ARABSPINE COURSE DIPLOMA

Module 4

Course Highlight Day-1

Deformity

Normal Growth & Congenital
Idiopathic Scoliosis
Degenerative Scoliosis
Neuromuscular Scoliosis
Sagittal Deformities
Spinal Malformations

Complications

related to:

Anterior and Posterior Approach

Cervical Spine
Lumbar Spine
Thoracic Spine
Revision Procedures

NASSi ADVANCING GLOBAL SPINE CARE

ArabSpine

RCSI

Dubai, UAE

Dear Participant,

It is our great pleasure to welcome you all to the ArabSpine Course Diploma.

The course is being presented by renowned experts in the field of Spine Surgery. It is intended for Neurosurgeons, Orthopedists, Spine Specialists and Spine related physicians wishing to acquire advanced theoretical knowledge and improve their practical skills.

ArabSpine Course Diploma offers an up to date knowledge on diagnosis, treatment options of spine pathologies in addition to wide exposure to different surgical techniques practiced in the laboratory on fresh cadavers along with hands-on training on advanced technology such as spinal navigation with O-Arm Imaging.

After the completion of 4 modules each attendee will be well proficient in the evaluation, diagnosis and management of spinal disorders.

We are certain that you will acquire the best knowledge and training in the spinal treatment through the courses of ArabSpine Course Diploma.

Best wishes

Prof. Zoher Ghogawala
President
North American Spine Society

Prof. Richard Assaker
Chairman
ArabSpine Educational Committee

Prof. Ciaran Bolger
Head of Clinical Neuroscience
Royal College of Surgeons in Ireland (RCSI)

Prof. Abdul Karim Msaddi
Chairman
ArabSpine Course Diploma (ASCD)

INTRODUCTION

The ASCD strive to establish Arab Education high standards and position itself as a major driving force in Spine Education for the Arab region to act as a reference point and resource for spine specialists wishing to acquire up to date knowledge on the evaluation and hands-on training in spinal surgery.

The ArabSpine Course Diploma is already accredited by the North American Spine Society (NASS) and Royal College of Surgeons in Ireland (RCSI)

The ASCD will offer to the participants an opportunity to learn, interact, discuss with the experts and practice hands-on workshops.

We believe that the initiative will further strenghten the Spine Care in the whole Arab Region and Neighbouring Countries.

The diploma outlines includes:

ArabSpine Course Diploma	
MODULES	Surgical Training
Module No. 1 Basic Science & Degenerative Lumbar Spine	Hands-on Cadaveric Workshop
Module No. 2 Cervical Spine Degenerative / Spinal Navigation/ Intra-operative Monitoring - IOM	Hands-on Cadaveric Workshop
Module No. 3 Tomur / Trauma / Infection	Hands-on Cadaveric Workshop
Module No. 4 Deformity / Complications / Malformations	Hands-on Cadaveric Workshop

Target Participants

Neurosurgeons, Orthopedists & Spine Care Related Physicians.

Prof. Richard Assaker
Chairman of Educational Committee (ASCD)

CONTENTS

MODULE 4 - DAY 1

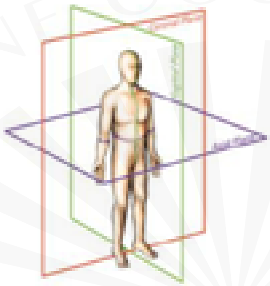
DEFORMITY PRINCIPLES

DEFORMITY SURGERY

Normal Spine Alignment and Spine Deformity

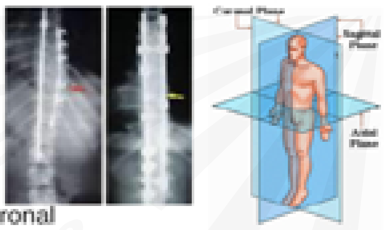
Normal Spine Alignment and Spinal Deformity

- Thorough understanding of normal spine alignment is crucial
- Goal of treatment
  - Normalize alignment
  - Reduce pain/restore function
- "Normal spine alignment" has wide range of variability
  - How much correction is sufficient?
- Multiplanar approach
- Three dimensional construct



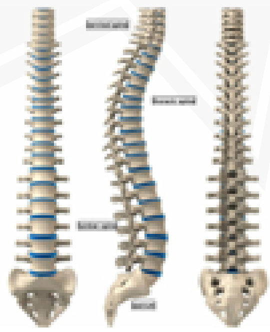
Normal Spine Alignment and Spinal Deformity

- Three planes to consider
  - Coronal
  - Sagittal
  - Axial
- Historical issue
  - Harrington address Coronal only



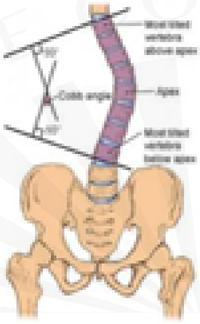
Normal Spine Alignment and Spinal Deformity - Coronal

- Coronal plane
  - Spine is typically straight
  - Standing anteroposterior radiograph:
    - Plumb line from tip of the dens (C2) should bisect each vertebral body below
    - From cervical spine to sacrum
  - Stable Zone
    - Plumb fall within SI joints



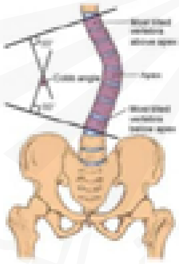
Normal Spine Alignment and Spinal Deformity - Coronal

- Curves in the coronal planes described by curve **convexity** (left vs right) **concavity** for measurement
- Cobb Angle
  - Invented in 1948
  - Most tilted vertebrae above and below
  - Lines parallel to endplate above and below
  - Angle between perpendiculars of these lines
- **Left thoraco-lumbar scoliosis T11-L3 of 20°**



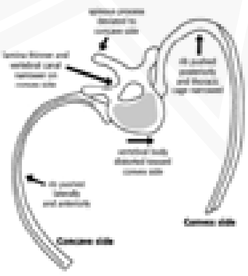
Normal Spine Alignment and Spinal Deformity - Coronal

- Cobb Angle
  - Scoliosis: >10 degrees in the coronal plane
  - Standard measurement error
    - 3-5 degrees within same observer
    - 5-7 degrees between two observers



Normal Spine Alignment and Spinal Deformity - Axial

- Axial plane
  - No rotation or translocation
  - Rotational deformities can and do occur with deformities in the coronal plane
  - High correlation of axial rotation with vertebral lateral deviation
  - Recognized as the "rib hump" in thoracic scoliosis

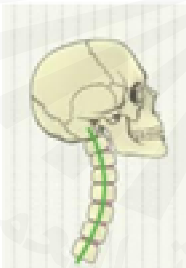


Normal Spine Alignment and Spinal Deformity - Sagittal

- Sagittal plane
  - "Normal" defined less easily
  - Significant variation
  - Typical "S-shape" curvature
  - Lordosis in the cephalad and caudal regions
  - Kyphosis in thoracic
- Toughest to correct "right"
  - How much "will do"

Normal Spine Alignment and Spinal Deformity - Sagittal

- Sagittal plane
  - Varying reports on normal values for acceptable kyphosis or lordosis
  - Cervical spine: 40 degrees +/- 9.7 degrees



Normal Spine Alignment and Spinal Deformity - Sagittal

- Sagittal plane
  - Normal thoracic kyphosis
  - Range of 20-50 degrees
  - Tends to increase with age
  - Apex between T6 and T8

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Normal Spine Alignment and Spinal Deformity - Sagittal

- Sagittal plane
  - Normal lumbar lordosis
  - Range from 30-80 degrees
  - Lordosis primarily occurs at L4-S1
    - 40% L5-S1
  - Wedging of intervertebral discs (80%)
  - Shape of vertebral bodies (20%)

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Normal Spine Alignment and Spinal Deformity - Sagittal

- Sagittal balance
  - C7 vertebral body usually in alignment with S1
    - Sagittal Vertical Axis(SVA)
  - Positive correlation between thoracic kyphosis and lumbar lordosis
  - Plumb line from center of C7 vertebral body lies within 2cm of sacral promontory
  - As individual ages, line can move forward
- Separate lecture on measurements

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Normal Spine Alignment and Spinal Deformity - Sagittal

- Sagittal balance
  - Most reliable predictor of clinical symptoms
  - Radiographic markers provide objective evaluation

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Normal Spine Alignment and Spinal Deformity - Sagittal

- Sagittal balance
  - Sagittal vertical axis (SVA)
  - Chin-Brow vertical angle
  - C7 plumb line
  - Kyphosis tilt angle
  - Pelvic incidence
  - Pelvic tilt
  - Sacral Slope
  - Spino-pelvic angle
- Separate lecture on measurement and radiologic findings
  - Top L4 horizontal to floor

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Normal Spine Alignment and Spinal Deformity

- Anatomical distinctions
  - Hyperlordosis – "swayback"
  - Kyphosis – typically greater than 50 degrees
  - Scoliosis – curve in coronal plane, usually C or S-shaped
- Clinical distinctions
  - Infantile
  - Juvenile
  - Adolescent
  - Adult

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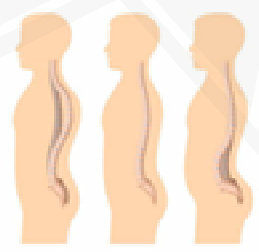
Normal Spine Alignment and Spinal Deformity

- Lordosis
  - Osteoporosis
  - Obesity
  - Kyphosis
  - Achondroplasia
  - Spondylolisthesis
- Kyphosis
  - Scheuermann's disease
  - Arthritis
  - Osteoporosis/fractures
  - Spinal Bifida
  - Postural Kyphosis
  - Congential



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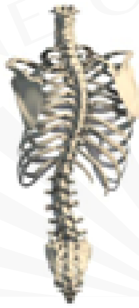
Normal Spine Alignment and Spinal Deformity

- Structural Scoliosis
  - Idiopathic
    - 80%
    - As name implies, unclear etiology
    - Age of onset divisions
  - Congenital
    - Abnormal formation during embryonic development
      - Most common presentation is **hemivertebra**
  - Acquired
    - Disease related – cerebral palsy, muscular dystrophy, Duchenne's muscular dystrophy



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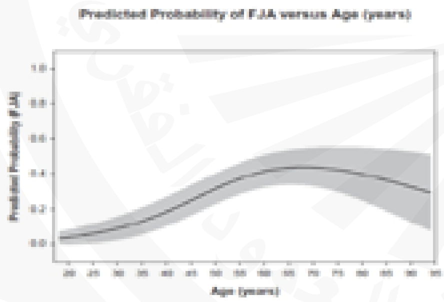

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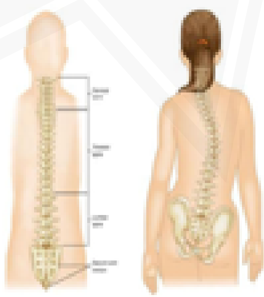
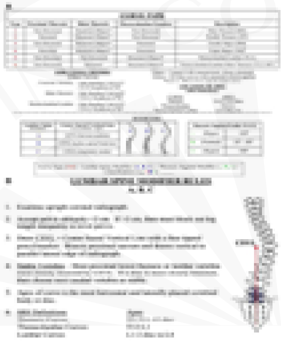
Normal Spine Alignment and Spinal Deformity

- **Adolescent Idiopathic Scoliosis**
  - 10-18 years
  - >10 degree cobb angle
  - Right thoracic curve most common
  - 10:1 female ratio for curves greater than 30 degrees
  - Unknown pathophysiology
  - Likely genetic component
  - Prevalence 1-2%
  - If Cobb angle <20 degrees, 10-20% will progress
  - >20° treatment options



Normal Spine Alignment and Spinal Deformity

- Adolescent Idiopathic Scoliosis
  - King-Moe Classification
    - 5 types
    - describing thoracic curve
  - Lenke Classification
    - Based on PA, Lateral, and Supine bending films
      - Identification of primary curve
      - Assign lumbar modifier
      - Assign sagittal modifier
  - Future lecture for details



Normal Spine Alignment and Spinal Deformity

- **Adult Spinal Deformity**
  - Mean age 60 years
  - 15% POPULATION @ 60 yr
  - Equal male/female distribution
  - Worldwide prevalence is not well established, estimated between 2.5—25%
  - PROGRESSION 1-6° A YEAR -AVG 3.5° /yr

Normal Spine Alignment and Spinal Deformity

- Adult Spinal Deformity
  - Asymmetric degeneration of discs and/or joints
    - Scoliosis – coronal plane
    - Kyphosis/lordosis – sagittal plane
  - Factors associated with ASD
    - osteoporosis
    - degenerative disc disease
    - instability
    - pre-existing scoliosis

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Normal Spine Alignment and Spinal Deformity

- Adult Spinal Deformity
  - Idiopathic (residual)
    - Follows classic curve patterns
    - Involves more vertebral segments
    - Primarily in thoracic spine
    - Larger curves
  - Degenerative (de novo)
    - Lack classic patterns
    - Fewer segments
    - More often in lumbar spine
    - Smaller magnitude
  - Additional lecture for detail

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Normal Spine Alignment and Spinal Deformity

Summary

- "Normal spine alignment" has wide range of variability
- Multiplanar approach
  - Three dimensional construct
- Fundamental goals of treatment for spinal deformity
  - Reduce or realign spinal curvature
  - Decrease cosmetic effect of curvature
  - Decrease pain and increase function
  - Maintain and protect organs

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Normal Spine Alignment and Spinal Deformity

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Normal Spine Alignment and Spinal Deformity

- Although methods for treatment of spinal deformities have changed, the fundamental goals remain the same
  - Reduce or realign spinal curvature
  - Decrease cosmetic effect of curvature
  - Decrease pain and increase function
  - Maintain and protect organs

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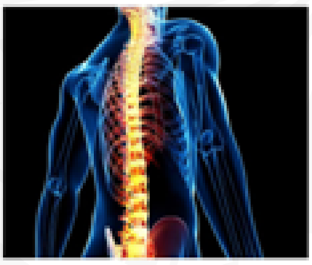
Normal Spine Alignment and Spinal Deformity

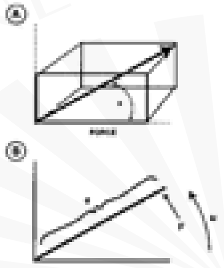
- Overall behavior of spine
  - Rigid pieces of bone
  - Semirigid discs and ligaments
  - Semifluid nucleus pulposis
  - Flexible rod



Biomechanics of the Deformed Spine

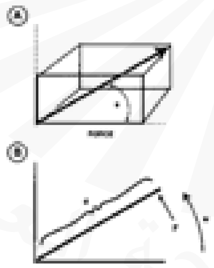
Biomechanics of the Deformed Spine

- Consider forces on the spine by evaluating component vectors
- Vector: force oriented in a fixed and defined direction in three dimensional space
- When a vector acts on a lever, creates a bending moment



Biomechanics of the Deformed Spine

- Bending moment
  - Torque applied by a circular force
  - Bending moment applied to a point causes rotation around an axis
  - Bending moment=Force on the lever x distance from the axis

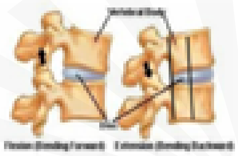


Biomechanics of the Deformed Spine

- Motion segment
  - Two adjacent vertebrae
  - Intervertebral disc
  - Zygapophsyseal joint
  - Allows for movement in
    - Flexion-extension
    - Lateral Flexion
    - Axial Rotation

Biomechanics of the Deformed Spine

- Motion segment
  - Anterior column
    - Anterior longitudinal ligament
    - Anterior 2/3 of vertebral body
  - Middle column
    - Posterior longitudinal ligament
    - Posterior 1/3 of vertebral body and annulus
  - Posterior column
    - Pedicles
    - Facets
    - Ligamentum flavum
    - Spinous process

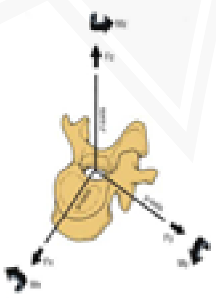


Biomechanics of the Deformed Spine

- Overall, movements of the spine are the sum total of small motions within each motion segment

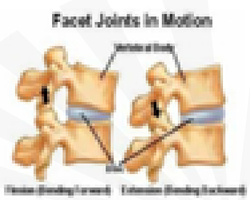
Biomechanics of the Deformed Spine

- Force vectors in three dimensional space
- Three axes of the spine: long axis, coronal axis, translational axis
- Two types of movements – rotation and translation
- Six fundamental segmental movements of the spine



Biomechanics of the Deformed Spine

- Rotational Deformation
  - Applies a bending moment on a spinal segment
  - Causes angular deformation
  - Can occur along one or both of the axially oriented axes (coronal or sagittal)
  - Deformities can occur at the level of the vertebral body, or the disc space

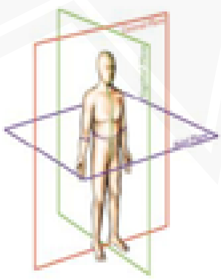


Biomechanics of the Deformed Spine

- Translational Deformation
  - Compression
    - Burst Fractures
  - Distraction
    - Uncommon (spinal traction, implant-induced)
  - Shearing
    - Fracture dislocation or spondylolisthesis

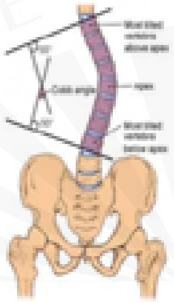
Biomechanics of the Deformed Spine

- Three main categories of spinal deformity
  - Sagittal
  - Coronal
  - Axial
- Coupling phenomenon
  - Deformity that occurs on one axis often produces another motion along or around another



Biomechanics of the Deformed Spine

- Coronal Plane
  - Cobb Angle
  - Measured from the rostral and caudal vertebrae with greatest curve
    - Some inter-rater variability
  - As Cobb angle increases
    - Increased moment arm applied
    - Greater bending moment



Sagittal Balance

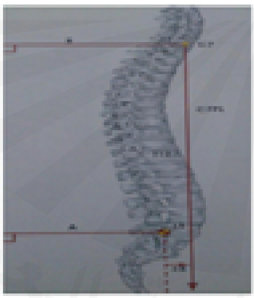
- Sagittal balance is the balance between the normal sagittal curves of the spine to center the head on the pelvis with the least energy expenditure.

- Sagittal vertical axis (plumb line):

-From center of C7 downwards.

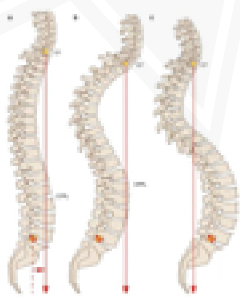
-Normally pass within 0.5 cm from the postero-superior aspect of S1.

-Offset >2.5-4 cm ant. Or post. is abnormal.



Biomechanics of the Deformed Spine

- Sagittal plane
  - Cervical lordosis
  - Thoracic kyphosis
  - Lumbar lordosis
- Positive Sagittal Balance
  - Flat-back syndrome
  - Kyphosis
  - Axis is anterior to the sacrum
- Negative Sagittal Balance
  - Lumbar hyperlordosis
  - Axis is posterior to the sacrum



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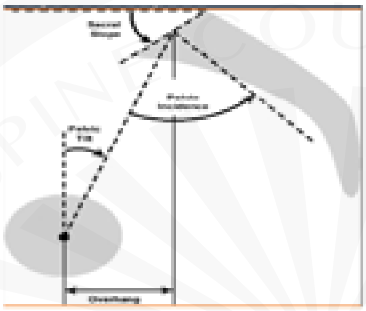
- On **whole spine** Xray (C7 – hip)
- **Sacropelvic parameters:**

- Pelvic incidence (PI): (50°-60°)
- Sacral slope (SS)
- Pelvic tilt angle (PT)

"PI = SS+PT"

" Lumbar lordosis is greatly related to PI"

LL= PI+ or – 9 degrees



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Sagittal imbalance cascade

Sagittal imbalance can be compensated by **pelvic retroversion** to maintain **erect posture**, resulting in a decreased sacral slope and increased pelvic tilt.

This will put the **femoral heads forward** and the **sacrum** and the **spine backwards**

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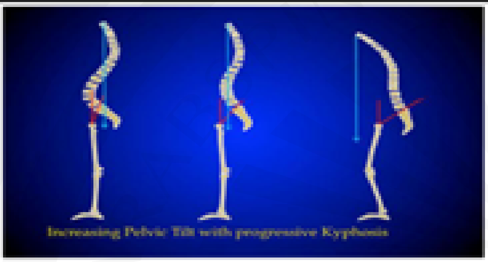
The consequence of backward rotation of the pelvis is **extension of the hips.**

The **extension reserve** will limit the amount of pelvic retroversion possible.

This change may result in **back muscle fatigue** and exhaustion, with back pain in standing posture.

When pelvis backward rotation overpasses, the only solution to stand with horizontal eyes axes is to **bend the knees** in order to keep the gravity line between the two feet. (J C Luec 2014)



- **Adjacent segment degeneration (ASD)** is often used to refer to the onset of degenerative changes in previously normal disc spaces adjacent to the fusion segment.
- This may become symptomatic in many cases and may need revision surgery.

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- The incidence of ASD increases with many factors, one of the most important is failure to restore the sagittal balance (lumbar lordosis).
- Radiological parameter that most highly correlates with pain and disability is the balance between pelvic incidence and lumbar lordosis.

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- Difference between pelvic incidence and lumbar lordosis is more than 15 dgrees ,there are 20 times higher risk for ASD. (M Senteller 2014)
- With simulated fusion at L4-5,sheer forces at L3-4 increases by 15% ,and by 23% with fusion at L4 S1.
  (at 30 degrees of flexion) (M Sentellar 2014)

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- Many factors predispose for ASD:
  Body mass index.
  Pre op. adjacent disc degeneration.
  Physically demanding occupation.

PI/ LL marked mismach is probably more important . (Jiqian Liang 2014)

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- **Penalties may occur in the form of:**

-Ruptured disc and neural deficit.

-Spondylo-retroliethesis.

-Rapid disc degeneration and Spinal canal stenosis.

-Compression fracture

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- The instantaneous axis of rotation normally passes through the anterior third of the lumbar disc spaces.
- The moment arm of the center of mass is balanced by the moment arm of the spinal muscles.
- With antepulsion, the moment arm of the center of mass increases and causes increased loading of the unfused motion segments.

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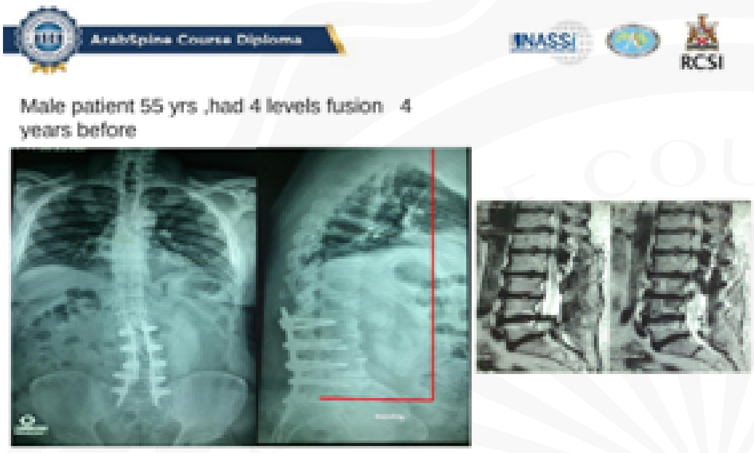
- Extensor muscle activity during attempts to maintain balance is a reason for disc degeneration as it increases the compressive loads of the discs (unfused levels).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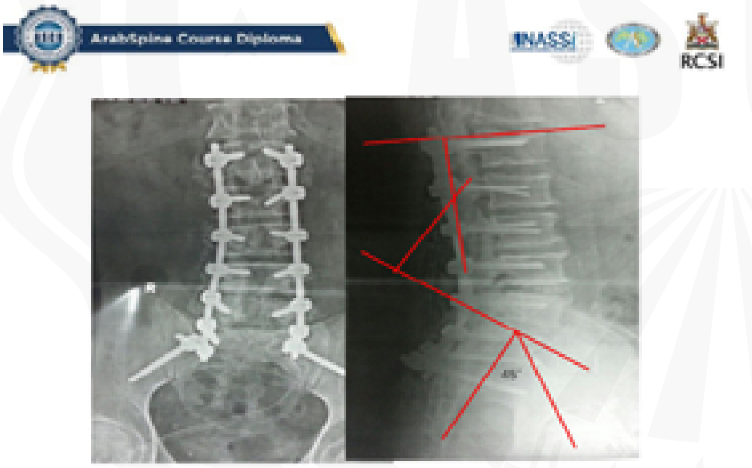
Male patient 55 yrs ,had 4 levels fusion 4 years before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Clinical Assessment and Imaging in Spine Deformity Patient

Classification

- Idiopathic
  - Infantile
    - Resolving
    - Progressive
  - Juvenile
    - (4ys to puberty)
  - Adolescent
    - (puberty onset to epiphyseal closure)
- Neuromuscular
  - Neuropathic
    - UMNL
      CP, Spinocerebellar degeneration, Syrinomyelia
    - LMNL
      Polio,SMA, Trauma
  - Myopathic
    - Arthrogryposis
    - Muscular Dystrophy

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AIS: Treatment Goals

- Curve correction *(Cosmetic correction)*
- Balance spine
- Minimal fusion levels

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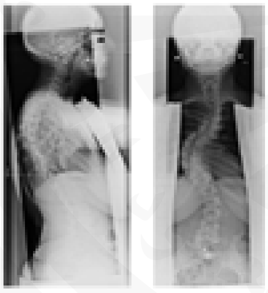
AIS

The Most Challenging Spinal Deformity

AIS

- Etiology
  - Familial ? Gene
  - Abnormal collagen content of the disc
  - Fibrilin fibres in the ligaments
  - Platelet calmodulin
  - ? Abnormal neuromuscular mechanism

The Case



Clinical Assessment

- Patient assessment
- Curve assessment
- Treatment strategy

General evaluation

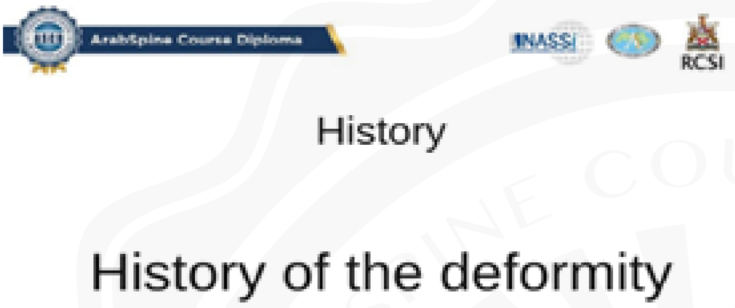
- History
  - Family history
  - Birth history & developmental milestones
  - Renal or Cardiac disorders (Congenital problems)
- History
  - Neurological symptom
  - Deformity history
  - Pain
  - Maturity (onset of menarche
  - Previous treatment history

History

Birth History

History

Developmental milestones
hospitalization, abnormal gait,learning difficulty,neurologic disorders, disorders in other organ systems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History
History of the deformity


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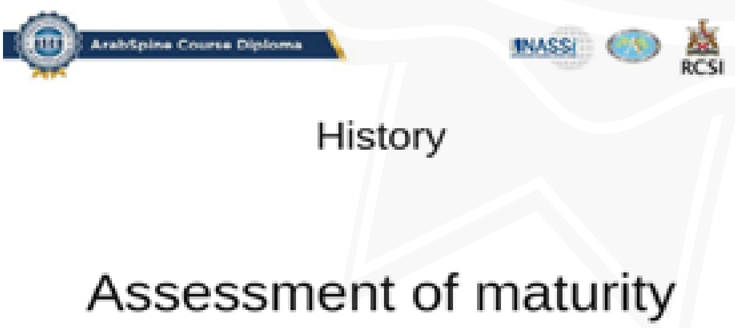
History
Pain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History
Assessment of maturity

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Examination

- Examin without clothing
- Observe the ability or inability of the child to interact during the examination

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Examination

- Explain (Consent)
- Expose (Respect)
- Evaluate (360)

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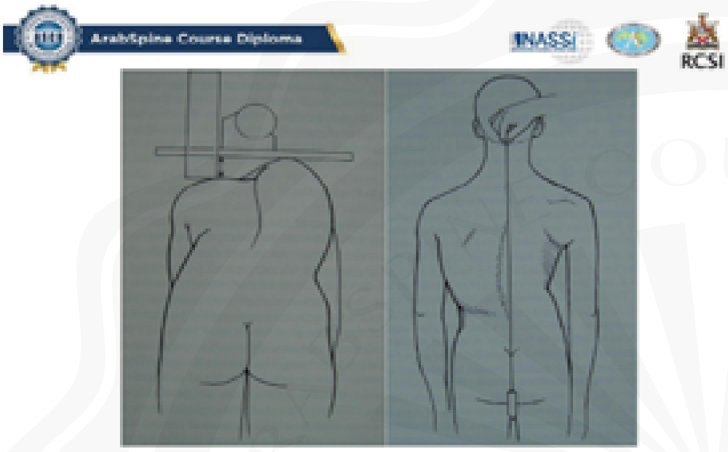
Examination

Inspection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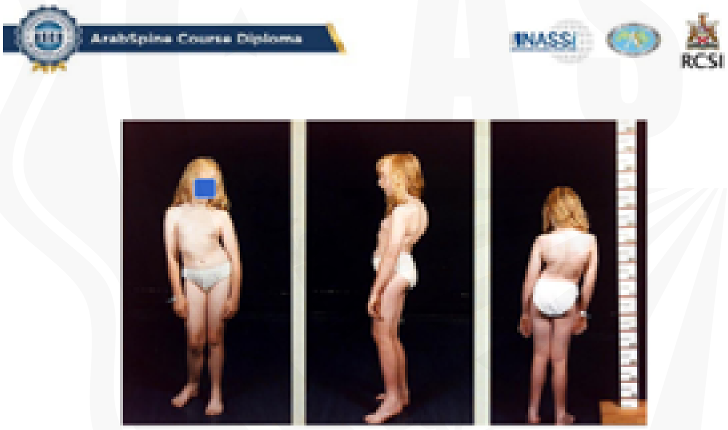
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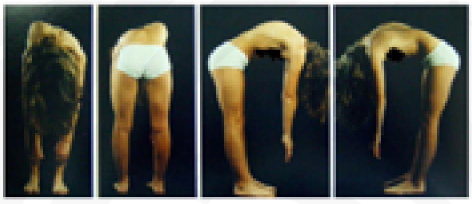
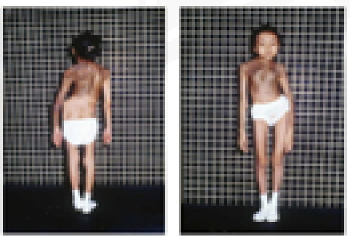
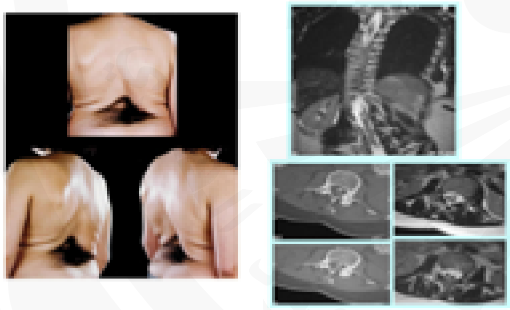
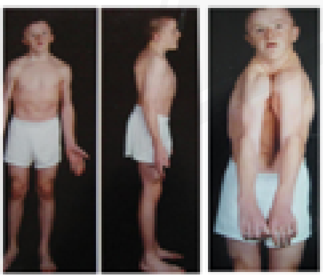
Adam's Test

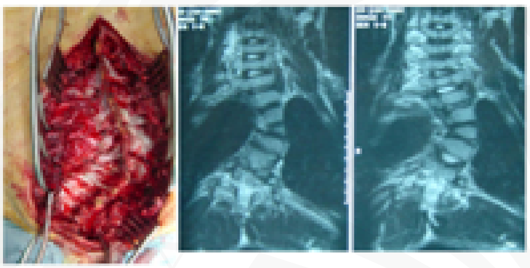


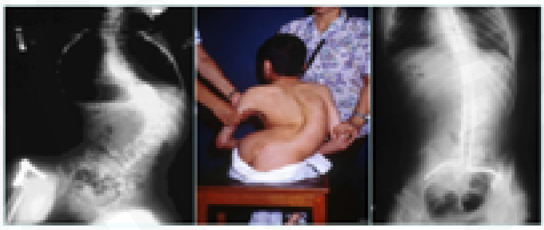
AIS:
Examination AIS



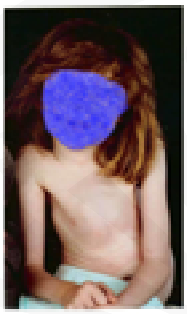


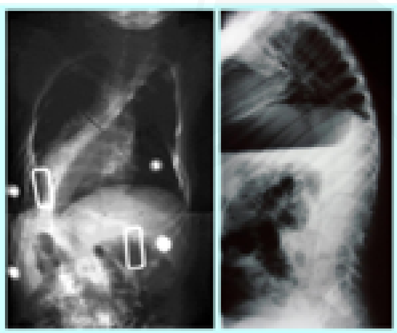






- SMA II
- Age 9
- 9 kgs
- Peg feeding



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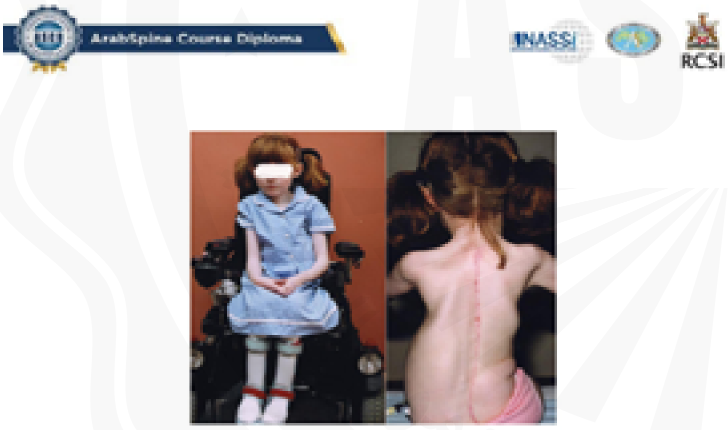
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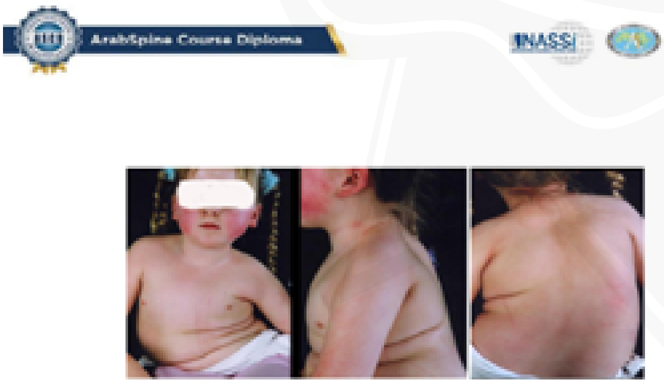
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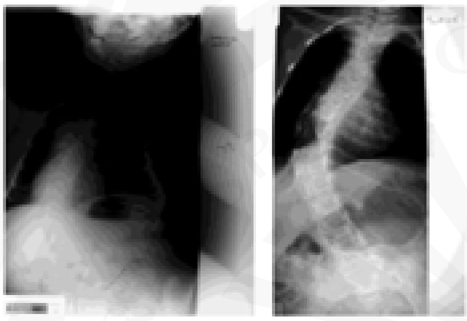
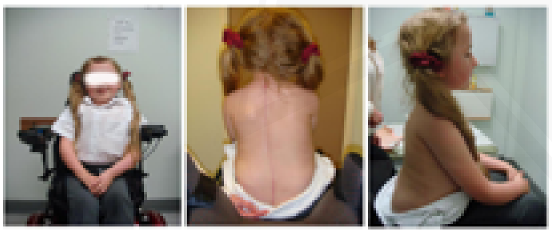
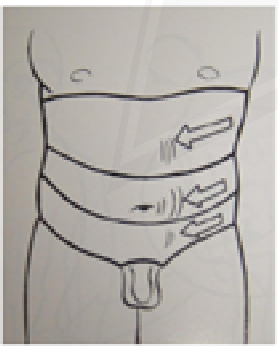
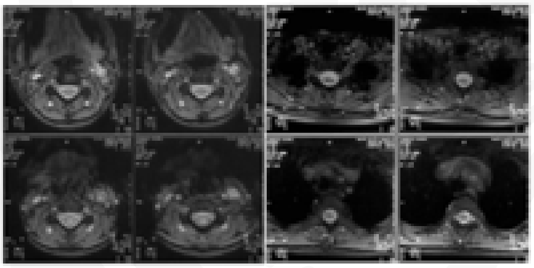




Neurological examination





Curve assessment - Clinical

- Side bending
- Suspension
- Traction

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Curve Assessment-Radiological

- Cob method
  - The angle between the top of the proximal vertebra that best delineates the curve and a line across the bottom of the distal vertebral body
  - Be consistent on subsequent measurments
- Vertebral rotation
  - Nash-Moe method
  - Perdriolle method

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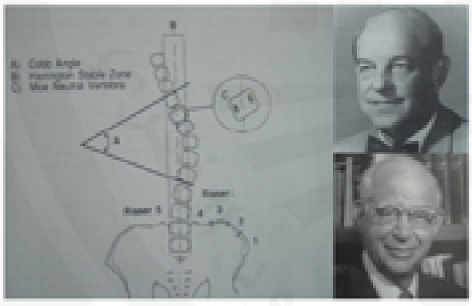

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AIS: X-ray evaluation

- Mandatory
  - Standing AP or PA
  - Standing lateral
  - Supine side bending
- Optional
  - Supine AP
  - Fulcrum bending
  - Traction AP
  - Push prone


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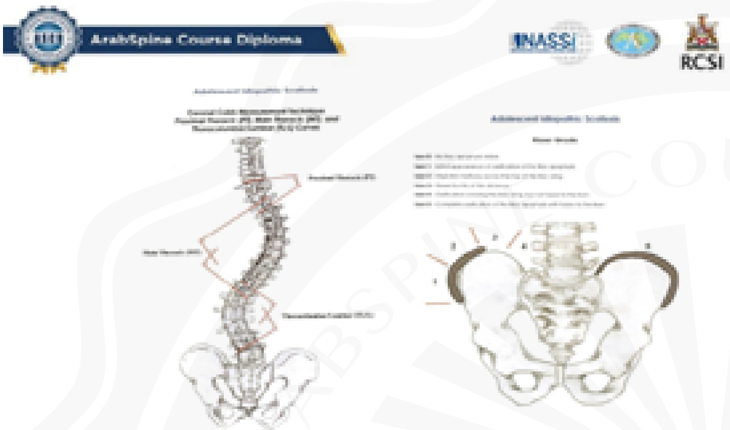
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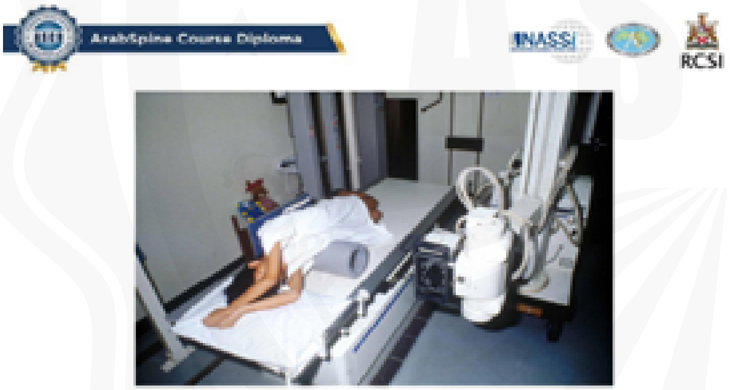
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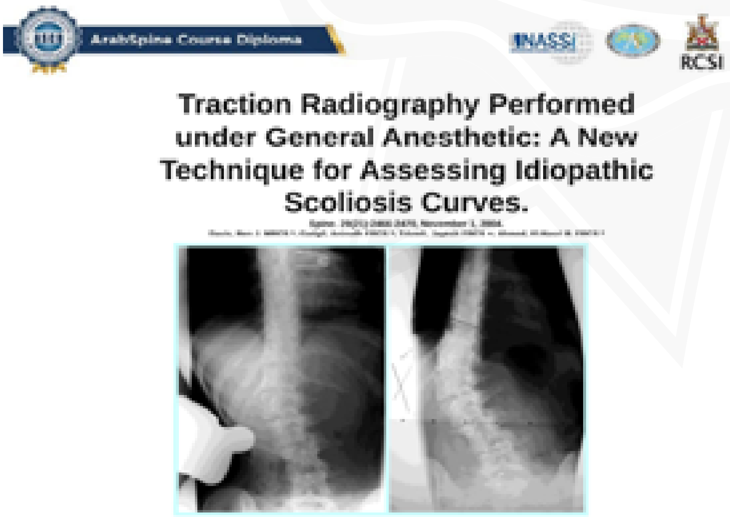
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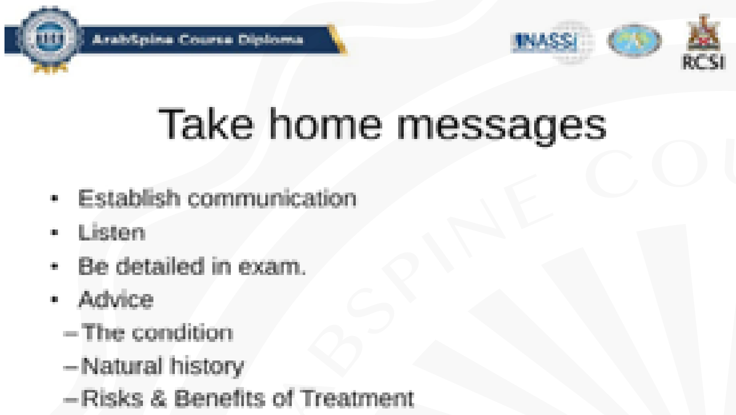
Traction Radiography Performed under General Anesthetic: A New Technique for Assessing Idiopathic Scoliosis Curves.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Take home messages
• Establish communication
• Listen
• Be detailed in exam.
• Advice
– The condition
– Natural history
– Risks & Benefits of Treatment

Adolescent Idiopathic Scoliosis: Natural History and Classification

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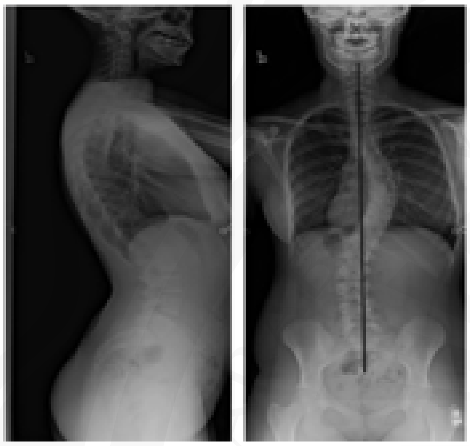

15 y.o. female
Otherwise healthy
Risser 4

MT 50° (right T6-11)

UT 26° (left T2-5)

TL 26° (left T12-L3)

End vertebrae T11 (?T12)

Neutral & stable vertebrae
T12 vs L1

Normal sagittal contour

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Disclosures

Please add your disclosures here. If you have nothing to disclose, please write "Nothing to Disclose".

