

Challenging Pedicle Screw Insertion/Salvage Techniques



Suken A. Shah, MD

Alfred I. duPont Hospital for Children
Division Chief, Spine and Scoliosis
Center

Wilmington, Delaware USA



Nemours

Alfred I. duPont
Hospital for Children

Nemours
Children's Clinic

Pedicle Screws in Deformity

- Biomechanical screw performance:
 - Hackenberg L, *Spine* 2002
 - O'Brien MF, *Spine* 2000
 - Hamill CL, et al, *Spine* 1996
- 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

- Suk S-I, et al, *Spine* 1995; 20: 1399-1405
 - TPS for correction of adolescent idiopathic scoliosis

	Coronal correction	Rotational correction
■ 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

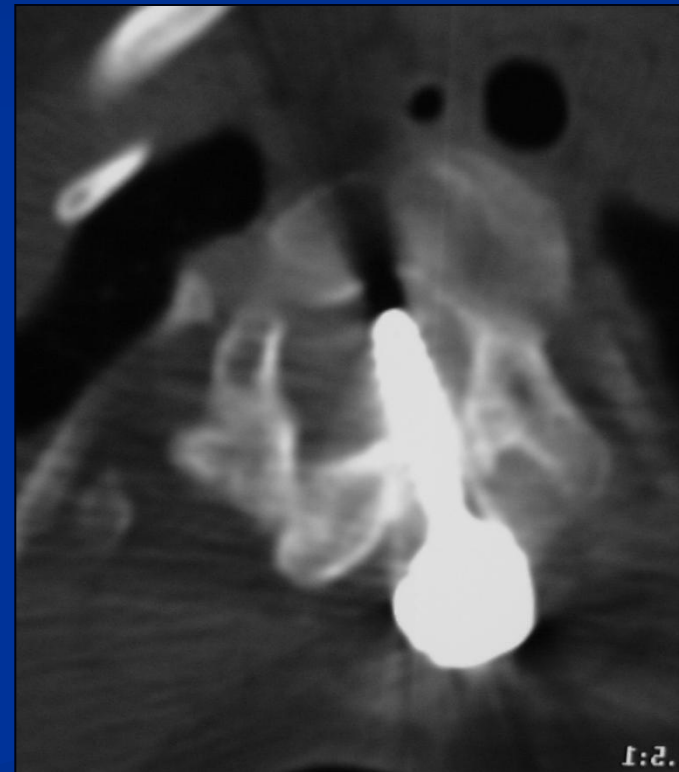
Thoracic Pedicle Screws in Deformity:

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:
- Kim Y, Lenke L, Bridwell K, et al *Spine* 2004
 - 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

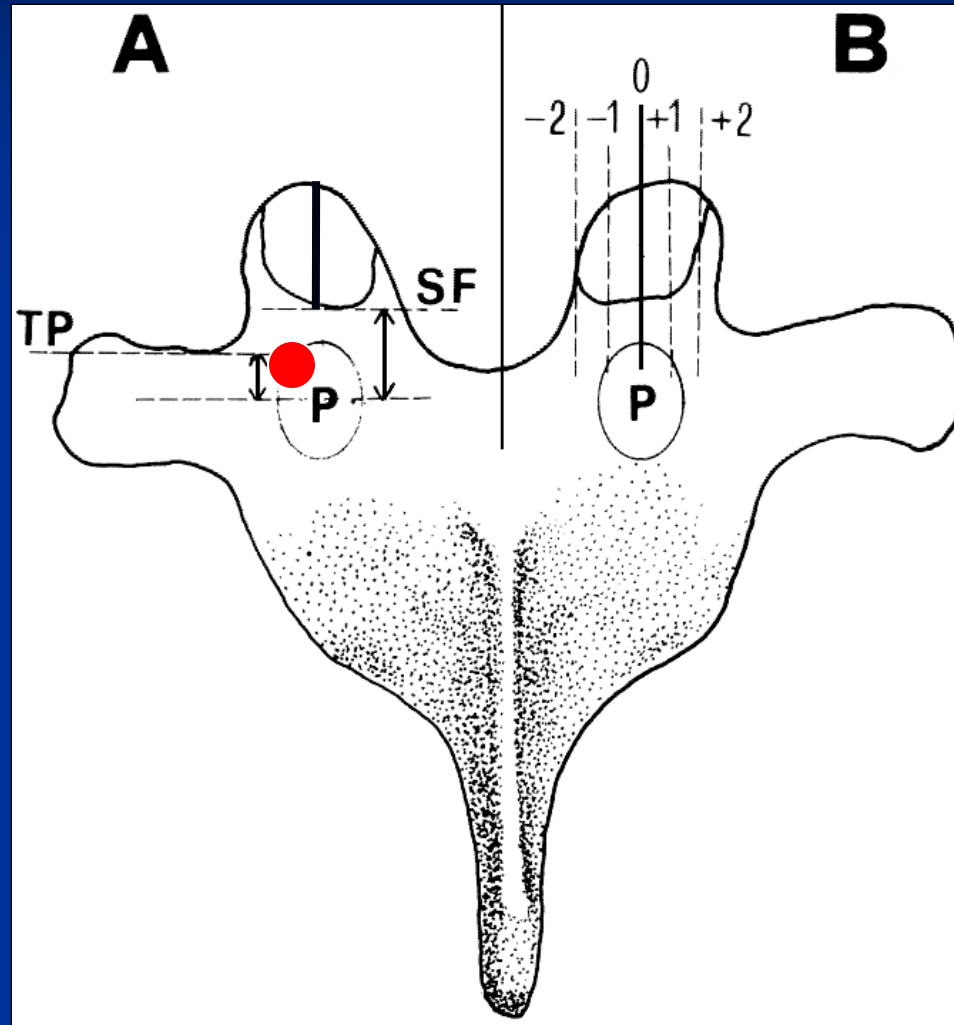
TPS Accuracy in Deformity

- Belmont, *Spine* 2001 and Kim, *Spine* 2004
 - Accuracy in nonscoliotic spines ~ 78-99%
 - Accuracy in deformity ~ 69-97.8%
- Kuklo, Lenke, O'Brien et al, *Spine* 2005
 - TPS Accuracy and Efficacy in Curves $> 90^\circ$
 - 94% of the planned screws were inserted
 - Accuracy ~ 96.3%, Efficacy ~ 68% correction

