MINIMALLY INVASIVE SAGITTAL PLANE DEFORMITY CORRECTION

Greg Mundis, MD
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3rd Annual UCSF Techniques in Complex Spine Surgery Course

DISCLOSURES

1. NuVasive: a, b, e
2. K2M: b, e
3. ISSGF: a

a. Grants/Research Support
b. Consultant
c. Stock/Shareholder
d. Speakers’ Bureau
e. Other Financial Support

Advantages of Ant. and Post. Approach for Adult Spinal Deformity

- Creation of a load sharing environment for segmental implants
- Reduction of lateralolisthesis
- Restoration of segmental lordosis
- Improvement of sagittal balance
- Improved fusion rates in difficult cases (absence of post. elements, revisions, L5-S1)

Historical Indications for A/P Fusion in TL/L Adult Deformity

<table>
<thead>
<tr>
<th>Condition</th>
<th>Radiographic Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronal Deformity</td>
<td>&gt;45° Cobb angle</td>
</tr>
<tr>
<td>Apical Translation</td>
<td>&gt;3 cm from the center sacral vertebral line (CSVL)</td>
</tr>
<tr>
<td>Lateral Olisthesis</td>
<td>&gt;5 mm</td>
</tr>
<tr>
<td>Sagittal Deformity</td>
<td>&lt;20° lordosis Cobb angle measured T12-S1</td>
</tr>
</tbody>
</table>

HOW DOES MIS SPINE SURGERY AFFECT THE INDICATIONS???
**Adult Scoliosis** Schwab et al 2007

- **Sagittal balance:**
  - Worse balance
    - Higher likelihood of fusion to sacrum
    - Higher likelihood of osteotomy
    - Higher likelihood of posterior only surgery
- **Subluxation:**
  - Greater subluxation → more likely to have A-P fusion

The results demonstrated an appreciable high rate of:
- Postoperative pain (32.3%)
- Bulging (43.5%),
- Functional disturbance (24.2%)

**INDICATIONS**
- Most important!
- What are you trying to accomplish?
  - MIS?
  - Indirect Decompression?
  - Fusion?
  - Segmental alignment?
  - Global alignment?
  - Deformity correction?

**WHY NOT LATERAL?**
- Previous retroperitoneal exposure
- Neurologic issues
- Vascular anatomic issues
- Fusion not indicated
- Comfort level?
WHY NOT LATERAL

• EXPECTATIONS…Surgeon and patient!
• Know there is a learning curve
• Know what the normal physiologic response to your surgery is
• Understand what role you play as the surgeon in minimizing the side effects or potential complications

Postoperative Period

What to Expect

Expected side effects:
- 8-10% psoas weakness (resolves within 1-2 weeks)
- 27% post-op change in hip flexion strength**
- 5-40% anterior thigh numbness (resolves within 1-2 mos)
- 0.5% thigh pain / dysesthesia (takes longer to resolve: 2-3 mos)
- 18% upper medial thigh sensory deficit (3 contralateral to approach)**
- 3% lower limb motor weakness (transient)**
- 1 due to postoperative subsidence**
- 2 due to pressure/ischemia (nerve identified & retracted)**

**US prospective multi-center study of LIF/NeuroVision® in 100 pts

IS LIF AN ACCEPTABLE APPROACH FOR SPINAL DEFORMITY?

Minimally Invasive Multilevel Percutaneous Correction and Fusion for Adult Lumbar Degenerative Scoliosis
- A Technique and Feasibility Study

Mid-term to long-term clinical and functional outcomes of minimally invasive correction and fusion for adults with scoliosis
50 yo F L1-L4 LIF; T11-L4 MIS PS w/ PSFI

73 YO M B leg & Back Pain

72 yo female
L3-5 LIF; L5-S1 ALIF; T10-Pelvis

SPO

HOW ABOUT THE SAGITTAL PLANE AND LIF?