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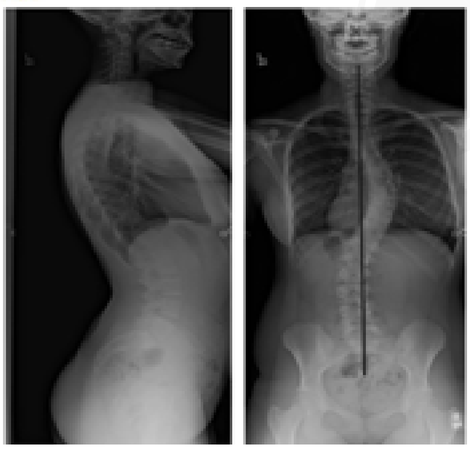

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TL 26° (left T12-L3)

End vertebrae T11 (?T12)

Neutral & stable vertebrae
T12 vs L1

Normal sagittal contour

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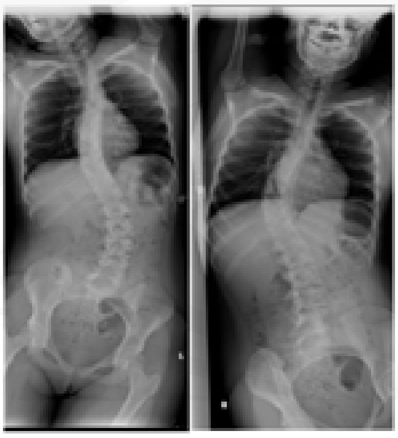
MT curve corrects to 26°

UT & TL curves correct to 12°



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How to Classify?

- Main curve or curves?
  - Right mid thoracic because it is the largest
- Which curves are structural?
  - Only the mid thoracic since the other 2 correct under 25 °
- Lumbar modifier?
  - B since center sacral line crosses apical lumbar vertebrae but not between pedicles

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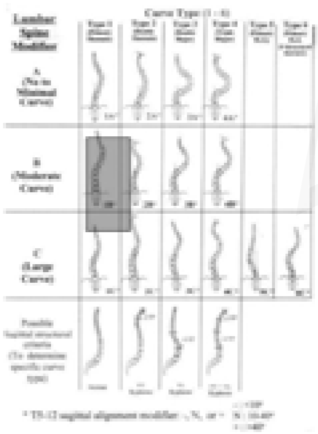
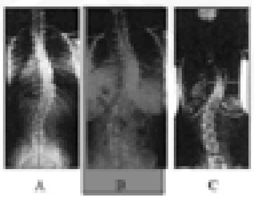


Curve Type	PT	MT	TL/L	Description
1	NS	S*	NS	Main Thoracic (MT)
2	S	S*	NS	Double Thoracic (DT)
3	NS	S*	S	Double Major (DM)
4	S	S*	S*	Triple Major (TM)
5	NS	NS	S*	Thoracolumbar/lumbar (TL/L)
6	NS	S	S*	Thoracolumbar/Lumbar-MT (TL/L - MT)



Major curve = largest curve
Structural curve = ≥25° on bender

Lenke et al, Spine 2003

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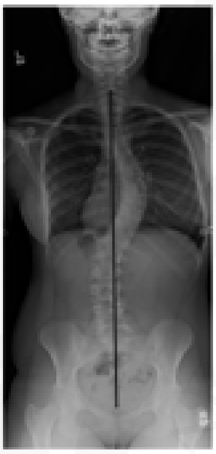
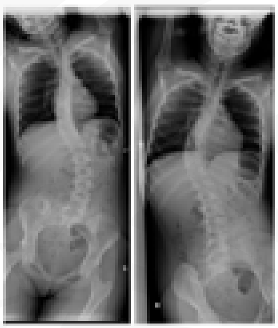
Criteria to Select Caudal Level





15 y.o. female
Otherwise healthy
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MT 50° (right T6-11)

UT 26° (left T2-5)

TL 26° (left T12-L3)

End vertebrae T11 (?T12)

Neutral & stable vertebrae T12 vs L1

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Criteria to Select Caudal Level

- Selective thoracic fusion or include lumbar curve
- Really a question for Lenke 1C curves
- Fusion of the main thoracic curve only is the norm in Lenke 1A or B curves
  - At the end vertebra or 1 below depend on central sacral line
- LIV comes to neutral on bendinding and disc below opens to either side

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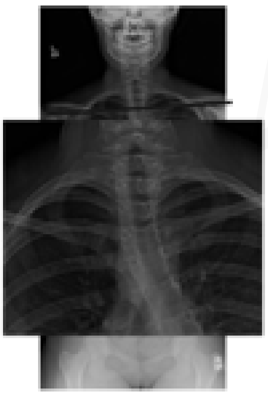
Criteria to Include Upper Thoracic Curve?



- Is it really a Lenke 2 (double thoracic)
- Is the left shoulder elevated? (clinically & radiographically)
- T1 tilt?
- Preoperative shoulder balance can predict postoperative imbalance

(Hong Eur Spine J. 2013)

How to treat our patient?

- Lenke 1B
- Caudal end easy to stop at 1 below end vertebrae (T12 or L1)
- Upper thoracic curve not structural & left shoulder lower than right
  - Don't need to include UT curve
- Anterior lost favor due to strength of posterior constructs
- Implants
  - Variety of options
  - Fixed screws
- Translation techniques used predominantly
  - Jury still out & evolving

Immed postop

3 months

1 year

2 year follow up

Doing well

Playing sports, softball

Nonoperative Management of Adolescent Idiopathic Scoliosis

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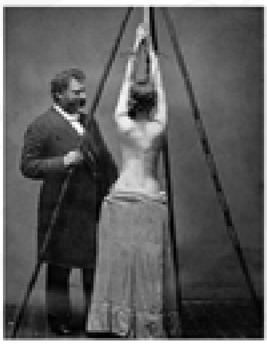
Role of Bracing, and Rehabilitation

- Bracing, and rehabilitative efforts depend largely on
  - Type/Degree of curvature
  - Skeletal maturity
- Early onset
  - Congenital
  - Infantile Idiopathic
- Juvenile Idiopathic Scoliosis
- Adolescent Idiopathic Scoliosis
- Scheurmann's Kyphosis
- Adult Spinal Deformity



Lewis Sayre, MD 1877

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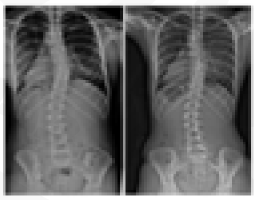
Goals of Conservative Treatments

- To stop curve progression at puberty (or possibly even reduce it)
- To prevent or treat respiratory dysfunction
- To prevent or treat spinal pain syndromes
- To improve aesthetics via postural correction



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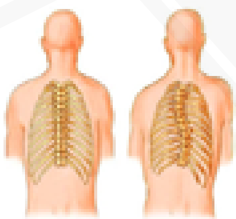
Role of Bracing, and Rehabilitation

- Adolescent Idiopathic Scoliosis
  - 10 years to skeletal maturity
  - Curve >10 degrees
  - Most common
  - High risk of progression



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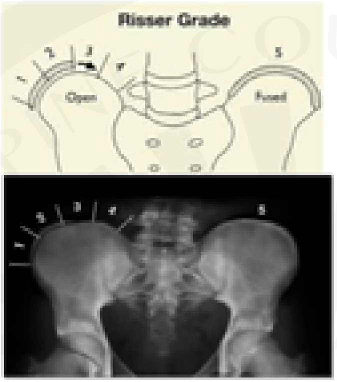
Role of Bracing and Rehabilitation

- Adolescent Idiopathic Scoliosis
- Bracing
  - Risser sign commonly used to establish level of bone maturity
  - Amount of calcification in the iliac apophysis
  - Measures ossification anterolaterally to posteromedially
  - Grade 1-5
  - More immature – higher probability of progression



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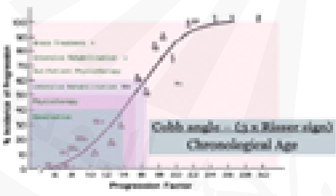
Role of Bracing and Rehabilitation

- Adolescent Idiopathic Scoliosis
- Risser 1: 25% iliac apophysis ossification
- Risser 2: 50% iliac apophysis ossification
- Risser 3: 75% iliac apophysis ossification
- Risser 4: 100% ossification, with no fusion to iliac crest
- Risser 5: Iliac apophysis fuses to iliac crest, cessation of growth

Table 2. Probabilities of Progression
Risser grade versus curve magnitude at detection

Risser Sign	Curve Magnitude	
Grade	5-19°	20-29°
0-1	22%	68%
2-4	1.6%	23%

(From Lonstein, J.E., and Carlson, J.M.: The Prediction of Curve Progression in Untreated Idiopathic Scoliosis During Growth. J. Bone and Jt. Surg.,66A:1061-1071,1984).



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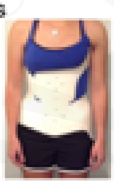
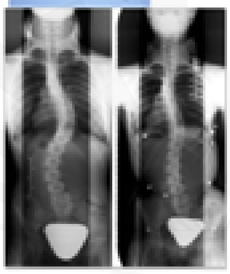
Adolescent Idiopathic Scoliosis

- Observation
  - Curve < 25 degrees and still growing
  - Curve < 50 degrees in skeletally mature patients
- Bracing
  - Curves between 25 – 40 degrees and not skeletally mature.
  - Goal: Slow down progression
  - Wear as close to 23 hours per day as possible
  - Wear until skeletal maturity

Boston Brace

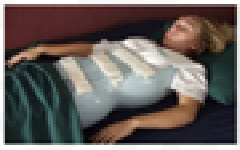
- Custom Molded Thoracolumbar pelvic orthosis
- High density polypropylene lined with polyethylene foam
- Pads are placed at the apex of the curves to provide pressure
- Areas of relief from pressure are positioned opposite the curves
- Full-time rigid brace

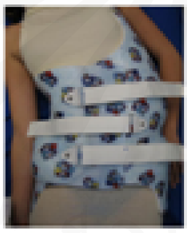




Nocturnal Orthosis

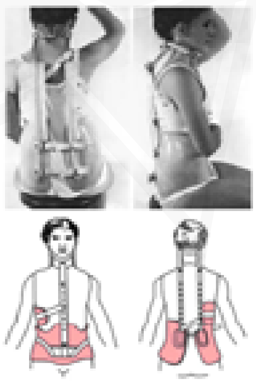
- Charleston brace
- Providence brace
- Molded TLSO that bends the patient to the opposite side (I.e. corrects the bend)





Milwaukee Brace

- CTLSO
  - Molded pelvic anchor
  - Metal uprights extending to an occipital support with cervical ring
  - Pads are added along the length of the uprights to direct a corrective force
- USE: Curves above T7



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Rehabilitation Programs

- SOSORT
  - Goals of rehabilitation program
    - 3-D autocorrection exercises
    - ADL training
    - Stabilization of the correct posture
    - Patient education
    - Multidisciplinary

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Physiotherapeutic Scoliosis Specific Exercises (PSSE)

- Multiple Schools/Methods
  - Schroth

The effect of Schroth exercises added to the standard of care on the quality of life and muscle endurance in adolescents with idiopathic scoliosis-an assessor and statistician blinded randomized controlled trial: "SOSORT 2015 Award Winner".

The efficacy of three-dimensional Schroth exercises in adolescent idiopathic scoliosis: a randomised controlled clinical trial

Tuğba Kuru, İpek Yeldan, E Elçin Dereli, Arzu R Özdinçler, Fatih Dikici, İlker Çolak

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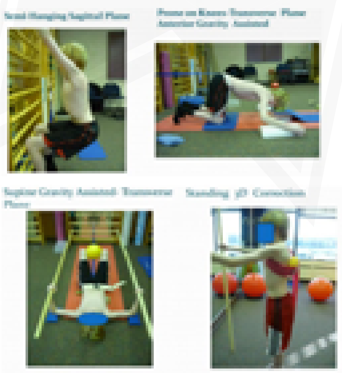
Schroth Method Physical Therapy

- 1921- Germany
  - Katharine Schroth
- USA- 2005 certified therapists.
- Principals
  - Muscular Symmetry
  - Rotational Angular Breathing
  - Postural Awareness.



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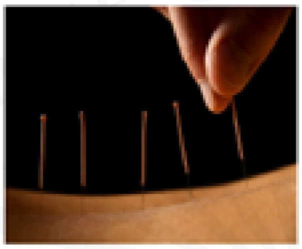
Role of Bracing and Rehabilitation

- Adolescent Idiopathic Scoliosis
- Alternative Treatments
  - Chiropractic medicine, physical therapy, yoga, etc. have little evidence to support use
  - Can be utilized for core strengthening, symptom relief
  - Not for treatment of curvature



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Role of Bracing, and Rehabilitation

- Scheuermann's Kyphosis
  - Asymmetrical growth of vertebrae
  - Angular and rigid kyphosis
  - Back pain primary symptoms in teens, can improve into adulthood

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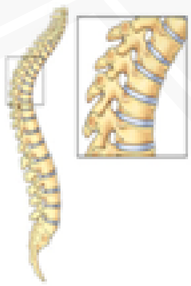
Role of Bracing and Rehabilitation

- Scheuermann's Kyphosis
  - 55-80 degrees and skeletally immature
    - brace with exercise program
    - Bracing full time (at least 20 hours/day)
    - Consider part time in last year of immaturity
    - Continue for 18 months post maturity
  - >80 degrees: Consider surgical intervention



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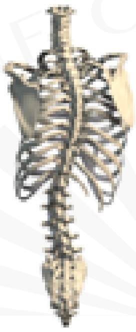
Role of Bracing and Rehabilitation

- Summary
- Goal is to prevent or decrease progression
- Bracing is effective in moderate scoliosis if compliant
- PSSE should be incorporated especially mild-moderate AIS
- Other rehabilitation methods can be considered for strengthening and pain control, however not for treatment of deformity



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Role of Bracing and Rehabilitation

- References

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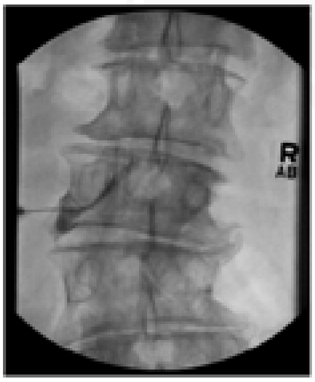
Interventional Pain Procedures in the Scoliotic Patient

Scoliosis Pain

- Mechanical
  - Coronal Balance
  - Sagittal Balance
  - Iliocostal
  - Muscular
    - Flat back
    - Side to side asymmetry
- Interventional Treatment Options:
  - NOTHING

- Anatomic
  - Intervertebral Disc
  - Facet Joint
  - SI Joint
  - Stenosis
- Treatment options:
  - Radiofrequency Ablation
  - SIJ injection
  - Epidural Steroid Injection

Epidural Steroid Injection



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Why

- Steroids:
  - inhibit phospholipase 2
  - inhibit leukocyte aggregation
  - prevent degranulation of granulocytes, mast cells, and macrophages
  - prevent transmission of nociceptive C-fibers
  - stabilize ectopic discharge of neuronal membranes

Cohen SP, BogdukN, Dragovich A, Buckenmaier CC 3rd, Griffith S, Kurihara C, et al. Randomized, double-blind, placebo-controlled, dose-response, and preclinical safety study of transforaminal epidural etanercept for the treatment of sciatica. Anesthesiology. 2009 May;110(5):1116–26.

Johansson A, Hao J, Sjölund B. Local corticosteroid application blocks transmission in normal nociceptive C-fibres. Acta Anaesthesiol Scand. 1990 Jul;34(5):335–8.

Takahashi H, Suguro T, Okazima Y, Motegi M, Okada Y, Kakiuchi T. Inflammatory cytokines in the herniated disc of the lumbar spine. Spine. 1996 Jan 15;21(2):218–24.

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Why - isn't it a "pinched nerve"?

- Radicular pain/radiculitis IS inflammatory (vs. neurogenic claudication)
  - Phospholipase A1
  - Prostaglandin E2
  - Leukotrienes
  - Cytokines
  - Nitric Oxide
  - Interleukin 6
  - Tumor Necrosis Factor alpha

Svennerholm L, Boström K, Fredman P, Månsson JE, Rosengren B, Rynmark BM. Human brain gangliosides: developmental changes from early fetal stage to advanced age. Biochim Biophys Acta. 1989 Sep 25;1005(2):109–17.

Takahashi H, Suguro T, Okazima Y, Motegi M, Okada Y, Kakiuchi T. Inflammatory cytokines in the herniated disc of the lumbar spine. Spine. 1996 Jan 15;21(2):218–24.

Goupille P, Jayson MI, Valat JP, Freemont AJ. The role of inflammation in disk herniation-associated radiculopathy. Semin Arthritis Rheum. 1998 Aug;28(1):60–71.

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Why

- Pure mechanical compression of spinal nerves does not necessarily produce pain
- The degree of nerve root compression does not correlate to pain severity
- Various inflammatory markers or cells are required for the dorsal root ganglion to generate the painful discharges in radiculitis

MacNab I. The mechanism of spondylogenic pain. In: Cervical pain. Oxford: Pergamon, 1972: 89-95.

Halperin N, Agasi M, Hendel D. Painless root compression following disc extrusion. A report of three cases. Arch Orthop Trauma Surg Arch Für Orthop Unf-Chir. 1982;101(1):63–6.

Wiesel SW, Tsourmas N, Feffer HL, Citrin CM, Patronas N. A study of computer-assisted tomography. I. The incidence of positive CAT scans in an asymptomatic group of patients. Spine. 1984 Sep;9(6):549–51.

Boden SD, Davis DO, Dina TS, Patronas NJ, Wiesel SW. Abnormal magnetic-resonance scans of the lumbar spine in asymptomatic subjects. A prospective investigation. J Bone Joint Surg Am. 1990 Mar;72(3):403–8.

Murphy RW. Nerve roots and spinal nerves in degenerative disk disease. Clin Orthop. 1977 Dec;(129):46–60.

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Transforaminal ESI

- 64% complete or somewhat better
  - 75% with average reduction of pain of 50% (Botwin)
- At 6 months 54% of patients had at least 50% improvement in radicular pain (Jeong)
- At 6 months 60% reported 60% improvement in pain (Narozny)
- 54% with at least 50% improvement in pain at 2 weeks
  - 88% of these persisted to 12 months (Cyteval)

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Fluoroscopically guided ILESI

- Observational studies
- Cosgrove found improvements in 6 minute walk and swiss spinal stenosis questionnaire
- Smith found mean improvment in pain score from 7.57/10 to 4.57/10 at 4-6 weeks
- Koc found mean improvement in VAS from 56/100 to 7/100 at 2 weeks and 23/100 at 6 months
  - Similar to PT/control arm
- Additional study found no improvement (Brown)

- ILESI of corticosteroid vs anesthetic (Manchikanti)
  - Decrease in ODI or VAS by >50%
  - 72% success in both groups up to 24 months

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ACRM

Archives of Physical Medicine and Rehabilitation

ORIGINAL RESEARCH

Long-Term Effects of Repeated Injections of Local Anesthetic With or Without Corticosteroid for Lumbar Spinal Stenosis: A Randomized Trial

Janna L. Friedly, MD, Bryan A. Comstock, MS, Judith A. Turner, PhD, Patrick J. Heagerty, PhD, Richard A. Deyo, MD, MPH, Zoya Bauer, MD, PhD, Andrew L. Avins, MD, MPH, Srdjan S. Nedeljkovic, MD, David R. Nerenz, PhD, Xu (Rita) Shi, PhD, Thiru Annaswamy, MD, Christopher J. Standaert, MD, Matthew Smuck, MD, David J. Kennedy, MD, Venu Akuthota, MD, David Sibell, MD, Ajay D. Wasan, MD, Felix Diehn, MD, Pradeep Suri, MD, MPH, Sean D. Rundell, PT, PhD, Larry Kessler, ScD, Allen S. Chen, MD, MPH, Jeffrey G. Jarvik, MD, MPH

ORIGINAL ARTICLE

A Randomized Trial of Epidural Glucocorticoid Injections for Spinal Stenosis

Janna L. Friedly, M.D., Bryan A. Comstock, M.S., Judith A. Turner, Ph.D., Patrick J. Heagerty, Ph.D., Richard A. Deyo, M.D., M.P.H., Sean D. Sullivan, Ph.D., Zoya Bauer, M.D., Ph.D., Brian W. Bresnahan, Ph.D., Andrew L. Avins, M.D., M.P.H., Srdjan S. Nedeljkovic, M.D., David R. Nerenz, Ph.D., Christopher Standaert, M.D. et al.

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Design

- Multicenter
- Double-blind
- Randomized controlled trial comparing epidural injections of corticosteroid plus lidocaine versus lidocaine alone
- cross-sectional imaging consistent with **central** lumbar spinal stenosis
- Symptoms consistent with:
  - neurogenic claudication AND
  - leg pain >4/10 on a 0 (no pain) AND
  - roland-Morris Disability Questionnaire (RDQ) score 7/24

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Table 1 RDQ score and leg pain intensity and change from baseline at each study time point by randomized treatment group

	Lidocaine Alone			Corticosteroid + Lidocaine			Treatment Comparison*	
Outcome	n	Crude Mean ± SD	Mean Change From Baseline ± SD	n	Crude Mean ± SD	Mean Change From Baseline ± SD	Adjusted Mean Difference (95% CI)	P
RDQ score								
Baseline[†]	200	15.8±4.3	-	200	16.0±4.5	-	0.4 (−0.4 to 1.3)	.32
3wk[†]	189	13.1±5.7	−2.6±4.4	191	11.7±6.1	−4.4±5.7	−1.9 (−2.9 to −0.9)	<.001
6wk[†]	193	12.5±6.4	−3.1±5.3	191	11.8±6.3	−4.2±5.8	−1.2 (−2.3 to −0.1)	.03
12wk	188	11.2±6.5	−4.3±6.0	188	12.0±6.0	−4.0±5.6	0.1 (−1.0 to 1.3)	.84
6mo	177	11.4±6.5	−3.9±5.5	182	12.2±5.9	−3.7±5.2	−0.0 (−1.1 to 1.1)	.99
12mo	174	11.5±7.1	−3.9±6.5	180	12.0±6.5	−4.0±6.0	−0.4 (−1.6 to 0.9)	.55
Leg pain intensity								
Baseline[†]	200	7.2±1.8	-	200	7.2±1.8	-	−0.0 (−0.4 to 0.3)	.86
3wk[†]	188	5.0±2.8	−2.2±2.9	191	4.4±2.7	−2.9±2.8	−0.7 (−1.2 to −0.2)	.01
6wk[†]	191	4.8±2.9	−2.4±3.0	191	4.4±2.9	−2.8±3.1	−0.3 (−0.9 to 0.3)	.32
12wk	188	4.3±3.0	−2.9±3.1	187	4.8±2.7	−2.7±3.0	0.1 (−0.5 to 0.7)	.70
6mo	177	4.5±2.9	−2.6±3.0	182	4.5±2.8	−2.7±2.9	−0.2 (−0.8 to 0.4)	.47
12mo	174	4.3±3.1	−2.8±3.4	180	4.7±3.1	−2.6±2.9	0.1 (−0.5 to 0.7)	.75

* Adjusted mean differences and P values were calculated using separate analysis of covariance models for the outcomes at each study time point and adjusted for the outcome measured at baseline, study recruitment site, and duration of pain as fixed effects.

† Previously reported by Friedly et al.

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Cross Over

	STEROID	LIDOCAINE
Repeat Injection	88/193 (44%)	111/193 (56%)*
Crossed Over	60/193 (30%)	90/193 (45%)**

- * X^2 $p < 0.03$
- **X^2 $p<0.02$
- The decision to cross over was reported as inadequate pain relief in 87% of patients.

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Authors Conclusions:

- "For lumbar spinal stenosis symptoms, epidural injections of corticosteroid plus lidocaine offered no benefits from 6 weeks to 12 months beyond that of injections of lidocaine alone in terms of self-reported pain and function"
- "In patients with improved pain and function 6 weeks after initial injection, these outcomes were maintained at 12 months"

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My Conclusions

- 3 weeks:
  - PAIN: Steroid group statistically favored
  - FUNCTION: Steroid group statistically favored
- 6 weeks:
  - PAIN: While pain scores showed no difference between groups at 6 weeks, patient behaviors was statistically different between groups favoring the steroid group
  - FUNCTION: Steroid group statistically favored
- 12 months:
  - PAIN: No difference in VAS reported pain scores
  - FUNCTION: No difference between groups

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Sacro-Iliac Joint Pain

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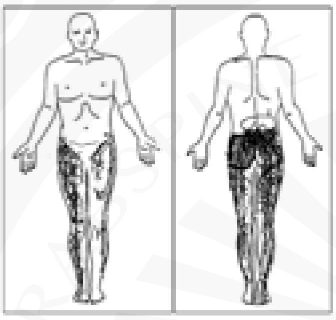
SIJ



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Steroid Injections

- Three studies have selected patients with SIJ mediated pain using dual blocks with anesthetic and corticosteroid with a threshold of at least 70% pain relief.
  - Retrospective studies
    - 42 subjects with positive diagnostic response (out of 194 injections) (Chou et al)
    - Irwin et al 91/158 met diagnostic criteria
  - Prospective
    - 16/48 met inclusion (Laslett et al)
- Kennedy combined the results from the three studies and showed that 43-67% of subjects had at least 50% pain relief for 4-6 weeks with 28% reporting 80% pain relief for 2 weeks

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Sacral Lateral Branch Radiofrequency

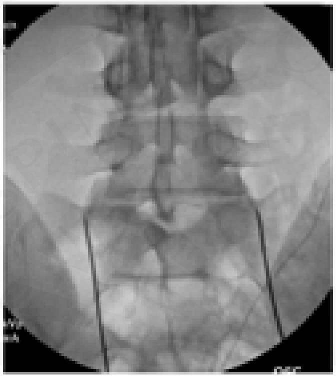
Success Rates for Explanatory Study by Cohen et al.[14] >50% relief of index pain at 6 months

Group	Treatment	Follow up	Pain	Relieved >50%
Active $N = 14$	Cooled RFA	6 months	8/14	57% (CI95 31-83)
Control $N = 14$	Sham	6 months	0/14	0%
Cross over $N = 11$	Monopolar RFA	6 months	4/11	36% (CI95 8-64)

Cohen SP, Hurley RW, Buckenmaier CC, 3rd, Kurihara C, Morlando B, Dragovich A. Randomized placebo-controlled study evaluating lateral branch radiofrequency denervation for sacroiliac joint pain. Anesthesiology. 2008;109(2):279-288.

Facet Joint

- Radiofrequency Ablation
- Medial branch blocks are vital for diagnosis but NOT therapeutic
- Best available evidence suggest intra-articular facet steroid injections are NOT therapeutic



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Degenerative Cascade

- Tripod – Three joint complex
  - Obliquity of lower facets (L4-5) predisposes to rotational strain
  - Disc orientation (and morphology) predisposes lower segments (L4-5) to compressive injury
  - Lesions affect each other and vice versa

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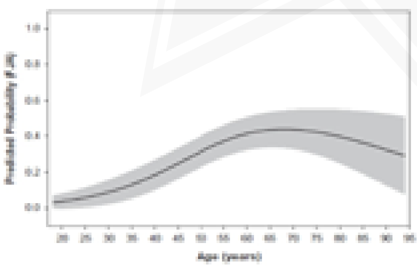
Facet

Predicted Probability of FJA versus Age (years)



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Injections as a Diagnostic Test

- History and Exam - no single feature (or combination) proven to be valid and reliable
- Leaves MBB as the gold standard
  - Due to relatively high false positive and low prevalence the test must be repeated
    - Dual controlled medial branch blocks

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Dual Blocks

- Non-Concordant dual positive blocks (reproducible relief regardless of the duration) the sensitivity is 100% but at the sacrifice of specificity (65%) as judged against placebo
- Concordant response 54% sensitive and 88% specific

(Lord et al. Clin J Pain. 1995 Sep;11:208-13)

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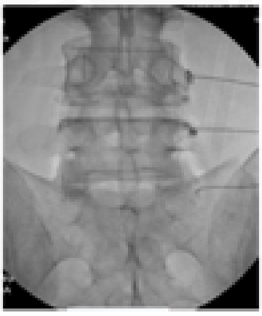
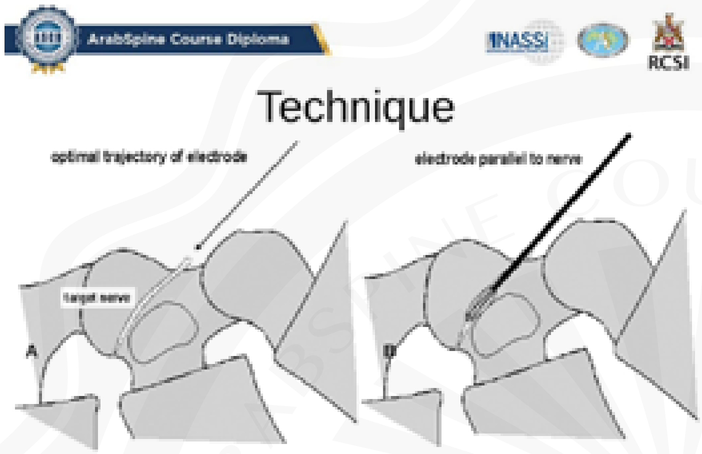
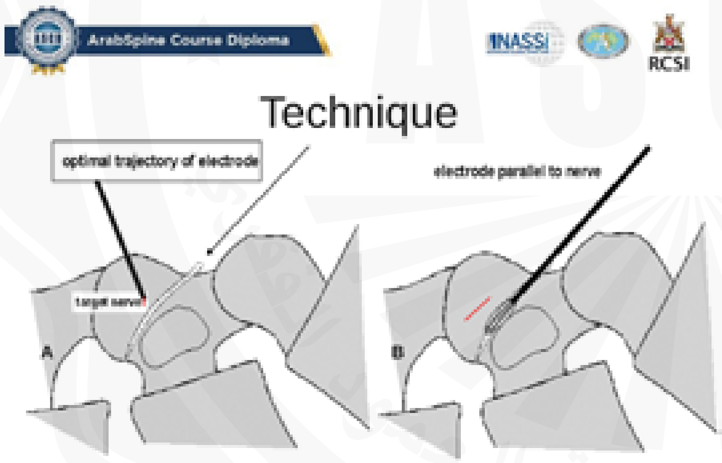
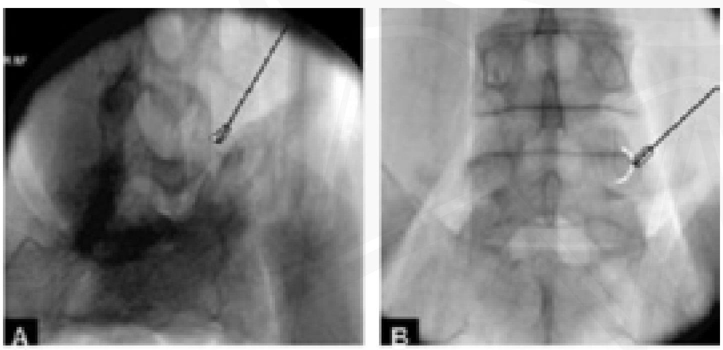
Radiofrequency Neurotomy

- Thermal Energy to ablate the medial branch of the dorsal ramus
- Precise procedure
  - Outcomes dependent on:
    - Patient selection
    - Technique









With a perpendicular approach the target nerve may not even be coagulated

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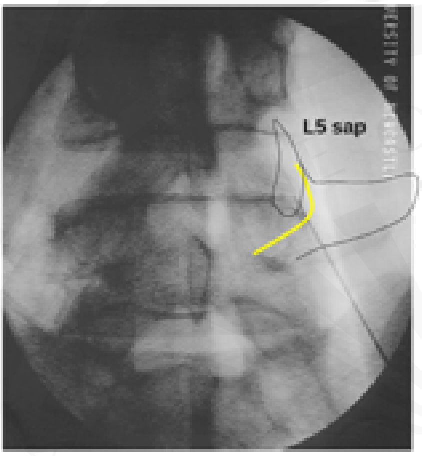

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Pain Med. 2013 May;14(5):639-45. doi: 10.1111/pme.12000. Epub 2012 Dec 28.

Lumbar medial branch radiofrequency neurotomy in New Zealand.

MacVicar J[1], Borowczyk JM, MacVicar AM, Loughnan BM, Bogduk N.

- Approximately 575 patients screened
- Enrollment based on comparative diagnostic blocks of lignocaine and bupivacaine
  - Patient AND physician AND assessor of response blinded
  - COMPLETE relief of pain AND perform typically aggravating activities without restriction
  - 106 proceeded to ablation

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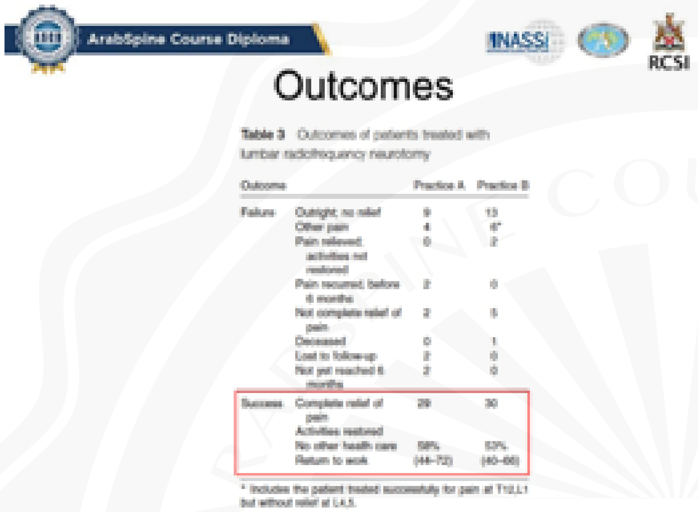
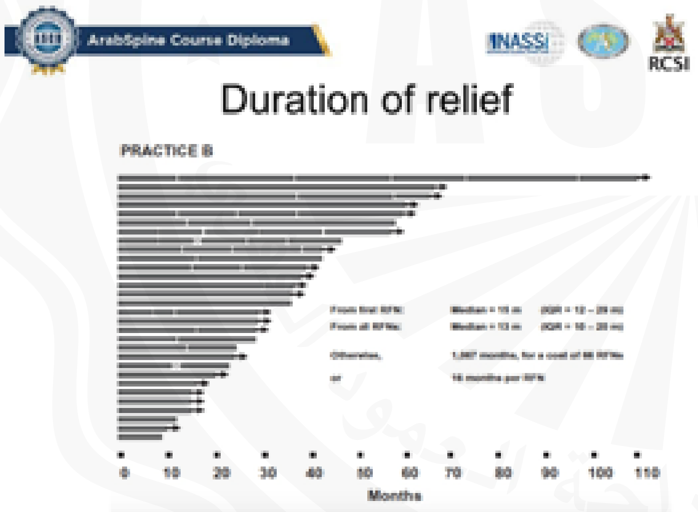
Design

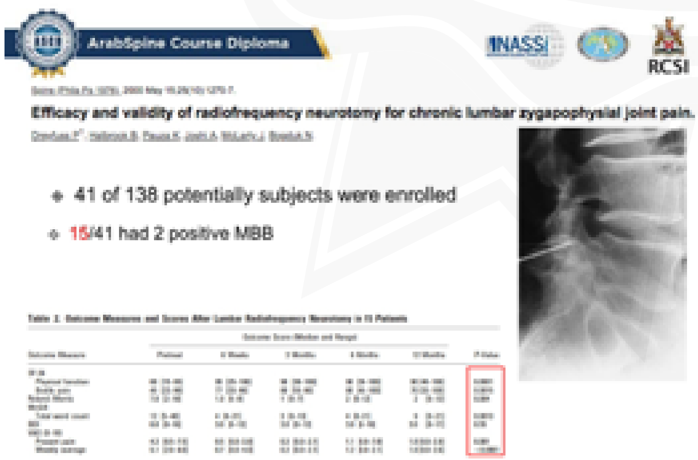
- RFN done with multiple parallel lesions with16 gauge needle
- Followed by primary care not involved in procedure
- Data analyzed by independent physician
- Success at 6 months defined as all 4 of:
  - 80% or more pain relief
  - Restoration of all desired ADLs
  - No other health care for LBP
  - Return to work



Outcome		Practice A	Practice B
Failure	Outright, no relief	9	13
	Other pain	4	6*
	Pain relieved, activities not restored	0	2
	Pain recurred, before 6 months	2	0
	Not complete relief of pain	2	5
	Deceased	0	1
	Lost to follow-up	2	0
	Not yet reached 6 months	2	0
Success	Complete relief of pain	29	30
	Activities restored		
	No other health care	58%	53%
	Return to work	(44–72)	(40–66)

* Includes the patient treated successfully for pain at T12,L1 but without relief at L4,5.