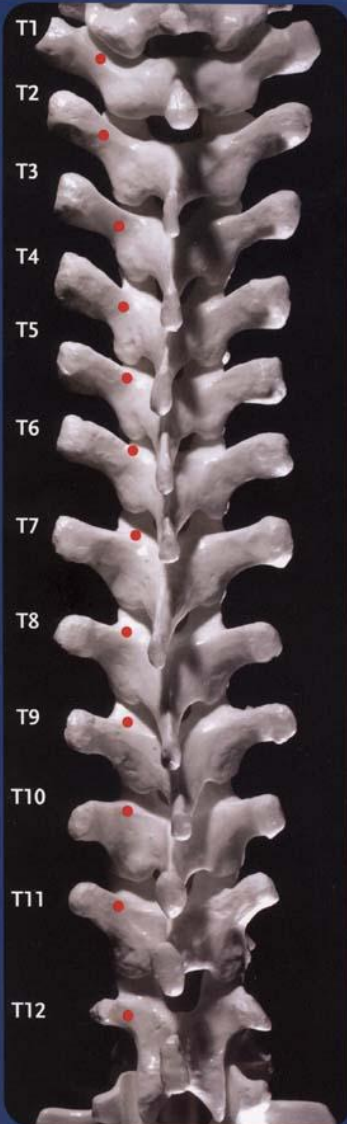
Dry Exposure - Visualization



Insertion Technique: Starting Point



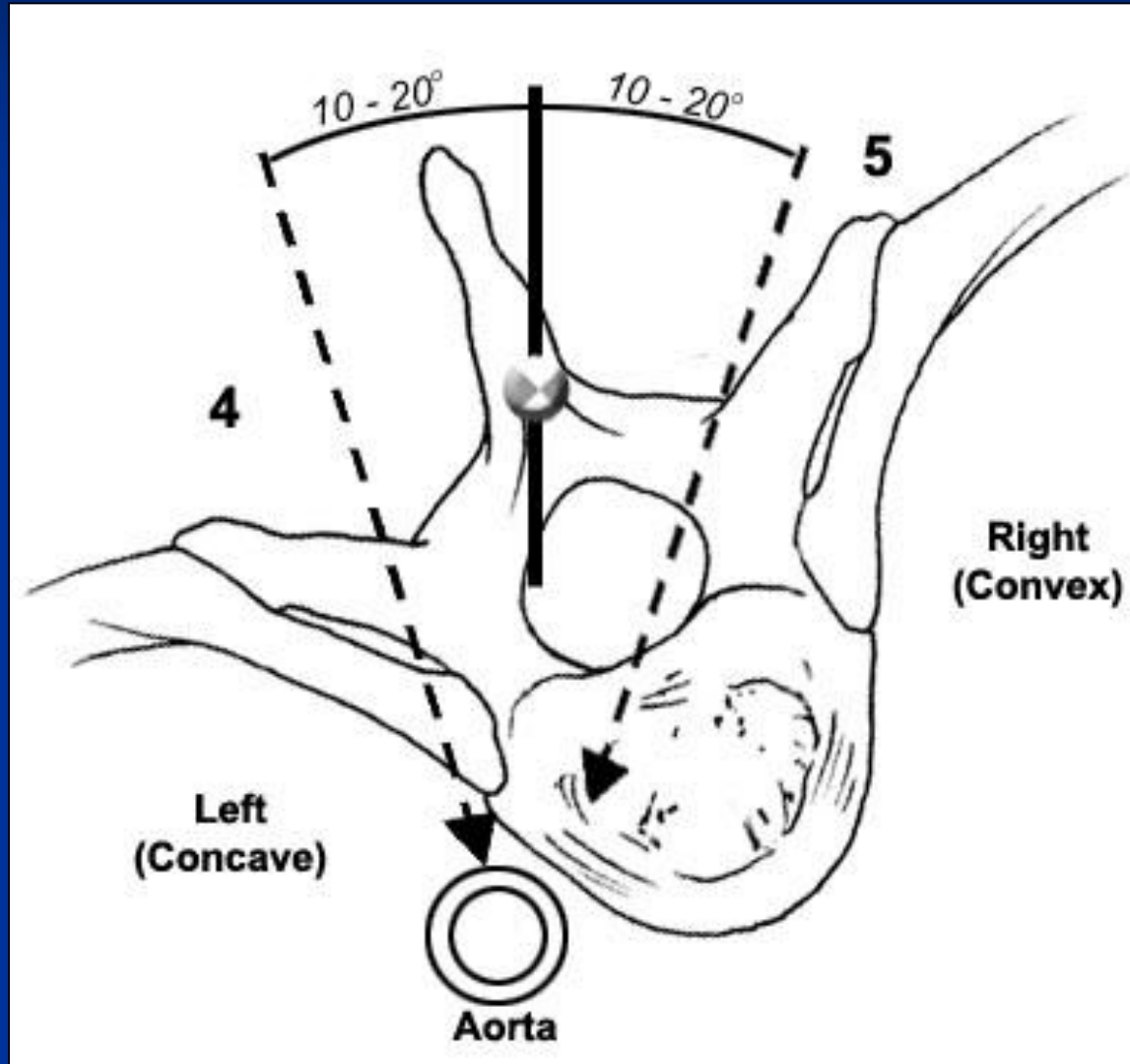
Insertion Technique: Starting Point



Thoracic Pedicle Screw Starting Points

Level	Cephalad-Caudad Starting Point	Medial-Lateral Starting Point
T1	Midpoint TP	Junction: TP-Lamina
T2	Midpoint TP	Junction: TP-Lamina
T3	Midpoint TP	Junction: TP-Lamina
T4	Junction: Proximal third-Midpoint TP	Junction: TP-Lamina
T5	Proximal third TP	Junction: TP-Lamina
T6	Junction: Proximal edge-Proximal third TP	Junction: TP-Lamina-Facet
T7	Proximal TP	Midpoint Facet
T8	Proximal TP	Midpoint Facet
T9	Proximal TP	Midpoint Facet
T10	Junction: Proximal edge-Proximal third TP	Junction: TP-Lamina-Facet
T11	Proximal third TP	Just medial to lateral pars
T12	Midpoint TP	At the level of lateral pars

Assess Rotation & Adjust Trajectory

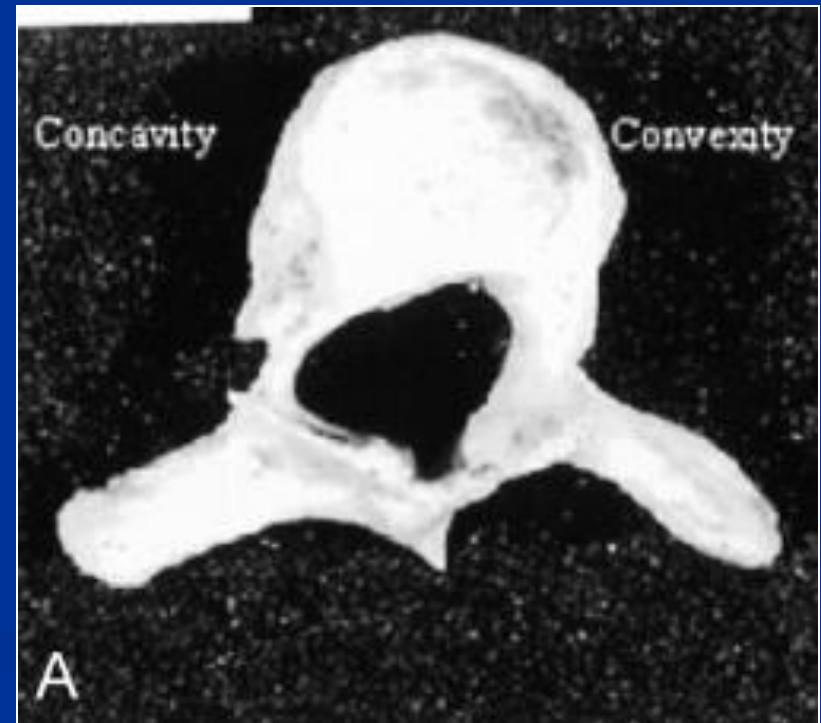
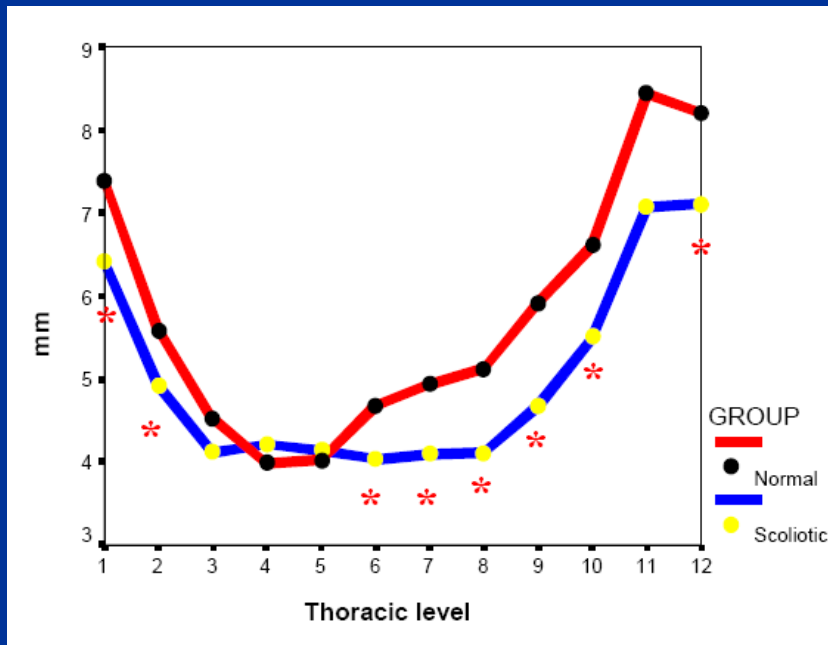


Pedicle Morphology in the Spine with *Scoliosis*

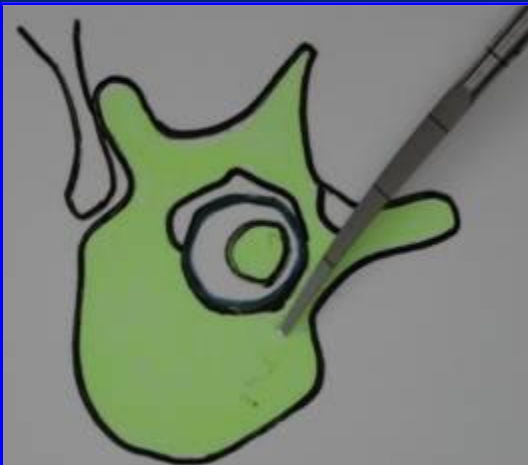
■ Parent S, et al, *Spine* 2004; 29: 239-248