Sagittal Imbalance Disability

- Can be mild to severe
- Early fatigue
- Pain
- Poor posture
- Functional limitations
- Neurologic symptoms from compression

Surgery may be indicated if non-operative treatments fail

Popular Osteotomy Options

- Smith Peterson Osteotomy
- Pedicle Subtraction Osteotomy
- Vertebral Column Resection
Short-term Morbidity and Mortality Associated With Correction of Thoracolumbar Fixed Sagittal Plane Deformity
A Report from the Scoliosis Research Society Morbidity and Mortality Committee

• 105 patients (87 PSO and 18 VCR) with 2 year FU
• Major medical and surgical complications occurred at similar rates in both PSOs and VCRs (38%, 33 of 87 vs. 22%, 4 of 18)
• The occurrence of a major complication did not have an impact on 2-year clinical outcome measures.
• Those patients with major permanent complications were the only group in which the outcome scores did not improve after surgery

Osteotomy Complications

• 105 patients (87 PSO and 18 VCR) with 2 year FU
• Major medical and surgical complications occurred at similar rates in both PSOs and VCRs (38%, 33 of 87 vs. 22%, 4 of 18)
• The occurrence of a major complication did not have an impact on 2-year clinical outcome measures.
• Those patients with major permanent complications were the only group in which the outcome scores did not improve after surgery

Anterior Column Realignment (ACR) for Focal Kyphotic Spinal Deformity Using a Lateral Transpsoas Approach and ALL Release

• 17 consecutive pts
• 24 mo f/u
• 14 with previous spine surgery
• 71% treated for ASD
• All had open posterior fusion
• 15/17 had a posterior release at the level of the ACR

Anterior Column Realignment (ACR) for Focal Kyphotic Spinal Deformity Using a Lateral Transpsoas Approach and ALL Release

• T1SPI:
  – 6 to -2 (p<0.05)
• LL:
  – 16 → 38 (ACR) → 45 after PSFI
• PT:
  – 34 → 24 (ACR)
• SRS-22, VAS improved pre → post (p<0.05)
• 8/17 complications
• 4 ACR related
  – 2 neurologic
  – 1 vascular (approach surgeon removing lateral plate)
64 y F with Previous Fusion L3-S1 and Focal Kyphosis L2-L3

**METHODS**

- Adults with ACR for FSD between 2005 and 2011.
- 17 (12 F, 5 M) patients, mean age of 63 yrs.
- Data collected included pre and post-ACR, 3-mon. FU, radiographic parameters and complications.
- All patients had posterior fixation in addition to ACR.

**ACR- Technique**

**PLANNING:**

- **CLINICAL ANALYSIS**
  - Hip flexion contractures
  - Neuromuscular conditions
- **RADIOGRAPHIC ANALYSIS**
  - 36° X-rays, CT, and MRI
  - Sagittal parameters
  - Pelvic parameters
  - Hyper-extension view to evaluate disk space motion
BOLSTER HYPER-EXTENSION LATERAL

ACR- Technique

PLANNING:

- DON’T FORGET
  - vascular anatomy and presence of vessel calcification
- Consider having vascular surgeon available
- History of previous retroperitoneal surgery...high risk

ACR- Technique

1. EXPOSURE
   - Usual technique with custom retractor
   - Gentle anterior dissection to identify anterior margin of body and ALL

ACR- Technique

2. DISCECTOMY
   - Wide annulus release both ipsi- and contralateral sides
   - Thorough discectomy behind ALL for safe release
   - NEED minimum of 24 mm exposure to fit a 22mm cage
3. RETRACTOR ADJUSTMENT

- Make sure exposure is adequate to visualize both endplates and anterior spine
- Anterior retractor is placed, wide enough not to fall into disc space after ALL release
- Secure with a shim to avoid anterior migration

4. Release ALL sharply or with curved Bovie

5. CONFIRM RELEASE

6. SELECT CAGE AND SIZE

- Hyperlordotic
- Flanged for internal fixation
- Graft size (lordosis) based on pre-op planning

7. PLACE CAGE

- Avoid anterior migration
8. Secure the cage with screw

9. Final images for planning the next stage

ACR- Technique
CASE EXAMPLE

IDA Change: 50 Degrees
MSA Change: 56 Degrees

CASE EXAMPLE

RESULTS

- Mean FU of 15.1 (3-58) months.