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12 months results

- 12/15 with at least 60% improvement
- 9/15 with at least 80% improvement

% Improvement	N	ΣN
100	5	5
90–100	2	7
80–90	2	9
70–80	2	11
60–70	1	12
50–60	1	13
40–50	0	13
30–40	0	13
20–30	1	14
10–20	0	15
0–10	1	15
0	0	15

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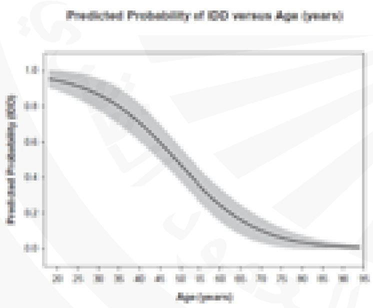
Intervertebral Disc



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Discogenic Procedures

- Intradiscal Steroid
- Intradiscal PRP
- Intradiscal Stem Cell
- Biacuplasty Radiofrequency ablation
- Intraosseous basivertebral nerve radiofrequency ablation

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Scoliosis Challenges

- Prevalence Changes
  - Facet vs Disc vs SIJ
  - Segmental differences
    - L4-5 and L5-S1 not necessarily most common
      - Palpation under fluoroscopy
- Technical challenges
  - Osteoporotic patients
  - "True AP"
  - "True Lateral"
  - Needle placement

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Helpful Considerations

- Palpation under fluoroscopy
- Proximal Radicular Pain
- Multiple Pain Generators
  - Manage Patient Expectations

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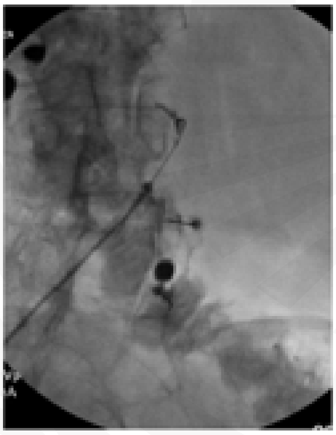
Case example

- 78 yo F
- Idiopathic Adolescent Scoliosis treated with bracing
- Avid walker
- Relatively pain free during adult life

Case- Continued

- Predominant complaint is right sided mid to low lumbar pain
- Almost exclusively present with walking
  - Underwent MBB after palpation under fluoroscopy



Case example

- Direct examination after MBB in clinic
  - No improvement in walking tolerance
- Noted to also have severe foraminal stenosis on right at L2-3 and canal stenosis at L1-2
- Proceed with right L2-3 TFESI

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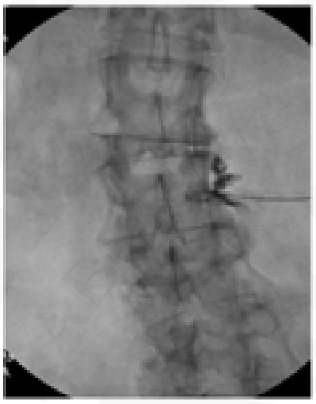

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Conclusions

- There are structural/biomechanical issues in scoliosis patients
  - Asymptomatic
  - Surgical
  - Minimal interventional options
- Susceptible otherwise to same causes of low back pain
  - Differing and poorly described prevalence
  - Facet RFN, SIJ procedures, ESI
    - Technical challenges

Adult Spine Deformity: Natural History and Classification

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Adult Scoliosis

- Definition
- Prevalence
- Classification
- Curve progression
- Functional outcome
- Quality of life
- Summary

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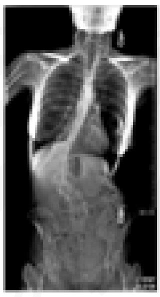
Definition

- Curve with a Cobb angle > 10 degrees
- Two distinct patient groups
  - Adults with idiopathic scoliosis
  - *De novo* scoliosis. Curves that develops later in life due to spondylosis, rotary lesthesis and asymmetrical disc collapse



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The prevalence and radiological findings in 1347 elderly patients with scoliosis

Hong et al, J Bone Joint Surg Br. 2010

- 478 subjects met the criteria for scoliosis (Cobb angle > or = 10 degrees)
- Prevalence of 35.5%
- Older adults had greater prevalence and more severe scoliosis
- Women were more affected

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Classification

- Adolescent Idiopathic Scoliosis

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The Selection of Fusion Levels in Thoracic Idiopathic Scoliosis

King et al.

- Retrospective review of postoperative cases
- Thoracic curves only
- Distraction techniques – Harrington Rods

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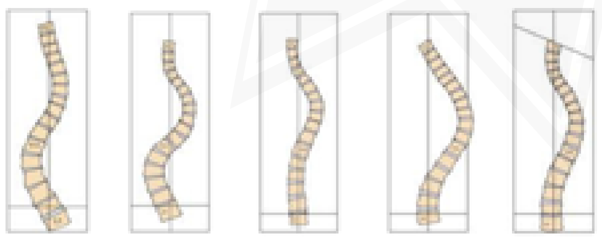
King Curves



King Type I King Type II King Type III King Type IV King Type V

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Limitations of King's Classification

- Not comprehensive
- Single plane classification
- Poor reliability and reproducibility
- Primarily Thoracic curves
- Does NOT consider sagittal alignment

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Lenke Classification Goals

- Comprehensive
- Ease of use
- Objective
- Include sagittal plane
- Good intra & inter observer reliability
- Help develop standardized treatment

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Lenke Classification

1) Curve Type (1-6)

+

2) Lumbar Modifier (A,B,C)

+

3) Thoracic Sagittal Profile (-,N,+)

Example = 1BN

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Curve Types

Curve Type

Type	Proximal Thoracic	Main Thoracic	Thoracolumbar / Lumbar	Curve Type
1	Non-Structural	Structural (Major*)	Non-Structural	Main Thoracic (MT)
2	Structural	Structural (Major*)	Non-Structural	Double Thoracic (DT)
3	Non-Structural	Structural (Major*)	Structural	Double Major (DM)
4	Structural	Structural (Major*)	Structural	Triple Major (TM)
5	Non-Structural	Non-Structural	Structural (Major*)	Thoracolumbar / Lumbar (TL/L)
6	Non-Structural	Structural	Structural (Major*)	Thoracolumbar / Lumbar - Main Thoracic (TL/L - MT)

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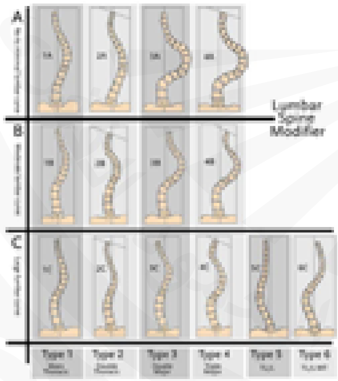
Lenke Curve Types



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Adult Deformity

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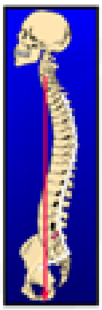
Spinal Balance



- **Sagittal balance:** *sagittal balance has consistently been shown to be the most reliable predictor of outcome in adult deformity correction.*
- **Coronal balance:** *is of less clear importance.*

Glassman et al: Spine 30 (18): 2024-2029. 2005
Ahn et al: Spine 27 (12) 1303-1311. 2002
Lagrone et al: JBJS (70) 569-80. 1988

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Curve type, location, magnitude and progression

- Coronal curve type: this is primarily important in determining procedure levels and end points
- Magnitude has an unclear correlation if any with indications and outcome in adults
- Progression rates have not been determined as indicators in adults
- Associated disc pathology (esp. at the curve apices)

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Proposed Adult Classification Systems

- Aebi M, et al: Eur Spine J 14:925-948, 2005
- Lowe T, Berven S, Schwab F et al: SRS Classification… Spine 31(19): 5119-5125
- Schwab F, Farcy JP, Bridwell K, et al.
- A Clinical Impact Classification of Scoliosis in the Adult. Spine 2006; 31(18):2109-14.
- Schwab F, Lafage V, Farcy JP
- Kuntz C, Schaffery C, Ondra S, et al:
- Spinal Deformity: A New
- Derived from NUSA

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Kuntz Classification System

- Descriptive and categorization
- Establishes normative values and tables for classification from a literature analysis
- Oriented to maintenance of spinal balance rather than spinal alignment*
- Comprehensive: includes the cranium, cervical spine and the pelvis
- Has not been validated for inter and intra observer reliability
- Does not guide treatment or relate to outcome at this time

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Lowe Classification

- Descriptive classification
- Sagittal balance is a modifier
- Rotary sublux is a modifier
- Disc degeneration at curve ends is considered
- No consideration of pelvis, C-spine or cranium
- Validated for intra and inter observer reliability
- Is not correlated with treatment or outcome

Lowe T, Berven SH, Schwab FJ, et al: Spine 31:S119-125, 2006

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Lowe Classification System

- **Basic Curve Types**

Single Thoracic
Double Thoracic
Double Major
Triple Major
Thoracolumbar
Lumbar "de novo"
Primary Sagittal Plane Deformity

Criteria for Major Curve Patterns:
Single curves are major by definition.
Double and triple curves require the apical vertebra to be outside the C7 plumbline (thoracic curves) or CSVL (lumbar curves).
Upper thoracic curves require T1 tilt ≥10°.

- **Modifiers (Not needed if parameters are normal)**

Regional Sagittal Modifier **(include only if outside normal range as listed)**
(PT) Proximal thoracic (T2-T5) ≥ +20o
(MT) Main thoracic (T5-T12) ≥ +40o
(TL) Thoracolumbar (T10-L2) ≥ +20o
(L) Lumbar (T12-S1) ≤ -40o
List all abnormal regions
Lumbar Modifier **(include only if present)**
(DDD) symptomatic degenerative disc disease and + MRI (add lowest involved level between L1 & S1)
(LIS) listhesis rotational, antero, retro (add lowest level between L1 & L5)
(JCT) junctional L5-S1 curve ≥15°
List only most distal modifier and (+) level if DDD or LIS
Global Balance Modifier **(include only if imbalance present)**
(SB) sagittal C7 plumb > +5cm anterior to sacral promontory
(CB) > + 5cm right or left of CSVL
List either or both if abnormal

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Schwab classification system

- Is coronal deformity based
- Incorporates regional and global sagittal alignment modifiers
- Has modifiers for global spinal balance
- Has been validated for intra and inter observer reliability
- Has been correlated with outcome and treatment strategies

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Schwab Classification System

Type: Location of the deformity (Apical level of the major curve OR Sagittal plane only)	
Type I	Thoracic only scoliosis (no thoracolumbar or lumbar component)
Type II	Upper thoracic major, apex T4-8 (with thoracolumbar or lumbar curve)
Type III	Lower thoracic major, apex T9-T10 (with thoracolumbar/lumbar curve)
Type IV	Thoracolumbar major curve, apex T11-L1 (with any other minor curve)
Type V	Lumbar major curve, apex L2-L4 (with any other minor curve)
Type K	Deformity in the Sagittal Plane Only
Lordosis modifier: Sagittal cobb angle from T12-S1	
A	marked lordosis >40°
B	moderate lordosis 0-40°
C	no lordosis present Cobb <0°
Subluxation modifier: Frontal or sagittal plane (anterior or posterior), max value	
0	no subluxation
+	subluxation 1-6mm
++	subluxation >7mm
Global Balance modifier: Sagittal plane C7 offset from posterior superior corner S1	
N	Normal: 0 to 4cm
P	Positive: 4 to 9.5cm
VP	Very Positive: >9.5cm

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SRS-Schwab Classification

4 Coronal curves type

- T **Thoracic only** – With lumbar curve < 30°
- L **TL/lumbar only** – With thoracic curve <30°
- D **Double curve** – With at least one T and one TL/L, both >30°
- N **No coronal curve** – All coronal curves <30°

3 Sagittal modifiers

PI minus LL
- 0 : within 10°
- + : moderate 10°-20°
- ++ : marked >20°

Global alignment
- 0 : SVA < 4cm
- + : SVA 4 to 9.5cm
- ++ : SVA > 9.5cm

Pelvic tilt
- 0 : PT<20°
- + : PT 20°-30°
- ++ : PT>30°

Schwab et al, Spine, 2012

Schwab classification system

- Outcome prediction

* Less lumbar lordosis pre op, the more patients disabled pre op and the more they are improved post op

*More positive the pre op sagittal imbalance the more patients disabled pre op and the more they are improved post op

* Rotatory subluxation was associated with an improved outcome

Curve Progression

Natural History of Untreated Idiopathic Scoliosis After Skeletal Maturity

Ascani et al. Spine 1986

- Average progression: 0.4º/year
- Thoracic > lumbar > TL >DM
- Pain in 61%
- Psychological disturbances (19%)

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Radiographic

- 46% increased ≥4°
- 20% pain complaints required treatment

Robin et al, Spine, 1982

- 41 patients 10 year follow-up, 73% progressed
- Risk factors?

Pritchett and Bortel, Spine, 1993

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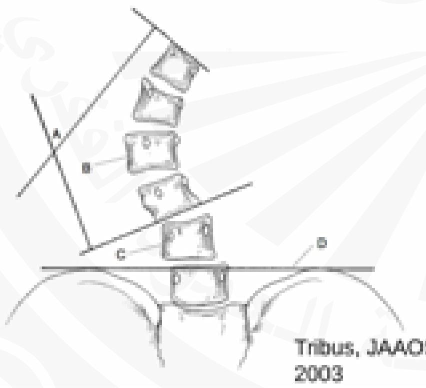
Risk Factors



Tribus, JAAOS, 2003

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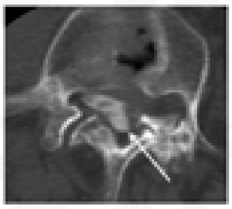
Natural history of progressive adult scoliosis

Marty-Poumarat et al. Spine 2007

- 51 patients with adult scoliosis
- Mean interval between first and last radiographs was 27 years
- Two subgroups
  - Type A – adolescent scoliosis with continued progression
  - Type B – late progression
- Rotary subluxation occurred during progression in Type A but seemed to be the initial event in Type B

Functional Outcome

- Back pain
- Neurogenic claudication and/or radicular pain



- Neurologic dysfunction
- Curve progression
- Cosmesis

Liu et al. The Spine Journal, 2003

Adult Scoliosis: A health assessment analysis by SF36

Schwab et al. Spine 2003

- Mean age 68 yo
- Much lower SF36 (7/8 categories) in scoliosis patients
- Much lower SF36 (7/8 categories) than patients with LBP/sciatica

Health and function of patients with untreated idiopathic scoliosis: a 50-year natural history study

Weinstein et al. JAMA 2003

- Late-onset idiopathic scoliosis (LIS)
- 117 untreated patients compared with 62 matched volunteers
- Conclusion – Untreated adults with LIS are productive and functional at a high level at 50-year follow up. Untreated LIS causes little physical impairment other than back pain and cosmetic concerns

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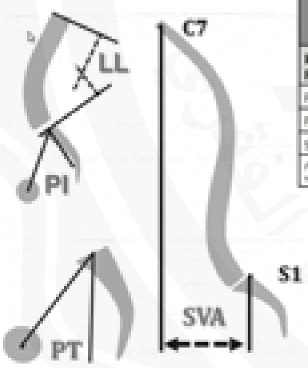

Lafage, Spine, 2009

TABLE 1. Radiographic Parameter Thresholds Predictive of an Oswestry Disability Index Score of 40

Radiographical Parameter	Radiographical Threshold	r
PI-LL	11°	0.45
PT	22°	0.38
SVA	46 mm	0.47

PI indicates pelvic incidence; LL, lumbar lordosis; PT, pelvic tilt; SVA, sagittal vertical axis.

Schwab et al, Spine, 2012

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Quality of Life

Nonoperative treatment for adolescent idiopathic scoliosis: a 10- to 60-year follow-up with special reference to health related quality of life

Haefeli et al. Spine 2006

- 135 patients with AIS treated nonoperatively with a minimum 10 year follow-up
- Compared with a healthy control group there was no significant difference in terms of HRQOL
- Curve size was found to be a predictor for pain in a long term follow-up

Quality of life in women with idiopathic scoliosis

Freidel et al. Spine 2002

- 226 female patients with idiopathic scoliosis compared with age-matched general population norms
- SF-36 or Brenner Questionnaire for Well-Being
- Women with IS had more physical complaints, lower self-esteem and higher depression scores
- Results were largely independent of age and Cobb angle

Summary

- Adult idiopathic scoliosis is a distinct form of adult deformity
- There is no agreed upon classification for adult scoliosis
- Impact on quality of life and functional outcome is controversial but there is some evidence of long term impairment
- Rate of progression has not been fully determined. Progressive curves appear to fall into two categories; those that continue to progress in a linear fashion after skeletal maturity and those that start to progress late, usually due to the development of spondylosis

Evaluation and Classification of Neuromuscular and Congenital Spine Deformities

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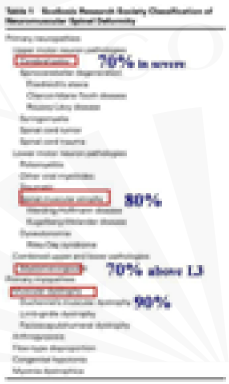
Neuromuscular Scoliosis

- Variety of underlying diagnosis
  - Spastic
    - Cerebral palsy, prior SCI
  - Flaccid
    - Duchenne's, spinal muscular atrophy
- Underlying disease effects prognosis & complications



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- Upper thoracic SCI < age10 near 100% risk of significant scoliosis
  - Mulcahey et al Spinal Cord Inj Rehabil 2013
- SMA type 2 curves 82° with 26 pelivc obliquity by age 14 or 15
  - Fujak et al BMC Musculoskelet Disord 2013
- Duchenne's Muscular Dystrophy untreated with steroids significantly progression with confined to wheelchair regardless of age
  - Shapiro et al. BoneJoint J. 2014
- CP curve >40° by age 12 & require tracheostomy high probability of severe curve
  - Gu Yet al. Pm R. 2011

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Assessment

- Goals of Treatment
  - Sitting balance
  - Pressure relief on skin
  - Free up hands
  - Hygiene
  - Care taker support
- Risk
  - Pulmonary
  - Infection 6x higher than idiopathic
  - Pressure sores
  - Nutrition


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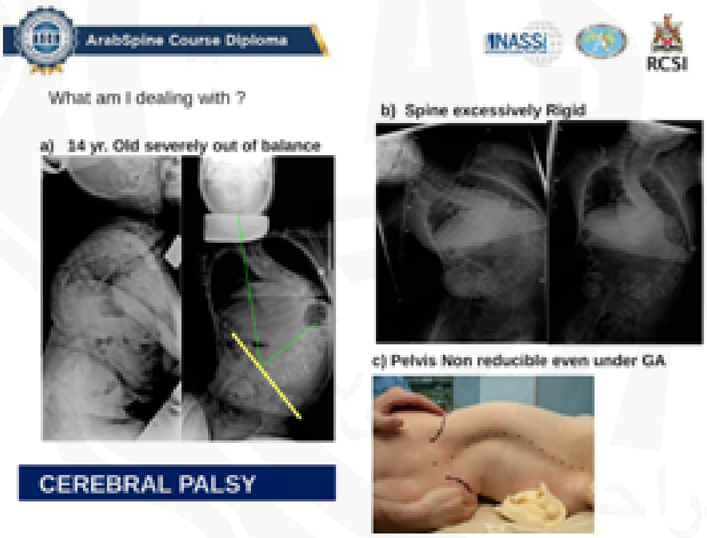
Things are not always what they appear to be :
Neurogenic Kyphoscoliosis: The rotational deformity of scoliosis cause an apparent kyphosis
a.
b.
c.
d.
Coronal deformity appears moderate. However due to the severe rotational deformity compounded by severe pelvic obliquity, PA x-ray is actually more of a lateral of the spine.
The apparent severe sagittal deformity (Kyphosis) is in fact the coronal scoliotic deformity. This is apparent as one notes the appearance of the lumbar vertebra in a PA orientation. This case illustrates the true three dimensional nature of spinal deformities.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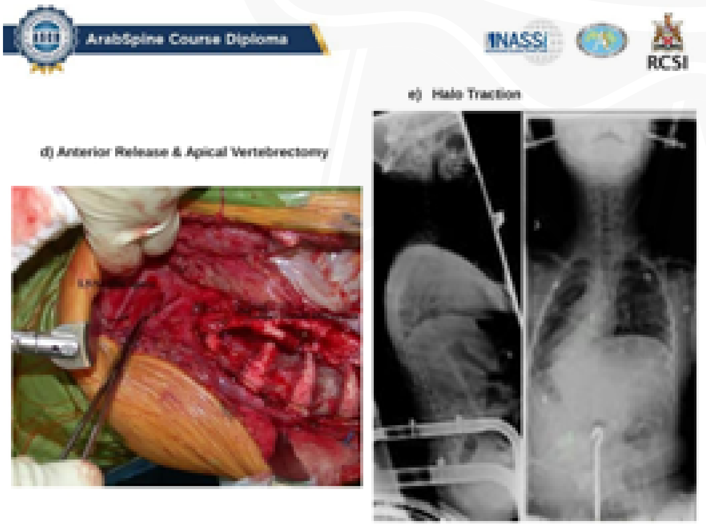
What am I dealing with ?
a) 14 yr. Old severely out of balance
b) Spine excessively Rigid
c) Pelvis Non reducible even under GA
CEREBRAL PALSY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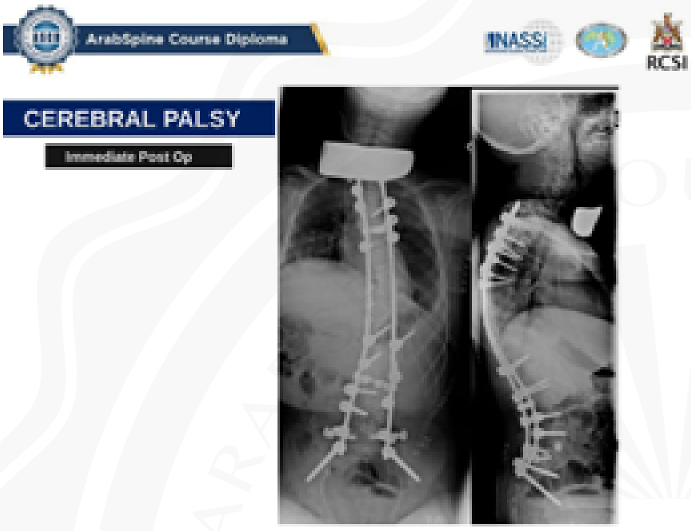
d) Anterior Release & Apical Vertebrectomy
e) Halo Traction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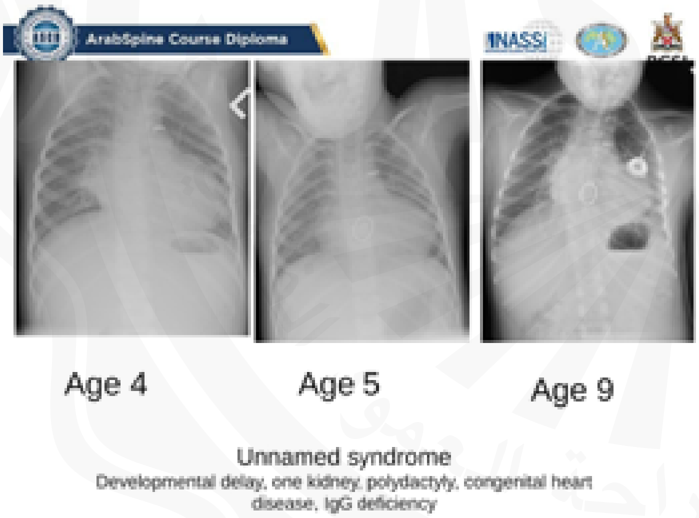
CEREBRAL PALSY
Immediate Post Op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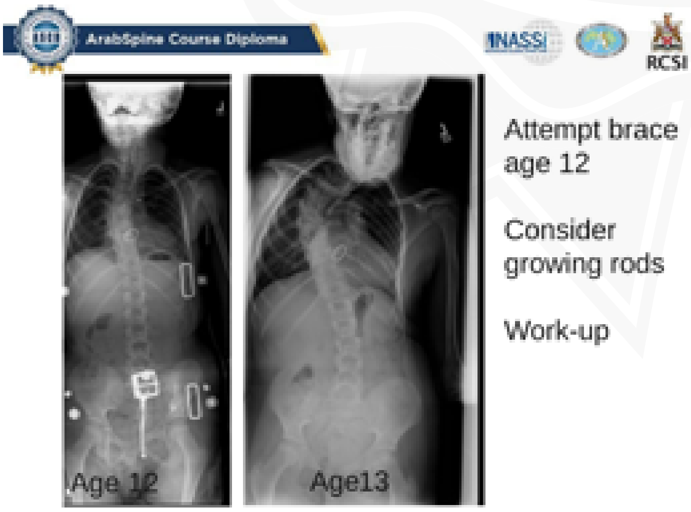
Age 4
Age 5
Age 9
Unnamed syndrome
Developmental delay, one kidney, polydactyly, congenital heart disease, IgG deficiency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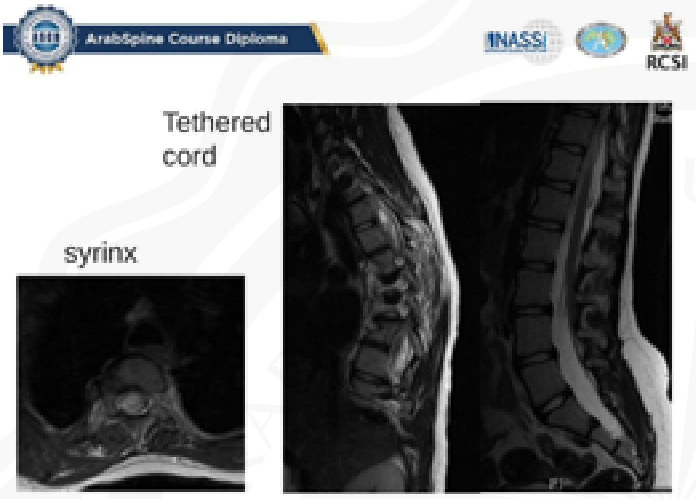
Age 12
Age13
Attempt brace age 12
Consider growing rods
Work-up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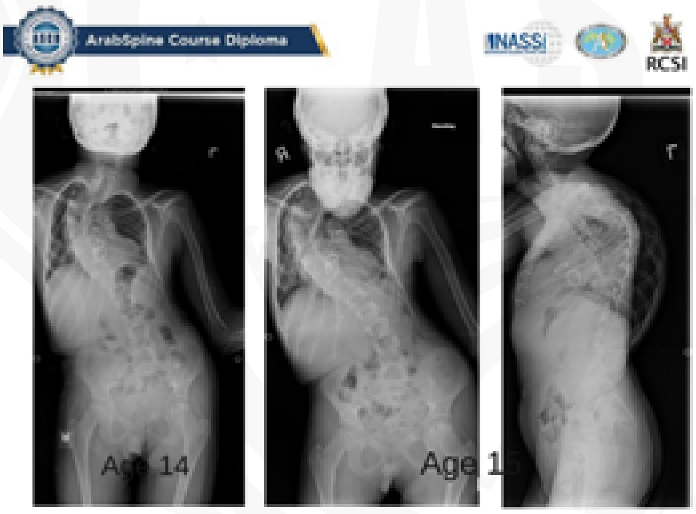
Tethered cord
syrinx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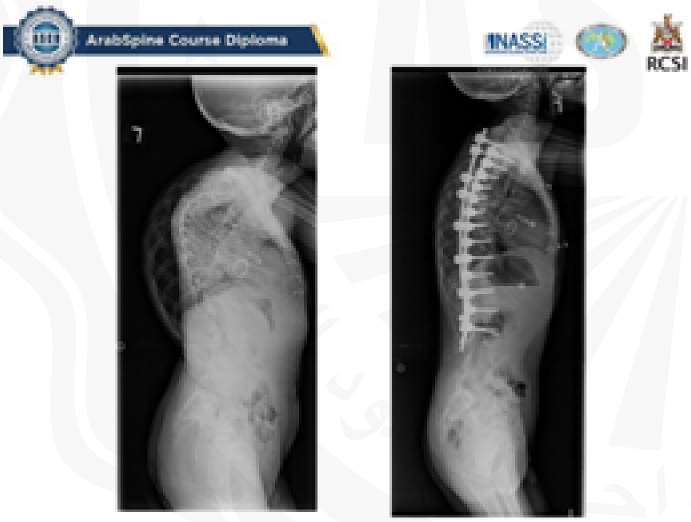
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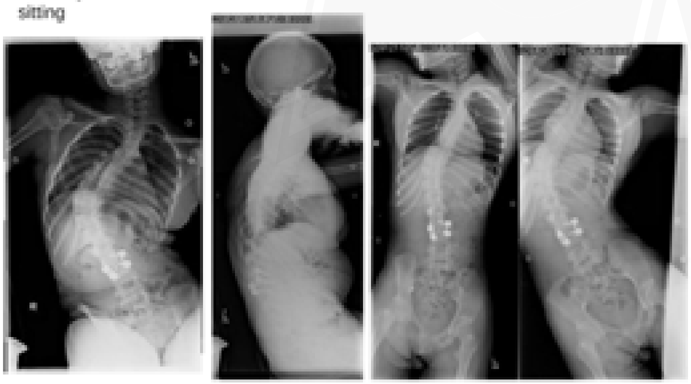
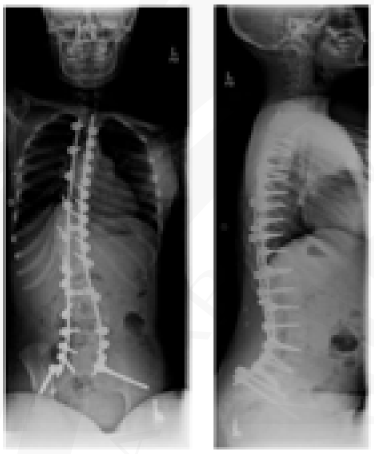
8 year
follow up
(age 23)

3 year old female, MVC 2001
paraplegic

2012 now 14 year old
Difficulty wheel chair
sitting





Currently in 2019
Age 21
Veterinary technician

Neuromuscular Summary

- Individualize to disease process
- Understand unique risks inherent with that disease
- Understand and set clear goals

Congenital Scoliosis Facts

- Syndrome e.g. VATER
- Urologic defects: 20%
- Congenital heart defect: 15%
- Spinal dysraphism: 10%

Renal ultrasound, Echo, MRI

Progression: *(Winter JBJS 1968)*

25% don't, 25 % mild, 50% need treatment

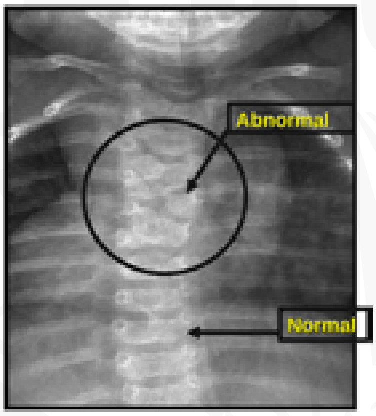
Congenital Scoliosis

- Scoliosis vs kyphosis vs lordosis
- Predict progressive vs benign patterns
- Guide treatment
- Failure of formation
- Failure of segmentation
- Mixed
- Often complex and difficult to fit cleanly into classification based of 2-D images

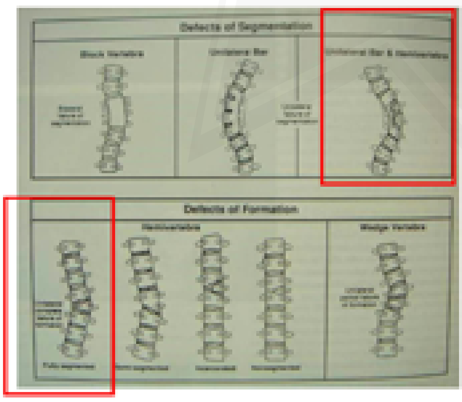
Winter RB, Moe JH, Wang JF. Congenital Kyphosis—Its natural history and treatment as observed in a study of one hundred thirty patients. *J Bone Joint Surg Am* 1973;55:223–56.
McMaster MJ, Ohtsuka K. The Natural history of congenital scoliosis: a study of two hundred and fifty-one patients. *J Bone Joint Surg Am* 1982;64:1128–47

- Congenital Scoliosis
  - Failure of formation
    or
  - Failure of segmentation

  Combination



Congenital Scoliosis



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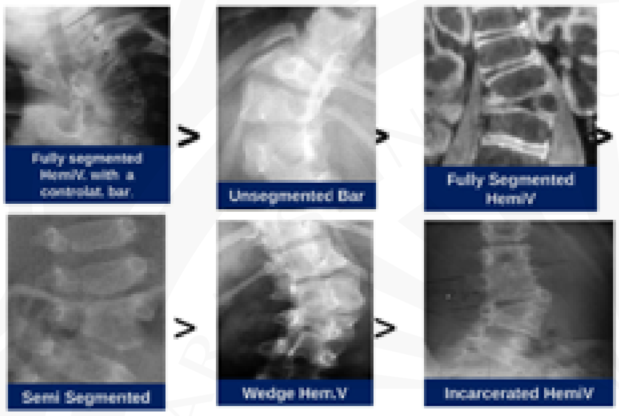
From High to low risk of Progression



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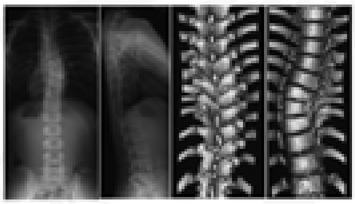
- 2-D based mostly on vertebral body
- Posterior elements more difficult to analyze on plain radiographs
- Severe deformity requires CT with 3-D formatting



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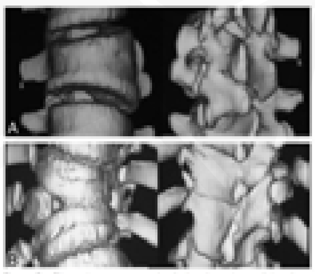
- Anterior elements don't always match posterior
- Discordant or complex
- Failure of segmentation can be anterior, anterolateral, posterior, posterolateral, circumferential



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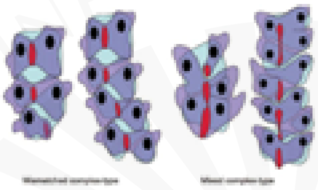
- Kawakami N, Tsuji T, Imagama S, et al. Classification of Congenital Scoliosis and Kyphosis. A New Approach to the Three-Dimensional Classification for Progressive Vertebral Anomalies Requiring Operative Treatment. Spine 34: 1756–1765. 2009.

Type 1.	Solitary simple
Type 2.	Multiple simple
Type 3.	Multiple complex Mismatched complex Mixed complex
Type 4.	Segmentation failure



Mismatched complex type — Mixed complex type

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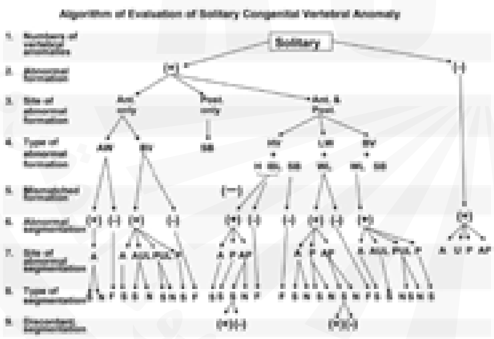
Figure 11. Algorithm for the solitary type. If only 1 congenitally abnormal vertebra exists in whole spinal column, we should follow the algorithm for the solitary type. Referring the Table 1 the abnormal vertebra should be evaluated step by step. This algorithm helps to clarify the characteristics of abnormal vertebra. A indicates anterior; P, posterior; BV, butterfly vertebra; W, wedged vertebra; HV, hemivertebra; SB, spina bifida; LW, lateral wedged vertebra; H, hemilamina; IBL, incomplete bilamina; AUL, anterior unilateral; PUL, posterior unilateral; S, semisegmented; N, nonsegmented; F, fully segmented; U, unilateral; AP, anteroposterior.



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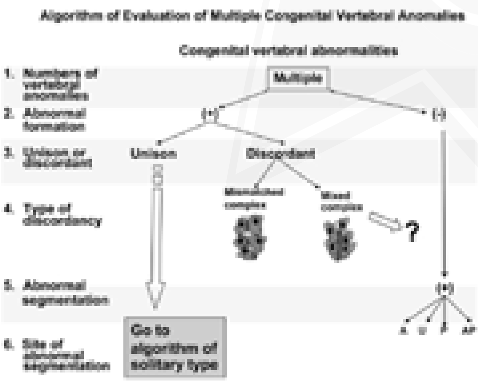

Figure 12. Algorithm for the multiple type.

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Table 2. Classification of Congenital Vertebral Abnormalities (Based on Presence or Absence of Abnormal Formation)

Type 1	Solitary simple (unison) type Hemivertebra Wedge vertebra Butterfly vertebra Defect Others
Type 2	Multiple simple (unison) type Combination of hemivertebra, wedge vertebra, or butterfly vertebra Discrete, adjacent, or others
Type 3	Complex (discordant) type Mismatched complex type Mixed complex type
Type 4	No abnormal formation type Pure segmentation failure

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Congenital Summary

- 3-D CT offers best understanding of the anatomy
  - Anterior and posterior elements
- Remember to eval for associated conditions
- Recognize higher risk for progression and follow closely

IONM in Deformity Surgery

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Objectives

- Review of IOM Modalities
- Why IOM is Critical in Spine Deformity Surgery
- Modalities we must use in Deformity surgeries & Case Study

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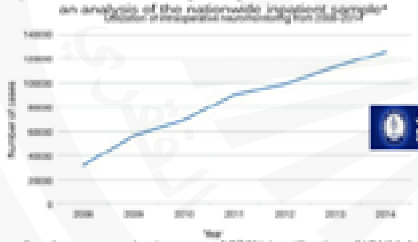
Utilization of intraoperative neuromonitoring throughout the United States over a recent decade: an analysis of the nationwide inpatient sample*



Journal of Spine Surgery

Conclusions
Over the last decade, there has been a massive increase of 296% in utilization of IONM during spine surgery. This is likely due to its proven benefit in reducing neurologic morbidity in spinal deformity surgery, while introducing minimal additional risk. While IONM may improve patient care, it is still rather isolated to teaching hospitals and patients from higher income zip codes.

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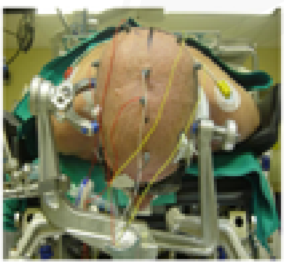
IONM Modalities



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What Monitoring Modalities are Available?

