Rationale for Lumbo-pelvic Fixation

- Stronger mechanical construct
  - Unload / protect sacral screws
  - Decrease risk of L5-S1 pseudarthrosis
  - Control sacro-pelvic alignment
In vitro bovine study evaluating multiple instrumentation types and fixation locations

• 10 total fixation constructs studied
  – Tested until failure in flexion

McCord et al. Study

• Introduced concept of the pivot point.
  – "At the intersection of the middle osteoligamentous column and the lumbosacral intervertebral disc”.

McCord et al. Study

• Location of failure
  • Occurred at the caudal bone-metal interface.
  • 2 constructs that withstood greatest load prior to failure
    • Both iliac fixation constructs.
McCord et al. Study

- Key was fixation ANTERIOR to center of rotation (pivot point).
  - Greatest flexion moment resistance.
  - Stiffness of construct proportional to distance of instrumentation anterior to pivot point.

Indications

- Why instrument to the pelvis?
  - Bypass incompetent lumbo-sacral articulation
  - Biomechanical strengthening of lumbo-sacral constructs

- Indications
  
  | Grade II or higher (L5–S1) spondylolisthesis |
  | Long-segment fusions to the sacrum (L2 or above to S1) |
  | Spinal deformity (scoliosis or kyphosis) |
  | Lumbar fractures |
  | Trauma |
  | Osteomyelitis |
  | Neoplasm |
  | Lesions that destroy the sacrum |
  | Neoplasm |
  | Osteomyelitis |
  | Fractures |
  | Treatment of L5–S1 pseudarthrosis |
Sacral/Pelvic Ring Injuries

- Bypass compromised sacrum
  - Denis type II, III fractures
  - Transverse fractures (Roy Camille type IV)
  - Tumor / infection reconstruction

Biomechanical Strengthening of Lumbo-Sacral Constructs

- Long constructs
- Deformity correction / spondy
- Revision pseudarthrosis
- Poor bone quality

Contemporary Fixation Techniques

- Traditional Iliac Screw Method
- Modified Iliac Screw Method
- S2 Alar Iliac Screw Method
Sacropelvic fixation should be considered in any patient with a long construct ending in the sacrum.

Patients with associated risk factors for loss of distal fixation or high risk for pseudarthrosis at L5-S1.

Those undergoing three-column osteotomies or vertebral body resections in the low lumbar spine.

Current pelvic fixation techniques with iliac screws, multiple screw/rod constructs, and S2-alar-iliac screws are all viable techniques for achieving pelvic fixation.

Growing evidence that pelvic fixation may become the standard for obtaining long fusions in adult scoliosis.

Indications and techniques should be individualized to the patient and based on surgeon preference and experience.

- 20 patients with the Galveston technique, 20 patients with an iliac screw undergoing posterior spinal fusion (T2-T3-pelvis) for neuromuscular spinal deformity.
- Statistically improved post-op PELVIC OBLIQUITY in the patients with an iliac screw (4.4°) versus those with the Galveston technique (7.3°) (P < 0.04).
- There were 13 patients with the Galveston technique versus 6 with an iliac screw who had RADIOGRAPHIC HOLEs more than 2 mm around the pelvic anchor devices at latest follow-up (P < 0.05).
- Galveston technique group had 4 BROKEN RODS and 2 REOPERATIONS.
- Iliac screw group had 1 broken screw and NO reoperations.
- The iliac screw technique avoids complex, lumbosacral 3-dimensional rod bends and yields minimal implant complications.

- Group 1: (11 patients) smooth L-rod and segmental sublaminar wires (Luque-Galveston technique).
- Group 2: (36 patients) posterior loda segmental instrumentation & combined iliac and sacral screws.
- Group 3: (12 patients) loda segmental instrumentation & bicortical sacral screws.
- 26 late complications. Pseudarthrosis developed in 10 patients, requiring revision surgery: 4 (36%) in the Group 1, 5 (14%) in Group 2, and 1 (8.5%) in Group 3.
- The Luque-Galveston fixation technique has an unacceptably high rate of PSEUDARTHROSIS, and this method is not recommended for adult deformities.
- Recommend using iliac fixation for adult spinal deformity.
- But.....Higher rate of painful hardware, requiring removal.
The overall prevalence of pseudarthrosis following long adult spinal deformity instrumentation and fusion to S1 was 24%.

Thoracolumbar kyphosis, osteoarthritis of the hip joint, thoracoabdominal approach (vs. paramedian approach), positive sagittal balance 5 cm at 8 weeks postoperatively, older age at surgery (older than 55 years), and INCOMPLETE sacropelvic fixation significantly increased the risks of pseudarthrosis to an extent that was statistically significant.

SRS outcomes scores at ultimate follow-up were adversely affected when pseudarthrosis developed.