Concave pedicles are smaller

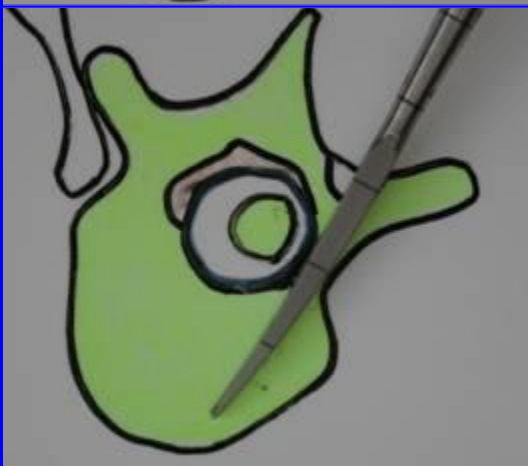
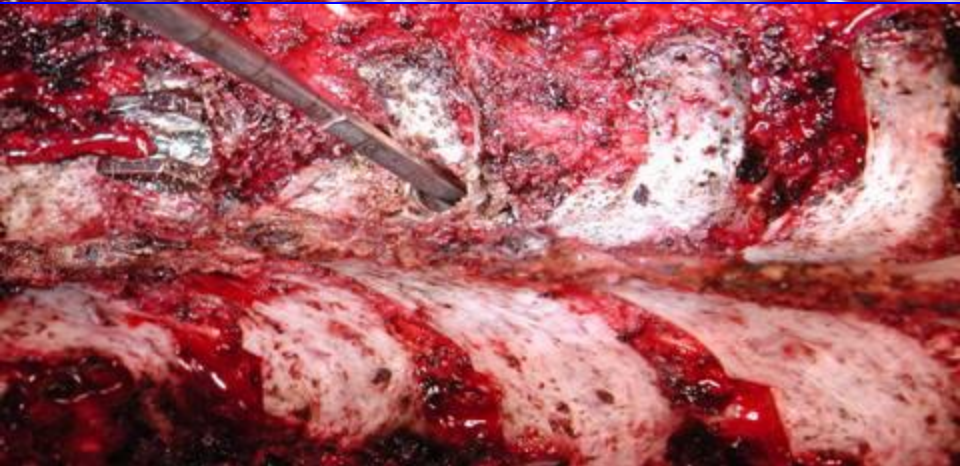
Left (concave) Pedicle Width



Freehand Screw Placement



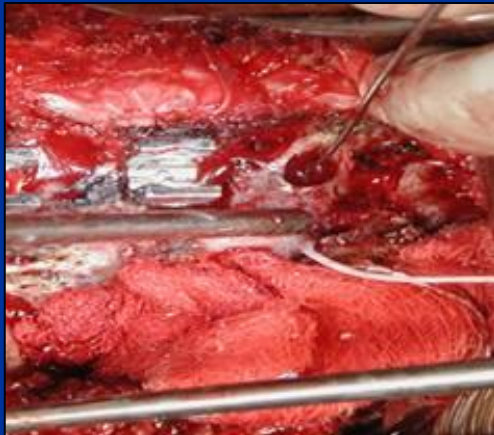
Outward
gearshift
until the
pedicle base