These are the must use modalities in spine deformity surgery:

- Somatosensory Evoked Potentials (SS
- Motor Evoked Potentials (MEPs)
- Descending Neurogenic Evoked Poten
- Spontaneous and Triggered EMG
- The Stagnara Wake Up Test

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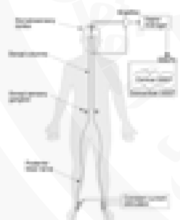
SSEP (Somatosensory evoked potential)



LOWER EXTREMITY SSEP STIMULATION SITES:
- POSTERIOR TIBIAL NERVE
- PERONEAL NERVE AT DORSUM OF FOOT
- PERONEAL NERVE BELOW FIBULAR HEAD

UPPER EXTREMITY SSEP STIMULATION SITES:
- MEDIAN NERVE
- ULNAR NERVE

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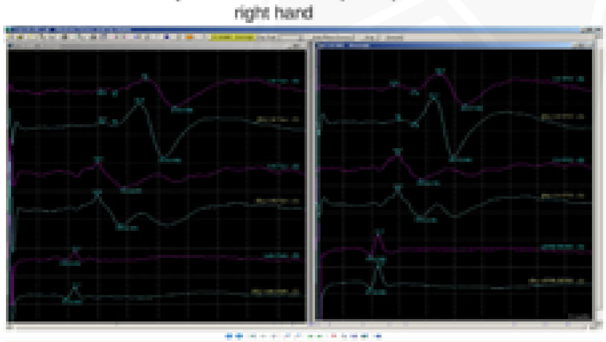
These are Somatosensory Evoked Potentials (SSEP) recorded from left and right hand

These are Somatosensory Evoked Potentials (SSEP) recorded from left and right hand



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Warning Criteria for SSEP

- > 50% Loss of Amplitude

OR

- > 10% Increase in Latency

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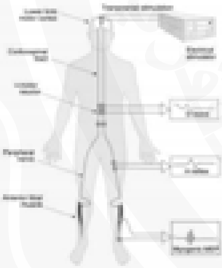
MEP (motor evoked potential)



MEP:

STIMULATORS USED FOR ACTIVATING NEURAL TISSUE MIGHT BE EITHER CONSTANT-CURRENT OR CONSTANT-VOLTAGE GENERATORS*

- STIMULATE THE SKULL (UP TO 200MA OR 800 V)
- RECORD FROM UPPER AND LOWER LIMBS MUSCLES
- NO MUSCLE RELAXANT SHOULD BE GIVEN TO THE PATIENT (TOF= 4/4)

*INTRAOPERATIVE NEUROPHYSIOLOGICAL MONITORING SECOND EDITION

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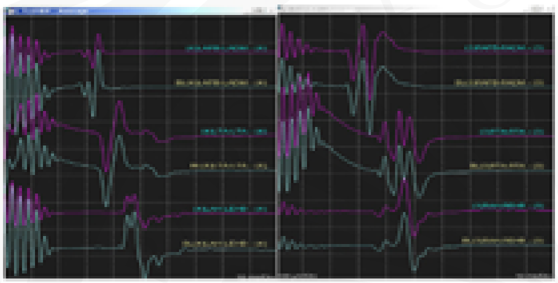
Commonly Used MEP Recording Sites

- Deltoid
- Biceps
- Triceps, wrist extensors/flexors
- Hand intrinsics
- Iliopsoas
- Adductor longus
- Adductors, vastus medialis
- Vastus medialis, vastus lateralis
- Anterior tibialis, extensor hallucis longus
- Medial gastrocnemius or abductor hallucis
- Perianal musculature

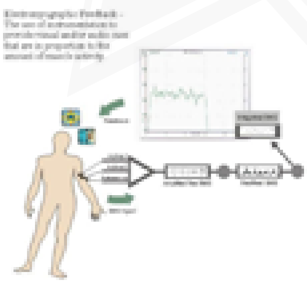
These are Motor Evoked Potentials recorded from left and right hand, leg and foot muscles

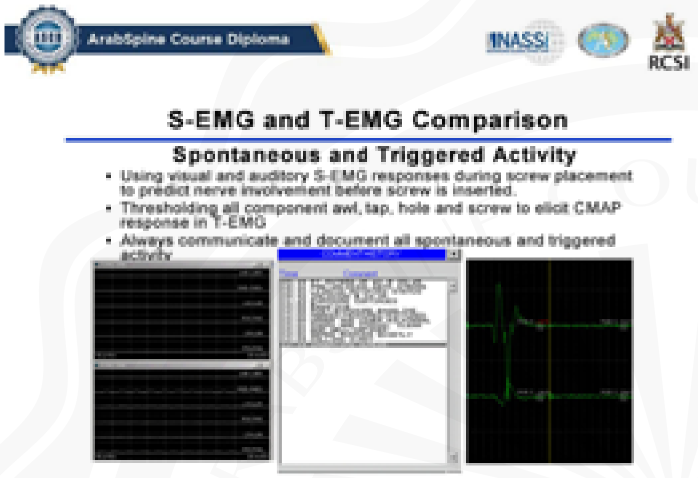


Warning Criteria for TcMEP

- 75% decrease in amplitude that does not return to acceptable limits following a stimulation increase of up to 100 volts above the baseline stimulation level

EMG (Electromyogram)

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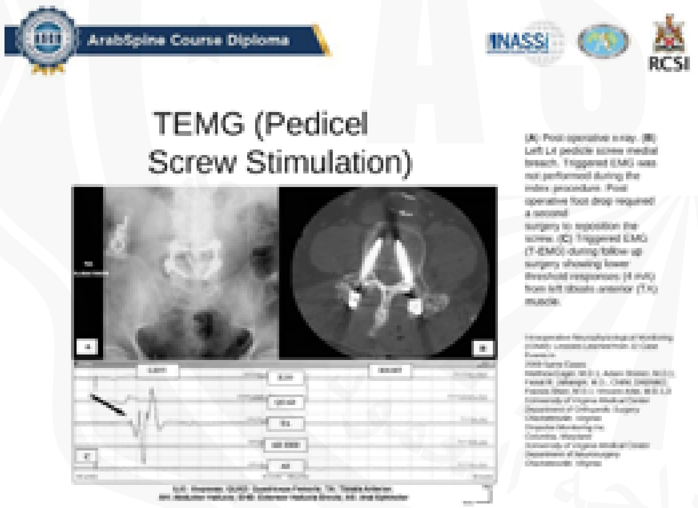
S-EMG and T-EMG Comparison
Spontaneous and Triggered Activity
• Using visual and auditory S-EMG responses during screw placement to predict nerve involvement before screw is inserted.
• Thresholding all component awl, tap, hole and screw to elicit CMAP response in T-EMG
• Always communicate and document all spontaneous and triggered activity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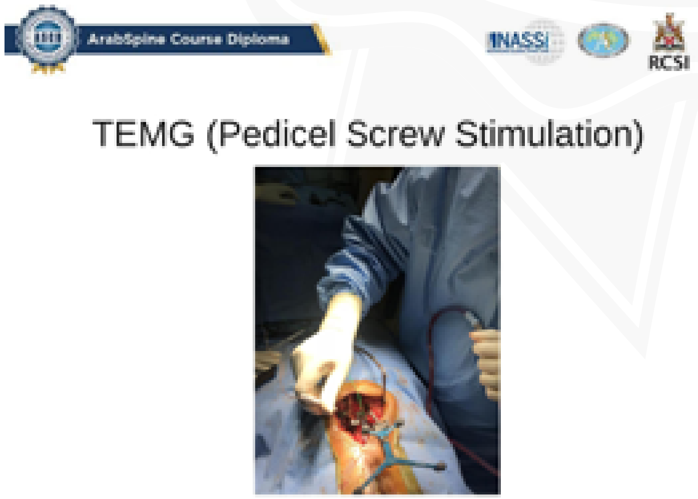
TEMG (Pedicel Screw Stimulation)
(A) Post-operative x-ray. (B) Left L4 pedicle screw medial breach. Triggered EMG was not performed during the index procedure. Post operative foot drop required a second surgery to reposition the screw. (C) Triggered EMG (T-EMG) during follow up surgery showing lower threshold responses (4 mA) from left tibialis anterior (TA) muscle.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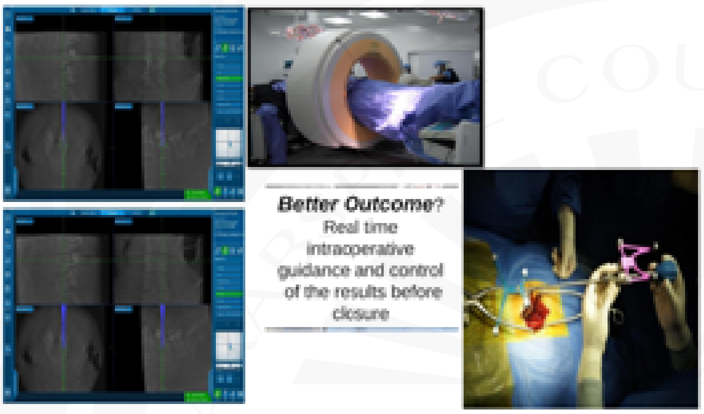
TEMG (Pedicel Screw Stimulation)



IOM & NAVIGATION

The setup

Neurological complications after spine and spinal cord surgeries

Statistics and history*:

- In 1975, a review by MacEwen et al. over 7,000 spine surgeries revealed an incidence of neurologic complications of less than 1%.
- The Scoliosis Research Society (SRS) In 1991 reported an incidence of neurological deficit after all forms of spinal surgery around 1.6%.
- The SRS reported that in 2005 the incidence of neurological deficits after surgery for scoliosis was about 1.2% (0.1% complete cord, 0.4% incomplete cord, 0.7% nerve root)

*EUR SPINE J. NOV 2007; 16(SUPPL 2): 229-231.

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AAN Recommendation*

- Surgeons and other members of the operating team should be alerted to the increased risk of severe adverse neurologic outcomes in patients with important IOM changes (**Level A**).

Level A = **Established** as effective

*the American Academy of Neurology

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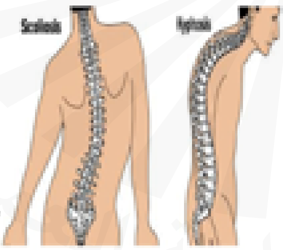
Why IOM is Critical in Spine Deformity Surgery

"Spinal cord monitoring is now considered standard care during surgery for spinal deformity"*

Mainly :
- Scoliosis

  &
- Kyphosis



*Risk factors for spinal cord injury during surgery for spinal deformity
J Bone Joint Surg Am. 2010 Jan;92(1):64-71. doi: 10.2106/JBJS.H.01839

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Events That Need Monitoring in Spine Deformity Surgery

In general, there are Several major events:
- Long Spinal cord involvement
- Long surgery time and potential for bleeding/ cord ischemia
- Multi level Instrumentation

And most important:
"The possibility of Spinal cord injury during correction and rotation"*

*"These maneuvers has the potential to stretch or impinge upon the neural elements , resulting in spinal cord injury"

Spine Deformity Surgery
Intraoperative Neurophysiology: A Comprehensive Guide to Monitoring and Mapping
By Mirela V. Simon, MD

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What Monitoring Modalities Should We Use?

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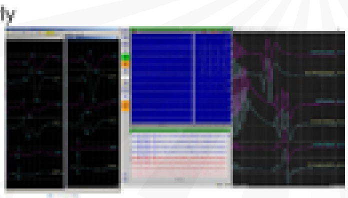
Multi Modalities Monitoring

"Combined somatosensory (SSEP)and motor evoked potential (MEP) monitoring allows the detection of early spinal cord dysfunction in most patients."*

SEMG/TEMG
For instrumentation and nerve root Protection.



SSEP SEMG/TEMG MEP

*Risk factors for spinal cord injury during surgery for spinal deformity. J Bone Joint Surg Am. 2010 Jan;92(1):64-71. doi: 10.2106/JBJS.H.01839

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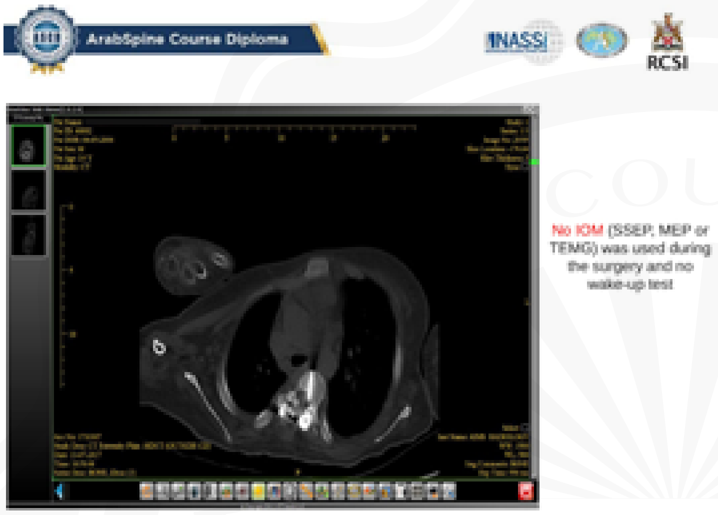
Case Study

14 Y.M. with scoliosis, with lowers weakness.

Procedure: Scoliosis correction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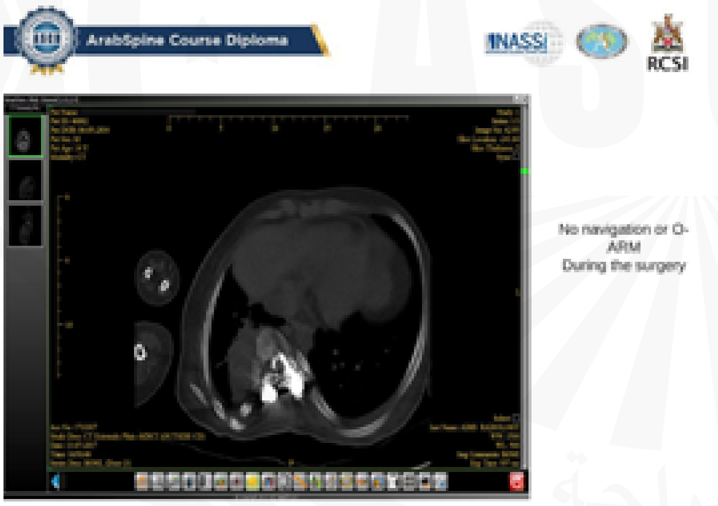
No IOM (SSEP, MEP or TEMG) was used during the surgery and no wake-up test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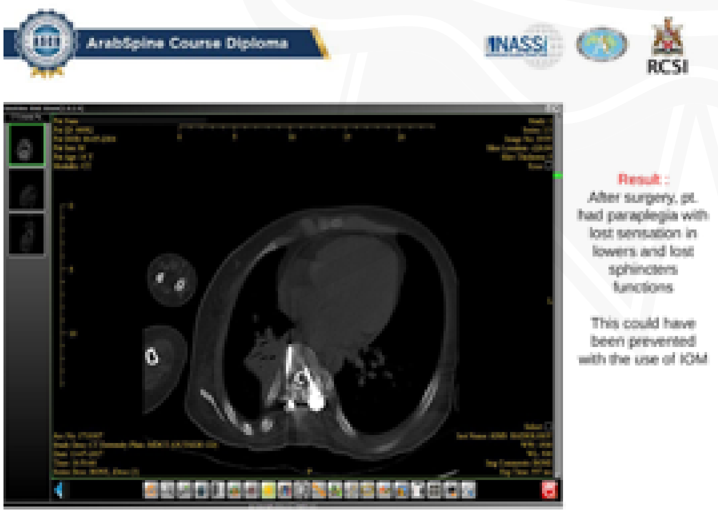
No navigation or O-ARM
During the surgery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Result :
After surgery, pt. had paraplegia with lost sensation in lowers and lost sphincters functions
This could have been prevented with the use of IOM

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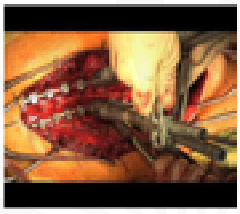
"What could happen during correction and rotation"*

Generally, we can have reversible interruption in the cord blood supply :

- Can result in acute spinal cord ischemia as a result of development of an anterior spinal artery syndrome (Stockl et al., 2005)
- The potential to stretch or impinge upon the neural elements



*Spine Deformity Surgery
Intraoperative Neurophysiology: A Comprehensive Guide to Monitoring and Mapping
By Mirela V. Simon, MD

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"AAN Report" How IOM Can help?*

- Anesthesiologists and surgeons are able to intervene in a variety of ways when IOM raises warnings:
  - Reduce the degree of distraction
  - Adjust retractors
  - Remove or adjust grafts or hardware
  - Re-implant or unclamp arteries
  - Minimize remaining portion of surgery
  - Check a wake-up test
  - Increase BP and keep MAP above 70

*The American Academy of Neurology

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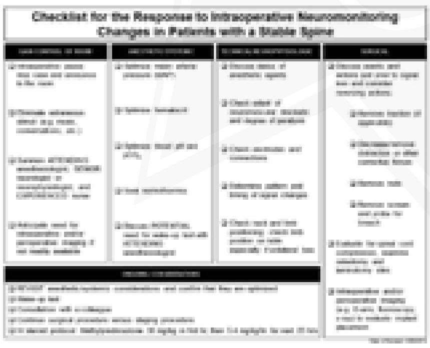
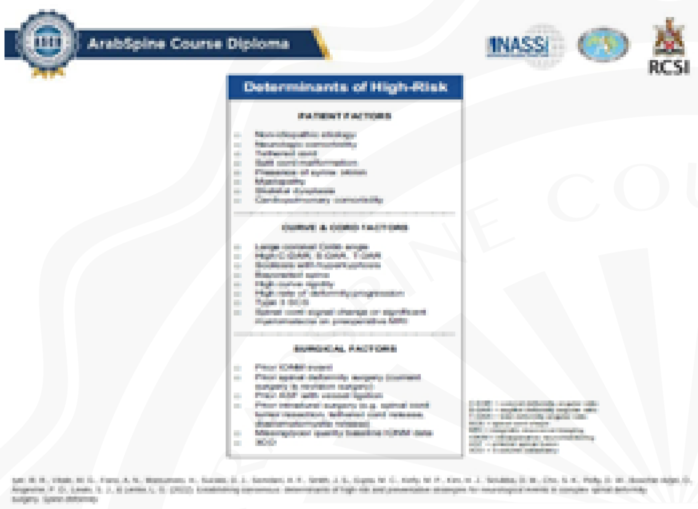

Checklist for the Response to Intraoperative Neuromonitoring Changes in Patients with a Stable Spine

Vitale, M. G., Skaggs, D. L., Pace, G. I., Wright, M. L., Matsumoto, H., Anderson, R. C., Brockmeyer, D. L., Dermott, J. P., Emans, J. B., Erickson, M. A., Flynn, J. M., Glotzbecker, M. P., Ibrahim, K. N., Lewis, S. J., Luhmann, S. J., Mendiratta, A., Richards, B. S., Sitt, Sanders, J. O., Shah, S. A., Smith, J. T., ... Lenke, L. G. (2014). Best Practices in Intraoperative Neuromonitoring in Spine Deformity Surgery: Development of an Intraoperative Checklist to Optimize Response. Spine deformity, 2(5), 333–339.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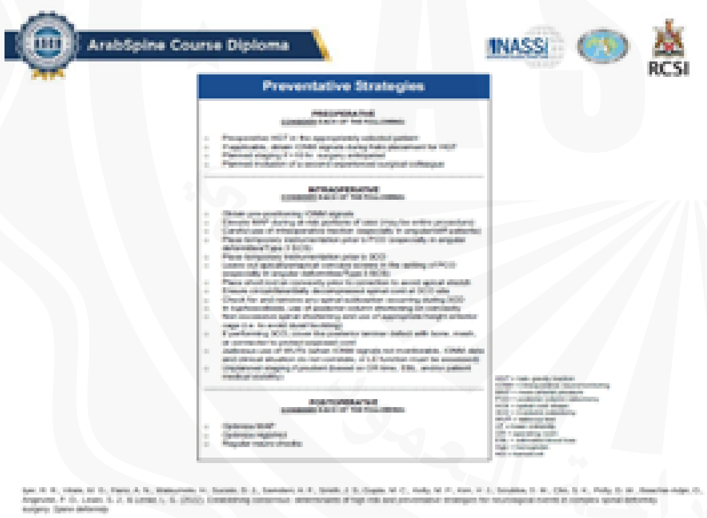
Determinants of High-Risk
PATIENT FACTORS
CURVE & CORD FACTORS
SURGICAL FACTORS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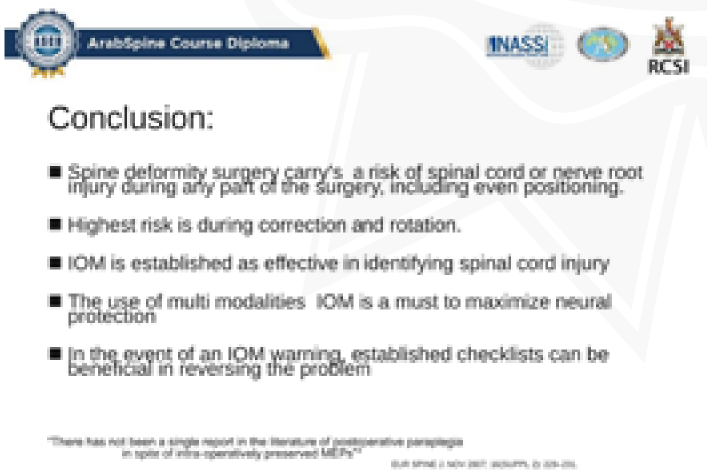
Preventative Strategies
PREOPERATIVE
INTRAOPERATIVE
POSTOPERATIVE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Conclusion:
Spine deformity surgery carry's a risk of spinal cord or nerve root injury during any part of the surgery, including even positioning.
Highest risk is during correction and rotation.
IOM is established as effective in identifying spinal cord injury
The use of multi modalities IOM is a must to maximize neural protection
In the event of an IOM warning, established checklists can be beneficial in reversing the problem
"There has not been a single report in the literature of postoperative paraplegia in spite of intra-operatively preserved MEPs"

Choosing Fusion Levels in Surgery fo Adolescent Idiopathic Scoliosis

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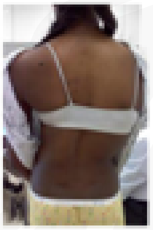
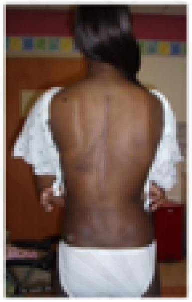
Selecting the right levels (hopefully) means:



- Optimal postoperative correction and balance
- Maximizing spine function/longevity
- Minimizing
  - anesthesia time
  - blood loss
  - cost



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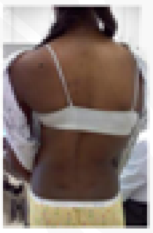
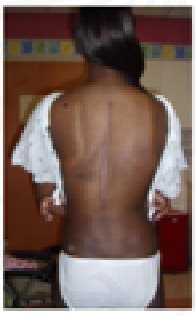
Decisions to be made when selecting fusion levels



- Selective vs non selective fusion
- Selection of upper instrumented vertebrae (UIV)
- Selection of lower instrumented vertebrae (LIV)



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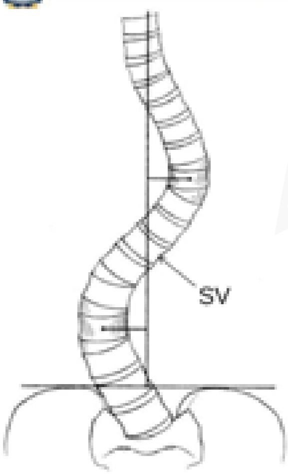

Terminology

- stable vertebra
- neutral vertebra
- end vertebra (UEV, LEV)
- LIV
- UIV
- apical vertebral translation

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Fuse all structural curves

Lenke Classification

Curve type				
Type	Proximal thoracic	Main thoracic	Thoracolumbar/lumbar	Description
1	Nonstructural	Structural (major)	Nonstructural	Main thoracic (MT)
2	Structural	Structural (major)	Nonstructural	Double thoracic (MT)
3	Nonstructural	Structural (major)	Structural	Double major (DM)
4	Structural	Structural (major)	Structural (major)	Triple major (TM)*
5	Nonstructural	Nonstructural	Structural (major)	Thoracolumbar/lumbar (TL/L)
6	Nonstructural	Structural	Structural (major)	Thoracolumbar/lumbar-main thoracic (TL/L-MT)

- Largest cobb angle always structural

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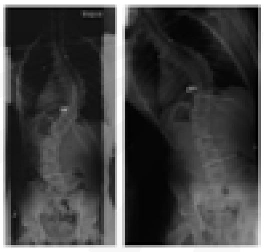
LENKE CLASSIFICATION

Structural criteria
(Minor curves)

Proximal thoracic – Side bending cobb ≥25°
– T2-T5 kyphosis ≥+20°

Main thoracic – Side bending cobb ≥25°
– T10-L2 kyphosis ≥+20°

Thoracolumbar/lumbar – Side bending cobb ≥25°
– T10-L2 kyphosis ≥+20°



- Minor curves can be structural

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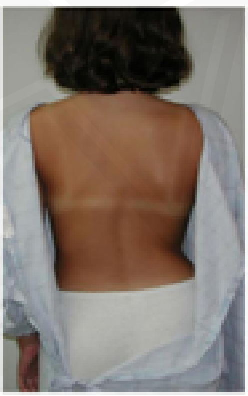
Decision making is a *combination* of radiographic and clinical guidelines:
take a long look at the patient!



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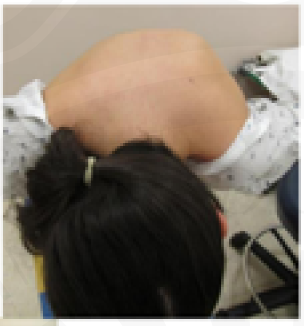
Note all prominences- including trapezial fullness



Ask the patient! Waistline asymmetry, chest wall, shoulder imbalance, lumbar prominence

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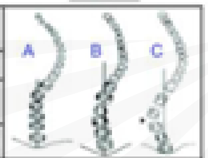
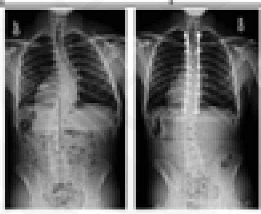
Lenke 1 and selective fusion

Lenke Classification

Lumbar spine modifier	CSVL to lumbar apex
A	CSVL between pedicles
B	CSVL touches apical body(ies)
C	CSVL completely medial





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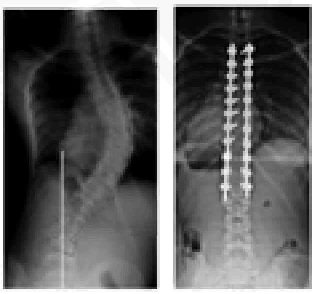
Lenke 1A, B

- Lenke 1A, B, selective thoracic fusions
- exception: TL kyphosis



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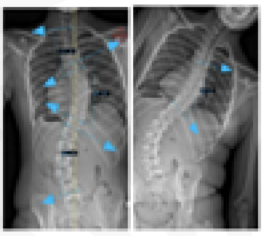
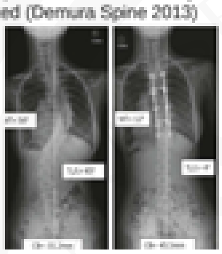
Lenke 1C can remain unfused if:

- approach midline on side benders
- measures <50 degrees with high flexibility
- Apical vertebral translation (AVT) and clinical deformity should be less than major curve
- 1C pts decompensated to the left may stay decompensated (Demura Spine 2013)





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Lenke 3,4,6

- Both curves fused

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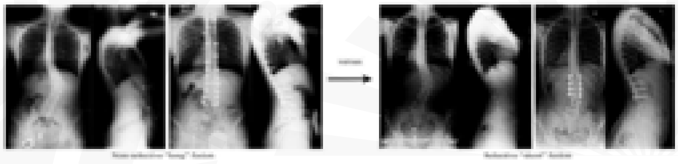
Selective lumbar or thoracolumbar fusion (Lenke 5)

- Appropriate when thoracic is non structural
- Be aware of rotation
- Be aware of shoulder asymmetry

Lenke 5

T spine inclusion (Lark et al *Spine 2013)*

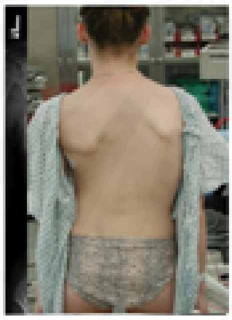
- T spine inclusion had decreased flexibility and T kyphosis at 2 yr follow up but SRS 22 scores same. ? significance



Rules for Choosing the UIV

Shoulder Imbalance

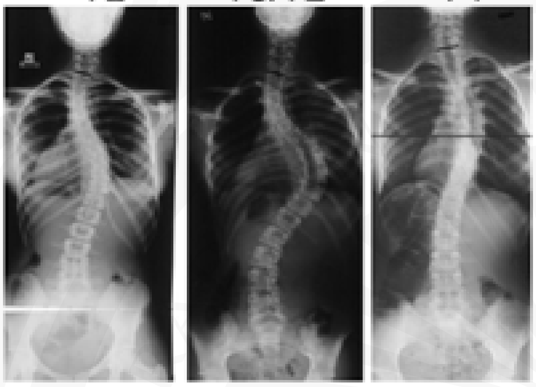
- difficult to quantify
- Ono et al *Spine 2012*
  - clavicular angle vs trapezial angle- trapezial angle may correlate better with postoperative T1 tilt but T1 tilt doesn't correlate with shoulder balance



Ilharreborde et al *JPO 2008*

- 132 Lenke 1 or 2 curves
- analyzed shoulder balance, T1 tilt, curve flexibility and proximal level fused
- if T1 tilt and shoulder balance are both to right, entire curve is fused (to T1)
- report 89% satisfaction of all criteria for balance at 2 yr f/u

T1 T3/T2 T4



Ilharreborde et al *JPO 2008*

Fusion Guidelines: UIV

Shoulder Level

- Right shoulder high → can stop at T4
- Shoulders level → T4, sometimes T3
- Left shoulder high, stiff curve, large curve → have to extend to T2 or even T1

Usually works because it correlates with stiffness of upper T curve

Fusion Guidelines: LIV

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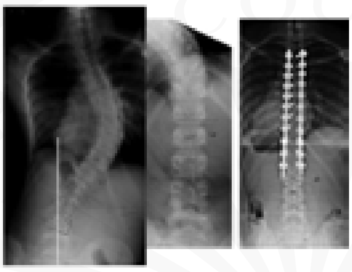
Lenke 1A

- Choose LIV that touches the CSVL
- Exception when disc below opens to concave side



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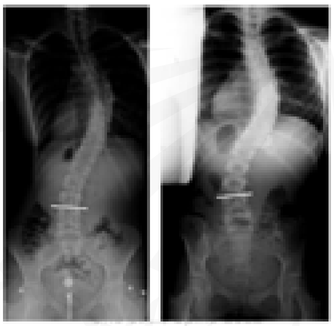
Lenke 1AL vs 1AR

Miyanaji *Spine 2008*

- Right tilting L4 (1AR)
- Left tilting L4 (1AL)



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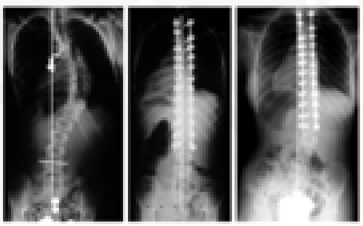
Lenke 1AL vs 1AR

Cho et al *Spine 2012*

- 1A-R pts who added on were fused 2 levels above stable- rec fusing to within 1-2 of SV

Wang *Spine 2011*

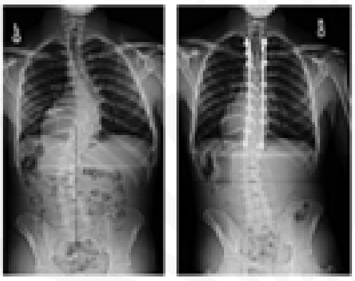
- choose LIV <10mm from CSVL to avoid adding on



Cho et al 2012

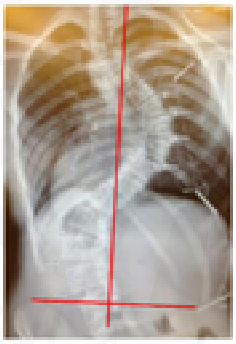
Lenke 1B, C

- Choose stable vertebra as the LIV



Lenke 3,4,6

- Typically fuse distally to most proximal level intersected by CSVL
  - Usualy LEV
- Exception LEV-1 crosses midline on bending



Summary

Fuse structural curves

- selective fusions for Lenke 1
- selective fusions for Lenke 5

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Summary

Choosing UIV

- T1/2 if L shoulder up
- T3 if shoulders level
- T4 if R shoulder up

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Summary

Choosing LIV

- Lenke 1A distal vertebrae that touches CSVL
- Lenke 1B, C stable vertebrae
- Lenke 2-6 end vertebrae

Correction Techniques in Adolescent Scoliosis Surgery

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Complications of pediatric scoliosis surgery

Overall complication rate 10,2%
-idiopathic: 6,3%
-congenital: 10,6%
-neuromuscular: 17,9%

Neurological complication rates
-idiopathic: 0,8%
-congenital: 2,0%
-neuromuscular: 1,1%

Reames et al. 2011

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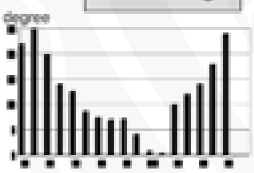
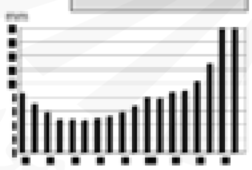
Pedicle Morphology of Nondeformed Spines

Knowledge, Practice, Experience: Anatomy and Pathoanatomy

Pedicle Angle



Pedicle diameter



Vaccaro et al. (JBJS Am 1995)

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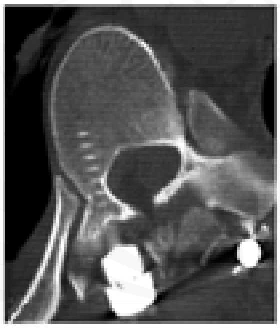
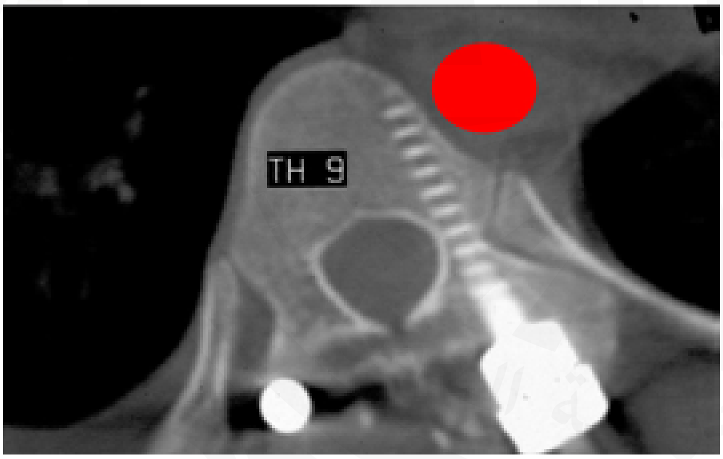
Vertebral morphology in scoliosis

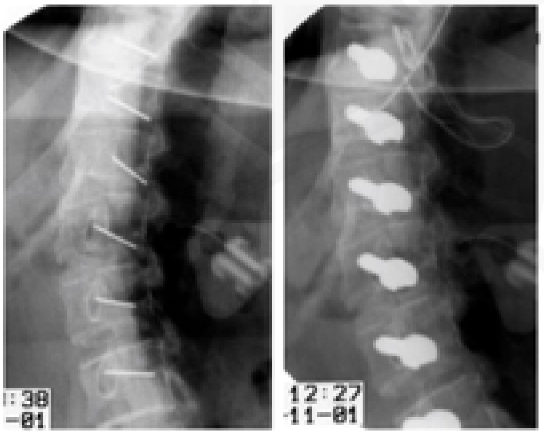
- **intravertebral deformity (torsion)**
- **concave pedicles thinner than convex pedicles**
- **Loss of epidural reserve space at the concavity**
  - *Liljenqvist et al.*, Spine 2001, JBJS 2002
  - *Parent et al.*, Spine 2002

Problems of pedicle screws in scoliosis surgery

- 3-D malformation
- Intravertebral deformity
- Concave pedicles smaller
  - *Liljenqvist et al.*, Spine 2000







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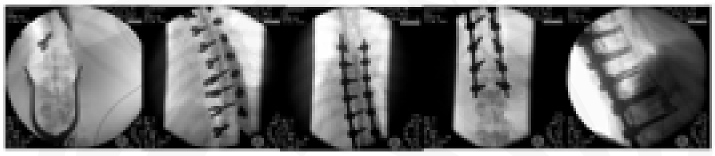
1. Fluoroscopic localization of vertebra with the first inserted pedicle screw. (T12)
2. Second fluoroscopic check after insertion of all pedicle screws in two planes (ap, lateral)
3. Final fluoroscopic check after correction in two planes (ap, lateral)
4. Mean fluoroscopic time (n=73): 24,05 Sekunden. (Lenke 1,3,6)



10 – 12 % of the intraoperative radiation radiation time with CT based navigation

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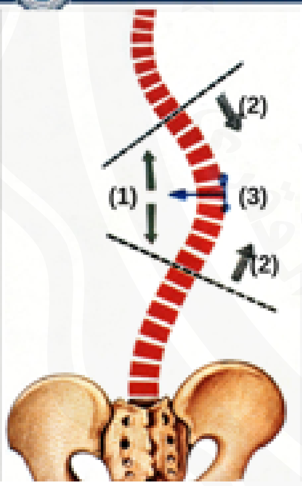

Correcting Principles

1. Distraction (koncav)
2. Compression (convex)
3. Translation (at/near Apex)

4. Derotation !!! Better with anterior

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Correcting Principles and its Effects on the sagittal plane !

Distraction: decreases kyphosis and lordosis (straigthens !)

Translation (at concave apex) : increases kyphosis

Compression (across convexity): reduces kyphosis

Derotation (DVR / Anterior: decreases Kyphosis, increases lordosis

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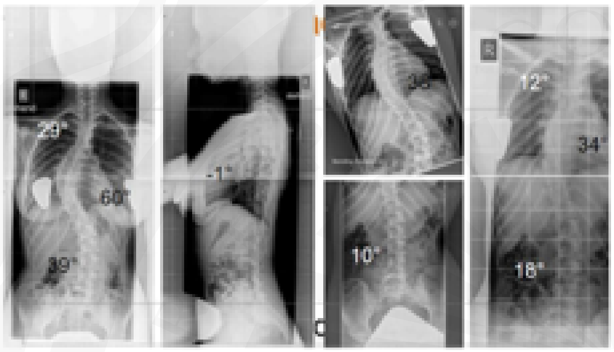
17-year old patient: Lenke 1C-



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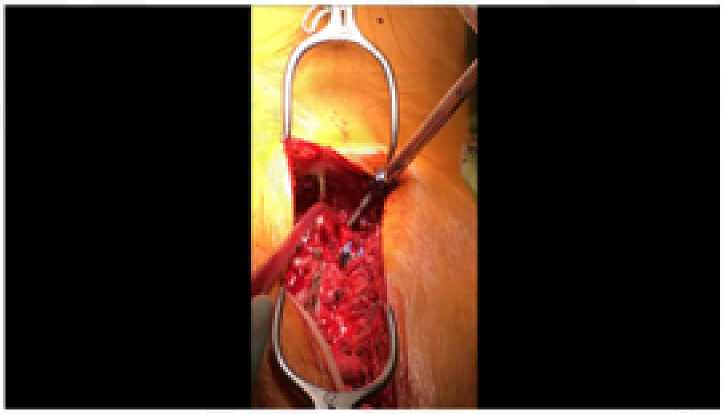
Free hand screw insertion after preparing the pedicle with awl



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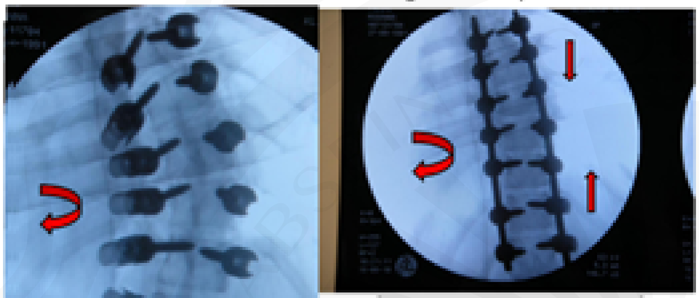
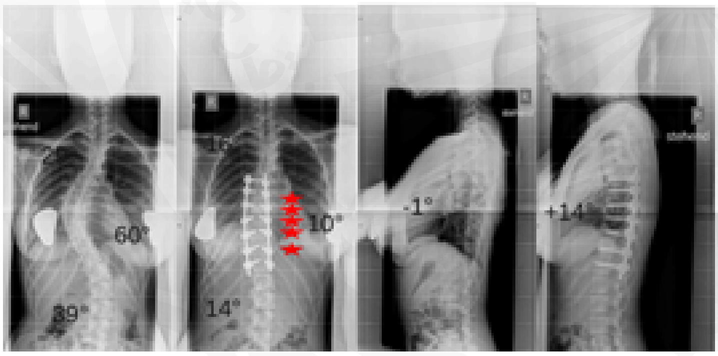
Correcting principles:
concave: rod rotation and segmental distraction
convex: Cantilever and segmental compression



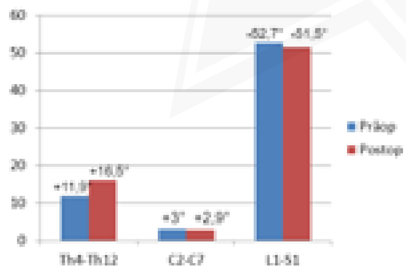
Intraoperative fluoroscopic check in 2 planes

Cr.-Co.- Rods: more rigid than Ti-rods, kyphosis correction
5 long sleeve reduction screws for apical translation



Results

Average 5° increase of kyphosis in hypokyphotic spines



Sagittal plane: thoracic / cervical / lumbar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17-year old patient: Lenke 1CN
33°
65°
54°
+17°
32°
17°
21
30°
18°


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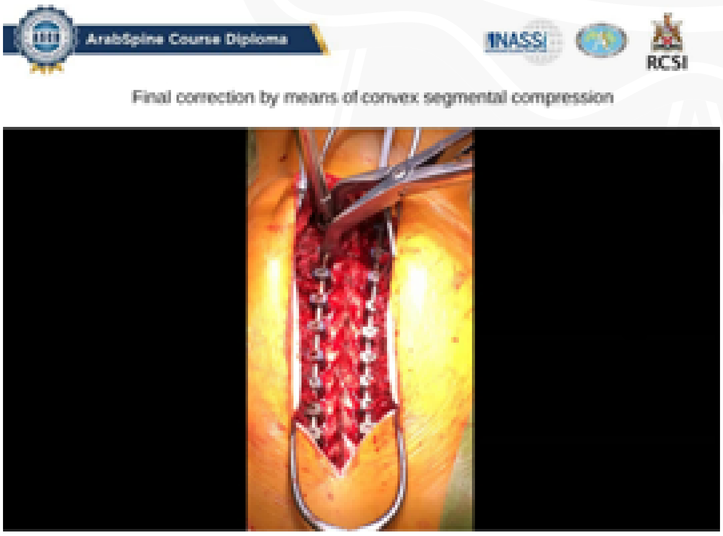
Correction my means of rod rotation maneuver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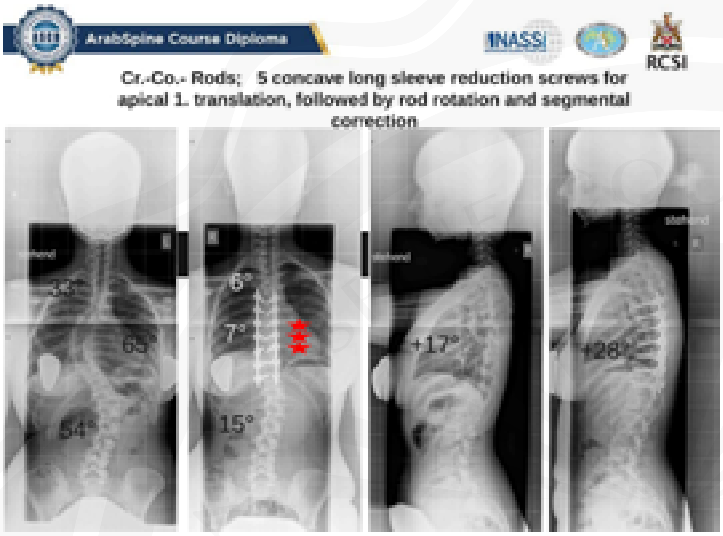
Final correction by means of convex segmental compression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Cr.-Co.- Rods; 5 concave long sleeve reduction screws for apical 1. translation, followed by rod rotation and segmental correction
34°
63°
54°
6°
7°
15°
+17°
+28°