- Fourteen of 17 (82%) had previous spine surgery and 12/17 (71%) had previous spine fusions.

- ACR was performed at L1-2 (n=6), L2-3 (n=2), L3-4 (n=1), and L4-5 (n=8).

- Mean EBL was 111 cc for the anterior procedure and 1484 cc for the posterior procedure.
Intradiscal (IDA) and Motion Segment (MSA) Angles

<table>
<thead>
<tr>
<th></th>
<th>Pre ACR</th>
<th>Post ACR</th>
<th>Δ1</th>
<th>Post PSF</th>
<th>Δ2</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDA</td>
<td>5.1°</td>
<td>-19.9°</td>
<td>25°</td>
<td>-27.4°</td>
<td>32.5°</td>
</tr>
<tr>
<td>MSA</td>
<td>8.8°</td>
<td>-19.4°</td>
<td>28.1°</td>
<td>-25.6°</td>
<td>37°</td>
</tr>
<tr>
<td>LL</td>
<td>-11.6°</td>
<td>-38°</td>
<td>26.5°</td>
<td>-48.8°</td>
<td>37.2°</td>
</tr>
</tbody>
</table>

RESULTS - SPINOPELVIC

<table>
<thead>
<tr>
<th></th>
<th>Preop*</th>
<th>Postop*</th>
<th>Δ1</th>
<th>Final FU*</th>
<th>Δ2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lumbar Lordosis</td>
<td>-17°</td>
<td>-44°</td>
<td>27.6</td>
<td>-50°</td>
<td>33.5</td>
</tr>
<tr>
<td>Pelvic Incidence</td>
<td>62</td>
<td>58</td>
<td>4.7</td>
<td>60</td>
<td>2.6</td>
</tr>
<tr>
<td>Pelvic Tilt</td>
<td>35</td>
<td>24</td>
<td>11.4</td>
<td>25</td>
<td>10.4</td>
</tr>
<tr>
<td>Sacral Slope</td>
<td>27</td>
<td>33</td>
<td>6.8</td>
<td>34</td>
<td>7.6</td>
</tr>
<tr>
<td>T1 Spinopelvic Inclination</td>
<td>+1.4°</td>
<td>-0.9°</td>
<td>1.7</td>
<td>-2.3°</td>
<td>3.6</td>
</tr>
<tr>
<td>Max Thoracic Kyphosis</td>
<td>23°</td>
<td>38°</td>
<td>16.8</td>
<td>44°</td>
<td>22.7</td>
</tr>
</tbody>
</table>

Δ1 = Postop – Preop
Δ2 = Final FU – Preop
* Rounded numbers

RESULTS

Patients with preop (+) T1 Spinopelvic inclination

<table>
<thead>
<tr>
<th>T1 Spinopelvic Inclination</th>
<th>Preop</th>
<th>Postop</th>
<th>Final FU</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5.9°</td>
<td>-0.1°</td>
<td>-2.2°</td>
</tr>
</tbody>
</table>

Patients with preop (-) T1 Spinopelvic inclination

<table>
<thead>
<tr>
<th>T1 Spinopelvic Inclination</th>
<th>Preop</th>
<th>Postop</th>
<th>Final FU</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-6.2°</td>
<td>-2.5°</td>
<td>-2.2°</td>
</tr>
</tbody>
</table>

Patients with preop (0) T1 Spinopelvic inclination

<table>
<thead>
<tr>
<th>T1 Spinopelvic Inclination</th>
<th>Preop</th>
<th>Postop</th>
<th>Final FU</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0°</td>
<td>-2°</td>
<td>-4.5°</td>
</tr>
</tbody>
</table>

COMPLICATIONS

- Eight patients had complications (47% of the patients in this series), four patients during or after ACR procedure and 6 patients after the posterior stage.
- Of these 8 patients, two had complications after both ACR and posterior procedure.
- When isolating complications by level of ACR, the complication rate was 50% at L4/5 (4/8) and 11% (1/9) among the remainder of the levels from L1-L4.
4 Complications after ACR