Inward
gearshift into
vertebral body
after the
pedicle base

Kim YJ, Lenke LG et al, *Spine* 20047

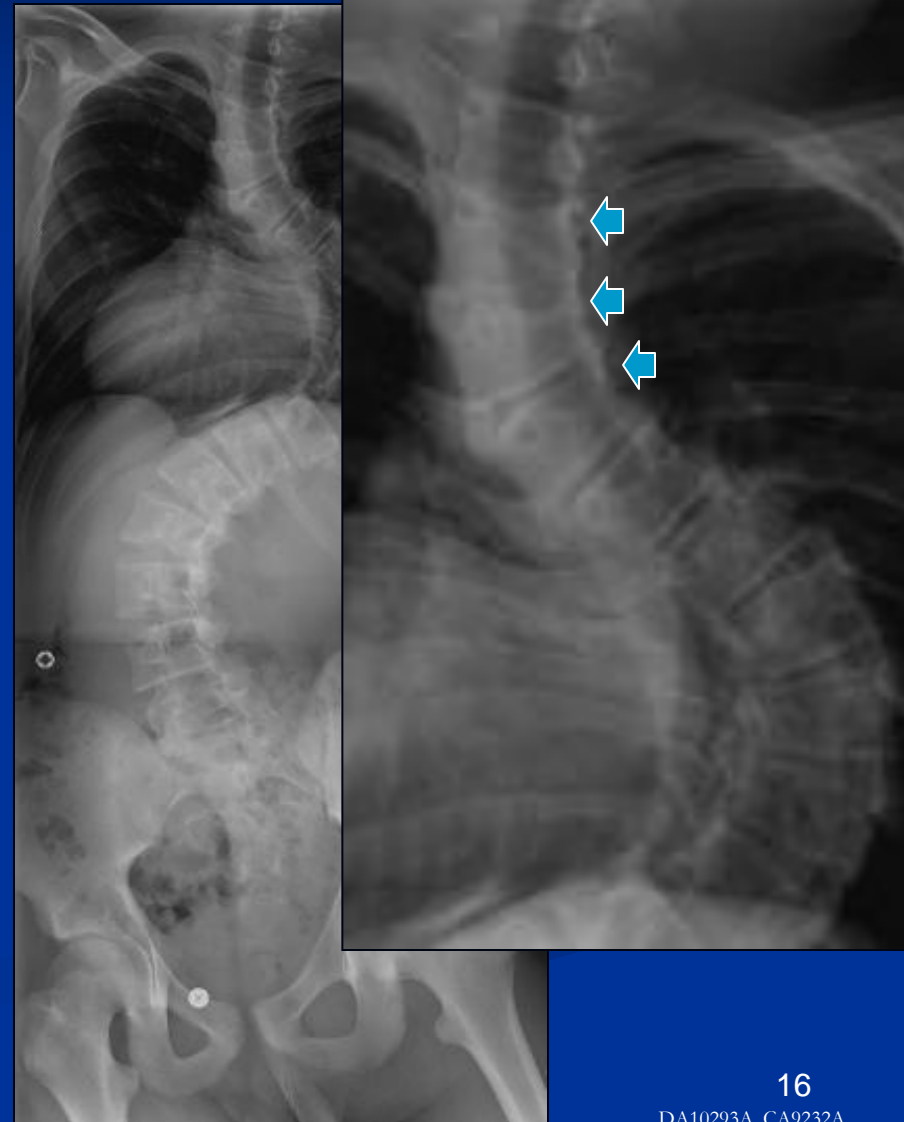
Freehand Screw Placement



Kim YJ, Lenke LG et al, *Spine* 2004

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



Type B



Type C



Type D

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



Type B



Type C

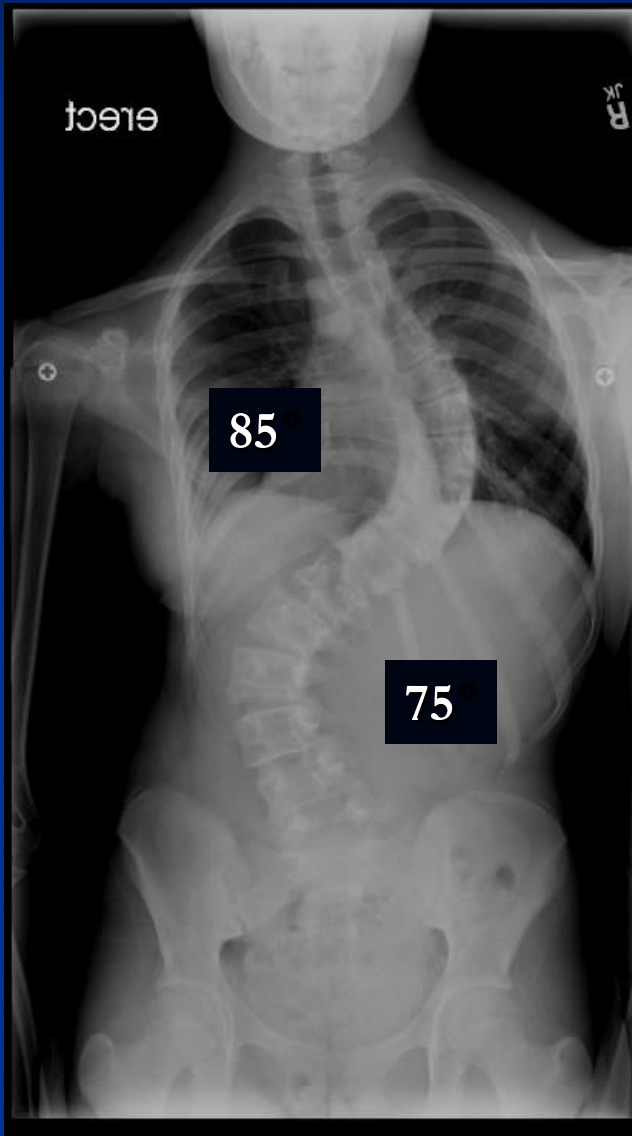


Type D

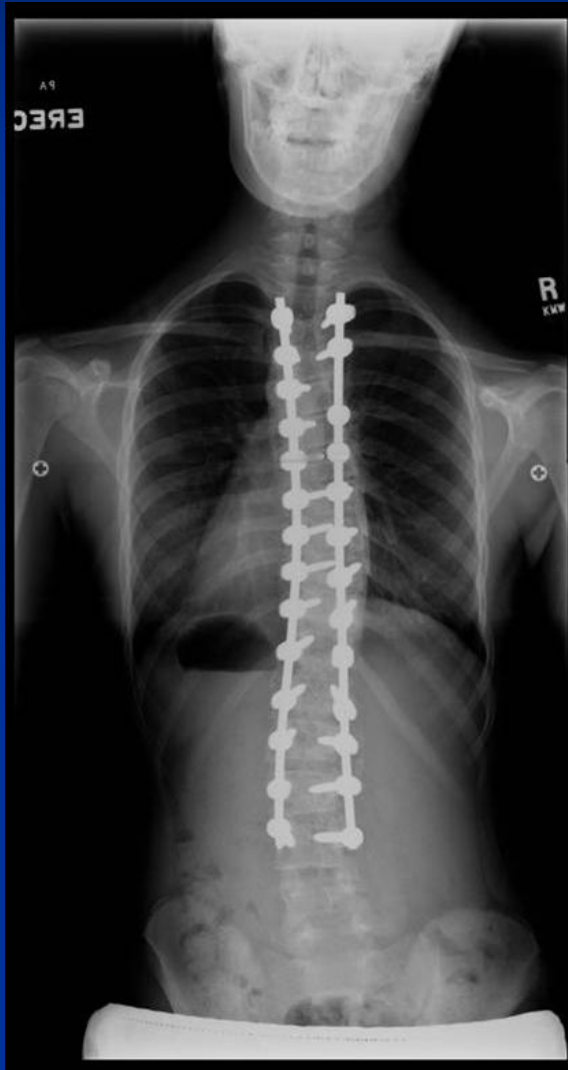
- Type A - Pedicle probe is smoothly inserted without difficulty
- Type B - Pedicle probe is inserted snugly with increased force
- Type C - Pedicle probe cannot be manually inserted but must be tapped with a mallet down into the body
- Type D - Necessitates a “juxtapedicular” pedicle probe insertion

