Challenging Pedicle Screw Insertion/Salvage Techniques

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Pedicle Screws in Deformity

- Biomechanical screw performance:
  - Hackenberg L, *Spine* 2002

- Three column control of vertebra

- Improved coronal, sagittal & rotational correction

- Minimal loss of correction over time

- Lower pseudarthrosis rates

- Lower implant failures

- Earlier return to activities

- Avoid anterior release, thoracoplasty
Thoracic Pedicle Screws for AIS

  - TPS for correction of adolescent idiopathic scoliosis
    - Hooks 49% 19%
    - Screws in a hook pattern 64% 26%
    - Segmental screws 72% 59%

- Less loss of correction at 2 yrs with TPS
- No implant failures with TPS
Thoracic Pedicle Screws in Deformity: 

**Concerns**

- Greater risk of misplaced screws
- Spinal cord, great vessels, viscera
- Truly intraosseous?
- Pedicle anatomy and morphology in scoliosis
- Thin pedicles
- Difficulty of placement
- Cost
- Outcomes?

*Vaccaro A, J Bone Joint Surg Am 1995*
Structures at Risk
Screw Insertion Techniques

- Freehand Placement
  - Pedicle gearshift / Probe
  - Drill
- Fluoroscopic Assisted
- Funnel Technique
- Intraoperative Navigation
- Electronic Conductivity Device
Freehand Screw Placement

- **Safety Data:**
    - Stepwise, consistent and compulsive
    - Accurate, reliable and safe
  - Schizas C, *Eur Spine J* 2007
    - Safety in upper T spine (T1-T3)
    - Equivalent to fluoro/navigation techniques
TPS Accuracy in Deformity

  - Accuracy in nonscoliotic spines ~ 78-99%
  - Accuracy in deformity ~ 69-97.8%

  - TPS Accuracy and Efficacy in Curves > 90°
  - 94% of the planned screws were inserted
  - Accuracy ~ 96.3%, Efficacy ~ 68% correction
Dry Exposure - Visualization
Insertion Technique: Starting Point

A

B

TP

SF

P

-2 -1 0 +1 +2
Insertion Technique: Starting Point

<table>
<thead>
<tr>
<th>Level</th>
<th>Cephalad-Caudal Starting Point</th>
<th>Medial-Lateral Starting Point</th>
</tr>
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<tbody>
<tr>
<td>T1</td>
<td>Midpoint TP</td>
<td>Junction: TP-Lamina</td>
</tr>
<tr>
<td>T2</td>
<td>Midpoint TP</td>
<td>Junction: TP-Lamina</td>
</tr>
<tr>
<td>T3</td>
<td>Midpoint TP</td>
<td>Junction: TP-Lamina</td>
</tr>
<tr>
<td>T4</td>
<td>Junction: Proximal third-Midpoint TP</td>
<td>Junction: TP-Lamina</td>
</tr>
<tr>
<td>T5</td>
<td>Proximal third TP</td>
<td>Junction: TP-Lamina</td>
</tr>
<tr>
<td>T6</td>
<td>Junction: Proximal edge-Proximal third TP</td>
<td>Junction: TP-Lamina-Facet</td>
</tr>
<tr>
<td>T7</td>
<td>Proximal TP</td>
<td>Midpoint Facet</td>
</tr>
<tr>
<td>T8</td>
<td>Proximal TP</td>
<td>Midpoint Facet</td>
</tr>
<tr>
<td>T9</td>
<td>Proximal TP</td>
<td>Midpoint Facet</td>
</tr>
<tr>
<td>T10</td>
<td>Junction: Proximal edge-Proximal third TP</td>
<td>Junction: TP-Lamina-Facet</td>
</tr>
<tr>
<td>T11</td>
<td>Proximal third TP</td>
<td>Just medial to lateral pars</td>
</tr>
<tr>
<td>T12</td>
<td>Midpoint TP</td>
<td>At the level of lateral pars</td>
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</table>
Assess Rotation & Adjust Trajectory
Pedicle Morphology in the Spine with Scoliosis


Concave pedicles are smaller

Left (concave) Pedicle Width

![Graph showing concave pedicle width](image)
Freehand Screw Placement

**Outward**

Gearshift until the pedicle base

**Inward**

Gearshift into vertebral body after the pedicle base

Freehand Screw Placement

Difficult Screw Placement

- Concavity of curves
  - Main thoracic
  - Proximal thoracic

- Senaran, Shah et al.
  *J Spinal Disord* 2007
  - T3, T4 concavity
  - 18% sclerotic, narrow
Pedicle Morphology Classification

Watanabe, Lenke et al *IMAST 2007 and under review*

Type A - “Large Cancellous Channel” (50%)
Type B - “Small Cancellous Channel” (40%)
Type C - “Cortical Channel” (7%)
Type D - “Absent Pedicle Channel” (3%)
Insertion Techniques

Type A - Pedicle probe is smoothly inserted without difficulty
Type B - Pedicle probe is inserted snugly with increased force
Type C - Pedicle probe cannot be manually inserted but must be tapped with a mallet down into the body
Type D - Necessitates a “juxtapedicular” pedicle probe insertion

Watanabe, Lenke et al IMAST 2007 and under review
13 yo ♀ AIS Lenke 3CN
13 yo ♀ AIS Lenke 3CN
PSF T4-L4
Severe Kyphoscoliosis
Difficult Screws