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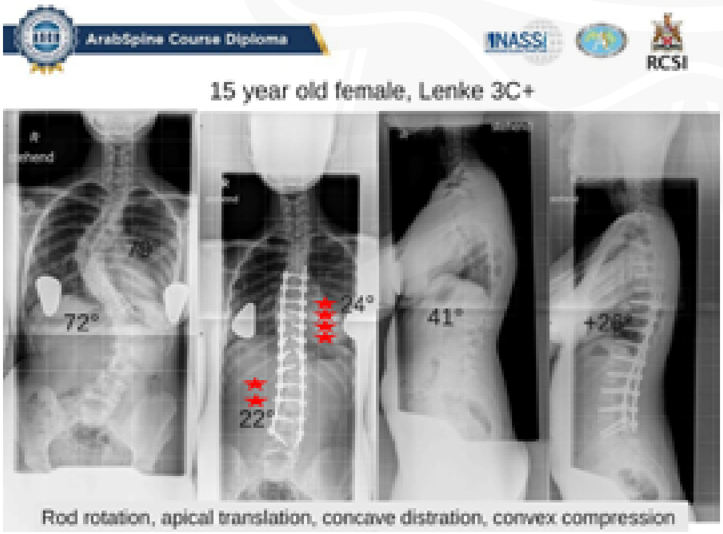
Lenke 2 curve: double major thoracic: upper major curve normally more rigid,
Thus avoid overcorrection of caudal major curve in relation to cranial major curve
Puno et al. (Spine 2003) „Correction of the upper thoracic curve, the first thoracic vertebral tilt and left shoulder elevation were better in the group with both thoracic curves fused"
CSVL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15 year old female, Lenke 3C+
79°
72°
24°
22°
41°
+28°
Rod rotation, apical translation, concave distraction, convex compression

With severity of scoliosis, the risks increase

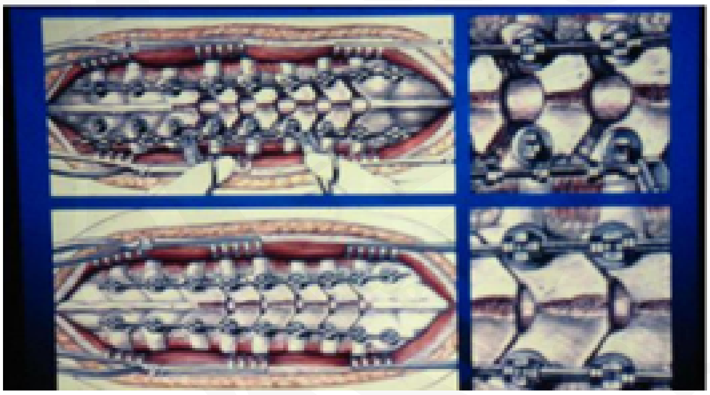
-Need for additional release or osteotomies

Additional anterior release doubles risk of complications

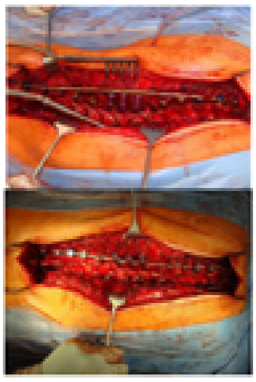
Osteotomies significantly increase complication rates

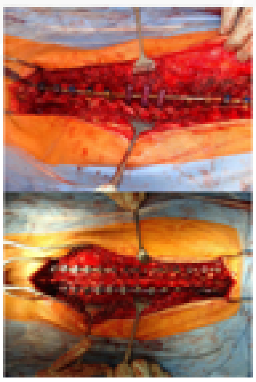
Try to convince adolescents with progressive scoliosis and their parents to have surgery done at early stage
-thoracic curves >50° Cobb angle
-lumbar curves > 40° Cobb angle

Ponte osteotomies (Zielke): multiple SPO´s (Schwab 2)



Chrome-Cobalt rods (5,5mm) and long sleeve reduction screws at concave apex to reduce lateral curvature and hypokyphosis



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16-year old boy, idiopathic thoracic scoliosis (Lenke 1)


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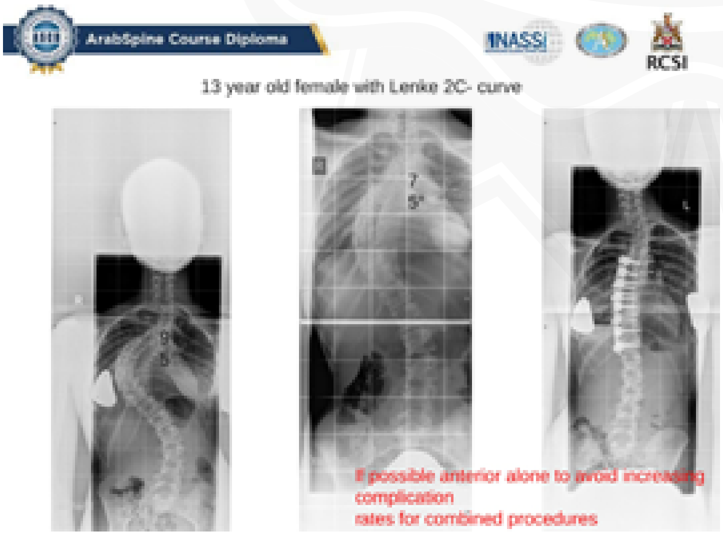
Lenke 1A-: convex anterior compression
increases kyphosis
End to end vertebra fusion levels allow for
shorter fusions
16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13 year old female with Lenke 2C- curve
If possible anterior alone to avoid increasing
complication
rates for combined procedures


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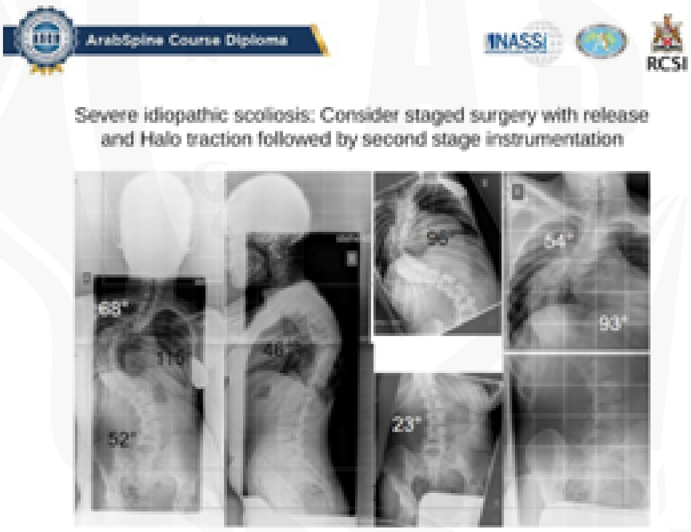
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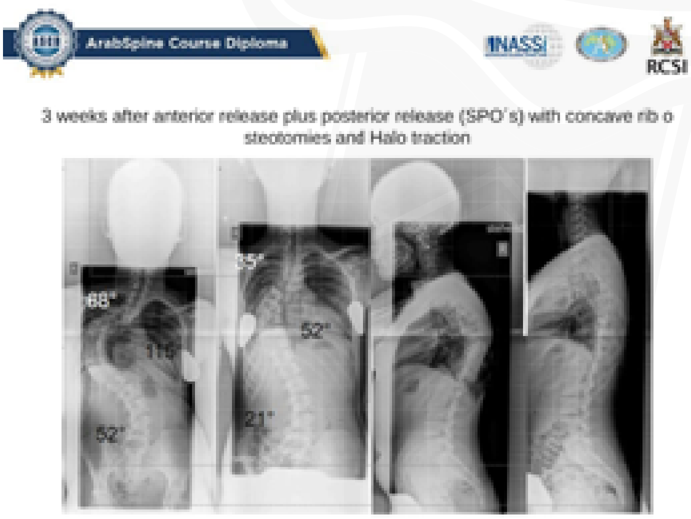
Severe idiopathic scoliosis: Consider staged surgery with release and Halo traction followed by second stage instrumentation
68°
115
52°
46°
96°
54°
93°
23°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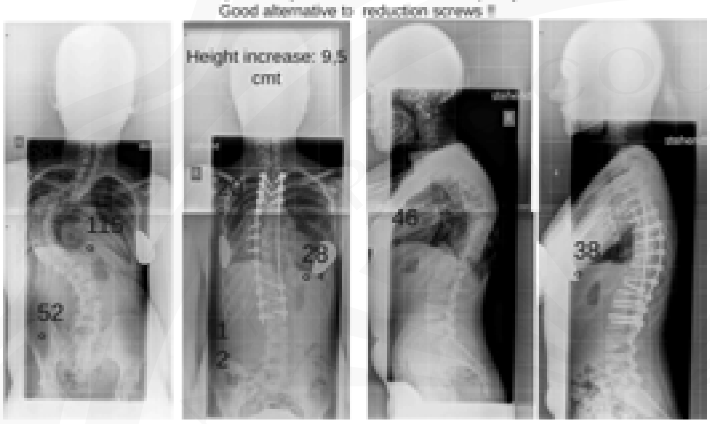
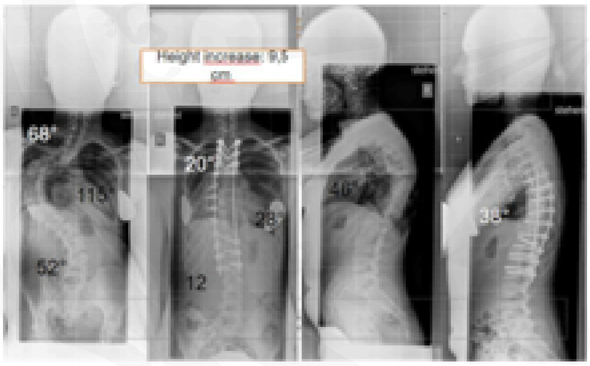
3 weeks after anterior release plus posterior release (SPO´s) with concave rib o steotomies and Halo traction
68°
115
52°
35°
52°
21°

Final result after further correction with convex cantilever technique and segmental compression plus concave costothoracoplasty
Good alternative to reduction screws !!



Final result after further correction with convex cantilever technique and segmental compression plus concave costothoracoplasty
Good alternative to reduction screws !!



Why is staged surgery with Halo traction a valid option ?

Posterior Vertebral Column Resection (PVCR) is the only alternative

-significantly increased neurological risk

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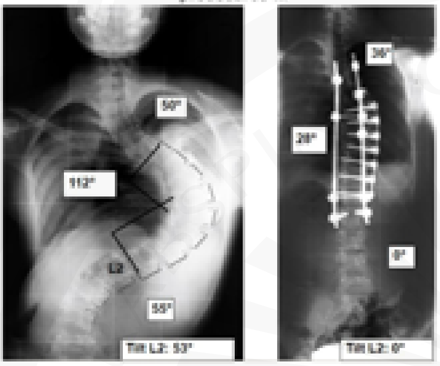
Management of severe AIS (>90-100 degrees): combined anterior/posterior procedures !!!



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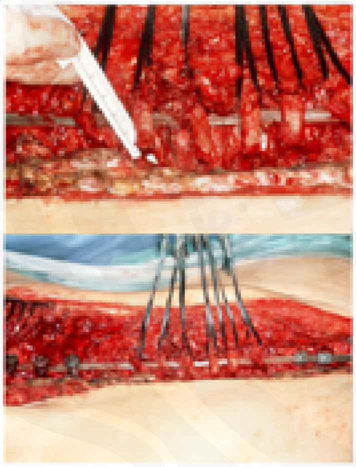

Concave rib osteotomies and rib valley elevation according to Stagnara

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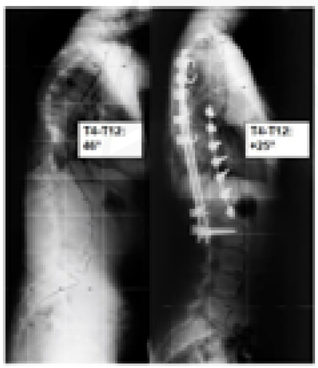

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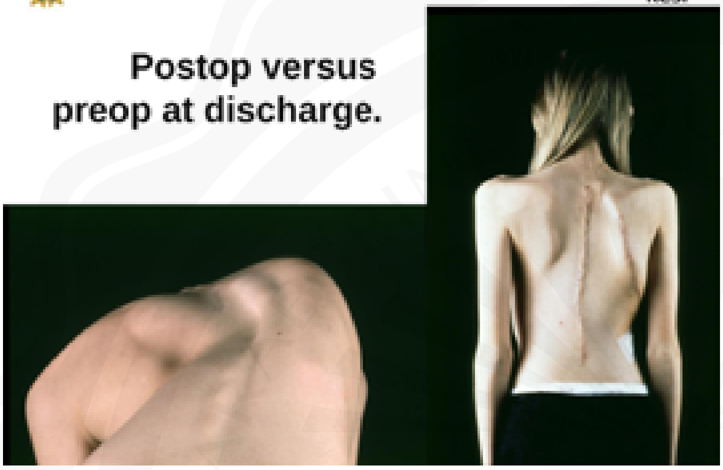
Postop versus preop at discharge.



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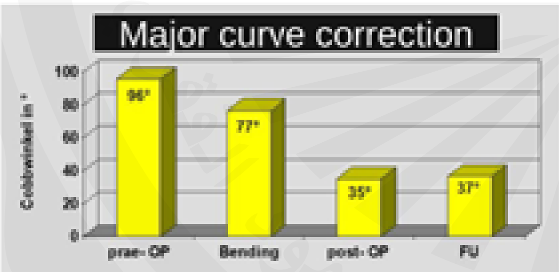
Results



Bullmann et al. (Eur Spine J. 2005)

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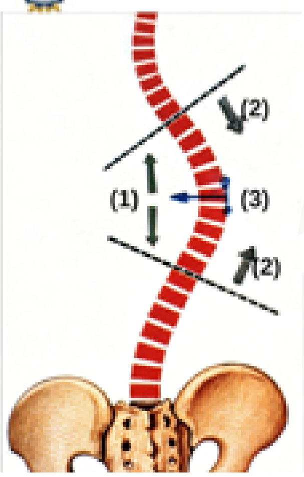


Correcting Principles

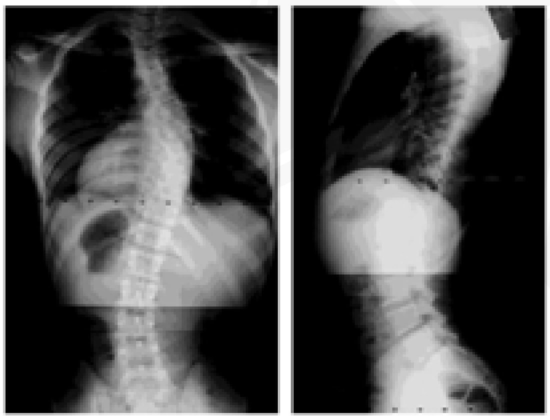
1. Distraction (concav)
2. Compression (convex)
3. Translation (at/near Apex)

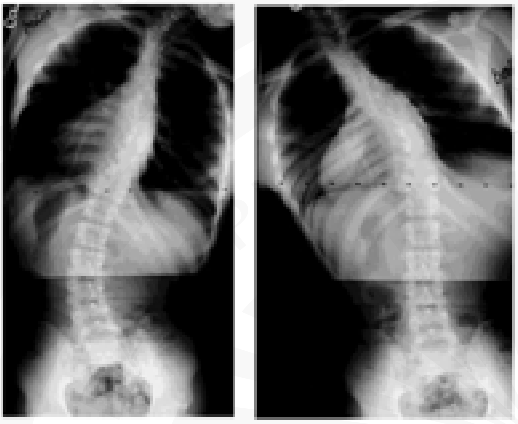
4. Derotation !!! Better with anterior

Anterior vs Posterior Approach in Adolescent Idiopathic Scoliosis

Case

- 14 yo male
- AIS
- Initial evaluation at age 12 : T4 – T10 29^0
- F/U 2.5 years later
- Curve 47^0





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Options?

1. Anterior approach
2. Posterior approach

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Anterior Approach

- Traditionally used for lumbar and thoracolumbar curves
- Popularized in the late 90's for thoracic curves by the Deformity Study Group
- May be open or thoracoscopic (VATS)

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Anterior Approach
Open vs. VATS

- Several studies show similar correction
- VATS seems to have less impact on pulmonary function
- VATS is associated with longer OR time but better cosmetic result (scar)

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A prospective comparison of thoracoscopic vs open anterior instrumentation for idiopathic thoracic scoliosis in children

Greenwall H, Betz RR, D'Andrea LP, Clements DH, Porter ST.
J Pediatr Surg. 2005 Jan;40(1)

- 155 children
- 114 open, 41 thoracoscopic
- Similar correction however longer OR time and more blood loss in thoracoscopic group

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Perioperative changes in pulmonary function after anterior scoliosis instrumentation: thoracoscopic versus open approaches

Faro FD, Marks MC, Newton PO, Blanke K, Lenke LG.
Spine. 2005 May 1;30(9)

- 54 patients with AIS
- 23 open, 31 thoracoscopic
- Smaller decline in PFTs at 3 months and 1 year in thoracoscopic group

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Advantages of Anterior Approach

- Save fusion levels??
- Improve thoracic hypokyphosis

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Anterior single-rod instrumentation of the thoracic and lumbar spine: saving levels

Lowe TG, Betz R, Lenke L, Clements D, Harms J, Newton P, Haher T, Merola A, Wenger D

- Single-rod anterior instrumentation will often save one to three distal fusion levels in major thoracic, thoracolumbar or lumbar curves
- Anterior single-rod instrumentation because of its kyphogenic nature will predictably improve hypokyphosis of the thoracic spine

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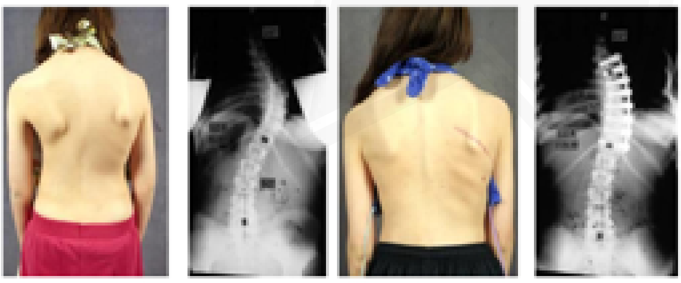


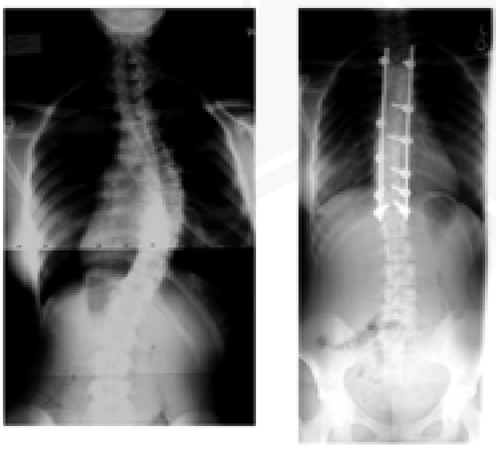
Advantages of Posterior Approach

- Surgeon familiarity
- No violation of chest wall
- Improved correction with pedicle screws?

Comparative analysis of pedicle screw versus hybrid instrumentation in posterior spinal fusion of adolescent idiopathic scoliosis.

Kim YJ, Lenke L, Kim J, Bridwell KH, Cho SK, Cheh G, Sides B.
Spine. 2006 Feb 1;31(3)

- 58 AIS patients
- 29 pedicle screws and 29 hybrid
- Pedicle screws resulted in significantly better correction



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Anterior vs. Posterior (Pedicle Screw)

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Complications in spinal fusion for adolescent idiopathic scoliosis in the new millennium. A report of the Scoliosis Research Society Morbidity and Mortality Committee.

Coe JD, Arlet V, Donaldson W, Berven S, Hanson DS, Mudiyam R, Perra JH, Shaffrey CI.
Spine. 2006 Feb 1;31(3)

- 6334 patients
- Overall complication rate 5.7%
- Anterior fusion (1164 patients): 5.2% complication rate
- Posterior fusion (4369 patients): 5.1% complication rate
- Combined Ant/Post procedures (801 patients): 10.2% complication rate

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Radiographic outcomes of anterior spinal fusion versus posterior spinal fusion with thoracic pedicle screws for treatment of Lenke Type 1 adolescent idiopathic scoliosis curves.

Potter BK, Kuklo TR, Lenke LG.
Spine. 2005 Aug 15;30(16)

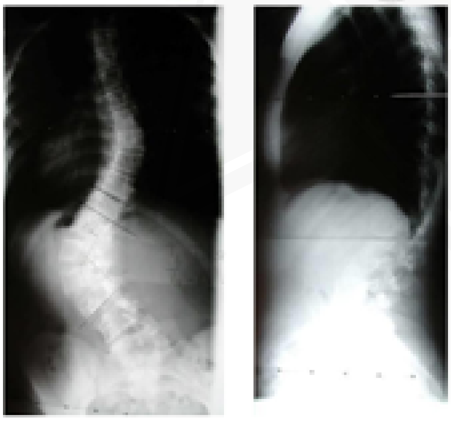
- 40 patients (20 anterior and 20 posterior)
- Curve-matched cohort
- PSF with pedicle screws provided better correction of main thoracic curve and spontaneous correction of TL/L curves with improved correction of thoracic torsion and rotation with only one additional spinal segment fused on average
- Thoracic kyphosis decreased 4.4^0 in the PSF group compared to an increase of 5.7^0 in the ASF group

Summary

- Pendulum appears to have swung back to posterior approaches
- Improved correction with pedicle screws
- Hypokyphosis may be a problem

Combined Anterior Posterior Fusion

- Large rigid curves - ??? Posterior osteotomies
- Young patients at risk for crankshaft - ??? Pedicle screw fixation



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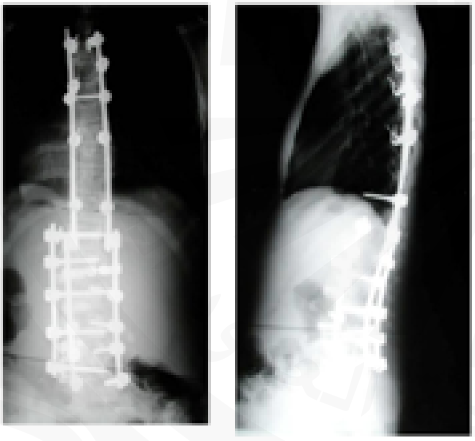

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Video-Assisted Thoracoscopic Surgery in the Prone Position

Andrew G. King, MB, ChB, FRACS,*† Tara E. Mills, BS,† William A. Lee, Jr, MD,†‡
Norman B. Chutkan, MD,*† and Tim S. Revels, MD*


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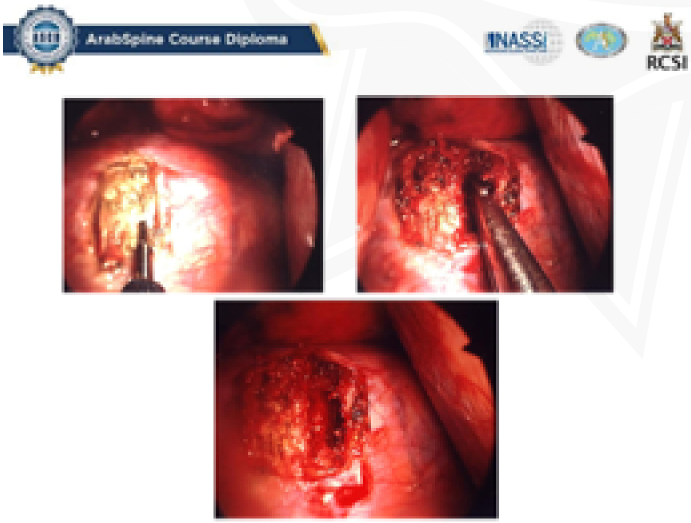
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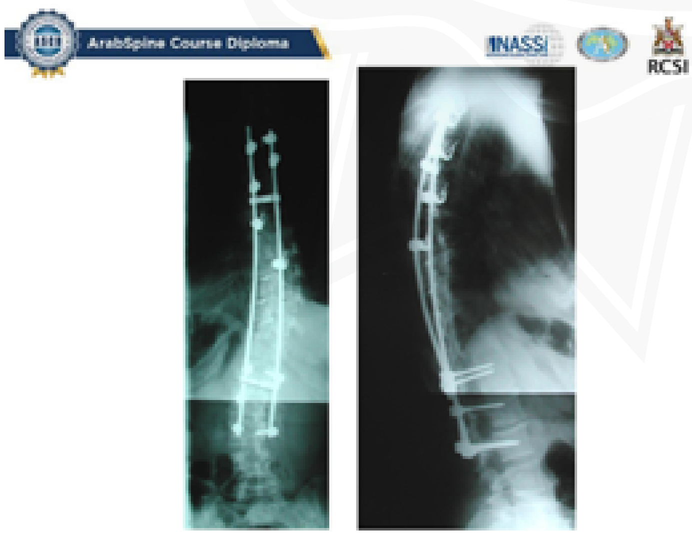
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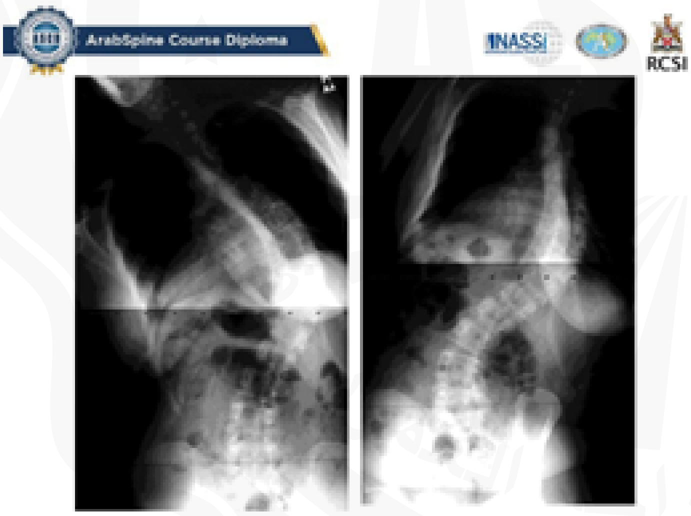
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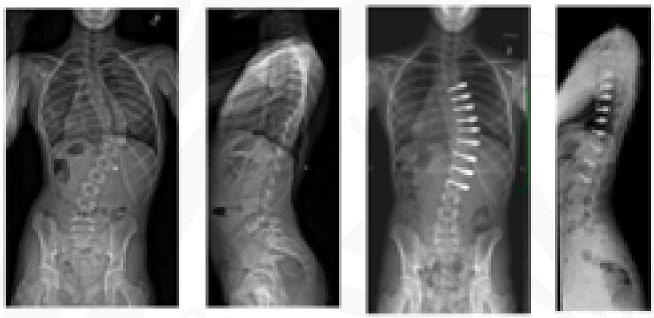
Vertebral Body Tethering



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Spine (Phila Pa 1976). 2014 Sep 15;39(20):1688-93. doi: 10.1097/BRS.0000000000000472.

Anterior vertebral body tethering for idiopathic scoliosis: two-year results.

Samdani AF[1], Ames RJ, Kimball JS, Pahys JM, Grewal H, Pelletier GJ, Betz RR.

Author information

Abstract

STUDY DESIGN: Retrospective review.

OBJECTIVE: To report the 2-year results of the initial cohort undergoing anterior vertebral body tethering (VBT).

SUMMARY OF BACKGROUND DATA: Anterior VBT is a promising new technique with abundant preclinical studies but very few clinical results. It is a growth modulation technique, which utilizes patients' growth to attain progressive correction of their scoliosis. We report 2-year results of the initial cohort undergoing this procedure.

METHODS: After obtaining institutional review board approval, we retrospectively reviewed our first 11 consecutive patients who underwent anterior VBT with 2-year follow-up. We collected pertinent preoperative, intraoperative, and most recent clinical and radiographical data. Student t test and Fisher exact test were utilized to compare different time points.

RESULTS: Eleven patients with thoracic idiopathic scoliosis (8 females) were identified, with a mean age of 12.3 ± 1.6 years. Preoperatively, all were skeletally immature (Sanders mean = 3.4 ± 1.1; Risser mean = 0.6 ± 1.1). All underwent tethering of an average of 7.8 ± 0.6 (range: 7-9) levels, with the most proximal being T5 and the most distal L2. Preoperative thoracic Cobb angle averaged 44.2 ± 9.0° and corrected to 20.3 ± 11.0° on first erect, with progressive improvement at 2 years (Cobb angle = 13.5 ± 11.6°, % correction = 70%; P < 0.00002). Similarly, the preoperative lumbar curve of 25.1 ± 6.7° demonstrated progressive correction (first erect = 14.9 ± 4.9°, 2 yr = 7.2 ± 5.1°, % correction = 71%; P < 0.0002). Thoracic axial rotation as measured by a scoliometer went from 12.4 ± 3.3° preoperatively to 6.9 ± 3.4° at the most recent measurement (P < 0.01). No major complications were observed. As anticipated, 2 patients returned to the operating room at 2 years postoperatively for loosening of the tether to prevent overcorrection.

CONCLUSION: Anterior VBT is a promising technique for skeletally immature patients with idiopathic scoliosis. This technique can be performed safely and can result in progressive correction.

LEVEL OF EVIDENCE: 4.

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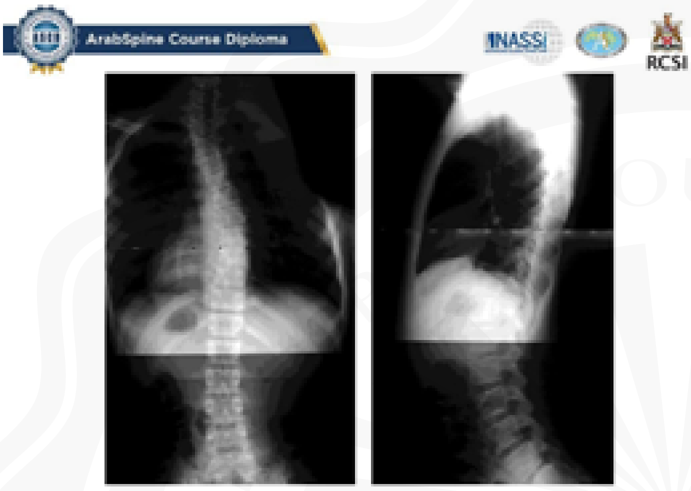
Case

- 14 yo male
- AIS
- Initial evaluation at age 12 : T4 – T10 29^0 Risser 3+
- F/U 2.5 years later
- Curve 47^0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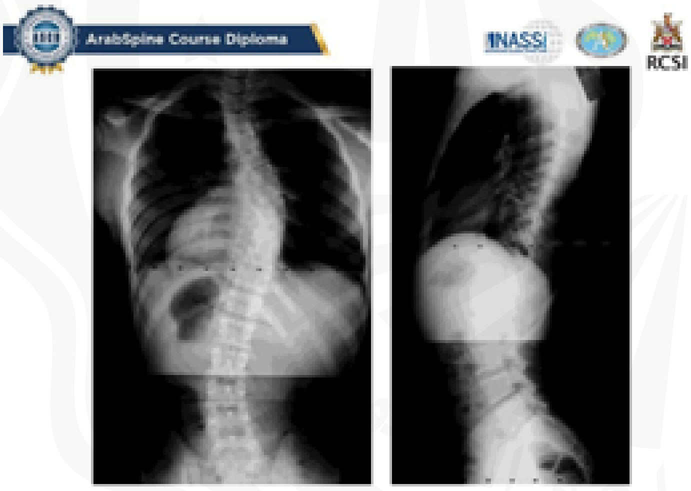
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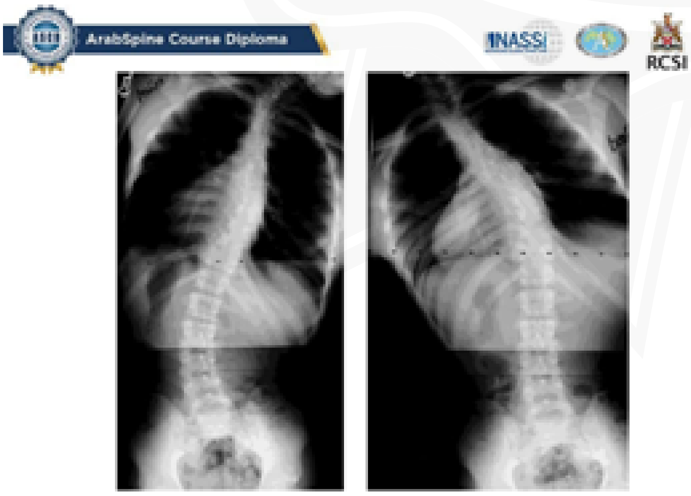
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Preoperative Optimization of the Adult Deformity Patient

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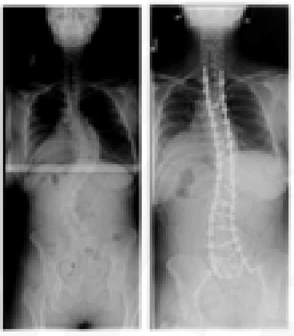
Spinal Deformity Surgery



- Complications range 25% to 80%
- Overall complication rate ~40%
  - Yadla et al. - 41.2%
- Daubs et al. –
  - 37.5% overall complication
  - 20% major morbidity
  - Mean OR time of 10hrs
  - Average EBL 2L
    - 5U pRBC
  - Average LOS 13.5 days
  - Pseudoarthrosis – 12.9%
  - 33% reoperation rate
- Infection rate 5-10%
- ~25% PJK

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Risk Factors for Complications

- Surgical Invasiveness/Complexity
  - Deyo et al. - Odds ratio for life-threatening complications was 2.95 for complex fusion compared with decompression
  - PSO 7x more likely for major complications
- Age
  - >69y/o associated with 9x risk of major complications
- Blood loss
  - Cho et al. found significant blood loss associated with increased peri-operative complications – 2.1L

"Nurse, get on the internet, go to SURGERY.COM, scroll down and click on the 'Are you totally lost?' icon."

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Potential Opportunity Targets

- Optimizing the patient's risk factors
  - Patient selection
  - Improving on patient physiology and medical condition
- Alter the surgical Approach
  - Decrease surgical invasiveness
  - Minimizing surgical blood loss

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Complication Prevention in ASD

- Preparation for prevention is paramount
- "By failing to prepare, you are preparing to fail."
  - By Benjamin Franklin
- "An ounce of prevention is worth a pound of cure."
  - By Benjamin Franklin

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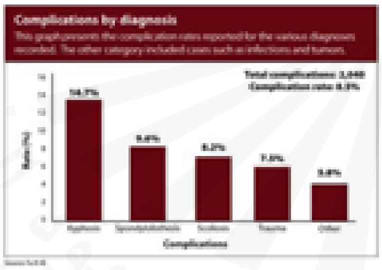
Potential Complications for ASD

- Neurologic
- Cardiovascular
- Pulmonary
- Nutrition
- Osteoporosis
- Other



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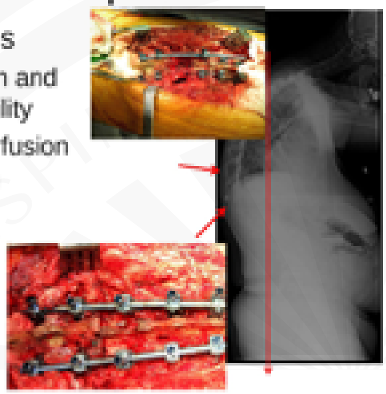
Neurologic Complication

- Risk factors
  - Cord compression
    - Cervical vs. thoracic vs. lumbar
  - Spinal instability
    - 3-column osteotomy
  - Cardiovascular co-morbidity
  - Acute blood loss

Neurologic Complications

- Prevention strategies
  - Wide decompression and maintain spinal stability
  - Maintaining cord perfusion
    - Keep MAP>85mmhg
    - Pre-induction BP?
  - Neurophysiological Monitoring
    - MEP
    - SSEP
    - EMG



Cardiac Risk

Major Criteria
- CAD
- Cerebrovascular disease
- IDDM
- Renal insufficiency

– Minor Criteria (>2 needed)
- Age >64
- Hypertension
- Smoking
- Hypercholesterolemia
- NIDDM

Hu and Berven. Spine 31:19 supplement. 2006.

Cardiac Risk

- What to do with high risk patients
  - Preoperative Stress test
  - Cardiology evaluation
  - Perioperative β-Blockade
    - Titrate to HR 60-80
    - 90% reduction in perioperative cardiac events
    - Reduced 1 and 2 year mortality

Hu and Berven. Spine 31:19 supplement. 2006.

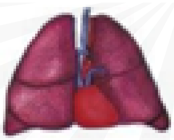
Pulmonary Risk

- Smoking
  - Risk increase with increasing pack/years and duration of surgery
  - Pulmonary complications up 4.3x
  - 6 months tobacco free risk significantly reduced
  - < 8 weeks tobacco free actually increases risk

Hu and Berven. Spine 31:19 supplement. 2006.

Pulmonary risk

- COPD
  - Relative risk 4.7x that of normal
  - PFTs and ABG inaccurate predictors of risk
  - Exercise tolerance test most closely correlates with outcome
    - >2 minutes of sustained supine exercise to a HR > 99.



Hu and Berven. Spine 31:19 supplement. 2006.

Medical Risk

- Nutritional
  - Significant impact on outcome after surgery
    - Significant increase in complications
      - Wound infections
      - Pneumonia
      - Increased hospital and ICU stays

Medical Risk

- Nutritional
  - Risk Factors
    - Age >60
    - Diabetes
    - Osteomyelitis
    - Spinal Cord Injury
    - Chronic disease

Klein et. al. Spine 1996

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Medical Risk

- Nutritional
  - Preoperative screening
    - Total Lymphocyte Count
    - Albumin level
    - Prealbumin level
  - Nutritional Supplementation
    - Enteral feeding
    - TPN
    - Especially if staged surgery

Lapp et. al. Spine 2001.

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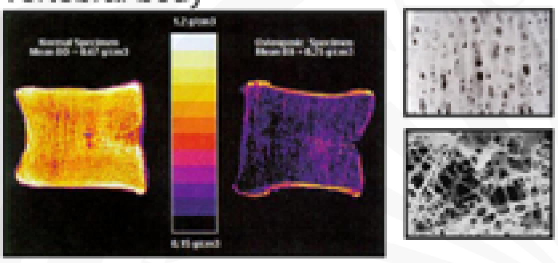
Osteoporosis

- Increasing problem
  - 1980: 12% of US > 65 yo
  - 2020: 17% of US > 65 yo
  - 2050: estimated 22% (68 million people!)
- Increased life expectancy
  - At age 65 → male 79 yo, female 83*

*US Bureau of Census

Osteoporosis

- Differential bone loss occurs within the vertebral body



Computed quantitative radiography (CQT)

Antonacci et al. Spine 22(20). 1997.

Osteoporosis

- Risk factors for fracture
  - Caucasian race
  - Age > 50
  - Postmenopausal
  - Female
  - Smoking
  - History of any fracture over age 40
  - History of fracture of Hip, Spine or Wrist in a first degree relative

Hu and Berven. Spine 31:19 supplement. 2006.

Osteoporosis

- Primary Vs. Secondary Osteoporosis
  - 95% are primary (idiopathic)
  - 5% secondary
    - Hyperthyroidism
    - Hypercortisolism
    - Estrogen withdrawal
    - Renal Failure
    - Steroid use
    - Alcohol and tobacco use

Hu and Berven. Spine 31:19 supplement. 2006.