Watanabe, Lenke et al IMAST 2007 and under review

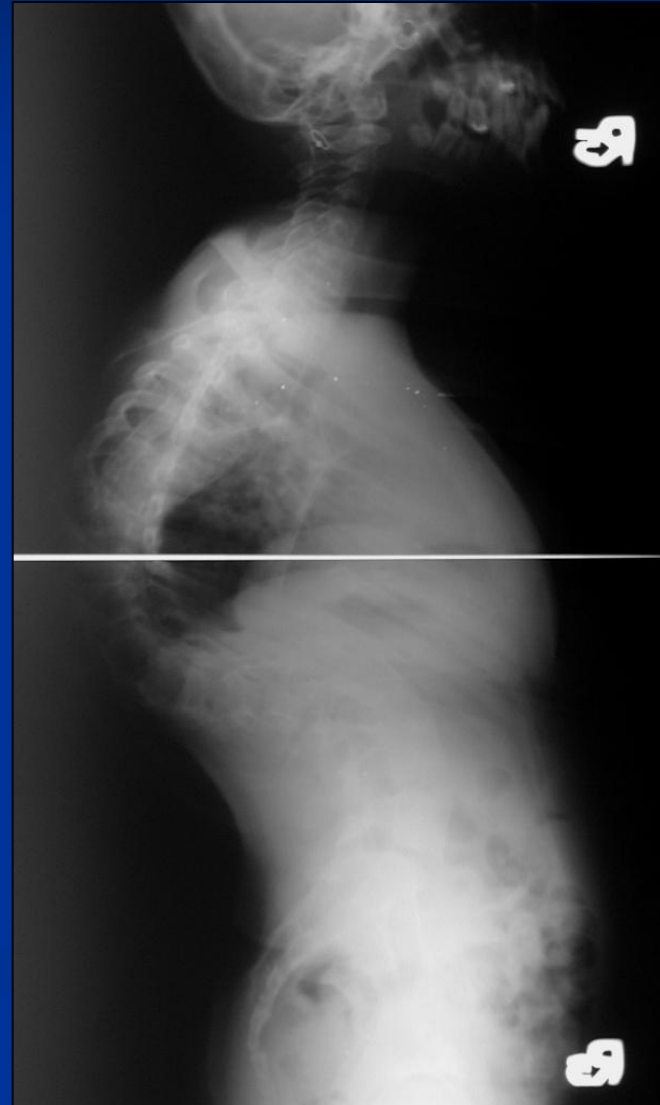
13 yo ♀ AIS Lenke 3CN



13 yo ♀ AIS Lenke 3CN PSF T4-L4



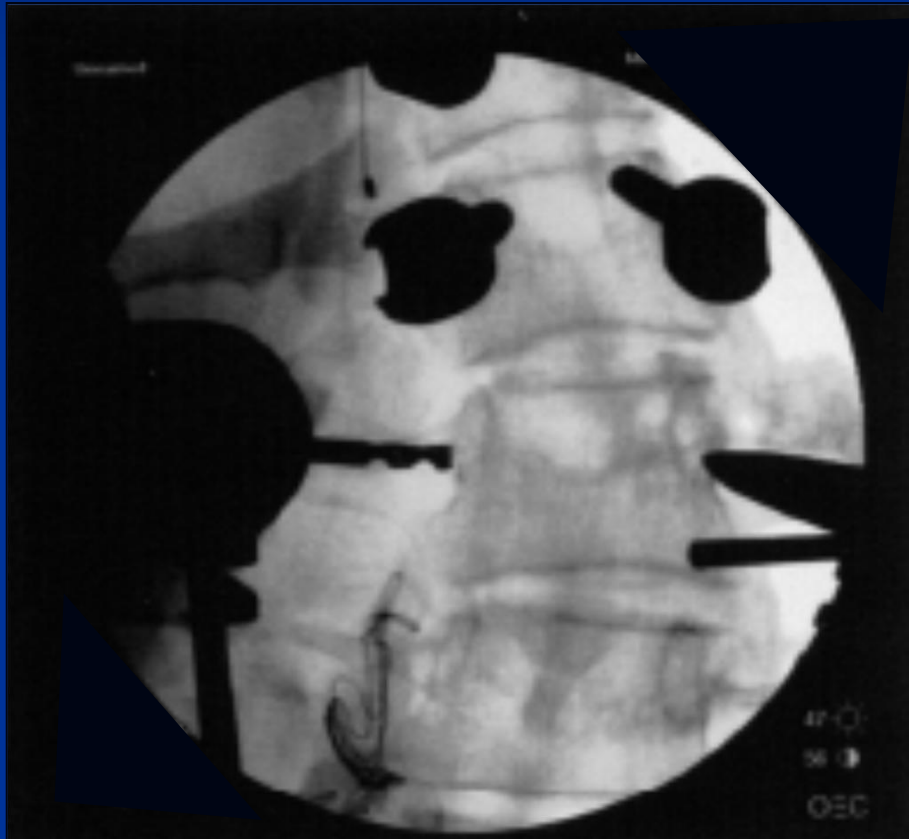
Severe Kyphoscoliosis



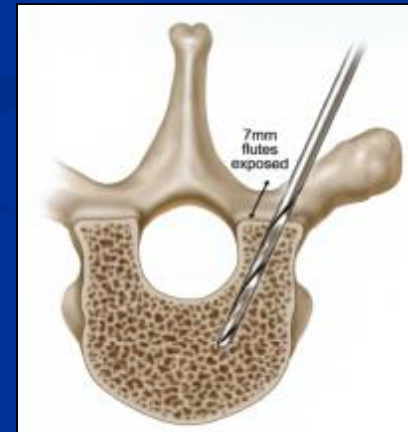
Difficult Screws

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

Fluoroscopic Assisted Screw Insertion



Collinear



fflebarger, DePuy Spine Technique Guide, 2007

Carbone J, *Spine* 2003

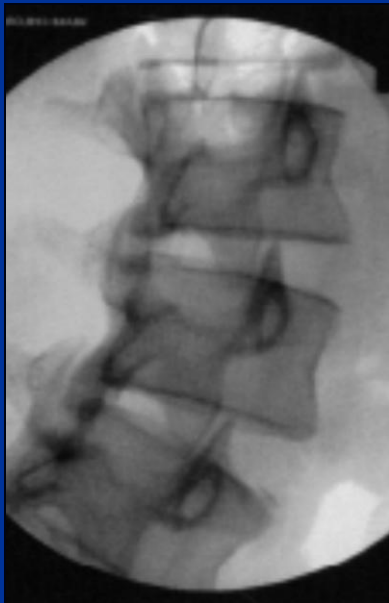
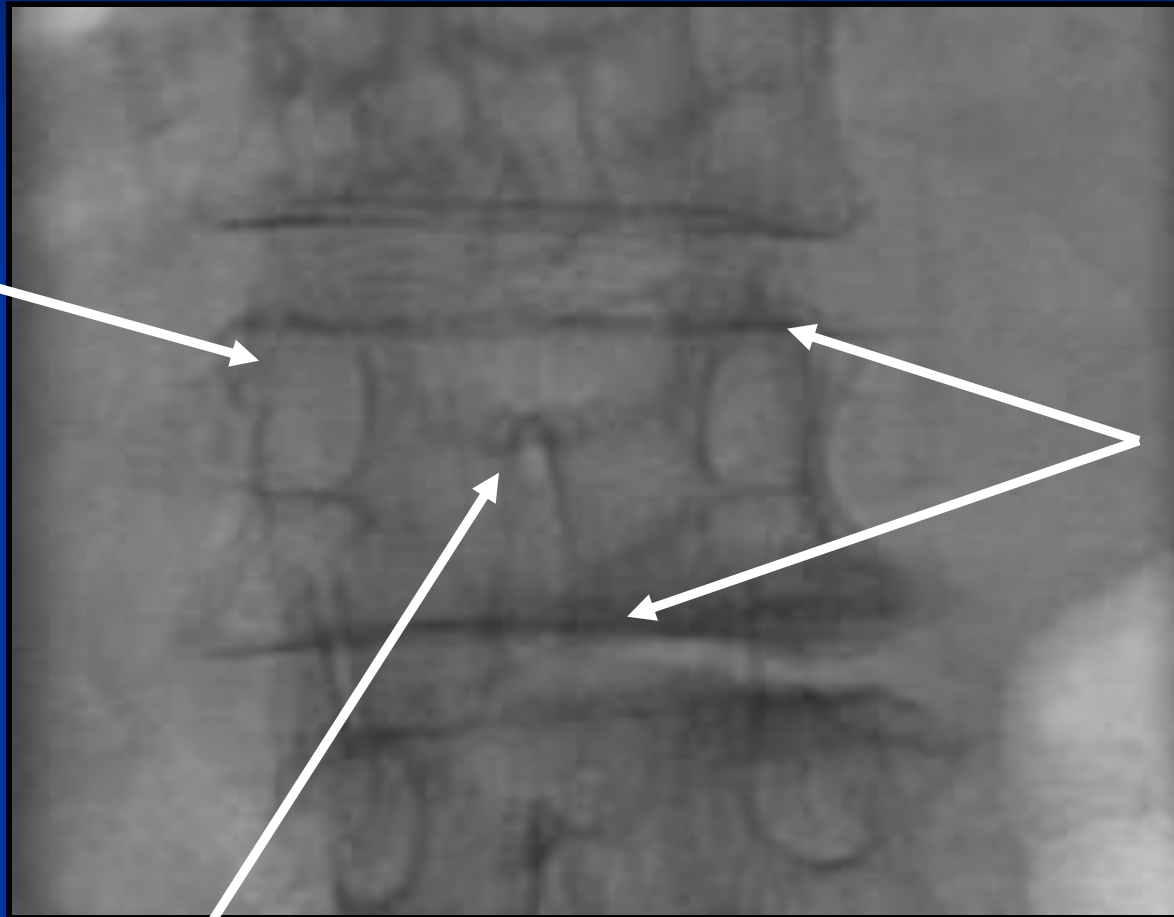
Rampersaud YR, *Spine* 2000