- Severe curves
- Difficult exposure: bleeding, ribs
- Small, narrow, sclerotic pedicles
- Osteoporotic bone
- Osteotomy stabilization
Fluoroscopic Assisted Screw Insertion

Carbone J, Spine 2003
Rampersaud YR, Spine 2000
Proper AP image for Fluoro

- Pedicles in upper half of vertebral body
- Endplates parallel
- Spinous process equidistant
Fluoroscopic Assisted Screw Insertion

- Multiplanar fluoro, Iso-C, O-arm
- Accuracy 78-93%
- Radiation exposure

Kuntz C, *J Spinal Disord* 2004
Intraoperative Navigation

- Kosmopoulos V et al, *Spine* 2007: improved accuracy over other techniques, except in thoracic spine
Intraoperative Navigation

The Challenges

- Learning curve (frustration)
- Registration of the patient’s anatomy in the OR
- Non sterile expert
- Still need fluoro or intraop CT
- Tools are cumbersome
Electronic Conductivity Device

- Breach anticipation (alert to surgeon)
- Immediate redirection if necessary
- Juxtapedicular technique
- Possible bicortical fixation
Electronic Conductivity Device

- Bolger et al. *Eur Spine J, in press*
  - Correctly identified intentional breaches
  - Decreased rate of medial breaches by 8%

<table>
<thead>
<tr>
<th>Table 2. Percentage of Breaches: Deformity Cases T11-S1, Titanium</th>
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<tr>
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<td>PediGuard™</td>
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<td>Fluoroscopy</td>
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<table>
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<tr>
<th>Table 3. Radiation Exposure</th>
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<tr>
<td>Time (seconds)</td>
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<tr>
<td>----------------</td>
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Salvage Techniques / Alternatives

- Tendency is to miss lateral and/or inferior
- Change Trajectory [anatomic / rotational traj.]
- Fluoroscopic Assistance
- Drill / smaller or sharper probe
- Laminotomy / Funnel Technique
- Extra- or Juxtedapticular (lateral) Placement
- Intralaminar Screws
Insertion Technique: Trajectory

- **Straight Ahead Trajectory**
  - Parallels superior end plate
  - Allows monoaxial screw
  - Higher IT and pullout (27%)

- **Anatomic Trajectory**
  - Along pedicle axis
  - Requires multi-axial screw
  - Salvage situation 62%

- Lehman RA, *Spine 2003*
Salvage Techniques for Screw Placement

Palpate the medial and inferior borders of the pedicle from the canal and start 2 mm lateral
Salvage Techniques for Screw Placement

Palpate the lateral border of the superior articular process / TP junction

Zeiller et al, Neurol India 2005
Cannulated tap developed for screw insertion in small pedicles
Extra/Juxtapedicular Techniques

- Pullout inferior than transpedicular
- But, acceptable (65-80%)
- Decent salvage alternative
- Maybe the only alternative (Type D pedicle)
  - White KK, *Spine* 2006
Extra/Juxtapedicular Techniques

- Pullout inferior than transpedicular
- But, acceptable (65-80%) [rib head]
- Decent salvage alternative
- Maybe the only alternative (Type D pedicle)
  - White KK, *Spine* 2006
Funnel Technique

Yingsakmonkol, Karaikovic, and Gaines, *J Spinal Disord* 2002
Intralaminar Screw Placement

Lewis SJ et al, *Spine 2009*

A curved pedicle probe is directed along the axis of the lamina with the curved tip aimed dorsally.

1. The trajectory is kept slightly less than the down slope of the lamina.
2. The screw is placed entirely within the cortical bone.
3. A- Axis of the lamina, B - ideal trajectory.

Biomechanics sound - Cardoso MJ *J Neurosurg Spine 2009*
**Screw Revision Techniques**

- Change trajectory
- Pedicle dilation
  - Clements D, *pilot data* – increased pullout 200Nm
- Larger diameter screws better than longer
  - Polly DW et al, *Spine 1998*
Other Alternatives

- Hooks (pedicle, laminar, TP)
- Cordista A, Spine 2006 “Biomechx of screws/hooks”
  - Hook claw config was 88% stronger than TPS
- Coe J, Spine 1990 “Infl of BMD on fix. strength”
  - Laminar hooks found to be the strongest
Other Alternatives

- **Sublaminar wires**
  - Cheng I et al *Spine 2005* “Wires vs. TPS”
  - Similar corrections, OR time, fusion length, SRS scores
  - Wires cheaper

- **Transverse process wires**
  - Fujita, *Spine 2006*

- **New materials**
Other Alternatives

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- **New materials**

- **Leave it out**
14 yo ♂ AIS
14 yo ♂ AIS

supine bending left

right bending supine
14 yo ♂ AIS

- Ant. Tscopic release
- Ponte osteotomies
- Rib head release

- Combination of techniques for screw insertion
Summary

- Many screw salvage techniques
  - Severe deformities
  - Small, narrow, sclerotic pedicles
  - Osteoporotic bone
  - Revision cases / fusion mass
- Extra- or juxtapedicular position is acceptable
- Fluoroscopy is helpful
- Segmental screw fixation is not necessary
- Other alternatives are available (hooks, wires)
Thank you