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Complications Associated with Osteoporosis in Adult Spinal Deformity (ASD) Surgery

- Instrumentation failures
  - Screw pull-out
  - Cage subsidence
- Proximal junctional failures
  - Screw pull-out
  - Fractures
- Pseudoarthrosis
- Consider altering surgical strategy

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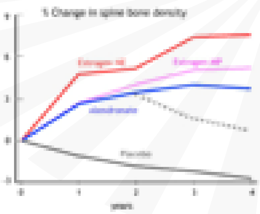
Osteoporosis

- Treatment
  - Vitamin D
  - Antiresorptive agents
    - Bisphosphonates
    - Calcitonin
    - Estrogens
    - Estrogen receptor modulators
  - Teriparatide (Forteo)
  - Treat primary disease in secondary Osteoporosis



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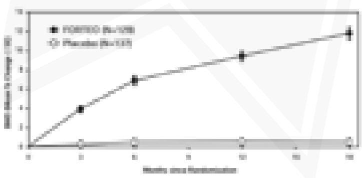
- Forteo (Teriparatide)
  - Recombinant human parathyroid hormone, [rhPTH(1–34)]



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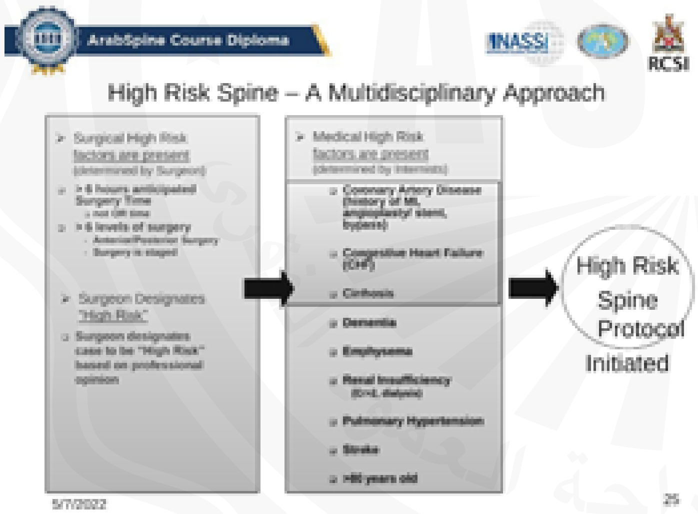
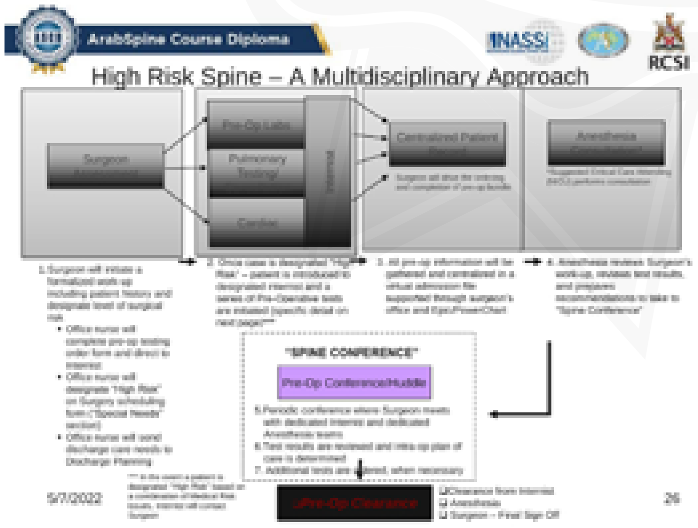
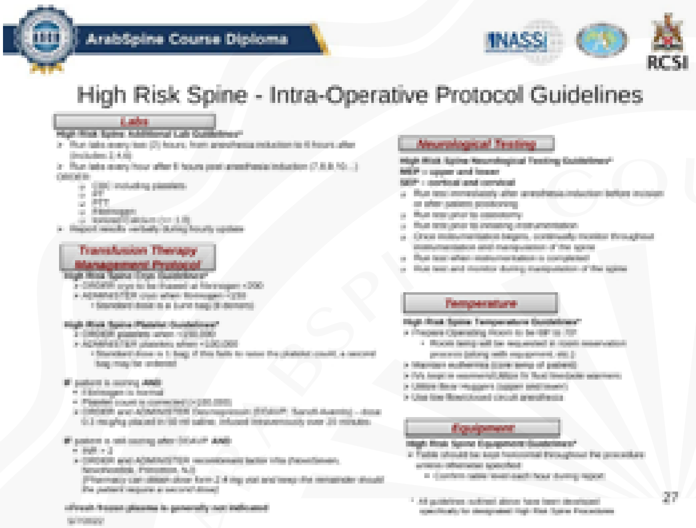
Formula for Success to Minimize Peri-Operative Complications

- Extensive preoperative screening
- Multidisciplinary involvement
  - Collaborate
  - Communicate
  - Follow up



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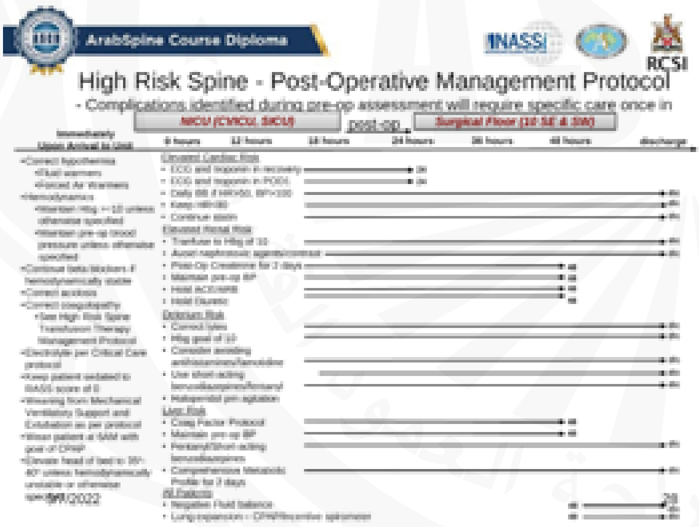
High Risk Spine - Intra-Operative Protocol Guidelines
Labs
Transfusion Therapy Management Protocol
Neurological Testing
Temperature
Equipment
27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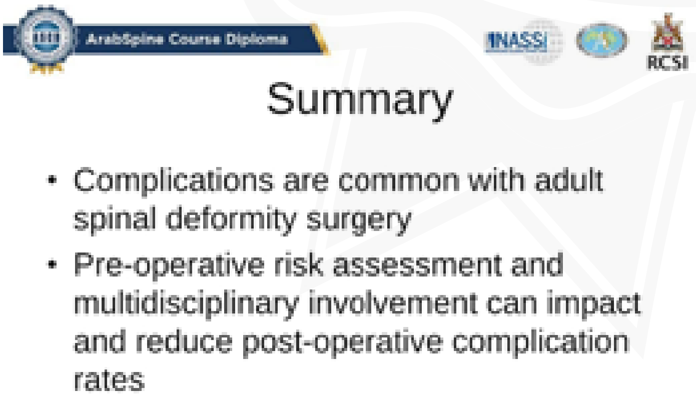
High Risk Spine - Post-Operative Management Protocol
- Complications identified during pre-op assessment will require specific care once in post-op
NICU (CVICU, SICU)
Surgical Floor (10 SE & 5W)
28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Summary
• Complications are common with adult spinal deformity surgery
• Pre-operative risk assessment and multidisciplinary involvement can impact and reduce post-operative complication rates

Roles and Options of Osteotomies in Deformity Correction

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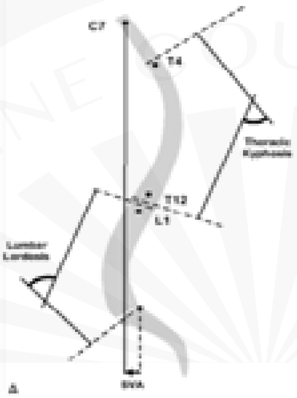
Sagittal Alignment

- Is the **relationship** between the **normal sagittal curves** of the spine to center the head on the pelvis with the least energy expenditure.
- Normal curves:
  Cervical lordosis (≈30°)
  Thoracic kyphosis (10°-40°)
  Lumbar lordosis (40°-60°)
  These curves should create alignment the occiput over the sacropelvic axis.
- Hips and Knees share spine and pelvis in sagittal dybamic balance control.



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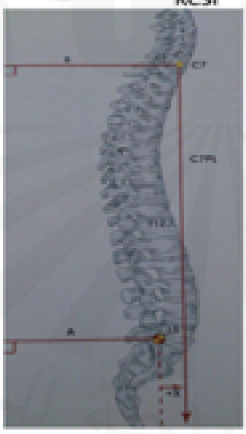
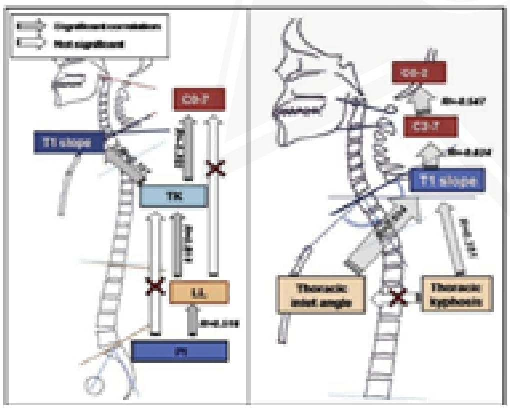
- Sagittal vertical axis (plumb line):
  - From center of C7 downwards.
  - Normally pass within 0.5 cm from the postero-superior aspect of S1.
  - Offset >2.5-4 cm ant. Or post. is abnormal.
- Thoracic kyphosis: from T2-T12
- Lumbar lordosis: from T12-S1

Normally lumbar lordosis should be 30° more than thoracic kyphosis



Factors determining cervical spine sagittal balance in asymptomatic adults: correlation with spinopelvic balance and thoracic inlet alignment

Sang-Hun Lee, MD, PhD[a,*], Eun-Seok Son, MD, PhD[b], Eun-Min Seo, MD, PhD[c], Kyung-Soo Suk, MD, PhD[a], Ki-Tack Kim, MD, PhD[a] The Spine Journal (2013)



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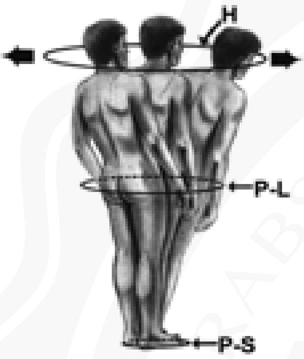
Cone of economy



Jean Dubousset

- Muscle demand
- Fatigue
- Pain/Disability
- Loss of forward gaze
- Loss of head over pelvis

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*

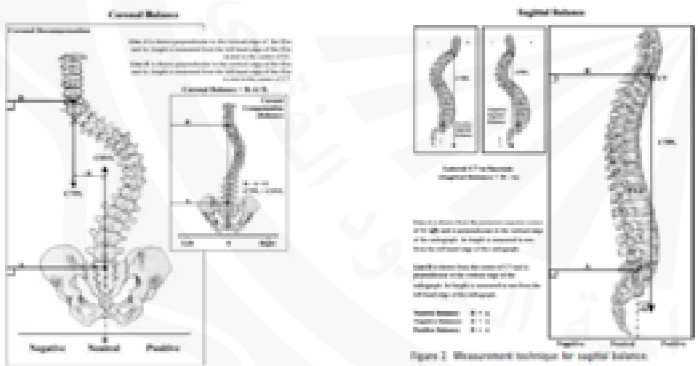


Figure 2. Measurement technique for sagittal balance.

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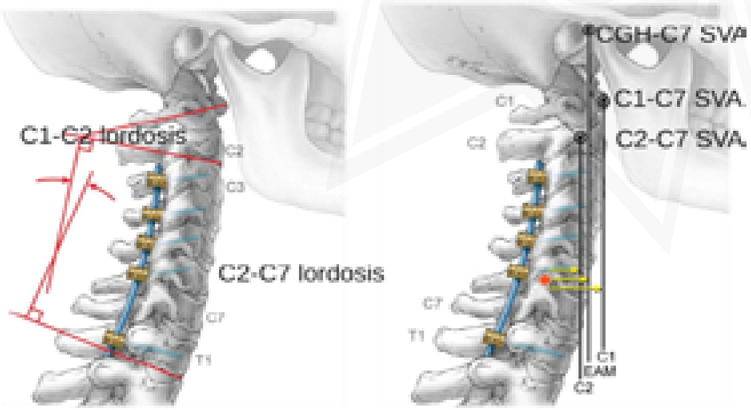
Cervical Measurements



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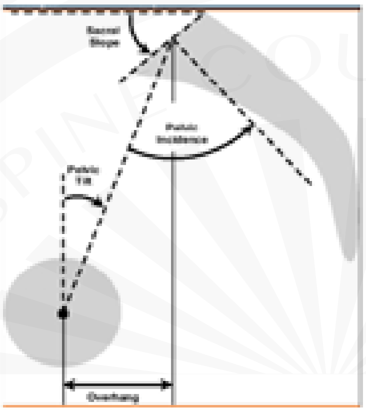
- Sacropelvic parameters:

- Pelvic incidence(PI): (50°-60°)
- Sacral slope (SS)
- Pelvic tilt angle (PT)

"PI = SS+PT"

" Lumbar lordosis is greatly related to PI"



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Causes of Sagittal imbalance

- **Primary spine causes:**

-All causes of kyphosis (congenital, ankylosis, Scheuermann, neuromuscular,........)
- Destructive lesions(Tumors, infections)
- Traumatic lesions (fractures)
-Degenerative lesions (multilevel disc disease, high grade spondylolythesis)

- **Secondary spine causes:**

- Iatrogenic flat back
- Postlaminectomy kyphosis
- Adjacent segment disease

- **Extra spinal causes:**

- Hips and knees contractures

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- There are two types of spinal imbalance in the sagittal plane:

Type 1: segmental or regional imbalance in the sagittal plane of the spine but still has a balanced spine (wedge fracture).

Type 2: global imbalance whereby the plumb line falls >5 cm in front of the L5-S1 disc (ank spond).

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Decision Making Regarding Smith-Petersen *vs.* Pedicle Subtraction Osteotomy *vs.* Vertebral Column Resection for Spinal Deformity

SPINE Volume 31, Number 19 Suppl, pp S171–S178
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Keith H. Bridwell, MD

Type 1 and 2 Coronal Decompensation. Relationship Of Shoulders To The Pelvis

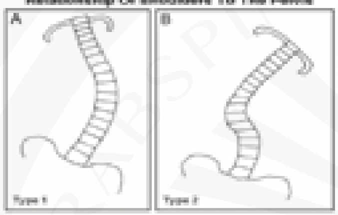

Figure 5. Type 1 and 2 coronal decompensation. (A) Depiction of Type 1 coronal deformity. With Type 1, shortening the spine on the right side will rebalance the spine. (B) Depiction of Type 2 coronal deformity. With Type 2, shortening one side of the spine will not accomplish coronal rebalancing.

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Decision Making Regarding Smith-Petersen *vs.* Pedicle Subtraction Osteotomy *vs.* Vertebral Column Resection for Spinal Deformity

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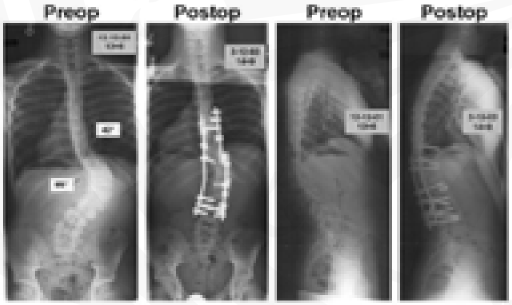

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- Bridwell classification of curves:

  - Totally flexible
  - Partially flexible through mobile segments
  - Totally inflexible (rigid)

PREOP SCENARIOS OF 3 FLEXIBILITY

- Type A – Flexible (passive)
- Type B – Stiff (actively correctable)
- Type C – Fixed/Stuck – not correctable preop

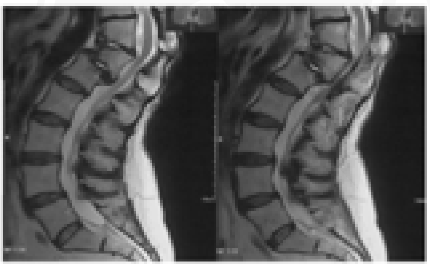
Larry Lenke

Radiographic Evaluation

- 36" Standing films:
  - Global alignment
  - Regional alignment
  - Segmental alignment
- Bending films
  - Passive
    - Fulcrom/bolster
    - Traction
    - Push-prone
  - Active
    - Supine Bending

Radiographic Evaluation

- 36" Standing films:
  - Supine over a bolster
  - MRI or CT evaluation



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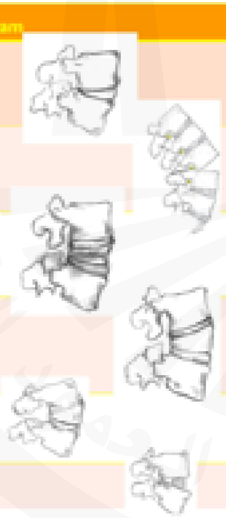
Continuum of Posterior-based Osteotomies

- Smith-Peterson Osteotomy
  - Requires osteoclasis through an ankylosed spine
  - Cervicothoracic deformity
- Ponte Osteotomy
  - Requires a mobile anterior column
- Pedicle Subtraction Osteotomy
  - Most useful in spine with prior circumferential fusion
- Apical Vertebral Column Resection

Type	Description	Diagram	Reference
1	Resection of posterior elements from mid pars above to pedicle below with realignment of the spine through hinging through a mobile disc anteriorly		Ponte
2	Resection of posterior elements from mid pars above to pedicle below with realignment of the spine through hinging through a mobile disc anteriorly		Smith-Peterson
3	Posterior based transpedicular decancellation of the vertebral body with realignment through controlled fracture of the anterior column		Heinig
4	Posterior based intraosseous wedge resection of the vertebral body with realignment through osteoclasis of the proximal third of the anterior vertebral body		Thomasen
5	Posterior based wedge resection with extension of the osteotomy into the supra-adjacent disc and realignment hinging on the anterior column at the intervertebral space		Modified Thomasen
6	Posterior based vertebral column resection including one or more vertebra with adjacent discs		Suk

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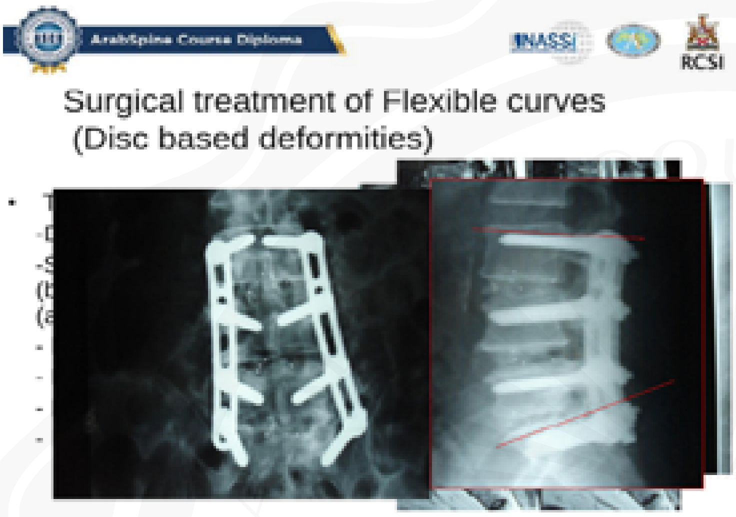
SCHWAB – SPINE MOBILIZATION ANATOMICAL CONSIDERATIONS

6 Grades of Destabilization:

1. Partial facet joint
2. Complete facet joints
3. Partial body*
4. Partial body and disc*
5. Complete body + discs*
6. >1 body, adjacent*

*posterior *vs.* anteroposterior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RCSI
Surgical treatment of Flexible curves
(Disc based deformities)


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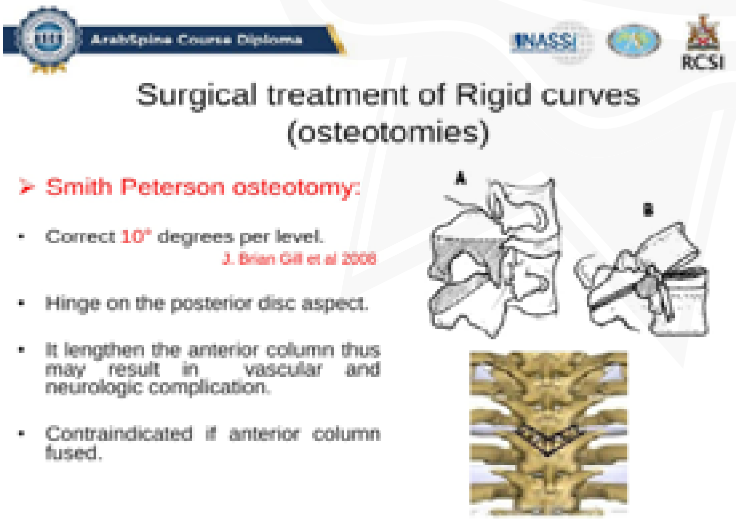
RCSI
Flexible thoracic deformity
Ponte
Journal of Spinal
Disorders & Techniques
The Ponte Procedure: Posterior Only Treatment of Scheuermann's Kyphosis Using Segmental Posterior Shortening and Pedicle Screw Instrumentation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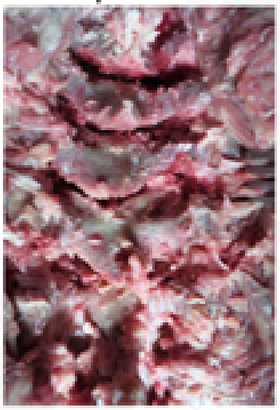
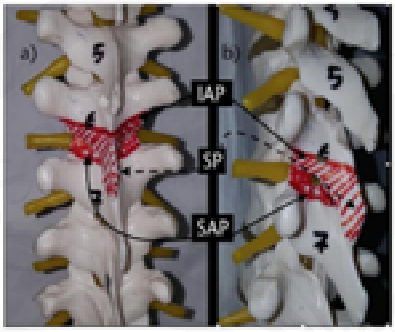
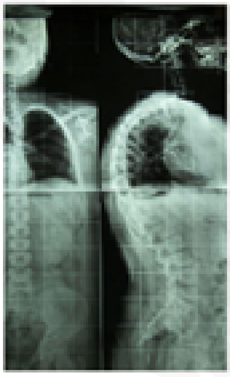
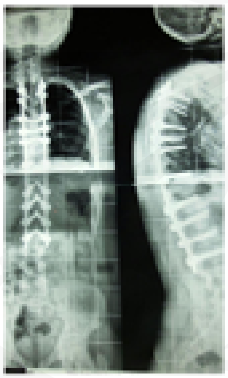
Surgical treatment of Rigid curves
(osteotomies)
Smith Peterson osteotomy:
Correct 10° degrees per level.
J. Brian Gill et al 2008
Hinge on the posterior disc aspect.
It lengthen the anterior column thus may result in vascular and neurologic complication.
Contraindicated if anterior column fused.
A
B

Multiple SPO V shaped osteotomies



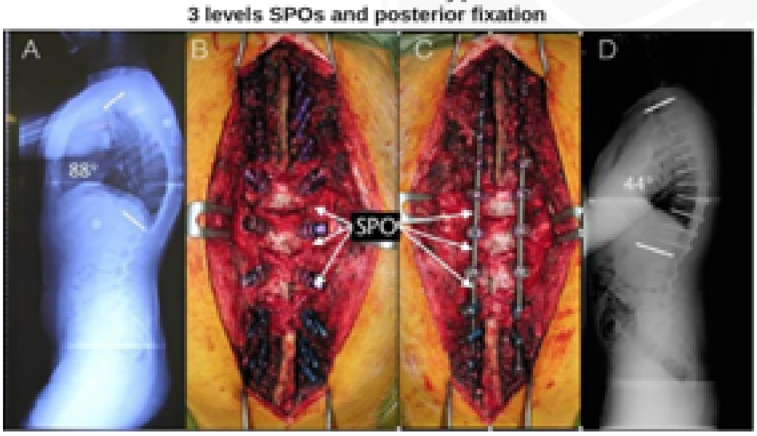






SCHEUERMAN Kyphosis

3 levels SPOs and posterior fixation



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Disadvantages:

-Limited correction

-Dural injuries

-Nerve root injuries

-Bleeding (small foraminal vessels)

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- Pedicle subtraction osteotomy:

- 3 columns osteotomy.
- 30° - 40° correction per lumbar level and 25 ° per dorsal level.
  J. Brian Gill et al 2008
- Hinge over the anterior body cortex.
- Shorten the posterior column without anterior column lengthening.

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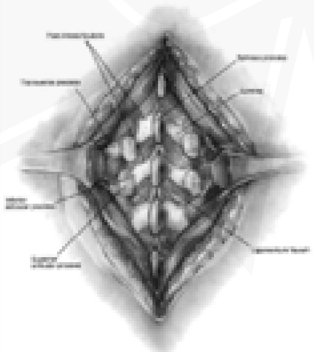
Operative steps

- **Posterior midline approach** with sub-periosteal paravertebral muscle dissection.
- Insertion of **pedicle screws** in the desired levels above and below the osteotomy level.



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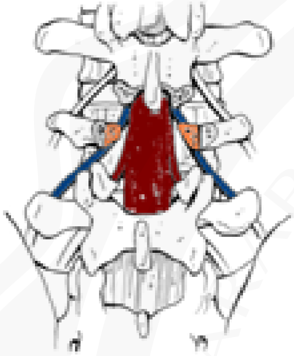
- **Wide laminectomy** over the osteotomy level and **exposure** of the **pedicle** bilaterally.

** The **dura** in long standing deformities is very **thin** and liable for injury.



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- Introduction of a **sharp osteotome** ;after **retraction of the dura**; just **above the pedicle** through the vertebral body with medial inclination.
- Introduction of the **other osteotome** below the pedicle ;after **retraction of the root;** passing below the pedicle through the body with proper angulation to produce the planned wedge.

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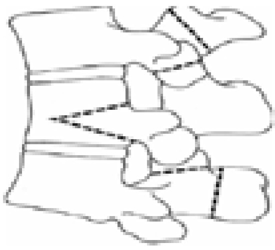
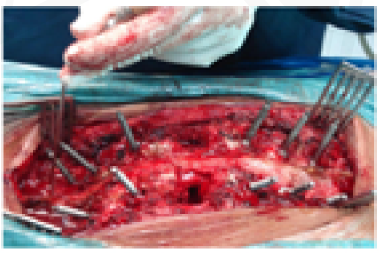
- Both osteotomes **stop behind the anterior vertebral cortex** leaving it intact.
- **Check** the position by the **image intensifier**.
- **Repeat** the same maneuver on the **contralateral pedicle**.
- **Remove the bony wedge** by manchers, curettes, rongeurs and electric burr.

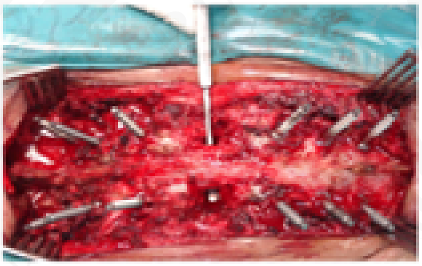




- Be sure of **removal** of the **posterior vertebral cortex** by curved curettes.

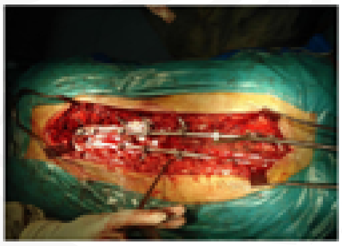
** The **dura** should be completely **free** anteriorly.

** Any **residual bone** will **buckle** against the dura when the wedge closed.

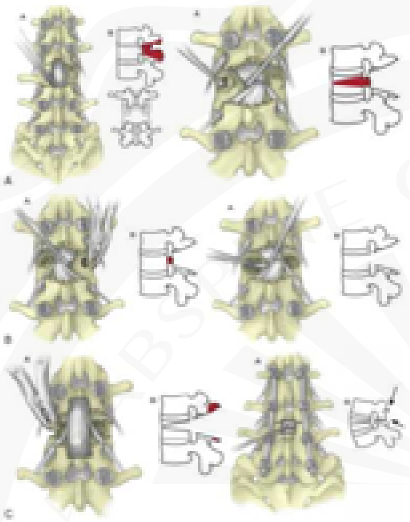


- After being sure that the dura is free all through, **extend the table** to close the wedge.

- **Assemble the rods** after contouring to the screws and apply **compression** to the screws above and below the osteotomy to finely close it.



- **Somatosensory** evoked potential or **Stagnara** wake up test.
- **Recheck the dura and roots** after closure of the wedge to be sure that they are not compressed.
- **Recheck** the **whole correction** by image intensifier.
- Closure of the wound after careful haemostasis with a **haemovac** application.



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Complications of pedicle subtraction osteotomy

- Pseudo arthrosis
  - 10 %(*Lapresle 2001)*
  - 23% (*Chiffolot 2004)*

- Metal failure

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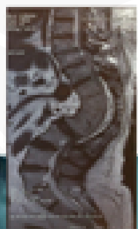
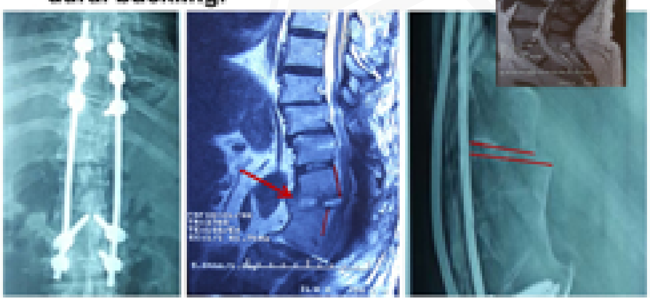
Neurological complications :

- **Deficits** due to:
  - **anterior subluxation,**
  - **residual dorsal impingement**
  - **dural buckling.**





- Jacob M. Buchowski and associates (110 patients) :
  Intra- and postoperative deficits: 10.9%
  Permanent deficits: 2.8%.

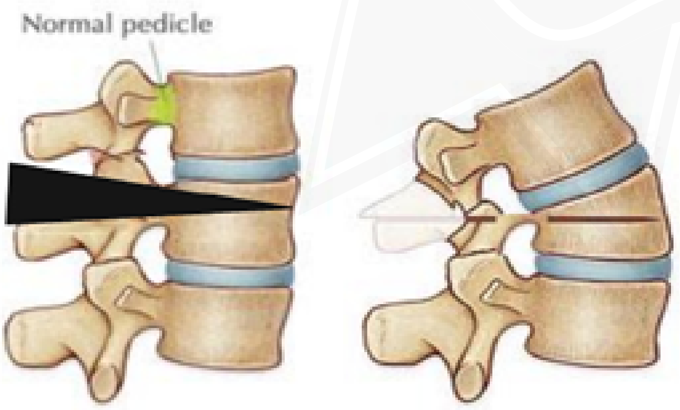
-Multicenteric french study of 402 cases: 18.7%.

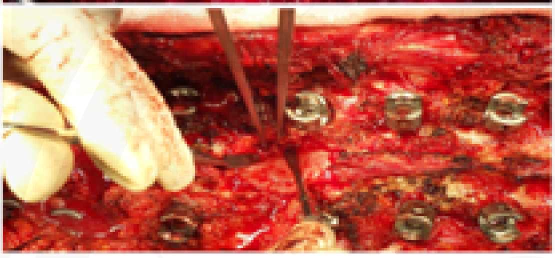
-Van Royen BJ (2006) listed among the complications of his series postoperative nerve root compression requiring reoperation.

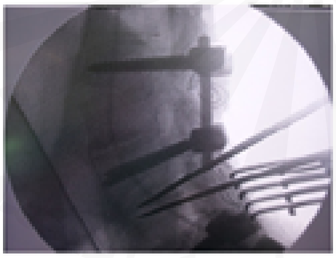
➢ Partial pedicle subtraction osteotomy:

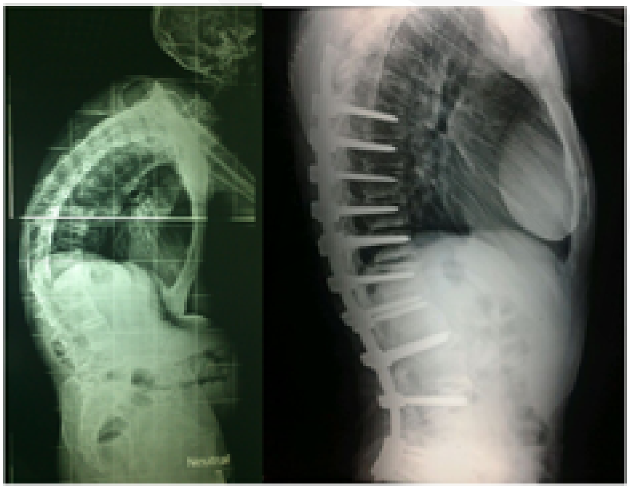
(Ain Shams Osteotomy)

- Modification of PSO.
- Preserve the lower one third of the pedicle.
- 22° per level correction.
- It protects the exiting nerve root, more smooth correction, preserve the intervertebral foramen with unchanged dimensions, no metal failure or subluxation.









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Advantages of partial pedicle subtraction osteotomy

- **Protection of the exiting nerve roots:**
  - due to preservation of the smooth inferior wall of the pedicle.
  - The vertical diameter of the intervertebral foramen unaffected.

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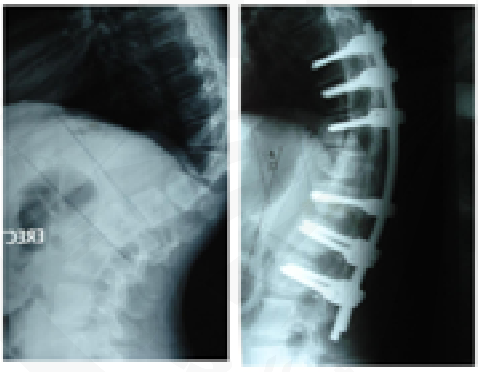
- **Being smaller wedges:**
  - Better apposition of the osteotomy site.
  - Better chances for fusion (no pseudoarthrosis).
  - No much force is needed to close the osteotomy (osteoporotic bone).



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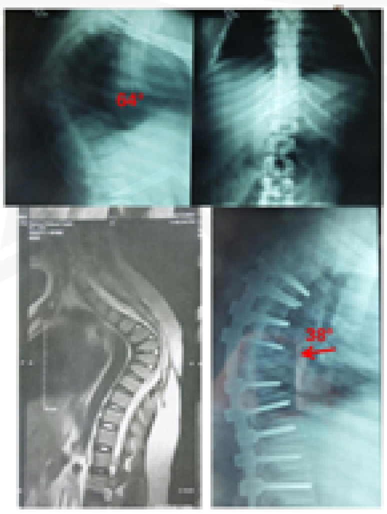
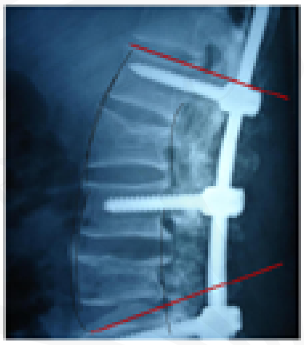
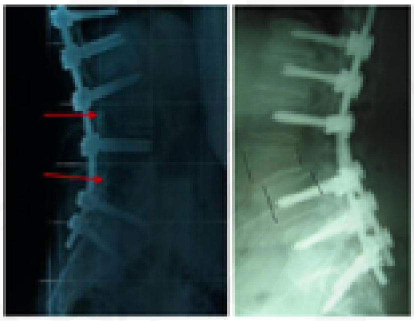
11 ys old female presented with progressive parapresis. H/O wide multilevel laminectoy for resection of cord tumour 5 ys before presentation.



- **Double level PPSO in global loss of lumbar lordosis:**
  - Provides more **smooth correction** of the deformity; rather than the sharp correction at one level.
  - It **decreases the incidence of anterior subluxation** that resulted due to closing of large wedges which endangers the neural elements posteriorly due to kinking at the osteotomy sites.



- **The remained lower third of the pedicle:**
  - **Adhere to the posterior fusion mass** and **transverse process** when fusion accomplished to connect the osteotomized vertebra to the posterior elements again.



Vertebral Column Resection

- For severe coronal, sagittal deformity, spondyloptosis, tumors.
- Resection of the entire vertebral body and the intervertebral discs above and below.
- Can be done totally posterior.
- Involve resection of a vertebra or more followed by anterior reconstruction and posterior fusion.

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- The posterior elements (spinous process and lamina), including the pedicles are removed.
- Costotransversectomy is performed with disarticulation of the rib head to get access to the lateral vertebral body.
- Once the rib is removed, a temporary rod is placed opposite the working side to stabilize the spine and protect the neural elements.
- Sacrifice of exiting nerve root in the thoracic spine is tolerated and makes exposure much easier.
- Reconstruction is needed with metal cage, structural autograft, or allograft.

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- The only procedure that will provide translation of spinal column.
- VCR reduces morbidity and complication and offers more reliable reconstruction of the vertebral column than the conventional anteroposterior VCR.

Suk et al. 2005

- Significant correction can be achieved at a single level.
- Offers the advantage of a controlled manipulation (translational and rotational) of both the anterior and posterior column at the same time through a single approach.