- Quadriceps palsy (N=2), one recovered to 5/5 after 12 m
  - Both with L4-5 ACR
- Common iliac artery laceration (N=1) during the exposure for a plate removal
  - Caused and repaired by vascular surgeon
  - At L4-5
- Bilateral L1-L2 foraminal stenosis (N=1)
  - Required posterior revision surgery

Comparison of One-level ACR vs. PSO

<table>
<thead>
<tr>
<th>One Level Segmental Lordosis Correction</th>
<th>ACR</th>
<th>PSO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akbarnia, ACR 2011</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bridwell, PSO 2005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bridwell, PSO 2007</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schwab, PSO 2011</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

L4-5 ACR/SPO; L2-3 LIF; T4-Pelvis PSFI

L1-2 ACR/SPO; T10 to Pelvis PSFI
60 yo M w/ L2-3 PJK

After Stage I

L2-3 ACR/SPO; T11-S1 PSFI

COMBINING THE APPROACHES FOR 3D CORRECTION
71 y F with Deg. Scoliosis

- T8-L2 = 39°
- SVA = 110 mm
- SS = 12°
- PI = 43°
- PT = 30°
- LL = 2°

L5-S1 TLIF; L2-3 ACR; L3-5 LIF; T10-Pelvis

- T8-L2 = 6°
- C7PL = 0
- SS = 37°
- PI = 47°
- PT = 10°
- LL = -62°
The principle…

Harmonious Anterior Correction

79 yo F; L2-5 LIF, L5-S1 ALIF, T11-
pelvis MIS PS

NO OSTEOTOMIES

72 yo F PJK S/P L1-S1

Does it compare to PSO?

Anterior Column Realignment (ACR) has similar results to Pedicle Subtraction Osteotomy (PSO) in treating adults with sagittal spinal deformity: A multicenter Study

Gregory M. Mundis, Jr., Behrouz A. Akbariani, Nitin Kabirian, Jeff Pawlick, Robert K. Eastlack, Chris Staffey, Eric Klineberg, Stasy Boss, Chris Ames, Yeot Deo, Virgini, Lefang, ISSG
CASE

- 77 yo M
- 3 previous spine surgeries
- c/o LBP, + sag balance
- Failed non-operative management

Sagittal Imbalance

- PI-LL mismatch
- ~ Pelvic Retroversion
- Sagittal Imbalance

CB Standing

- Set Pelvic Tilt prior planning

Set Pelvic Tilt prior planning

- Image Rotation
  - PT < 20deg
L3 PSO

<table>
<thead>
<tr>
<th>Measure</th>
<th>Post-Op</th>
<th>Pre-Op</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1 SPI</td>
<td>0°</td>
<td>14°</td>
</tr>
<tr>
<td>L Lordo 1</td>
<td>60°</td>
<td>67°</td>
</tr>
<tr>
<td>Wedge 1</td>
<td>30° 77:22</td>
<td></td>
</tr>
<tr>
<td>Pelvic</td>
<td>38° 19° 57° Ant/Post</td>
<td></td>
</tr>
</tbody>
</table>

L1-L2 ACR

- Lordotic cage
  - 30deg
  - 6mm post

T12-L1 ACR

- Lordotic Cage
  - 8deg
  - 6mm post
- Taper 8deg
Intraop following Stage 1

POST OP

Intraop portable following Stage 2
Methods

- Seventeen ACRs vs. a retrospective multicenter PSO dataset (N=100)
- Propensity match by PI, LL and TK
- Inclusion criteria:
  1. Adult sagittal plane deformity requiring ACR or PSO
  2. Minimum 1-year follow-up

T1 Pelvic Angle (TPA)

- It is the sum of T1SPI and PT and takes both variables into account in sagittal imbalance assessment

LUMBAR LORDOSIS

<table>
<thead>
<tr>
<th>LL</th>
<th>Preop</th>
<th>3-month</th>
<th>1-year</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACR</td>
<td>-16°</td>
<td>-45°</td>
<td>-51°</td>
</tr>
<tr>
<td>PSO</td>
<td>-21°</td>
<td>-47°</td>
<td>-47°</td>
</tr>
</tbody>
</table>