Proper AP image for Fluoro

Pedicles in upper half of vertebral body

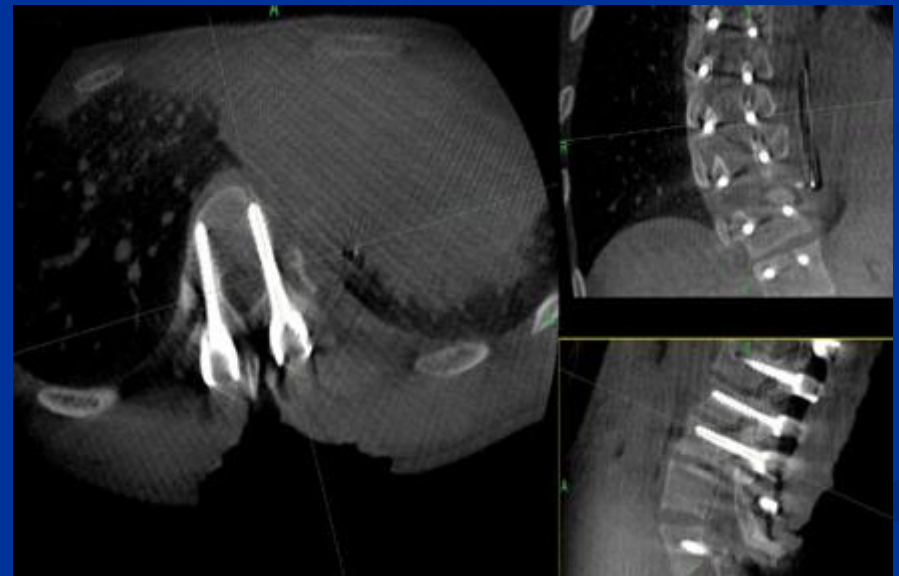
Endplates parallel

Spinous process equidistant



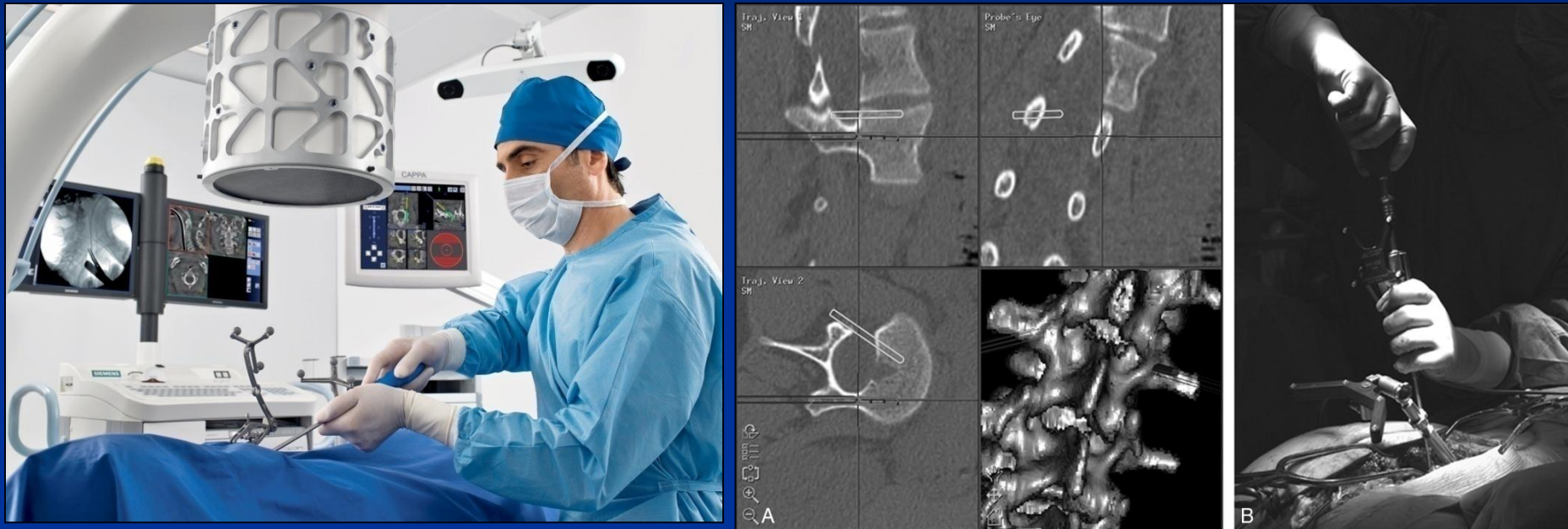
Fluoroscopic Assisted Screw Insertion

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



Wang M et al, *Neurosurgery* 2004
Kuntz C, *J Spinal Disord* 2004

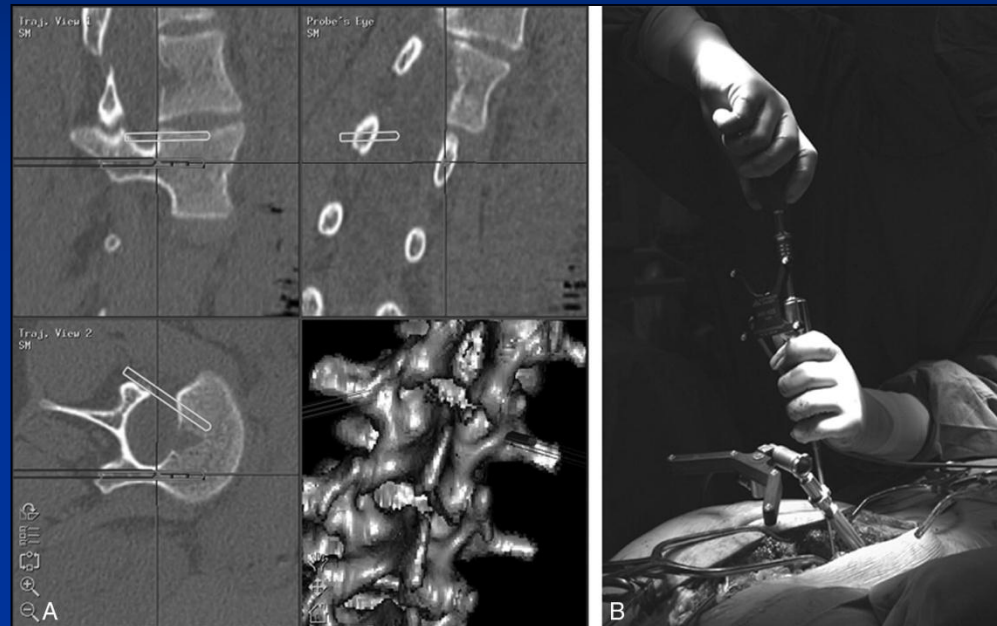
Intraoperative Navigation



- Kotani Y et al, *Spine* 2007: improved accuracy over fluoro
- Mirza S et al, *Spine* 2003: multiple reference markers
- Kosmopoulos V et al, *Spine* 2007: improved accuracy over other techniques, except in thoracic spine

Intraoperative Navigation

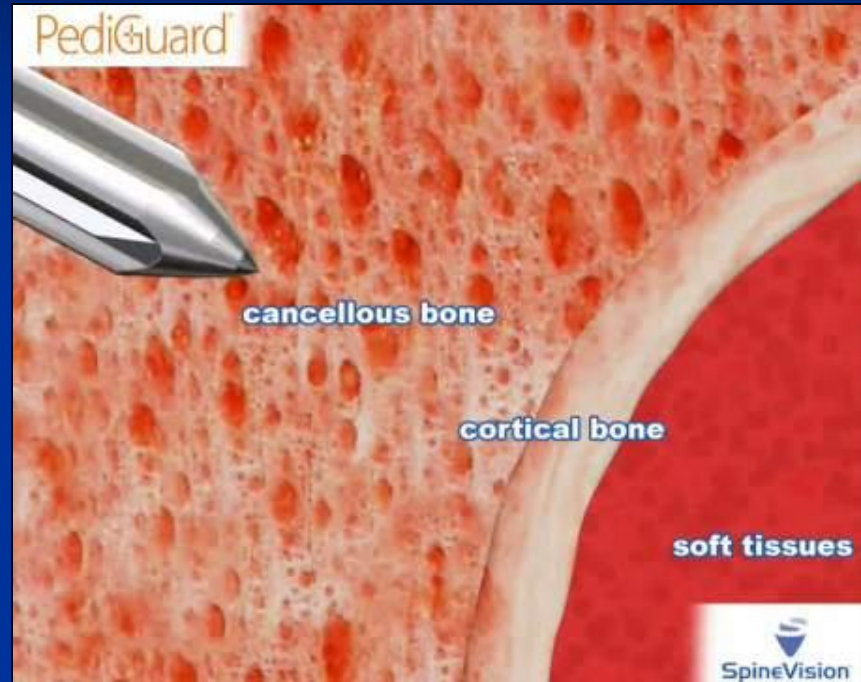
The Challenges



- 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
- Betz, Samdani et al. *Temple J Orthop Surg 2008*
 - Decreased rate of medial breaches by 8%

**Table 2. Percentage of Breaches:
Deformity Cases T11-S1, Titanium**

	In	Out > 2 mm
PediGuard™	81.4	18.5
Fluoroscopy	80.7	19.2

Table 3. Radiation Exposure

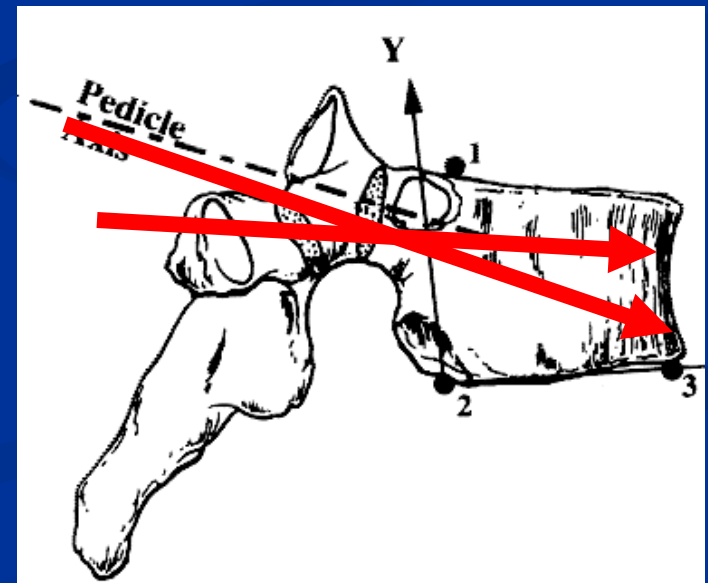
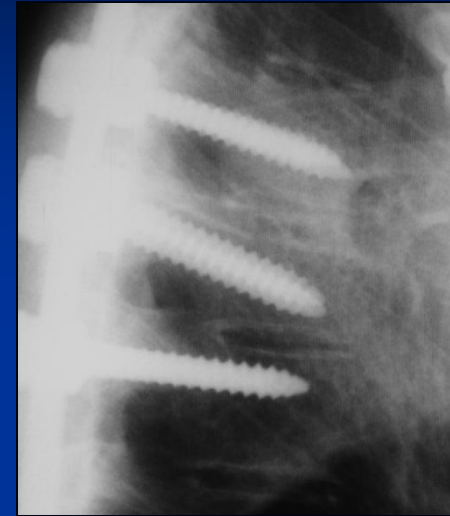
	Time (seconds)	Number of Fluoro Shots
PediGuard™	211	3.2
Fluoroscopy	229	4.5

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 Juxtapedicular (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