Lawrence G. Lenke 2007

Azmi Hamzaoglu et al. 2012

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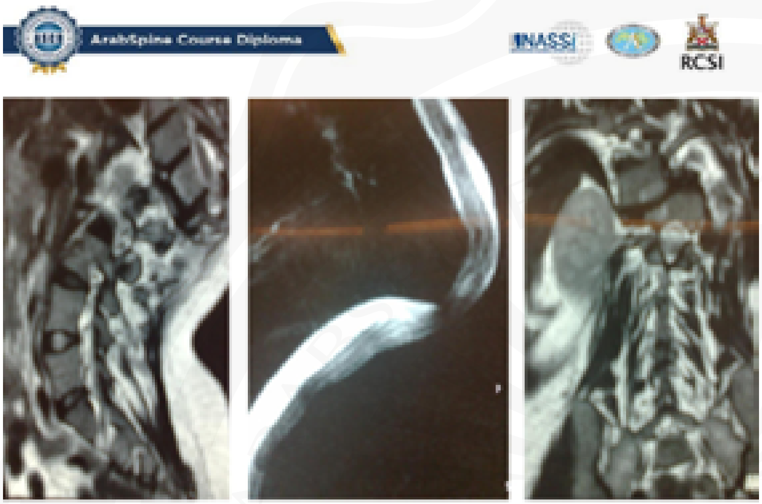
- Female
- 30 yrs
- Deformity since birth
- Severe Kyphosis
- Resection D12 + Fixation D8→L4
- Reconstruction Rib strut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INASSI
RCSI


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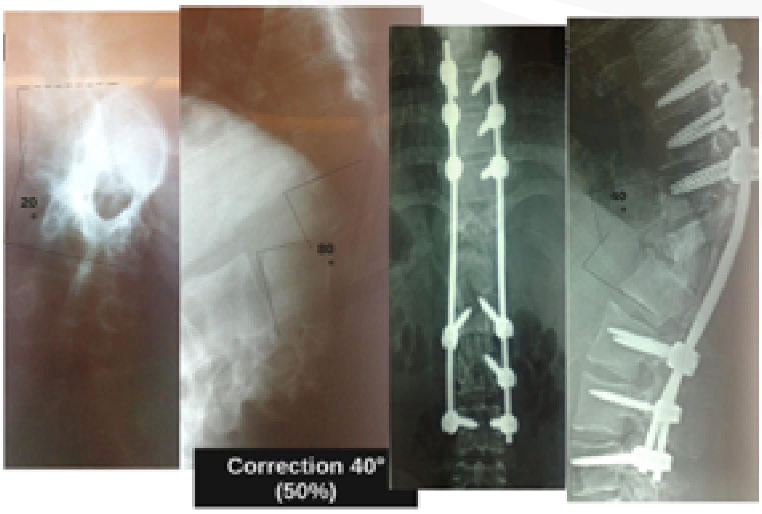
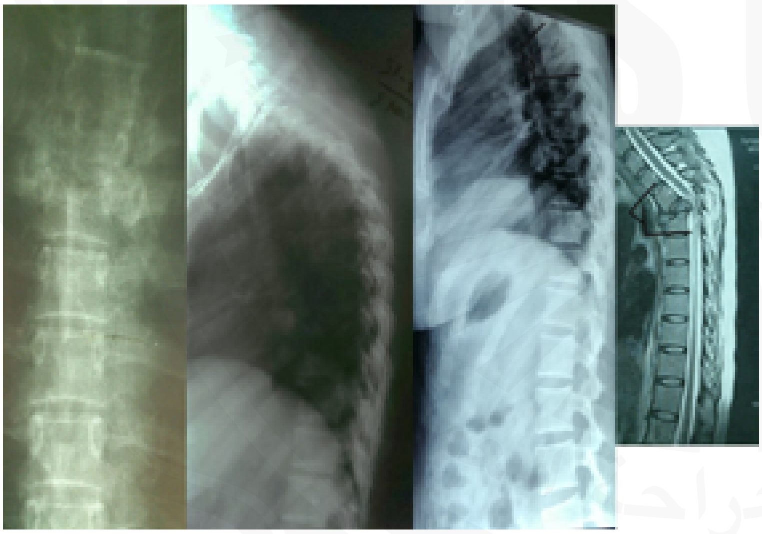
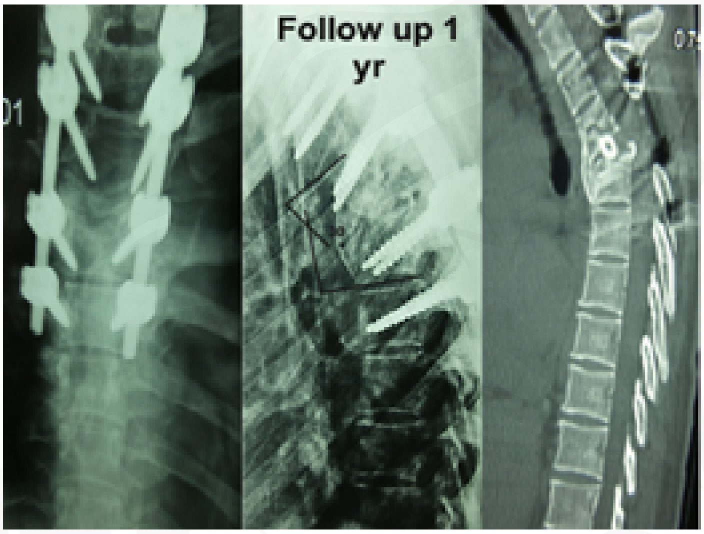
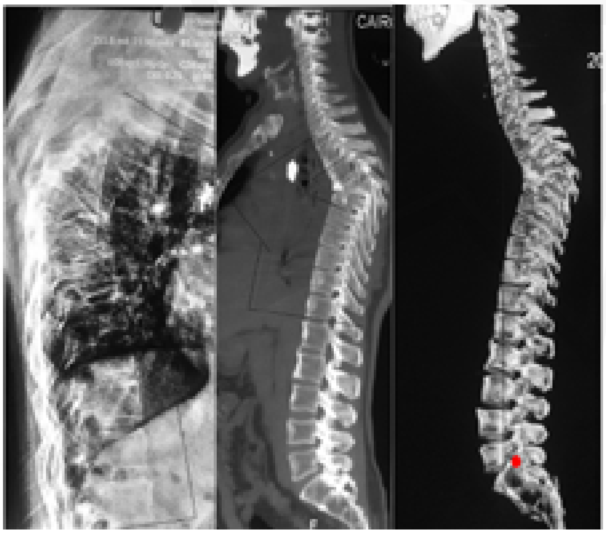

20
80
Correction 40°
(50%)
40

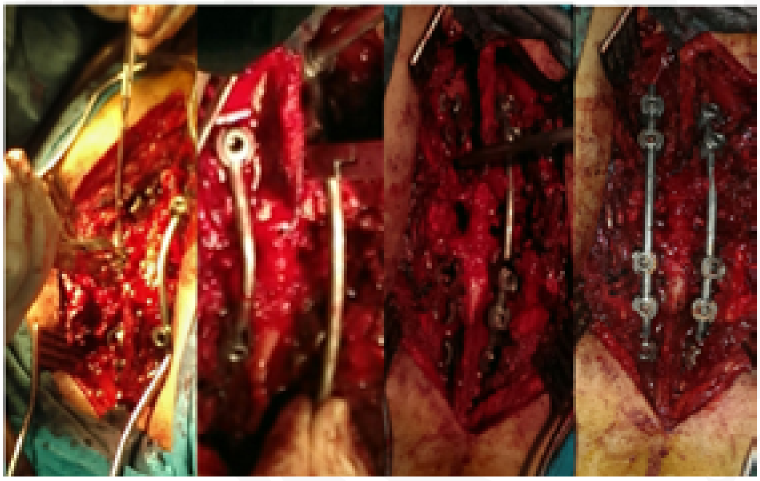
- Female
- 30 yrs
- MCA → Missed Burst D4 Fracture
- Paraparetic
- Resection D4 Fixation D2→ D6
- Reconstruction by Rib strut
- Fusion after 1 yr (Mild loss of 5°)
- Pt regained L.L function Grade III

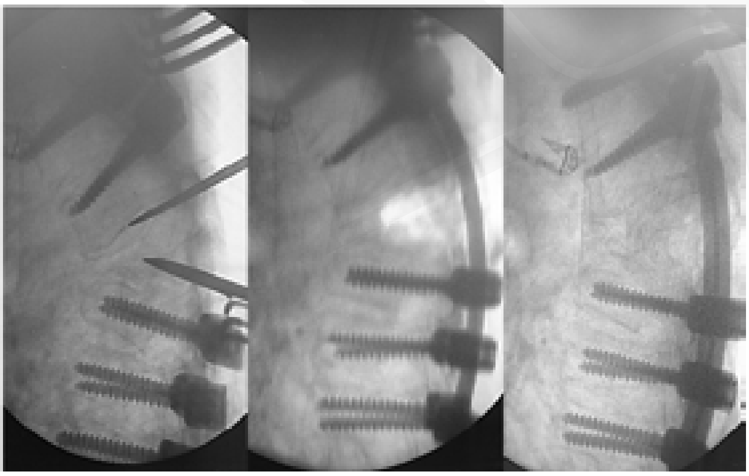


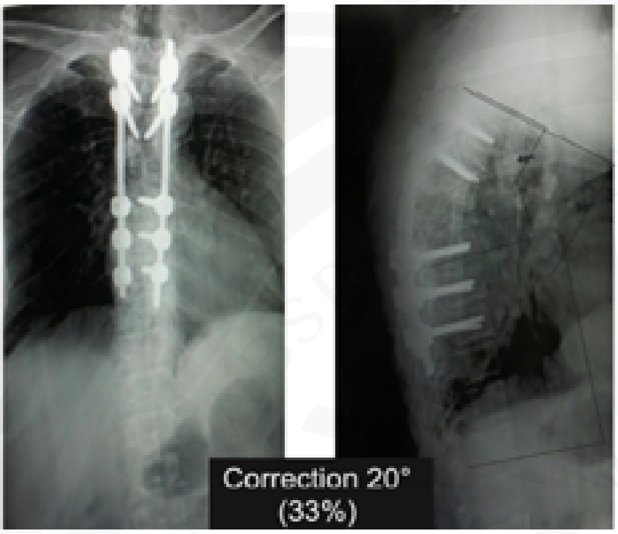


- Male
- 52 yrs
- Back pain (progressively inc.)
- UMNL manifestation (clonus, Hyper-reflexia, retention with overflow)
- Congenital wedging D4,5,6
- Resection D4,5,6 + Fixation D2-D9
- Reconstruction Rib strut + Morselized B.G
- Postoperative → Brace

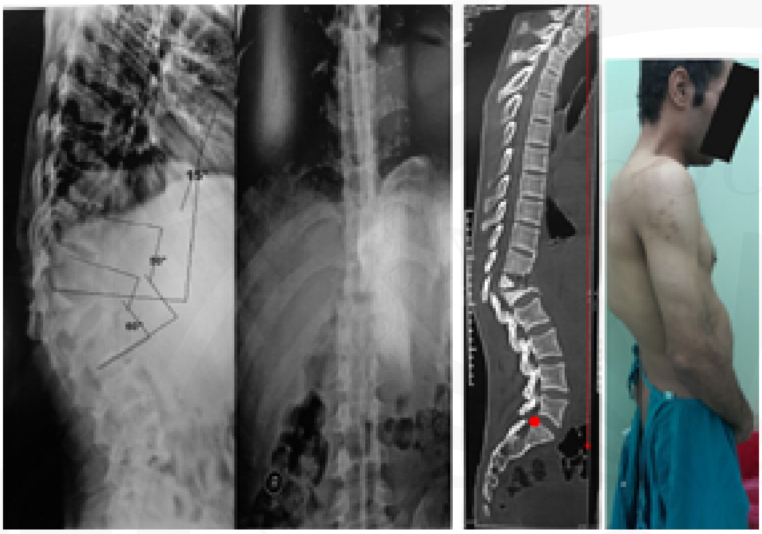


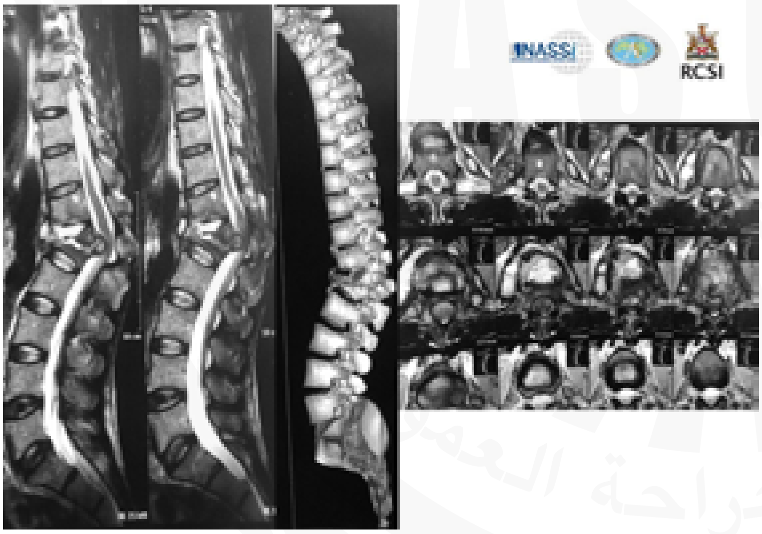


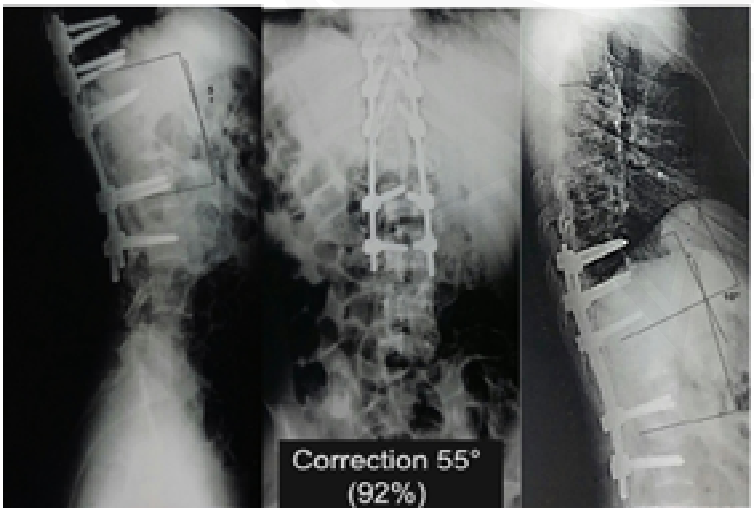


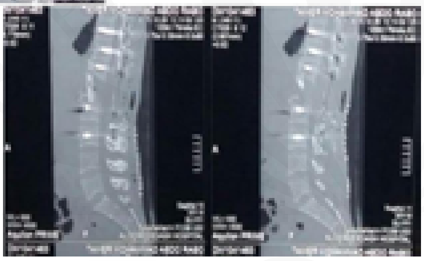


- Male
- 35 yrs
- Addict HCV + ve
- Painful Deformity of back .
- No Toxic symptoms
- Neurologically intact
- Spondylodiscitis D12,L1(Pott's spine)
- Resection D12,L1 + Fixation D9-L3
- Reconstruction Rib strut + Morselized B.G
- Dural tear + avulsion L1 root → CSF leak
- C&S → T.B

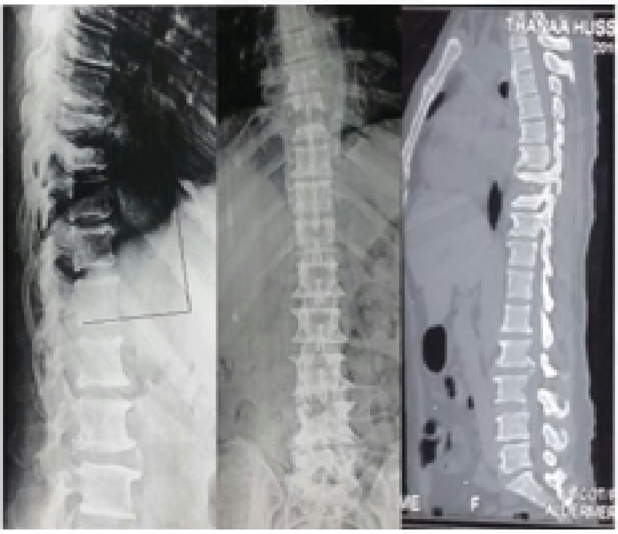


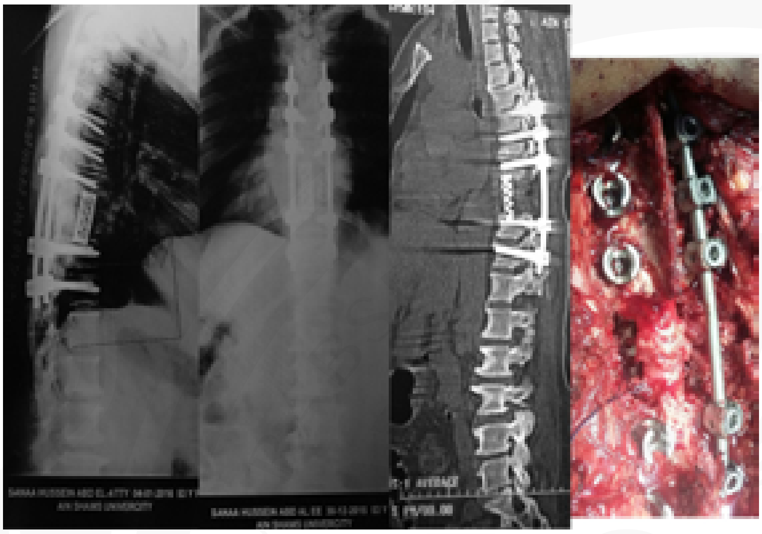



Correction 55°
(92%)

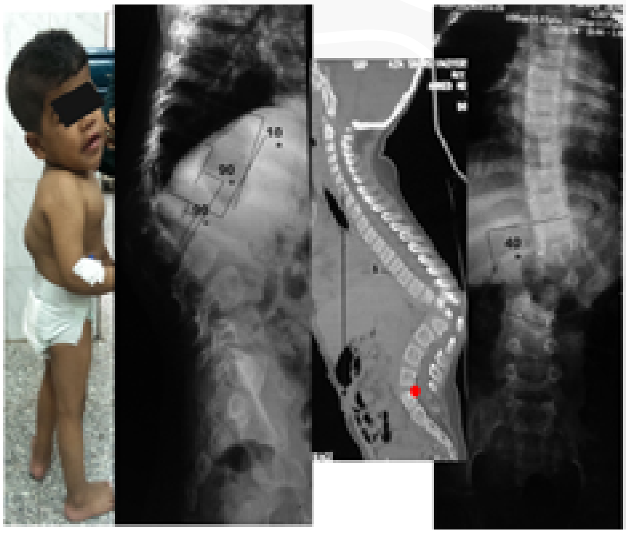


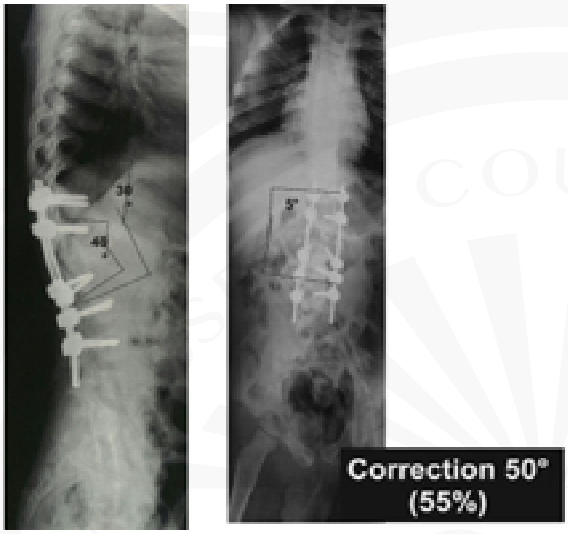
- Female
- 53 yrs
- Back pain 3 months ago
- Complete Paraplegia + sensory level umbilicus
- Urine + Stool incontinence
- Spondylodiscitis D8,9
- Resection D8,9 + Fixation D5→D11
- Reconstruction Mesh cage + B.G
- Post operative infection → Debridement

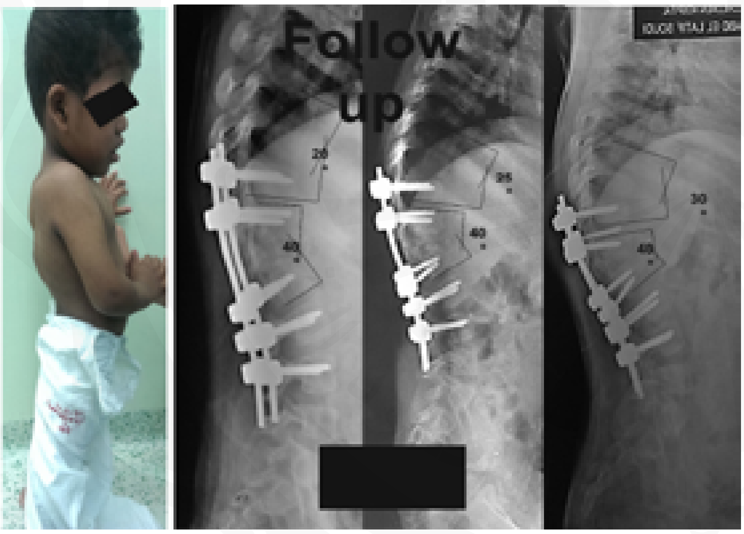


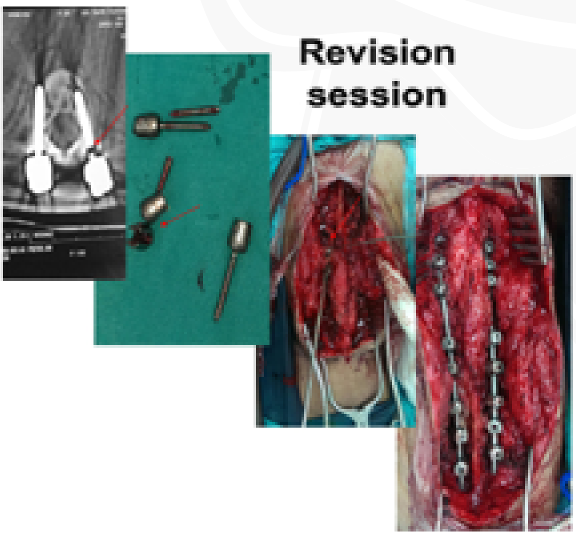


- Male
- 4 yrs
- Deformity since birth (progressively inc.)
- Congenital dislocation of the spine
- Neurologically intact
- Resection L1 + Fixation D11-L4
- Reconstruction Morselized B.G
- Postoperative casting → Brace




Correction 50°
(55%)


Follow
up


Revision
session

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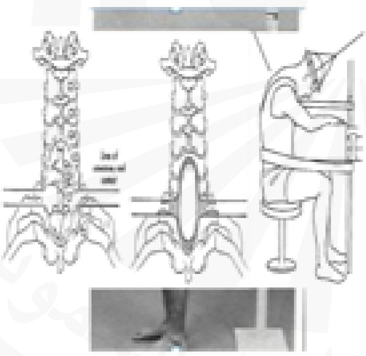
➢ Cervical osteotomy:

- To elevate the chin from the sternum (chin-brow to vertical angle).
- Prevent atlantoaxial and cervical subluxations and dislocations by weight of the head.
- To relieve tracheal and esophageal distortion.
- To prevent **irritation** of the **spinal cord** tracts or excessive traction on the nerve roots.
- Usually done at the **lower cervical spine**.



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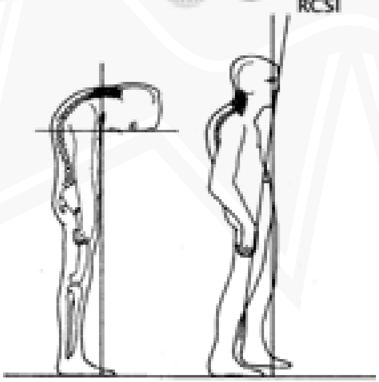
- The cervical extension osteotomy can be performed in one of two ways:

➢ Removal of the posterior elements (spinous process and lamina) and the pedicles. However, an osteotomy of the vertebral body is not performed.

➢ Transpedicular osteotomy, which is similar to the pedicle subtraction osteotomy in that an osteotomy of the vertebral body is performed.



Chin-brow to vertical angle

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Schwab classification(2013):

TABLE 1. Spinal Osteotomy Classification

	Anatomic Resection	Description	Surgical Approach Modifiers
Grade 1	Partial facet joint	Resection of the inferior facet and joint capsule at a given spinal level	P (posterior approach only)
Grade 2	Complete facet joint	Both superior and inferior facets at a given spinal segment are resected with complete ligamentum flavum removal; other posterior elements of the vertebra including the lamina, and the spinous processes may also be resected	P (posterior approach only) A/P (anterior soft tissue release combined with posterior resection)
Grade 3	Pedicle/partial body	Partial wedge resection of a segment of the posterior vertebral body and a portion of the posterior vertebral elements with pedicles	P (posterior approach only) A/P (both)
Grade 4	Pedicle/partial body/disc	Wider wedge resection through the vertebral body; includes a substantial portion of the posterior vertebral body, posterior elements with pedicles, and includes resection of at least a portion of 1 endplate with the adjacent intervertebral disc	P (posterior approach only) A/P (both)
Grade 5	Complete vertebra and discs	Complete removal of a vertebra and both adjacent discs (rib resection in the thoracic region)	P (posterior approach only) A/P (both)
Grade 6	Multiple vertebrae and discs	Resection of more than one entire vertebra and adjacent discs; Grade 5 resection and additional adjacent vertebral resection	P (posterior approach only) A/P (both)

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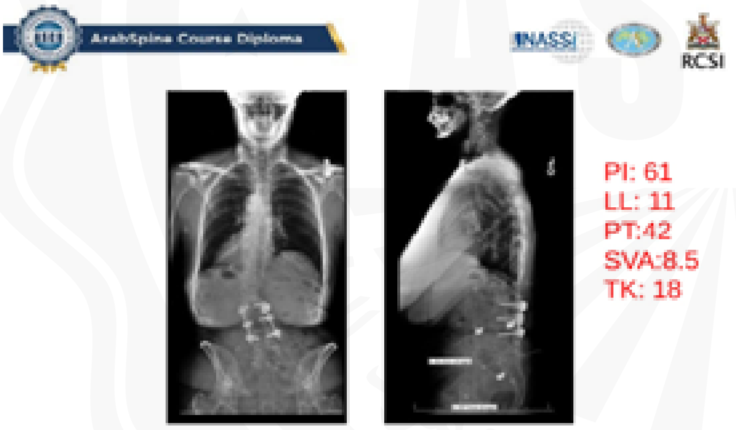
Conclusions

- Posterior column osteotomies encompass a continuum of approaches to the management of spinal deformity
- PSO is most appropriate in the patient with a prior circumferential fusion of the spine
- VCR is most useful to address translation of the trunk

Preventing Proximal Junctional Kyphosis and Failure



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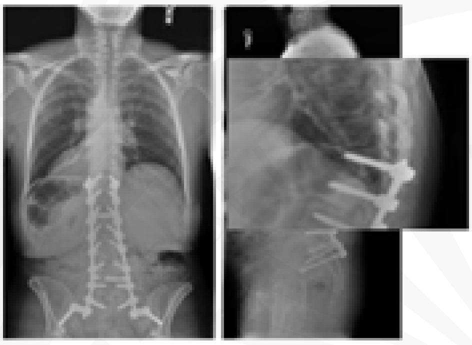

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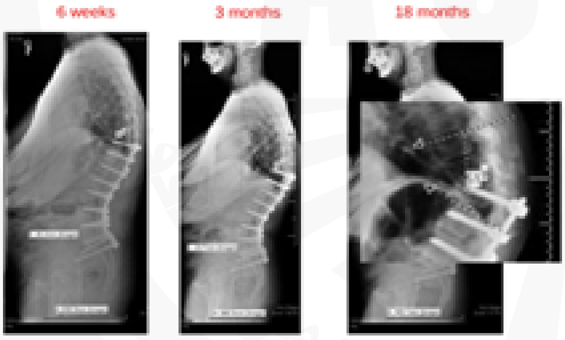

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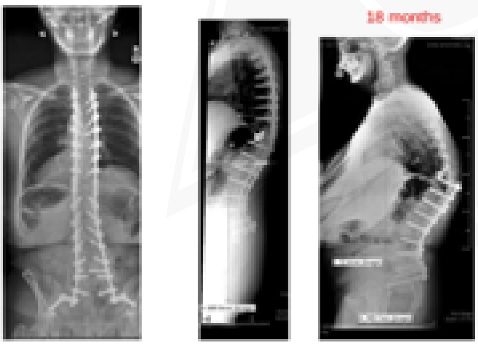

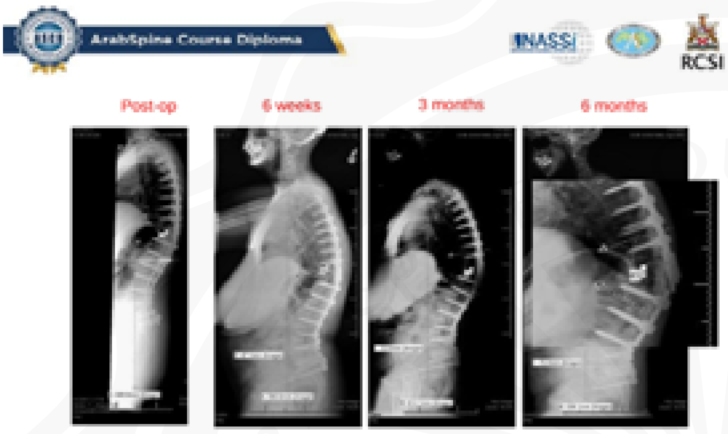
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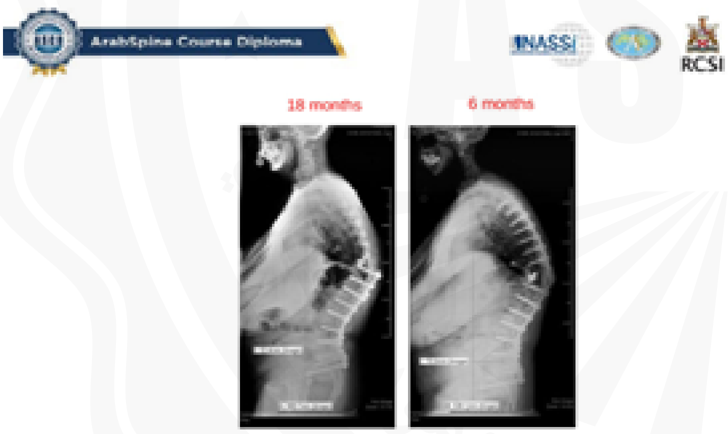
Post-op
6 weeks
3 months
6 months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RCSI
18 months
6 months


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RCSI

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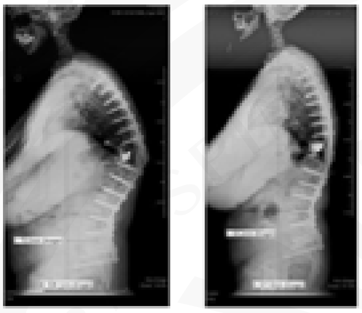
NASS RCSI

6 months 3 years



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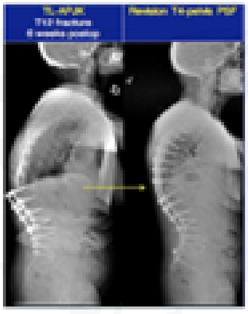
Consensus on Prevention and Treatment Junctional Kyphosis

Why no consensus?

- Pathology not well defined
  - PJK-benign kyphosis
  - Proximal junctional failure (PJF)
  - Catastrophic PJF
- Discrepancy clinical impact
- Risk factors complex
- Disease prevention emerging



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Incidence, Risk Factors and Classification of Proximal Junctional Kyphosis: Surgical Outcomes Review of Adult Idiopathic Scoliosis

Spine 201 ... Dec 1

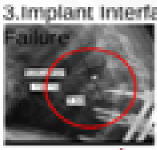
Radiographic PJK

Symptomatic PJK

1. Ligamentous

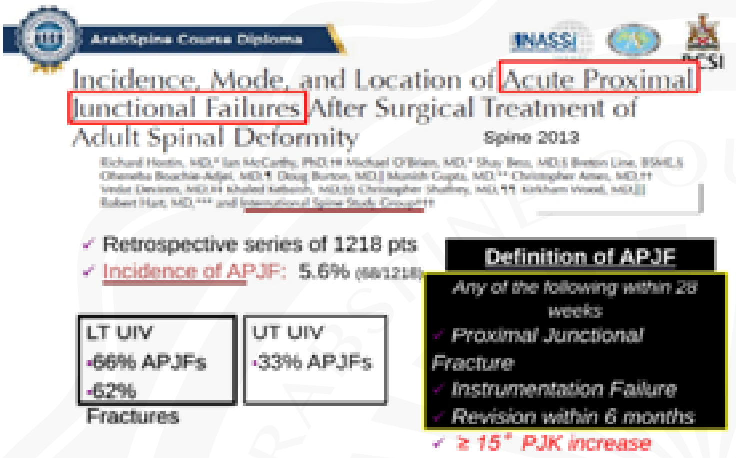
2. Osseous

3. Implant Interface Failure



Type	Description
1	Disc and ligamentous failure
2	Bone failure
3	Implant/bone interface failure
Grade	
A	Proximal junctional increase 10°-19°
B	Proximal junctional increase 20°-29°
C	Proximal junctional increase 30°
Spondylolisthesis	
PJF-N	No obvious spondylolisthesis above UIV
PJF-S	Spondylolisthesis above UIV

Significantly higher ODI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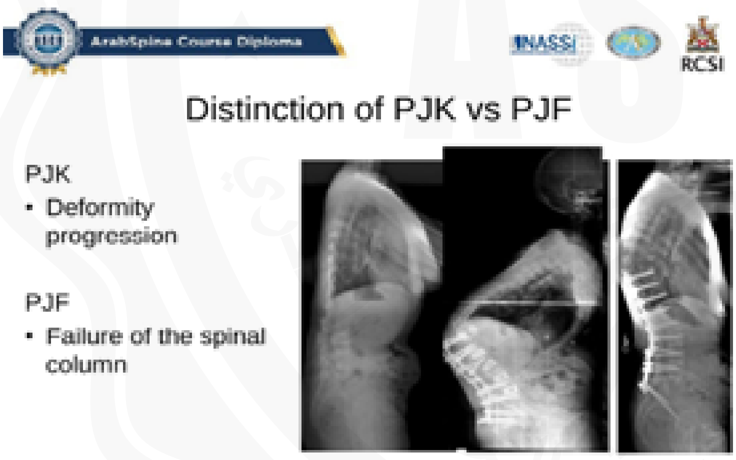
Incidence, Mode, and Location of Acute Proximal Junctional Failures After Surgical Treatment of Adult Spinal Deformity
Spine 2013
✓ Retrospective series of 1218 pts
✓ Incidence of APJF: 5.6% (68/1218)
LT UIV
-66% APJFs
-62% Fractures
UT UIV
-33% APJFs
Definition of APJF
Any of the following within 28 weeks
✓ Proximal Junctional Fracture
✓ Instrumentation Failure
✓ Revision within 6 months
✓ ≥ 15° PJK increase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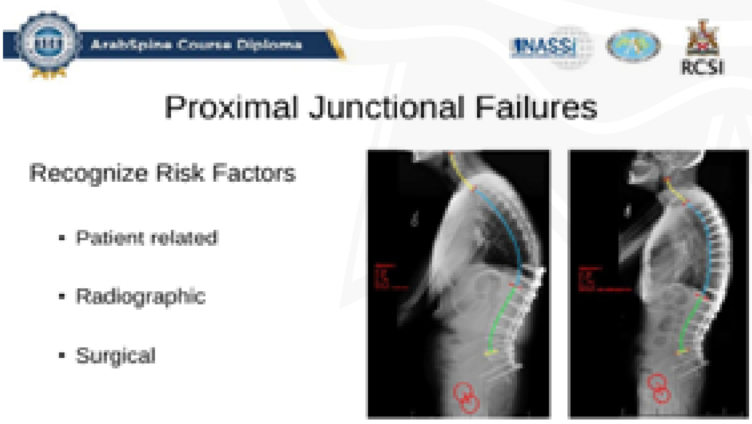
Distinction of PJK vs PJF
PJK
• Deformity progression
PJF
• Failure of the spinal column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Proximal Junctional Failures
Recognize Risk Factors
• Patient related
• Radiographic
• Surgical

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Proximal Junctional Failure (PJF) Risk Factors

Patient Factors

Age

- 55

Bone Density

Muscle control

Comorbidities

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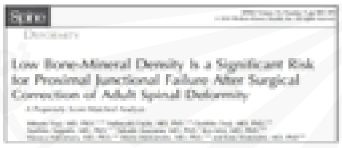
Bone Density

- T score ≤ -1.5 with higher rates of PJF
  - T score may not accurately assess bone strength
- Continuum of disease


Spine

Deformity

Low Bone-Mineral Density Is a Significant Risk for Proximal Junctional Failure After Surgical Correction of Adult Spinal Deformity

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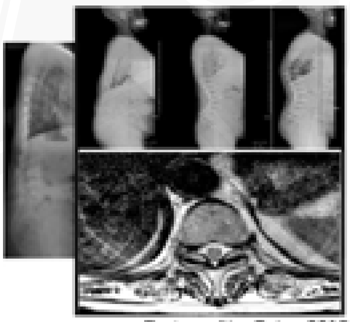
Muscle Control

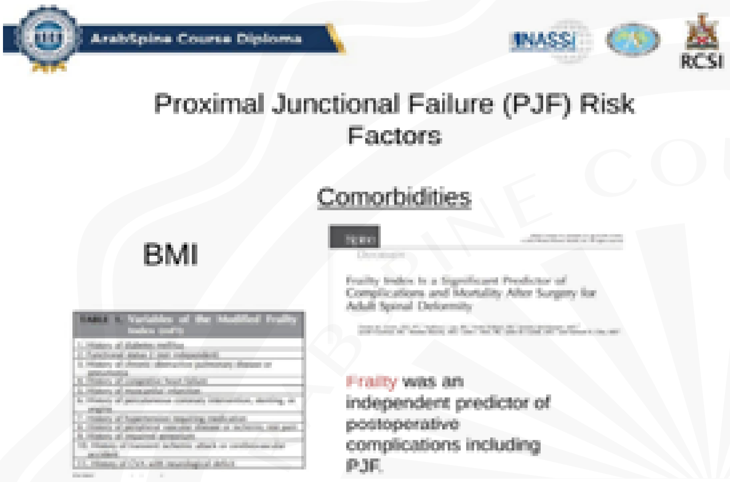
Reciprocal Change

- For every action there is an equal and opposite reaction
- Tries to predict thoracic motion from preop thoracic compensation
  - More compensation = more motion
- Those with reciprocal change have higher rate of PJK

Fatty Infiltration



Protopsaltis, Spine 2018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Proximal Junctional Failure (PJF) Risk Factors
Comorbidities
BMI
Frailty Index Is a Significant Predictor of Complications and Mortality After Surgery for Adult Spinal Deformity
Frailty was an independent predictor of postoperative complications including PJF.


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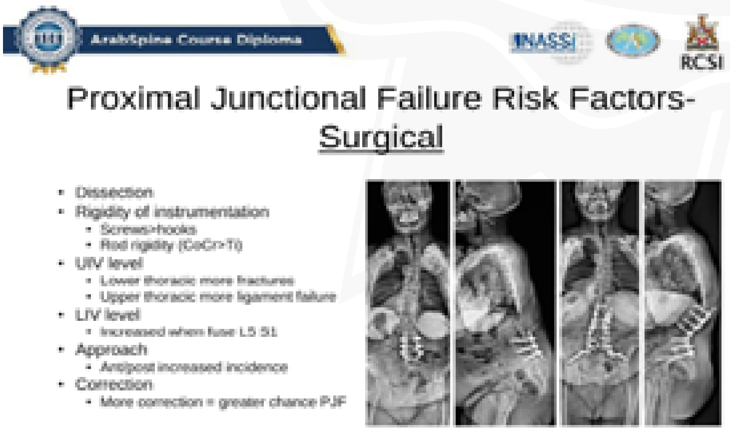
Proximal Junctional Failures Risk Factors
Radiographic
Risks
Greater preop sagittal malalignment (SVA, PI-LL mismatch)
Proximal junctional angle at UIV +1 > 5 degrees preop
PJA
PJA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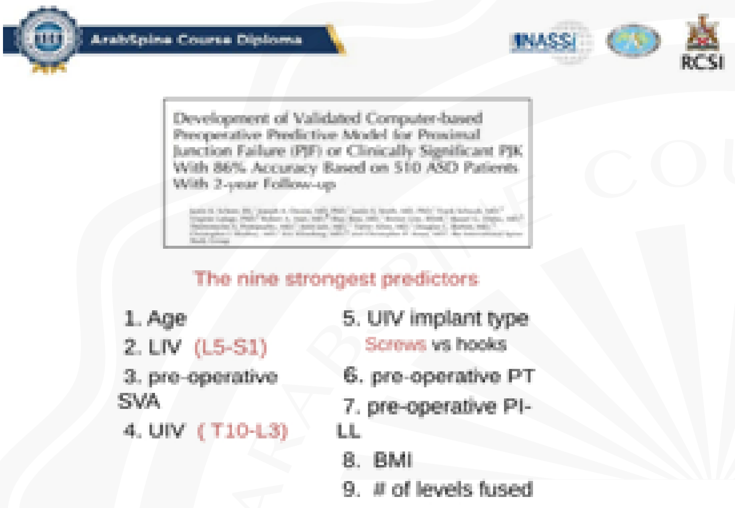
Proximal Junctional Failure Risk Factors-Surgical
Dissection
Rigidity of instrumentation
Screws>hooks
Rod rigidity (CoCr>Ti)
UIV level
Lower thoracic more fractures
Upper thoracic more ligament failure
LIV level
Increased when fuse L5 S1
Approach
Ant/post increased incidence
Correction
More correction = greater chance PJF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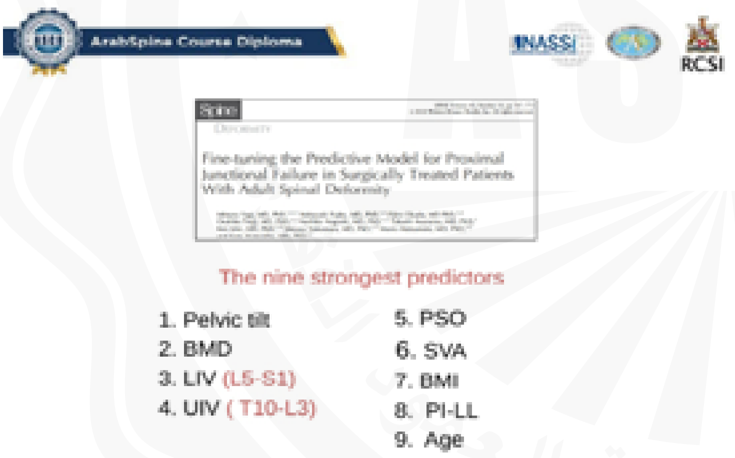
Development of Validated Computer-based Preoperative Predictive Model for Proximal Junction Failure (PJF) or Clinically Significant PJK With 86% Accuracy Based on 510 ASD Patients With 2-year Follow-up
The nine strongest predictors
1. Age
2. LIV (L5-S1)
3. pre-operative SVA
4. UIV (T10-L3)
5. UIV implant type
Screws vs hooks
6. pre-operative PT
7. pre-operative PI-LL
8. BMI
9. # of levels fused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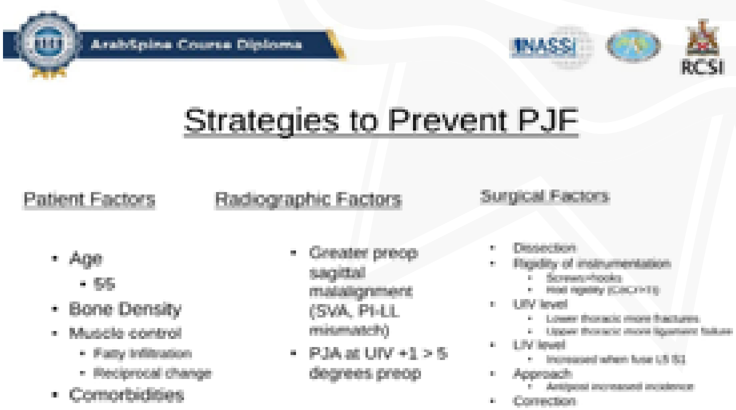
Fine-tuning the Predictive Model for Proximal Junctional Failure in Surgically Treated Patients With Adult Spinal Deformity
The nine strongest predictors
1. Pelvic tilt
2. BMD
3. LIV (L5-S1)
4. UIV (T10-L3)
5. PSO
6. SVA
7. BMI
8. PI-LL
9. Age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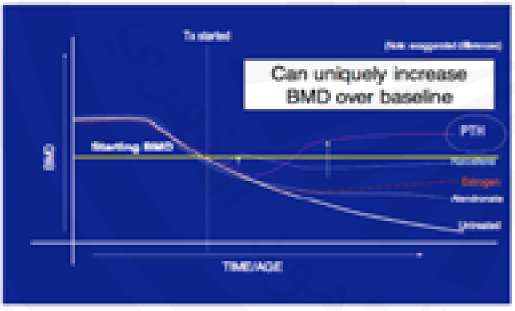
Strategies to Prevent PJF
Patient Factors
Age
55
Bone Density
Muscle control
Fatty Infiltration
Reciprocal change
Comorbidities
Radiographic Factors
Greater preop sagittal malalignment (SVA, PI-LL mismatch)
PJA at UIV +1 > 5 degrees preop
Surgical Factors
Dissection
Rigidity of instrumentation
Screws/hooks
UIV level
Lower thoracic more fractures
Upper thoracic more ligament failure
LIV level
Increased when fuse L5 S1
Approach
Correction

Strategies to Prevent PJF

- Use of Forteo (PTH)
- Vertebral Augmentation
- Tethers

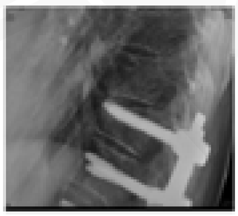
Use of Forteo

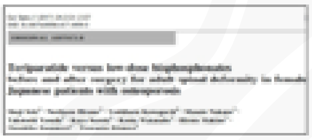


Forteo and Prevention of PJF

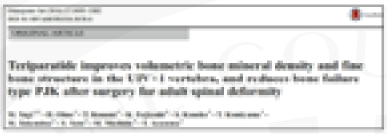
Best for Prevention of Type 2 PJF
– Vertebral Fracture

Type 2 PJF




Teriparatide versus low-dose bisphosphonates before and after surgery for adult spinal deformity in female Japanese patients with osteoporosis

- Fewer adjacent vertebral fractures
- Increased fusion rate
- Started 3 months preop


Teriparatide improves volumetric bone mineral density and fine bone structure in the UIV+1 vertebra, and reduces bone failure type PJK after surgery for adult spinal deformity

- Decreased type 2 PJF
- Increased BMD and bone strength
- Started postop day #1

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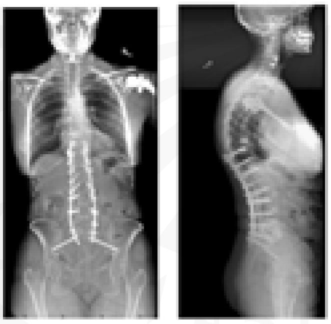
Vertebral Augmentation

- Stress is increased at UIV and UIV +1
- Upper screw pullout can occur



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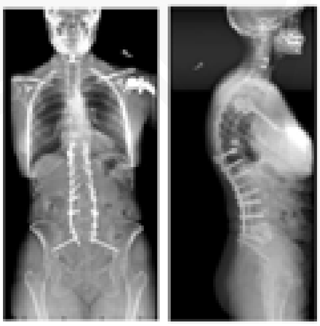
Vertebral Augmentation

- Stress is increased at UIV and UIV +1
- Upper screw pullout can occur
- Is prophylactic vertebroplasty helpful?