- Significant improvement from pre- to final follow-up from both techniques
- NO (p<0.05) difference between PSO vs. ACR in 3-m and 1-yr LL

PELVIC TILT

<table>
<thead>
<tr>
<th>PT</th>
<th>Preop</th>
<th>3-month</th>
<th>1-year</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACR</td>
<td>34°</td>
<td>24°</td>
<td>25°</td>
</tr>
<tr>
<td>PSO</td>
<td>31°</td>
<td>27°</td>
<td>28°</td>
</tr>
</tbody>
</table>

- PT improved from pre- to final follow-up ONLY in ACR group
- NO (p<0.05) difference between PSO vs. ACR in 3-m and 1-yr PT
**PELVIC INCIDENCE**

<table>
<thead>
<tr>
<th></th>
<th>Preop</th>
<th>3-month</th>
<th>1-year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PI</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACR</td>
<td>60°</td>
<td>59°</td>
<td>61°</td>
</tr>
<tr>
<td>PSO</td>
<td>63°</td>
<td>63°</td>
<td>63°</td>
</tr>
</tbody>
</table>

- Significant improvement from pre- to final follow-up in both techniques.
- PSO had a better correction of PI at 1-yr FU.

**T1SPI**

<table>
<thead>
<tr>
<th></th>
<th>Preop</th>
<th>3-month</th>
<th>1-year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>T1SPI</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACR</td>
<td>1.4°</td>
<td>-0.4°</td>
<td>-2.3°</td>
</tr>
<tr>
<td>PSO</td>
<td>4.3°</td>
<td>-3.6°</td>
<td>-3.8°</td>
</tr>
</tbody>
</table>

- Significant improvement from pre- to final follow-up from both techniques.

**TPA**

<table>
<thead>
<tr>
<th></th>
<th>Preop</th>
<th>3-month</th>
<th>1-year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TPA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACR</td>
<td>36°</td>
<td>23°</td>
<td>23°</td>
</tr>
<tr>
<td>PSO</td>
<td>35°</td>
<td>24°</td>
<td>24°</td>
</tr>
</tbody>
</table>

- Significant improvement from pre- to final follow-up in both.
- NO (p<0.05) difference between PSO vs. ACR in 3-m and 1-yr LL.

**ACR vs. PSO**

- SRS-Schwab Classification modifiers
  
P>0.05

- EBL (ACR=1.6 L vs. PSO=3.6 L)
  
P<0.007

  - Overall complication rates
    (ACR=41.2% vs. PSO=47.1%)
    
P>0.05
Conclusion

• ACR appears to achieve similar radiographic results as PSO
• ACR has significantly less EBL but equal complication profile

Conclusion

• While ACR has more PT correction, PSO patients have more trunk correction (T1SPi)
• The lack of difference in TPA suggests equal spinopelvic correction and the difference is likely postural.

PITFALL

• ACR= The first 17 cases by the authors
• PSO= Database of experts in the field

Further study beyond the learning curve of ACR will likely give a more realistic idea of its place in ASD

FINAL CASE

• HPI
  – 66 yo M with longstanding h/o low back pain
  – Over the last year, had noticed a significant decline in overall function
  – Feels significant pain after 10 steps or after a couple mins standing
  – Denies any radicular symptoms currently
  – Very active individual and has tried numerous modalities of conservative care
• **PE**
  – Ni strength and sensations BLEs
  – Grossly positive sagittal and coronal kyphoscoliosis
  – 7 cm truncal shift
  – Unable to stand up straight
  – Difficulty in laying down supine
• Assessment
  – Severe kyphoscoliosis
  – Severe coronal and sagittal imbalance

• Plan
  – L4-S1 ALIF, L1-L4 LLIF with ACRs
  – T4 – pelvis PSFI
Summary

• MIS deformity correction may be an alternative for selected patients
• Short-term outcomes are comparable with posterior procedures
• Larger long-term and prospective data collection are needed to assess the effectiveness of lateral approach versus classic open techniques.

Don’t be afraid to try new things

THANK YOU