### Traditional Iliac Screw Placement

**Anatomic and Radiographic Considerations for Placement of Transiliac Screws in Lumbopelvic Fixation**

- Analyzed CT in 40 patients with additional cadaveric evaluation
  - Determined intra-iliac length, inner width, cortical thickness
  - Determine radiographic measures to safely insert iliac screws

### Iliac Trajectories

- Evaluated 3 trajectories
- Mean length PSIS to AIS
  - 141 mm in males
  - 129 mm in females

<table>
<thead>
<tr>
<th>Table 1: Transiliac length to minimize nerve damage for male and female patients</th>
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<tbody>
<tr>
<td><strong>Male</strong></td>
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<tr>
<td>Average</td>
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<tr>
<td>128±5.2</td>
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<td>129±5.6</td>
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<td>130±5.6</td>
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L1: Length between the Spine and AIIS. L2: Length between the Spine and IT. L3: Length between the IT and AIF. L4: Length between the IT and S1. L5: Length between the IT and PSIS.
Iliac Trajectories

- 2 iliac constrictions noted
  - Anterior joint surface of the sacroiliac joint.
  - Narrowest part of the iliac wing, just anterior and superior to the greater sciatic notch.

<table>
<thead>
<tr>
<th>TABLE 2.</th>
<th>The distance between the superior margin points and the first (D1) and second (D2) constrictions.</th>
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<tbody>
<tr>
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<td><strong>Average ± SD, cm</strong></td>
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<tr>
<td>D1 ( D1 )</td>
<td>(cm)</td>
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<tr>
<td>Male</td>
<td>13.3 ± 2.2</td>
</tr>
<tr>
<td>Female</td>
<td>12.3 ± 1.8</td>
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Iliac Trajectories

- Goal would be to engage the inner cortical bone for better purchase at BOTH constrictions points.
- Suggested screw diameter of 8 mm in males and 6 - 7 mm in females.
- Smaller than previous studies reported.

Radiographic Guidance

- Typically need two views
  - Lateral
  - Obturator oblique-outlet
- Lateral view
  - Direct screw above sciatic notch and acetabulum
  - Be sure to wig-wag to get clear view
Radiographic Guidance

- Obturator oblique–outlet view known as a "teardrop"
  - "safer and intraosseous when directed along the teardrop figure on its medial border"
  - PSIS to AIIS trajectory

Iliac Screw Trajectory
Intraoperative Complications

- Vascular injury
  - Superior gluteal artery
- Neurological injury
  - Sciatic nerve
  - Superior gluteal nerve
- Screw malposition
  - Cortical breech
  - Acetabular breech

INTRAOPERATIVE COMPLICATIONS – VERIFY PLACEMENT

Lateral View

Iliac Oblique

Obturator Oblique

Modified Iliac Screw Technique - Vaccaro
46 patients underwent unilateral and 26 bilateral iliac screw fixation in adult spinal deformity.

- 41% (n = 19) of the unilateral cases and 50% (n = 13) of the bilateral cases were treated with reoperation (p = 0.48).
- In addition, 13% (n = 5) of the unilateral and 19% (n = 5) of the bilateral cases developed L5-S1 pseudarthrosis (p = 0.51).
- There were no sacral insufficiency fractures. 13% (n = 6) of the unilateral and 7.7% (n = 2) of the bilateral cases developed postoperative infection (p = 0.70).

Retrospective single-institution study, single versus dual pelvic screws led to comparable rates of reoperation, iliac screw removal, postoperative infection, pseudarthrosis, and sacral insufficiency fractures.

- Bilateral pelvic screws provided NO ADDED CLINICAL BENEFIT in most cases (vs unilateral).

Biomechanical testing was performed on a material testing machine for evaluating the stiffness of the L3-iliac fixation construct in compression and torsion.

- Single iliac screw technique was found to effectively restore the local stability in under 50% S1 resection.
- However, it could not provide adequate stability for further resection of one-side sacroiliac joint in torsion and total sacrectomy in compression.
- Dual iliac screw technique could restore the stability to the intact condition after total sacrectomy in both compression and torsion.

- 2 groups were tested (short screws - 70 mm and long screws - 138 mm).

Biomechanical testing was performed on a material testing machine under 800 N compression and 7 Nm torsion loading modes for stiffness evaluations.

- Pullout testing was performed for all the iliac screws to measure the maximum pullout force.
- Longer iliac screws resisted significantly greater axial pullout force.
- BUT UNDER PHYSIOLOGICAL, torsional, and compressive loading conditions, the mechanical stability of lumbo-pelvic fixation construct with short iliac screws WERE COMPARABLE with that of the long SCREWS.

Therefore, the use of short iliac screws, which are only about half the length of the long iliac screws, could reduce the implantation risk without significantly compromising on the stability of the construct.
24 patients had 47 screws placed for fixation at the lumbosacral junction.

- No cases required aborting the procedure or conversion to an open operation.
- All of the percutaneous screws were placed appropriately as verified by postoperative computed tomography scanning with 3-dimensional reconstruction.
- There were no hardware-related complications.
- Iliac screw placement can be performed safely with a low likelihood of bony violation.
- MIS technique offers biomechanical advantages of iliac fixation without the soft-tissue exposure traditionally needed.
- The technique relies on high-quality intraoperative fluoroscopic imaging.

Of 395 consecutive walking patients who had iliac screws placed during fusion to the sacrum for adult spinal deformity, 24 (6.1%) underwent elective removal.

