the fusion cephalad
  - 83% survival at >5 years



Berven SH. Neurosurg Clin N Am. 2007 Apr;18(2):261-72.

Severe, out of balance and inflexible curves can benefit from osteotomies or vertebral column resection procedures



Spine

SPINE Volume 36, Number 10, pp 817–824

DEFORMITY

Risk-Benefit Assessment of Surgery for Adult Scoliosis

An Analysis Based on Patient Age

Justin S. Smith, MD, PhD,*† Christopher I. Shaffrey, MD,*† Steven D. Glassman, MD,‡ Sigurd H. Berven, MD,§ Frank J. Schwab, MD,¶ Christopher L. Hamill, MD,|| William C. Horton, MD,** Stephen L. Ondra, MD,†† Charles A. Sansur, MD,‡‡ and Keith H. Bridwell, MD,§§ the Spinal Deformity Study Group

- A retrospective review of a prospective, multicenter spinal deformity database assessing 206 patients who were analyzed by age group (25 to 44, 45 to 64 and 65 to 85)
- At baseline, elderly patients (65-85 years) had greater disability, worse health status and more severe back and leg pain than younger patients
- These groups had perioperative complication rates of 17%, 42% and 71%

Spine

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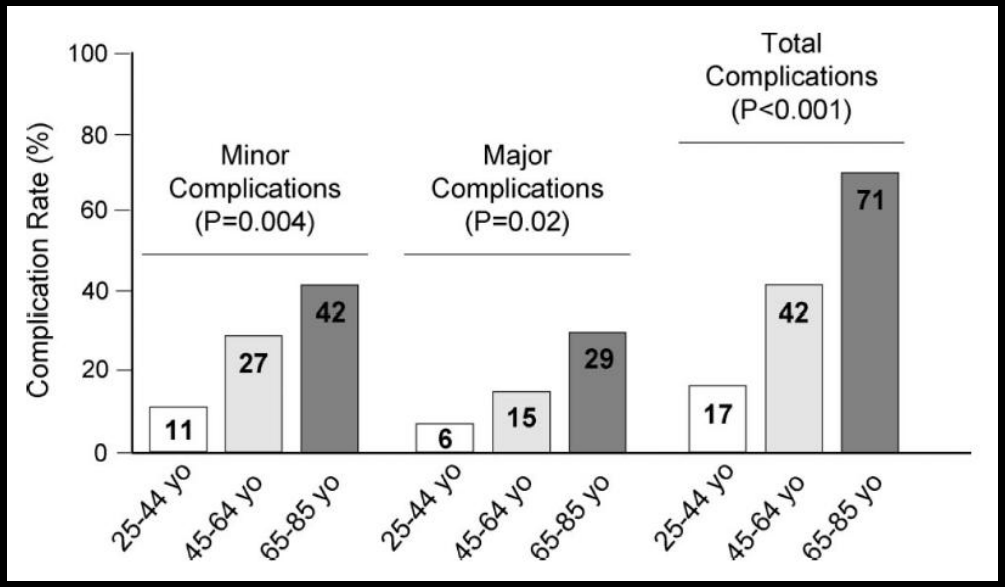
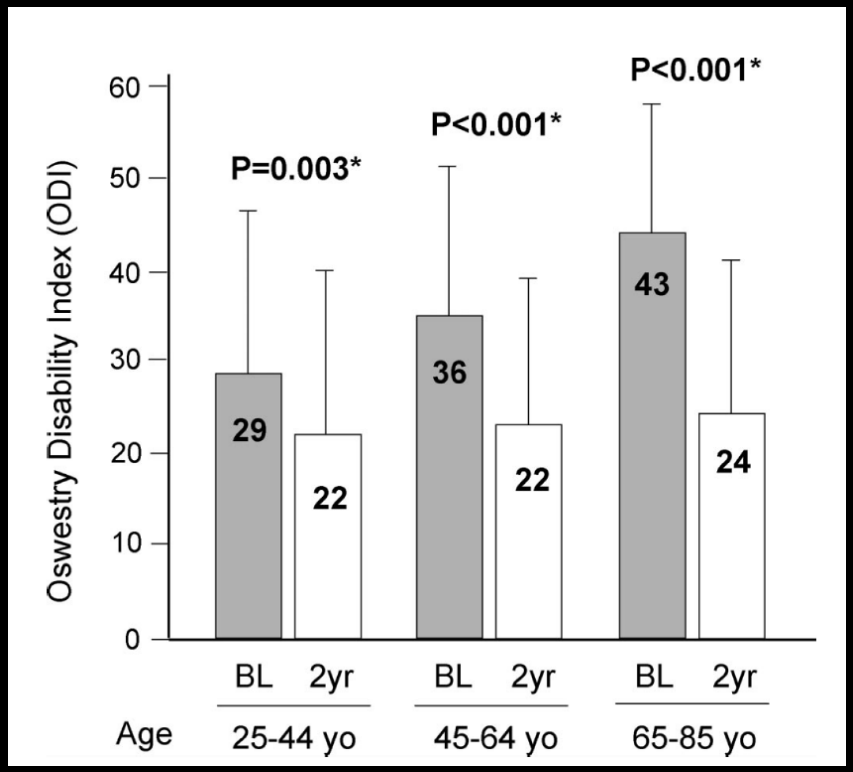
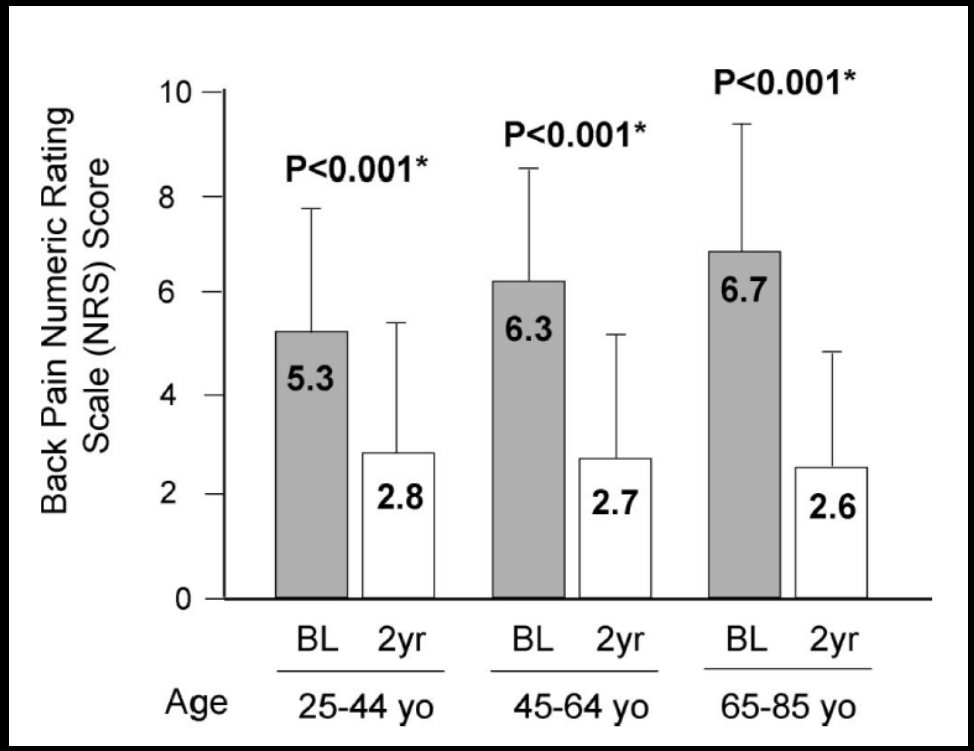
- Within each age group, at 2-year follow-up there were significant improvements in ODI ($P \leq 0.004$), SRS-22 ($P \leq 0.001$), back pain ($P < 0.001$), and leg pain ($P \leq 0.04$)
- Improvement in ODI and leg pain NRS were significantly greater among elderly patients ($P = 0.003$, $P = 0.02$, respectively) when compared with younger patients