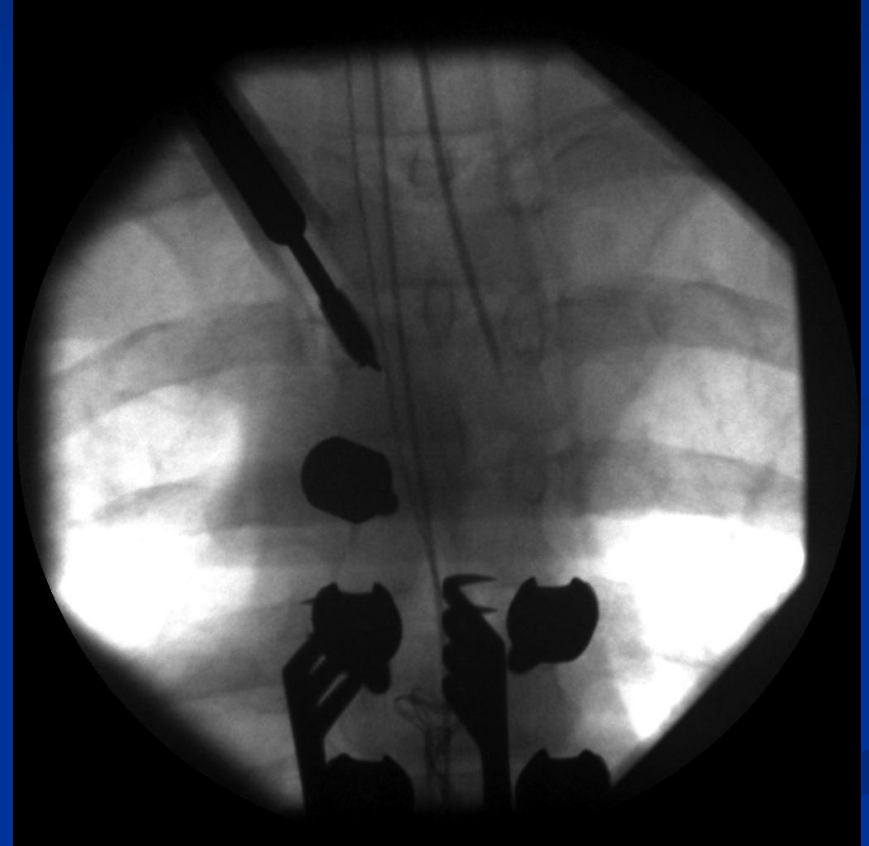
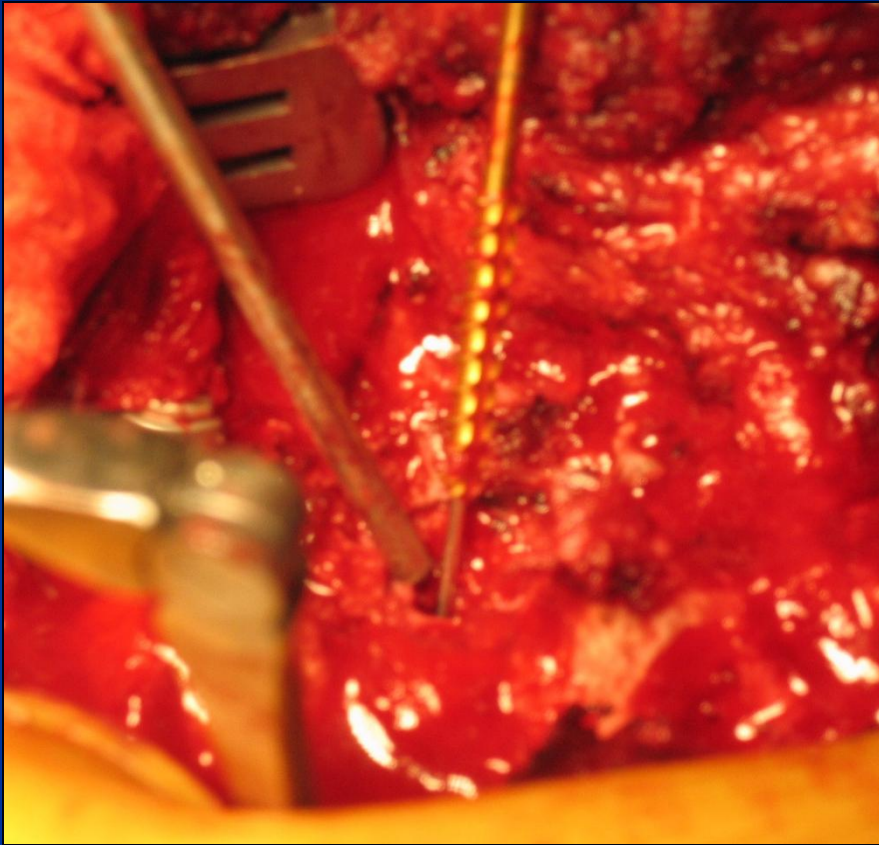
Salvage Techniques for Screw Placement



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

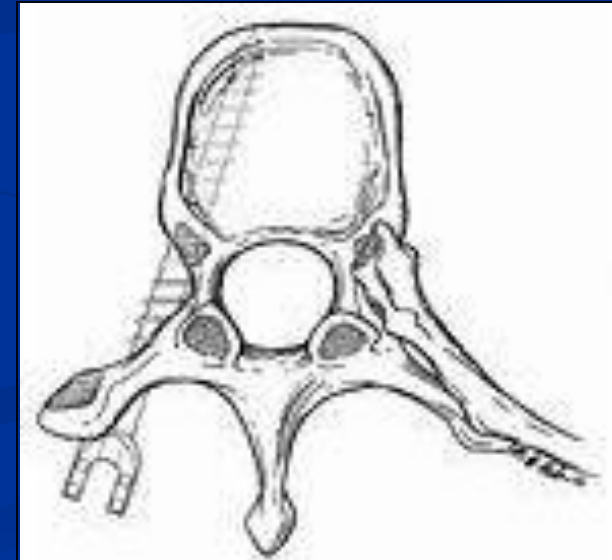
Zeiller et al, *Neurol India* 2005

Cannulated tap developed for screw insertion in small pedicles



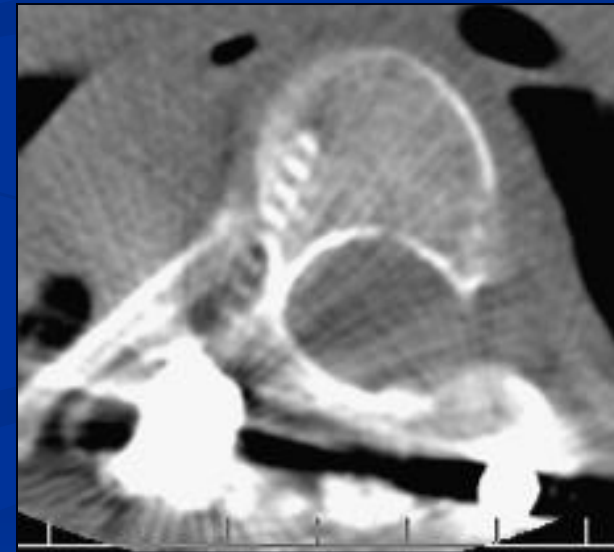
Extra/Juxtapedicular Techniques

- Pullout inferior than transpedicular
- But, acceptable (65-80%)
- Decent salvage alternative
- Maybe the only alternative (Type D pedicle)
 - White KK, *Spine* 2006
 - Yuksel KZ, *Spine* 2007

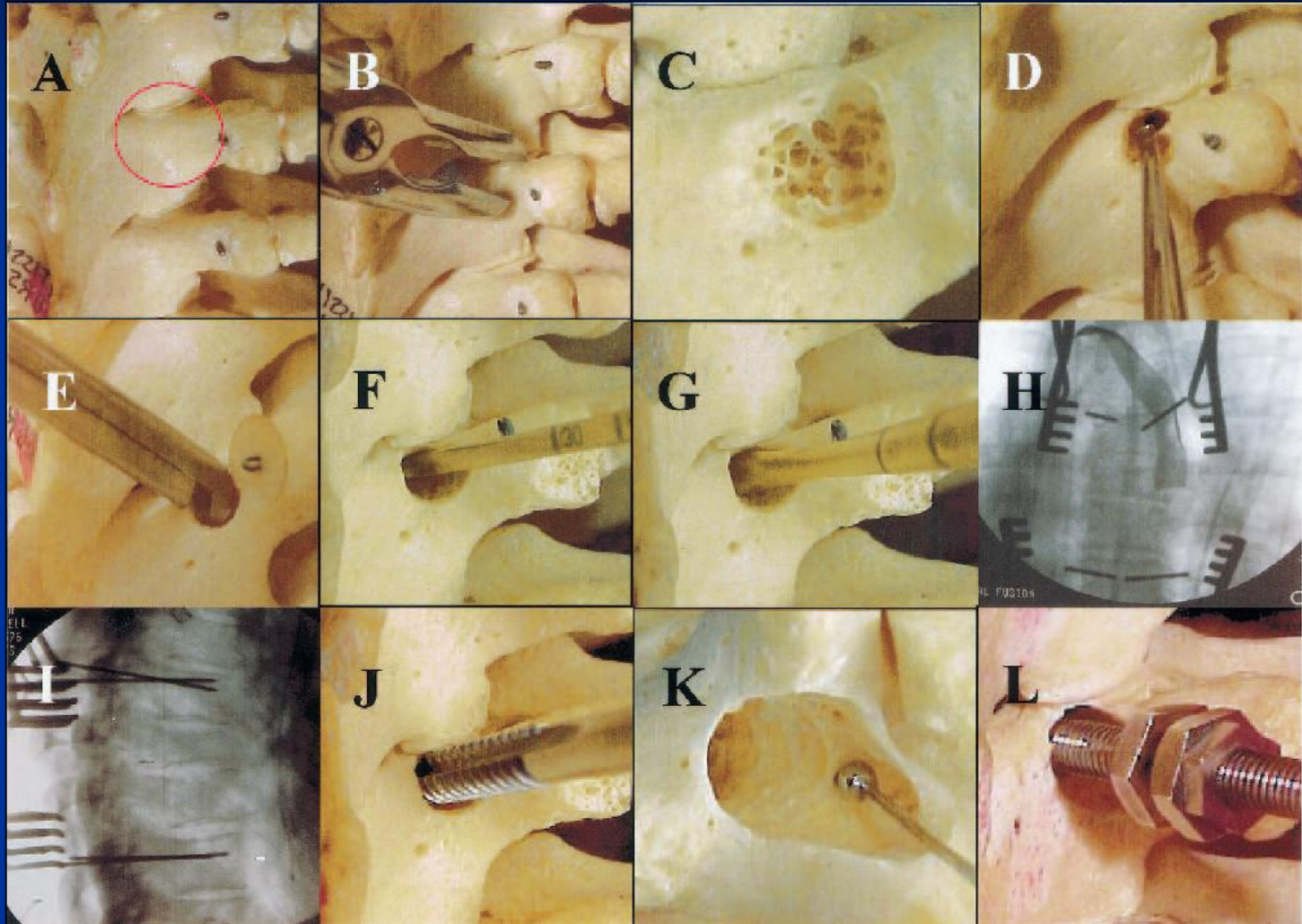


Extra/Juxtapedicular Techniques

- Pullout inferior than transpedicular
- But, acceptable (65-80%) [rib head]
- Decent salvage alternative
- Maybe the only alternative (Type D pedicle)
 - White KK, *Spine* 2006
 - Yuksel KZ, *Spine* 2007