- Patients had a statistically significant improvement in hip / buttock pain after screw removal, and a low prevalence of complications after the procedure was observed.

**Iliac Screws**

**Pros**
- Pass pivot point
- Ease of insertion
- Safe technique

**Cons**
- Screw prominence
- Often extensive soft tissue dissection
- Not inline with S1 screws (off-set connector needed)
- Screw loosening
S2 Alar Iliac Screw

• Alternative to the traditional iliac screw
• Advantages
  – Allows pelvic fixation without extensive muscle stripping or having to make a separate fascial incision
  – Instrumentation alignment (in-line with other screws)
  – Low profile
  – Multi-cortical fixation

• Cadaveric study
  • To determine anatomic feasibility and course of S2 alar iliac screws in relation to the SI joint, vital structures, cortical breeches
  • To determine length and trajectory of screws

An Anatomic Study of the S2 Iliac Technique for Lumbar Screw Placement

- 65 adult patients (43 IS, 22 S2AI) and 55 pediatric patients (40 IS/unit rod, 15 S2AI) in a consecutive series who underwent spinopelvic fixation.
- Adult cohort found an 18.9% absolute risk reduction (ARR) in implant loosening (P=0.029) and a 21.1% ARR (P=0.05) in late pain with the S2AI method.
- Pediatric population, the S2AI method demonstrated a 22.2% ARR (P=0.049) in both occurrence of revision surgery secondary to spinopelvic implant failure and late pain.
- Pooled cohort, the S2AI method had a 13% ARR (P=0.033) in acute infections, 18.1% ARR (P=0.003) in implant loosening, 14.5% ARR (P=0.009) in revision surgery, 18.7% ARR (P=0.015) in late pain, and a 10.8% ARR (P=0.031) in delayed wound issues.
- The S2AI technique is associated with significantly less clinical and radiographic complications in both the pediatric and adult populations when compared with the iliac screws technique.
• 7 human cadaveric spines (L2–Pelvis) were fixed at L2 proximally and the pubis distally.

• Pedicle screws were placed from L3–S1 with S2AI screw lengths of 65-mm, 80-mm, or 90-mm iliac screws. S2AI screws were tested with and without quad-cortical purchase.

• All the instrumented constructs significantly reduced range of motion compared with the intact spine.

• The L3–S1 construct was statistically significantly less stable than all instrumented constructs in flexion-extension.

• There was statistically no significant difference between the S2AI screws of all lengths and the iliac screw constructs with offset connectors.

• S2AI screws are biomechanically as stable as the test constructs using iliac screws in all loading modes.

• 65mm S2AI screws were biomechanically equivalent to 90-mm iliac screws and 80-mm S2AI screws.

• Quad-cortical purchase did not statistically significantly improve the biomechanical strength of S2AI screws.

Anatomic Trajectory

• Starting point was 1mm inferior and 1mm lateral to the dorsal S1 foramen (*).
  - 40-50° relative to the horizontal line connecting the PSIS
  - 20-30° caudal to straight lateral
  - Typically only 10° from parallel to the lamina
  - Lateral fluoroscopy to stay above sciatic notch
S2 Alar Iliac Screw Characteristics

- 60% of screws violated the articular portion of the SI joint.
- Average screw length was 84 mm (70-100mm)
- No screw intra-pelvic
- No risk to vascular or neural structures
- 3 screws (15%) violated posterior cortex of ilium
- All screws in-line with S1

Sacral Alar-Iliac (SAI) Pathway

- Iliac Fixation
  - Starting on sacral ala
  - Deeper, within muscle envelope
  - In line with other spinal anchors
  - Ideal for pelvic obliquity correction mechanics
  - Good platform for de-rotation

Starting Point Derived

- 25 ± 1 mm below S1 endplate
- 22 ± 1 mm lateral to midline
Technique: SAI Start

- Lateral to Sacral foramen
- Fluoro finds major Alar projection
- ~40° laterally
- ~25-40° caudal
  - Varies w. pathology!
- Pass just above notch
- Aim for AIIS

Technique

- Resistance increases at SI joint
- You can use an awl or a drill
- Continue till AIIS or lateral cortex

Technique

- SAI
Feasibility of Minimally Invasive Sacropelvic Fixation
Feasibility of Minimally Invasive Sacropelvic Fixation

Summary

• Many indications to consider iliac screw fixation
  – Bypass incompetent sacrum
  – Sacral Fractures / Pelvic Ring Injuries
  – Strengthen LS construct
  – Improve L5-S1 fusion rate

Summary

• Traditional Iliac Screw Placement
  – PSIS typical starting point (notch to recess screw head or modified technique).
  – Use lateral and obturator oblique-inlet view as needed.
  – Use long enough screw to traverse both iliac constrictions.
  – Use large enough screw to engage inner cortical bone.
Summary

• S2 Alar Iliac Screws
  – Appear to be viable alternative.
  – Lower prominence and in-line with other screws.
  – Fixation appears to be equivalent to traditional iliac screws.
  – 60% articular surface violation.

Thank you