Complication Rate (%)
100
80
60
40
20
0
Minor Complications (P=0.004)
Major Complications (P=0.02)
Total Complications (P<0.001)
11
27
42
6
15
29
17
42
71
25-44 yo
45-64 yo
65-85 yo
25-44 yo
45-64 yo
65-85 yo
25-44 yo
45-64 yo
65-85 yo


Oswestry Disability Index (ODI)
60
50
40
30
20
10
0
P=0.003*
P<0.001*
P<0.001*
29
22
36
22
43
24
BL
2yr
BL
2yr
BL
2yr
Age
25-44 yo
45-64 yo
65-85 yo


Back Pain Numeric Rating Scale (NRS) Score
10
8
6
4
2
0
P<0.001*
P<0.001*
P<0.001*
5.3
2.8
6.3
2.7
6.7
2.6
BL
2yr
BL
2yr
BL
2yr
Age
25-44 yo
45-64 yo
65-85 yo

SPINE Volume 35, Number 20, pp 1849–1854

Changes in Radiographic and Clinical Outcomes With Primary Treatment Adult Spinal Deformity Surgeries From Two Years to Three- to Five-Years Follow-up

Keith H. Bridwell, MD,* Christine Baldus, RN,* Sigurd Berven, MD,†
Charles Edwards II, MD,‡ Steven Glassman, MD,§ Christopher Hamill, MD,¶
William Horton, MD,|| Lawrence G. Lenke, MD,* Stephen Ondra, MD,** Frank Schwab, MD,††
Christopher Shaffrey, MD,‡‡ and David Wootten, PhD§§

- A cohort of 113 patients entered into a multicenter database with complete reoperative, 2-year, and 3- to 5-year data
- The mean Cobb angle and lumbar lordosis did not change from the 2-year to ultimate follow-up
- Coronal and sagittal balance parameters were the same at 2-year and ultimate follow-up

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Christopher Shaffrey, MD,‡‡ and David Wootten, PhD§§

- SRS total scores and modified ODI were similar at the 2 year and final follow-up
- 10% of patients did experience a new complication at the 3- to 5-year point, most commonly implant failure/nonunion and/or junctional kyphosis, which did negatively effect the patient-reported outcome

Factors Impacting Adult Deformity Surgery Outcomes

- Primary
  - Sagittal Alignment
  - Improvement in Neurological Symptoms
  - Improvement of Pelvic Tilt
- Secondary
  - Complications
    - Minor complications have minimal long-term impact on outcomes
  - Coronal Alignment
  - Fusion Success

Conclusions

- Adult deformity that becomes significantly symptomatic responds poorly to non-operative measures
- Adult scoliosis management is grounded in appropriate patient selection, performing expeditious surgical procedure and appreciating that alignment objectives need to be achieved
- Advancements in less invasive techniques may lead to reduced complications and improved outcomes in the future

Lessons Learned

- Doing an inadequate operation is often worse than doing nothing
- Not every patient can benefit from surgery even with substantial deformity
  - Some are too sick, have too poor of bone quality or have inadequate social support to have a major surgery
- These operations require long term patient-surgeon commitment

Thank You