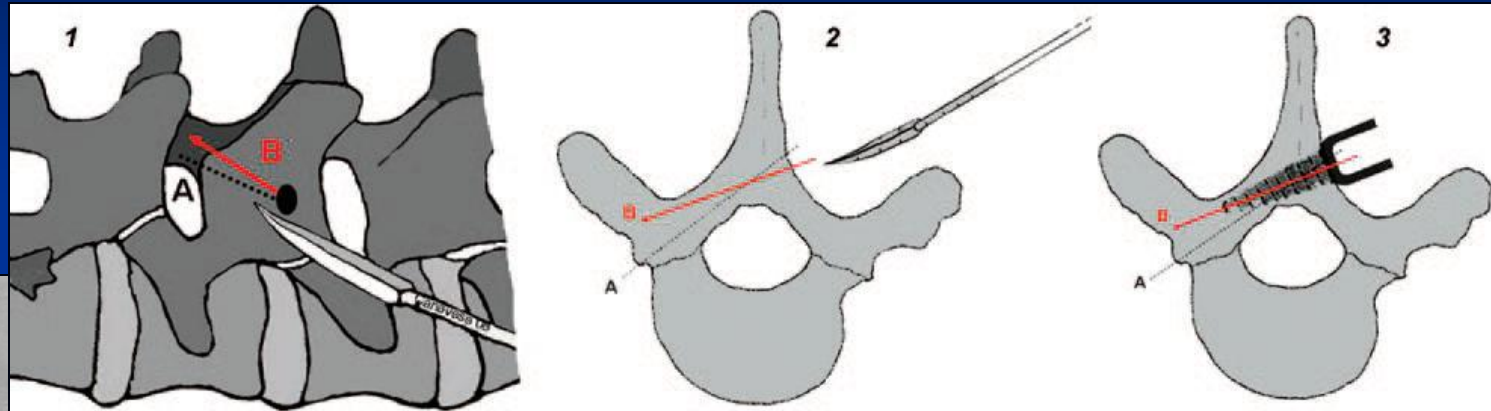
Funnel Technique



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
- Erel, *Acta Orthop Scand* 2003

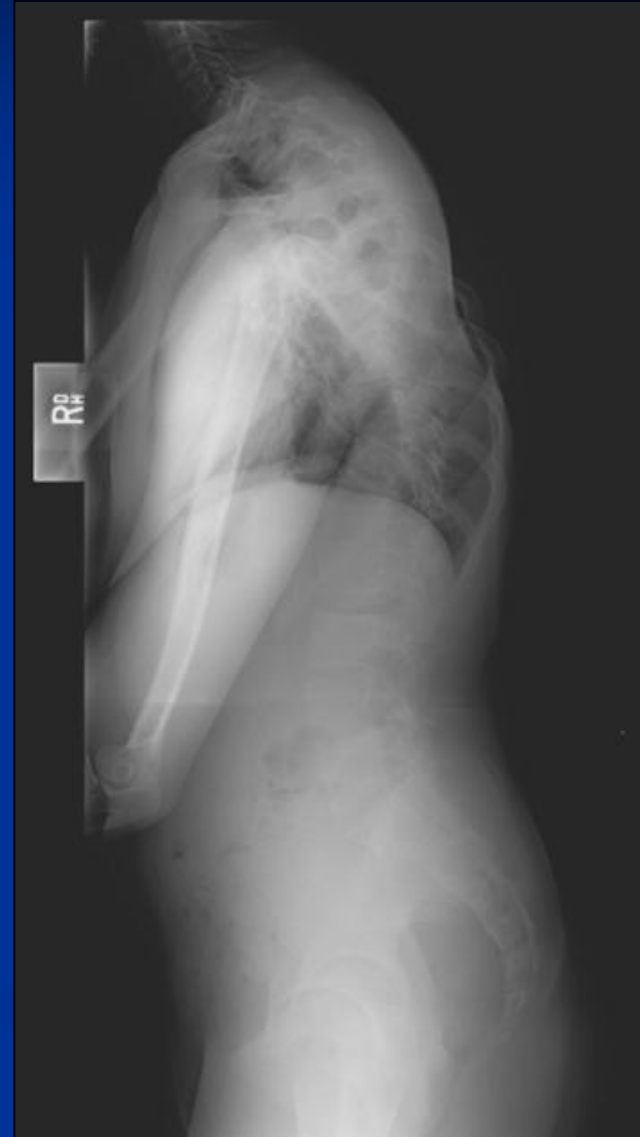
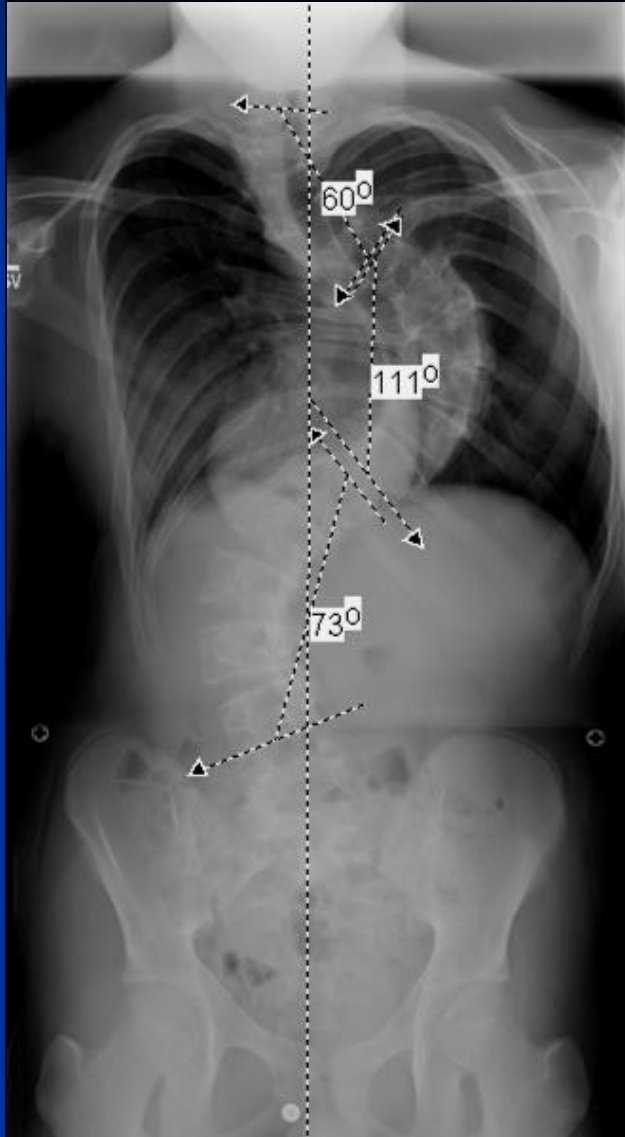
■ New materials



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
 - Erel, *Acta Orthop Scand* 2003
- New materials
- Leave it out

14 yo ♂ AIS



14 yo ♂ AIS



14 yo ♂ AIS



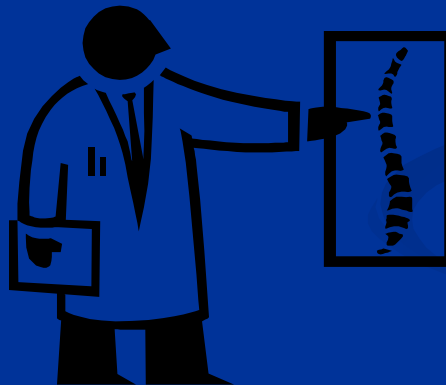
- Ant. Tscopic release
- Ponte osteotomies
- Rib head release

- 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



Nemours

Alfred I. duPont
Hospital for Children

Nemours
Children's Clinic