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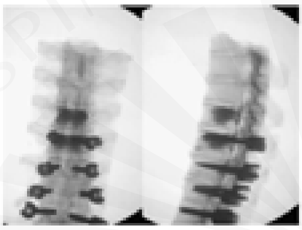
Basic Science

Use of vertebroplasty to prevent proximal junctional fractures in adult deformity surgery: a biomechanical cadaveric study

Khaled M. Kebaish, MD*, Christopher T. Martin, MD, Joseph R. O'Brien, MD, MPH, Ivan E. LaMotta, MD, Galen D. Voros, MD, Stephen M. Belkoff, PhD, MPH

Cadaveric Model

- UIV only with no decreased incidence of fracture
- UIV and UIV+1 with decreased incidence of fracture



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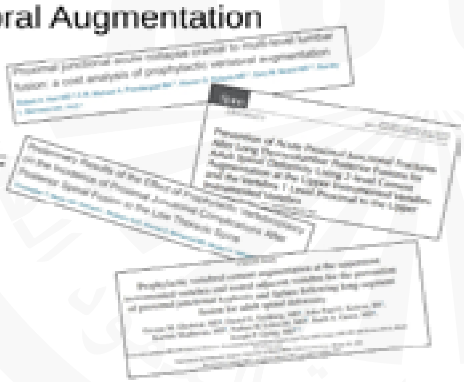
Vertebral Augmentation

Short term results

Decrease in acute PJF

– Hart et al - 0%
– Theologis et al – 0%
– Martin et al – 5%
– Ghobrial et al – 0%



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Clinical Study

The effect of prophylactic vertebroplasty on the incidence of proximal junctional kyphosis and proximal junctional failure following posterior spinal fusion in adult spinal deformity: a 5-year follow-up study

Tina Raman, MD*, Emily Miller, MD, Christopher T. Martin, MD, Khaled M. Kebaish, MD

Long term outcome (5 years)

- No difference in PJK compared with cohort (28%)

Prophylactic Vertebroplasty

- May prevent acute PJF
- Does not prevent PJK in long term

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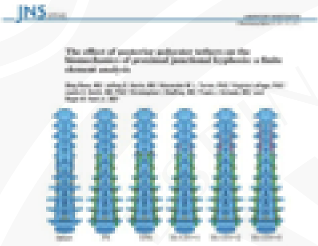
Tethers in Preventing PJF/PJK



- Tether Created a gradual transition of forces compared to pedicle screws and hooks

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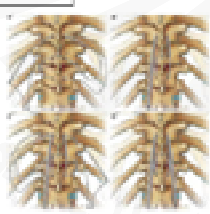
Tethers in Preventing PJF/PJK

Ligament augmentation for prevention of proximal junctional kyphosis and proximal junctional failure in adult spinal deformity

JNS 2018

Tether UIV-1, UIV, UIV+1



- Reduced PJA
- Associated with < PJF

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Conclusions

1. PJF/PJK are poorly defined but a significant source of morbidity

2. Recognize the risk factors :

Patient Factors
- Age
  - 55
- Bone Density
- Muscle control
  - Fatty infiltration
  - Reciprocal change
- Comorbidities

Radiographic Factors
- Greater preop sagittal malalignment (SVA, PI-LL mismatch)
- Greater preop thoracic kyphosis (TK)
- PJA at UIV +1 > 5 degrees preop

Surgical Factors
- Dissection
- Rigidity of instrumentation
  - Screws/hooks
  - Rod rigidity (CoCr/Ti)
- UIV level
  - Lower thoracic more fractures
  - Upper thoracic more ligament failure
- LIV level
  - Increased when fuse L5 S1
- Approach
  - Ant/post increased incidence
- Correction

Conclusions

3. Current prevention strategies

   a. Forteo
      - Shown to increase bone strength and ↓ PJF due to fracture

   b. Vertebral Augmentation
      - Good short term decrease of vertebral fracture
      - Long term results poor

   c. Tethers
      - Initial results promising
      - Probably best at multiple levels

Choosing the Proper Implants and Fixation in Deformity Surgery (Screws, Hooks, Wires, Hybrid)

Early Beginnings

- 1891

  Hadra attempted wiring of the spinous processes in a patient with progressive deformity due to Pott's Disease.
- 1911

  Hibbs introduced the concept of non-instrumented osseous fusion for stabilization of a deformed spine.
  - Relied heavily on casts
  - Failed to provide correction of deformity

New York Medical Journal

INCORPORATING THE

Philadelphia Medical Journal and The Medical News

A Weekly Review of Medicine, Established 1843

XCIII, No. 21. NEW YORK, MAY 27, 1911 Whole No. 1695

AN OPERATION FOR PROGRESSIVE SPINAL DEFORMITIES

A Preliminary Report of Three Cases for the Service of the Orthopaedic Hospital.

By Russell A. Hibbs, M.D.,

New York,

Surgeon in Chief of the Orthopaedic Dispensary and Hospital

TRANSPLANTATION OF A PORTION OF THE TIBIA INTO THE SPINE FOR POTT'S DISEASE

A PRELIMINARY REPORT

FRED H. ALBEE, M.D.

Assistant Professor (Head of Department) of Orthopedic Surgery, Cornell University; Professor and Adjunct Professor of Orthopedic Surgery, University of Vermont, and Post-Graduate Medical School and Hospital, etc.

NEW YORK

Journal of the American Medical Association, 1911

Early Beginnings

- Fritz Lange
  - Early 1900's, he began to attempt to splint the spine internally by using an "artificial spinal column of steel."
  - In 1908, he used two 5 mm thick and 10 cm long steel wires coated with tin, with tin knobs on the ends to reduce irritation. These were fastened to the spinous process by using paraffin-silk.

Entering the Modern Era

Treatment of Scoliosis:
Correction and Internal Fixation by Spine Instrumentation

-Paul R. Harrington
JBJS 1962

Harrington Rods

- Development began in 1947 while working with approximately 3,000 poliomyelitis patients with debilitating spinal deformities.
- 1949-1954:
  - 19 patients treated with poor results (11 of 19 resulting in instrumentation failure)
  - 35 modifications to the instrumentation

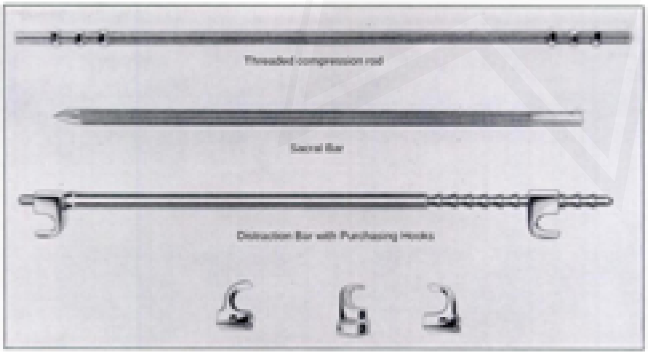
Harrington Rods

- 1955-1960:
  - 46 patients treated with improving results (14 of 46 resulting in instrument failure)
  - 12 further modifications to instrumentation
- 1960
  - 68 patients treated with the final "refined" technique described in his landmark article

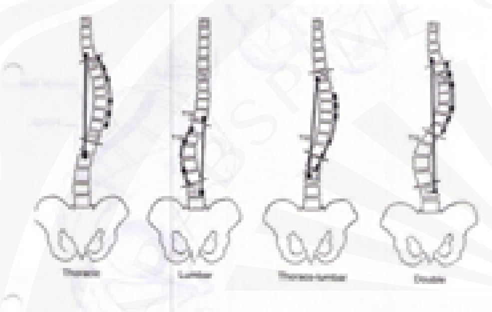
Harrington Rods

- Basic Principles:
  1. Distraction is applied to the concave side of the upper transitional vertebra (or one above) and to 1-2 vertebra below the lower transitional vertebra.
  2. Compression is applied on the convex side to multiple vertebra between the transitional levels
  3. Secondary forces are applied via connection to the pelvis if sacral triangle is obtuse (the apex of the curve is not over the base formed by the lumbosacral articulations).

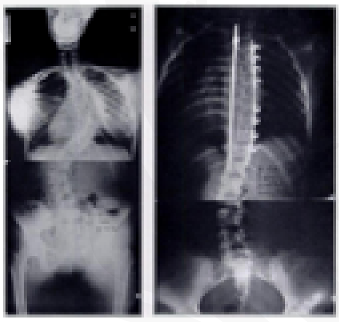
Harrington Instrumentation



Harrington Rods



Original Case Example:



- 13 y/o WF with idiopathic scoliosis.
- Thoracic curve = 75°
  - Corrected to 12°
- Lumbar curve = 55°
  - Corrected to 18°

Harrington Rods

- Post-op Treatment:
  - Log-roll only for 10-14 days until sutures removed.
  - Plaster body cast applied and patient discharged.
  - Recumbent position in cast for additional 6-8 weeks, then slowly progressed to walking in cast.
  - X-rays obtained and compared to post-op films.

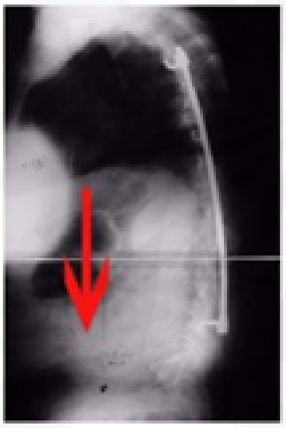
    If more than 10° correction lost:
    - > 15 y/o = additional 1 month in cast
    - 15-25 y/o = additional 4 months in cast
    - < 35 y/o = additional 5 months in cast

Long term f/u of Harrington Rods

- Several problems/limitations became apparent.
  1. Long constructs with lack of multiple (segmental) fixation points, which led to loosening and re-operation.
  2. Difficulty correcting multiple curves
  3. Lack of ability to control sagittal plane contour.

Flatback Syndrome

- Sequelae of distraction instrumentation in the lower lumbar spine
- Increased stress on remaining motion segments with premature breakdown below fusion
- Sagittal plane imbalance due to loss of lordosis
- Hallmarks:
  - Back Pain
  - Forward Inclination
  - Inability to stand erect



Next Generation

Segmental Spinal Instrumentation for Correction of Scoliosis

-Eduardo R. Luque

Clinical Orthop 1981

Luque Instrumentation

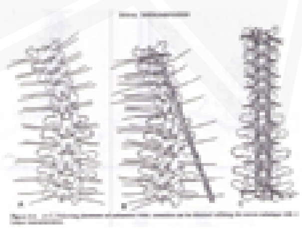
- The use of sublaminar wires, which had been used for treatment of cervical fractures in 1970's, was first adapted for use in spinal deformity by Luque in 1976.
- Originally, combined with concave Harrington rods
- Approached spinal deformity as three dimensional, as well as, segmental.
- Major objective of alignment should be to position the head over the middle of the sacrum in all three dimensions.

Luque SSI Technique

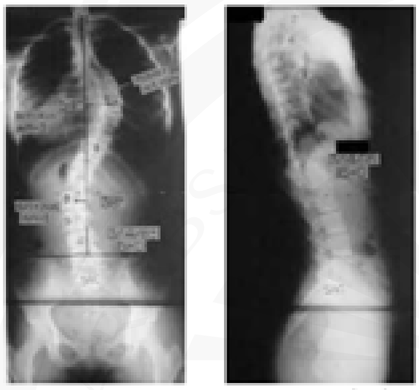
- Utilized principles of a transverse correction force (opposed to the distraction force of Harrington)
- Multiple fixation points with the passage of sublaminar wires, which allowed correction forces to be distributed over many levels
- Restored normal sagittal alignment when combined with pre-contoured rods

Luque SSI Technique

- Crosslinking of rods:
  - ✓ to avoid rod migration
  - ✓ give some control over rotational and unequal longitudinal forces
  - ✓ Distribute forces equally along both rods
- Decreased the need for post-op bracing/casting



Luque Instrumentation



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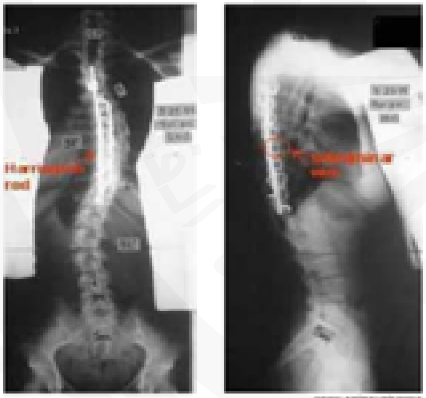
Luque Instrumentation



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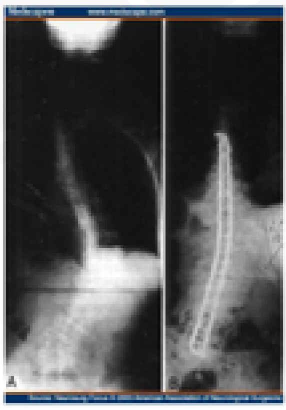
Luque SSI Results

- Sublaminar wires in conjunction with rods have been shown to provide good stabilization of the spine
  - Herndon et al, J Bone Joint Surg [Am] 69:851-859, 1987.
- Advantages include versatility and relatively low cost.

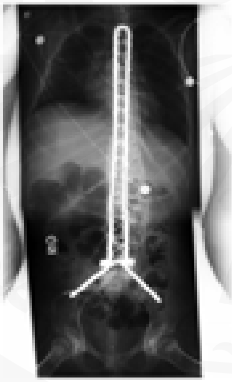


Luque SSI Results

- Incidence of neurological compromise raised the biggest concern.
  - Wilber et al, JBJS 1984; 66:1178-1187.
    - Reported 17% incidence of neurological compromise in retrospective review (12 of 69 pts.)
    - When divided into three equal chronological groups:
      26% (6 of first 23 pts.)
      17% (4 of next 23 pts.)
      9% (2 of last 23 pts.)
  - Other authors report between 1 – 15%
  - 8 cited articles reported 0 % post-op complication

Luque Instrumentation

- Successful use of Luque instrumentation in NM scoliosis has been reported in literature by multiple groups.
- Currently used in conjunction with Galveston technique, presented by Allen and Ferguson at 1983 SRS annual meeting.



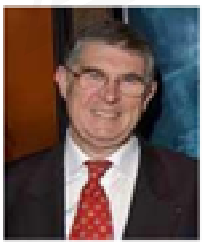
Next Generation

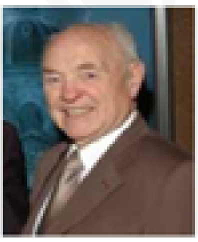
New Segmental Posterior Instrumentation of the Spine

Y. Cotrel
J. Dubousset

Presented at the 19th annual meeting of the Scoliosis Research Society

Orlando, Sept. 1984





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CD Instrumentation

- Designed to allow selective and three-dimensional correction of deformity.
- Applied asymmetric forces through compression/distraction on opposite sides
- Addressed axial plane with derotation of the vertebrae achieved by the relative motion of the instrumented vertebrae.
- Technique performed through rotation of the concave rod.

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CD Instrumentation

Based on 3 elements:

1. Two rods
   - Stainless Steel
   - Uniform in diameter
   - Pre-bent to follow or restore normal sagittal contour

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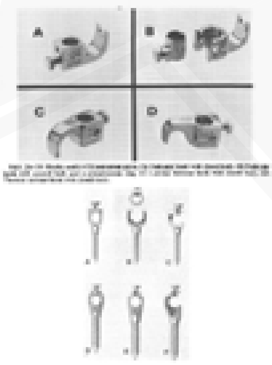
CD Instrumentation

Based on 3 elements:

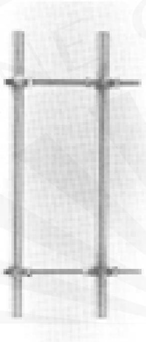
2. Hooks/ Screws
   - Open vs. Closed
   - Pedicle vs. Laminar/TP hooks
   - Screws described **only** for lumbar or sacral levels



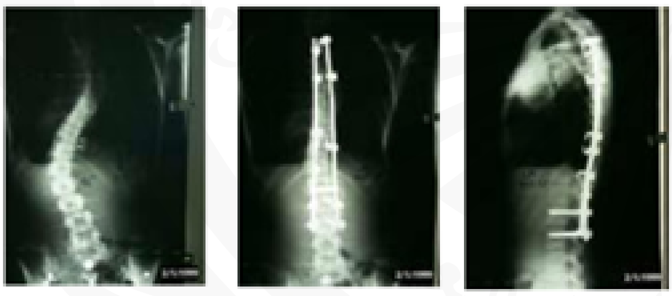
CD Instrumentation

Based on 3 elements:

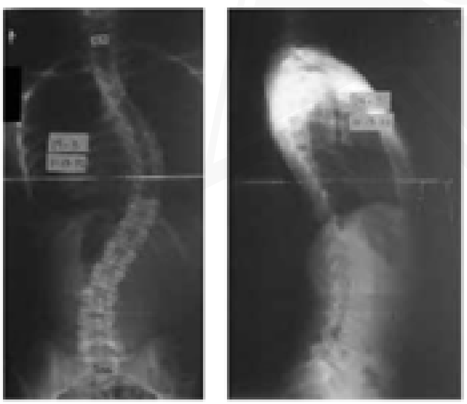
3. Device for transverse traction (DTT)
   - Firmly locks in two rod construct
   - Creating strong, frame-like set-up



CD Instrumentation Case



CD Instrumentation



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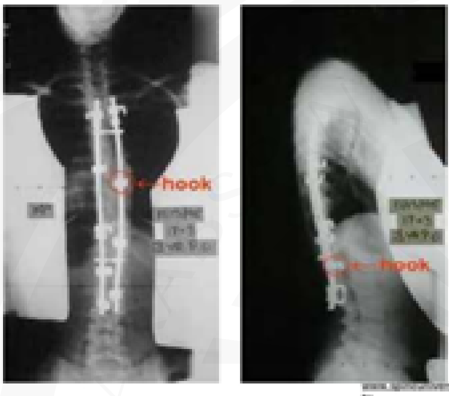
CD Instrumentation



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CD Results

- Cotrel and Dubousset originally reported on 250 procedures performed for scoliosis between 1983 and 1985.
  - Mean Cobb correction of 66%
  - Demonstrated up to 40% correction of the vertebral rotation

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CD Results

- Complications:
  - 2 transient neurologic injuries
  - 2 infections
  - 6 patients with dislodgement of upper open hooks
  - 2 fractures of transverse processes

Long Term Outcomes of CD

- Lenke et al. (JBJS 1998) reported 5 and 10 year f/u of CD instrumentation for 66 pts. with adolescent idiopathic scoliosis.
  - All appeared to have solid fusion
  - No noted loss of correction
  - No progressive sagittal plane deformities
  - 38% reported occasional pain, but none severe enough to keep them out of school or work
  - 62 of 63 reported that they would have surgery again

Long Term Outcomes of CD

- Lenke et al. also cited several reports that showed that the axial realignment, initially believed to be far superior to Harrington and Luque, was actually minimal.

- The introduction of CD instrumentation and its three-dimensional theory spread throughout the world and had a significant impact on the practice of spinal surgery.
- Several other systems presenting a variation on both the theory and mechanism of CD instrumentation:
  - Texas Scottish Rite Hospital system
  - Isola system
  - Miami Moss Instrumentation
  - Synergy System

- Growing interest in pedicle screw use sparked studies comparing distal screws vs. hooks with CD instrumentation.
- Lumbar pedicle screw shown have superior primary and secondary curve correction, with shorter fusion length, and no increase in complications.
  - Hamill, Lenke, et al. Spine 1996 May 15; 21(10): 1241-1249.
  - Barr et al. Spine 1997 Jun 15; 22(12):1369-79.
  - Liljenqvist et al. Eur Spine J. 2002 Aug; 11(4):336-43.

So How Do Screws Measure Up?

"Ring the bell you pansy!"

Biomechanical Comparison

- As previously mentioned, distal screw constructs have been shown to be superior than hooks by several authors.
- Gurr et al. JBJS 1988

  Screws shown to be biomechanically superior to hooks or sublaminar wires.


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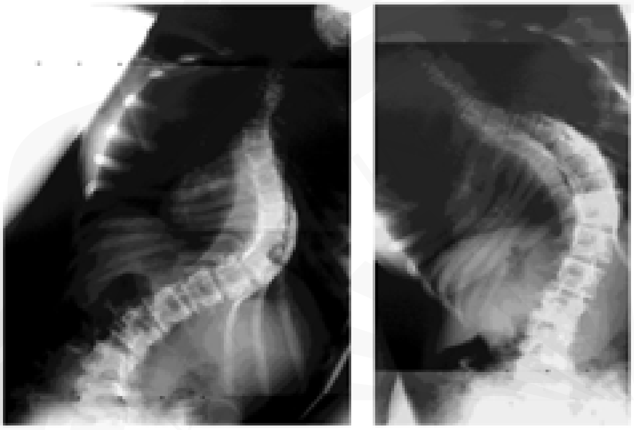
Biomechanical Comparison

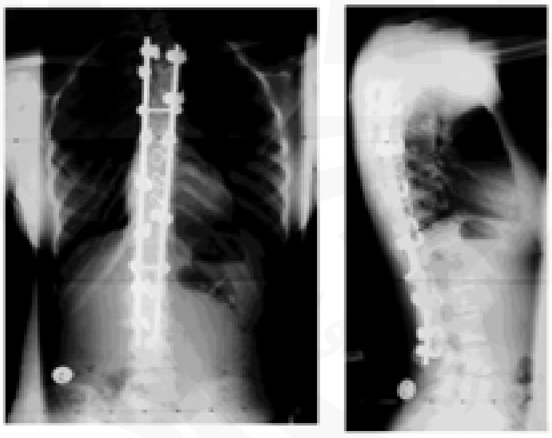
- Failure Characteristics for Proximal Fixation of Pedicle Hook and Laminar Hook Segmental Constructs vs. Pedicle Screw Segmental Constructs Under Eccentric and Concentric Bending Loads
  - Chutkan NB, Kasow DB, Zhou H, Wenger KH
- Compared pullout loads of segmental constructs
- PS/PS vs. LH/PS in 10 calf lumbar spines tested with eccentric bending loads.
- PS/PS vs. PS/PH in 10 calf lumbar spines tested with concentric bending loads.
- **Results: Use of PS/PS construct strengthens the fixation by 25%**

Sublaminar wires vs. Pedicle screws

Cheng et al. Spine 2005 Sep 15; 30(18):2104-12

- 50 patients with Adolescent Idiopathic scoliosis
- 25 with sublaminar wire / 25 With all pedicle screws
- Ave. correction: 64.7 % / 68.1%
- Loss of correction at 2 year f/u: 4.6 % / 5.1%
- Operative time: 350 min / 357 min
- Blood Loss: 1791 cc / 824 cc
- Implant cost: $8341.00 (16 fix. points) / $13,462.00 (17.1 fix. points)
- No neurologic or visceral complications and no reoperations at 2 year f/u for either group.





Hybrid Constructs vs. Screws

Lowenstein et al. Spine 2007 Feb 15;32(4):448-52

- 34 patients divided into 17 Hybrid (Lumbar pedicle screw / thoracic hooks) vs. all Screw constructs
- No statistically significant difference seen, although a trend was observed toward better correction of the main thoracic curve in the all screw group.

Kim, Lenke et al. Spine 2006 Feb 1; 31(3):291-8

- 29 Hybrid pts. Vs. 29 all pedicle screw pts.
- Ave. Major curve correction: 56% vs. 70% (p=0.001)
- Correction at 2 year f/u: 46% vs. 65% (p< 0.001)
- No difference in lowest instrumented vertebra, operative time, blood loss, or post-op SRS-24 scores.
- No Neurological complications reported for either group

Hooks vs. Screws

Kim, Lenke et al. Spine 2004 Sep 15;29(18):2040-8

- 52 pts (26 with all pedicle screws vs. 26 with hooks)
- Major curve correction: 76% vs. 50% ($p<0.001$)
- Loss of correction at 2 year f/u: 5.4% vs. 8.0%
- Ave of 0.8 levels from the distal end vertebra saved using pedicle screws ($p=0.002$)
- No significant difference in blood loss, operative time, or post-op SRS-24 scores
- Average Implant cost:
  $11,508 (11.8 fix. points) vs. $5, 816 (11.8 fix. Points)
- Conclusion: although more expensive, screws offer significantly better correction

Hooks vs. Screws

Dobbs, Lenke et al. Spine 2006 Sep 15;31(20):2400-4

- 66 patients with Adolescent Idiopathic Scoliosis underwent selective thoracic fusion.
- 34 with Hooks vs. 36 with all pedicle screws
- Statistically significant curve correction in the screw group compared to hooks ($p<0.001$)
- Incidence of decompensation, with a >20mm shift to the left of C7 plumbline, was higher in the hook group (13 pts.) vs. screw group (4 pts.)
- No complications or reoperations.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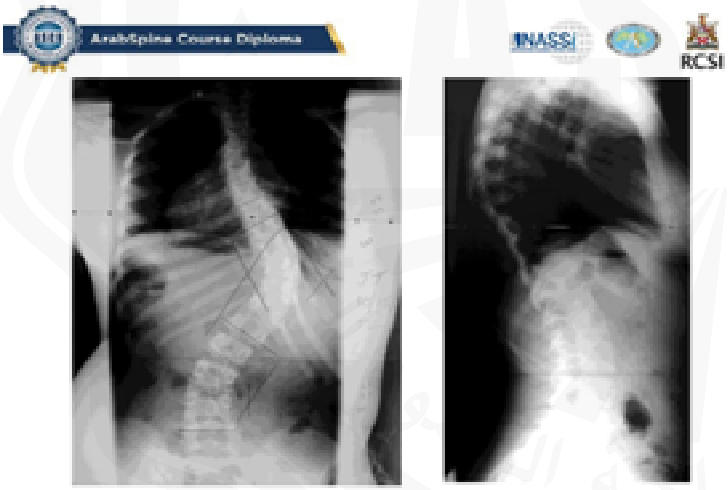
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Summary

- Segmental fixation allows correction of deformity in all planes
- All screw constructs appear to give better correction but at additional expense.
- Hybrid constructs have been shown to be also effective.

Navigation in Deformity Surgery

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Latest Assistive Technologies and Tools

- UNiD™ Pre-op planning software
- Patient specific pre-bend rods
- Computer Navigation
- Robotic-assisted surgery
- Expandable TLIF cage
- Clinical and radiographic outcome tracking

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Reasons I Use Navigation/Robotics

- Improves screw accuracy
- Maximized screw size and bony purchase
- Decreases intraoperative stress
- Enables me to focus energy on critical parts of surgery (osteotomy, deformity correction, tumor resection, etc)
- Enables MIS surgery/ MIS deformity correction
- Facilitates osteotomy in complex revision cases
- Facilitates tumor resection

→ Better Patient Outcome, Less Complications, Less Revisions In My Practice

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Common Reasons for Revision Spinal Deformity Surgery

- Adjacent level issues (PJK/DJK/adding-on)
- Pseudarthrosis
- Instrumentation related problems (screw malposition/loosening, screw/rod fractures, etc)
- Persistent neural compression
- Iatrogenic deformity

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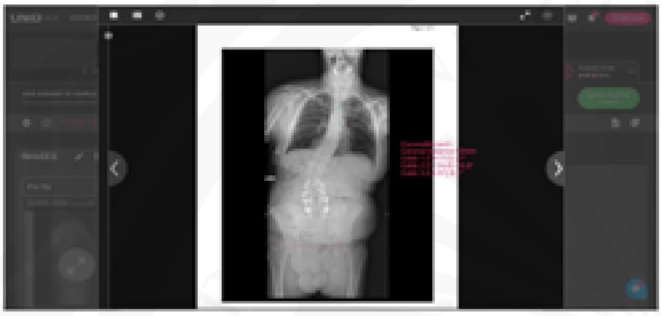
UNiD™ Pre-op Planning Software



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UNiD™ Pre-op Planning Software

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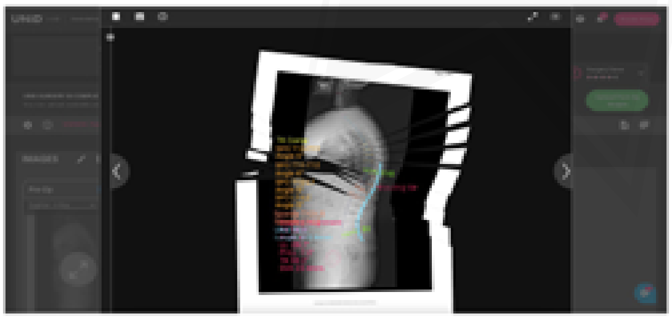
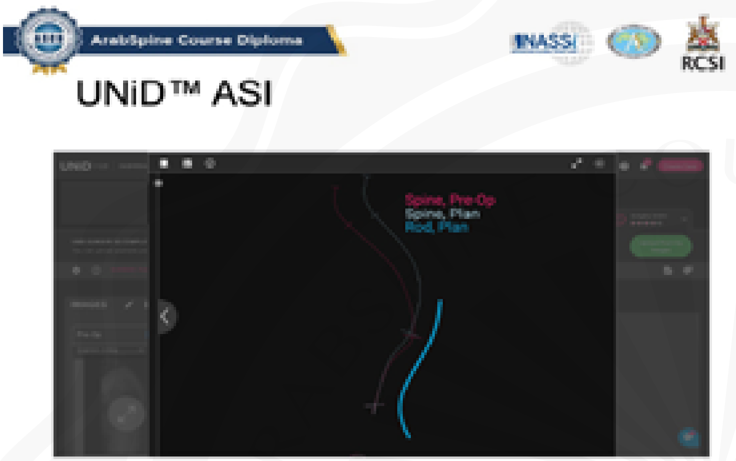
UNiD™ ASI

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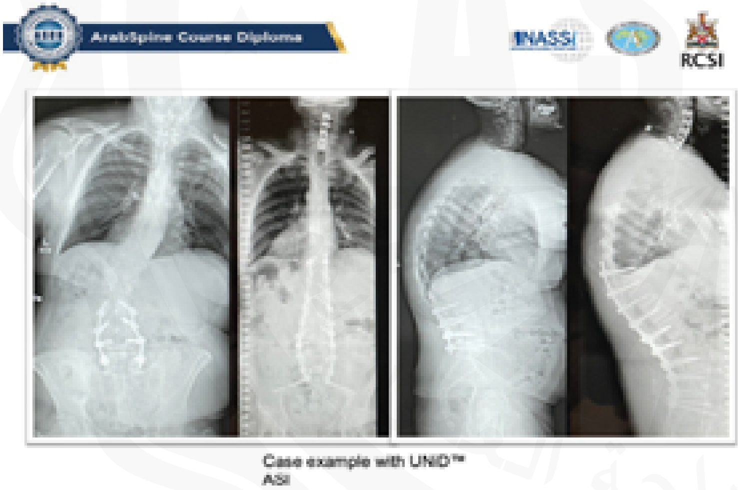
UNiD™ ASI
Spine, Pre-Op
Spine, Plan
Rod, Plan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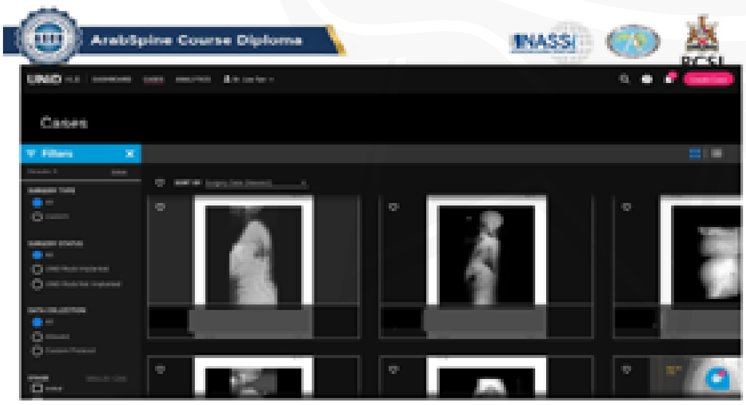
Case example with UNiD™ ASI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Cases
Filters

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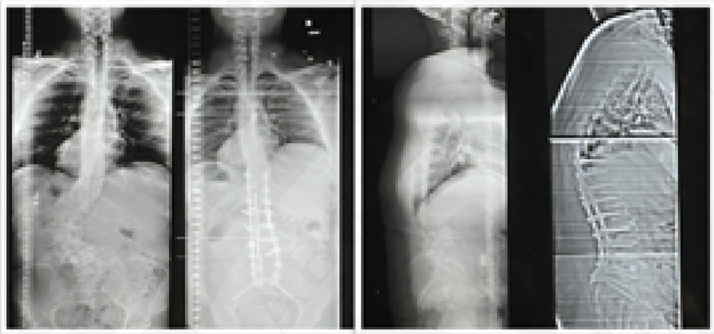

Case example with UNiD™
ASI

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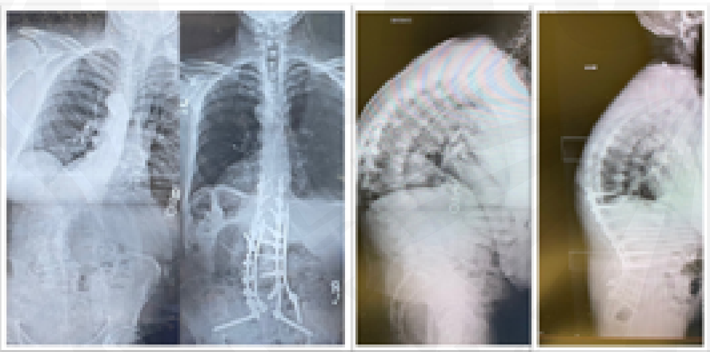

Case example with UNiD™
ASI

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Case example with UNiD™
ASI

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Reasons I Use Navigation/Robotics

- Improves screw accuracy
- Decreases intraoperative stress
- Enables me to focus energy on critical parts of surgery (osteotomy, deformity correction, tumor resection, etc)
- Enables MIS deformity correction
- Facilitates osteotomy in complex revision cases
- Facilitates tumor resection

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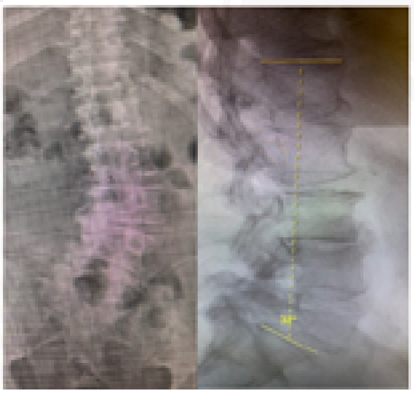
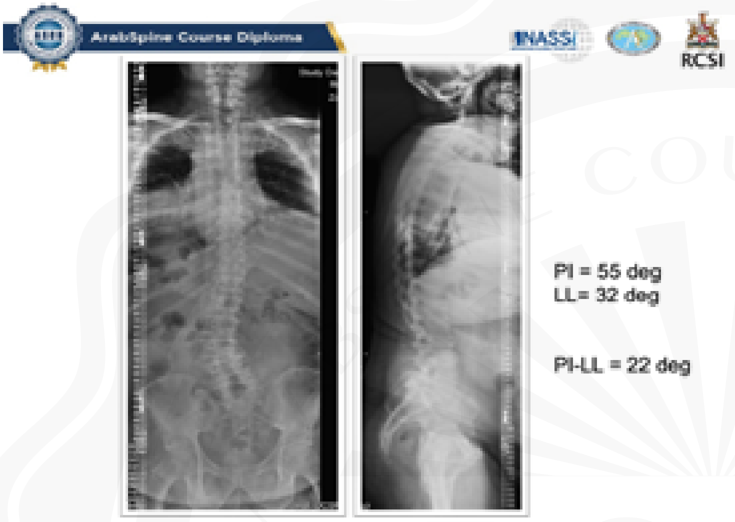
60M Jehovah's witness, severe back and BLE pain, DDD & spondylolisthesis at L5-S1



PI = 55 deg
LL= 32 deg

PI-LL = 22 deg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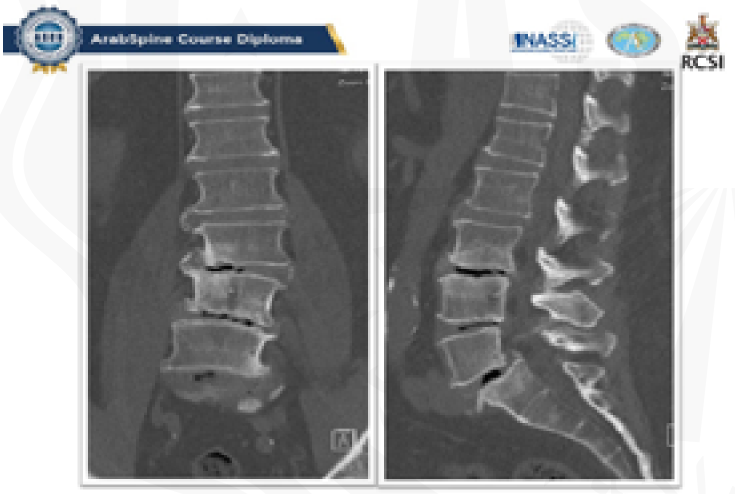
PI = 55 deg
LL= 32 deg
PI-LL = 22 deg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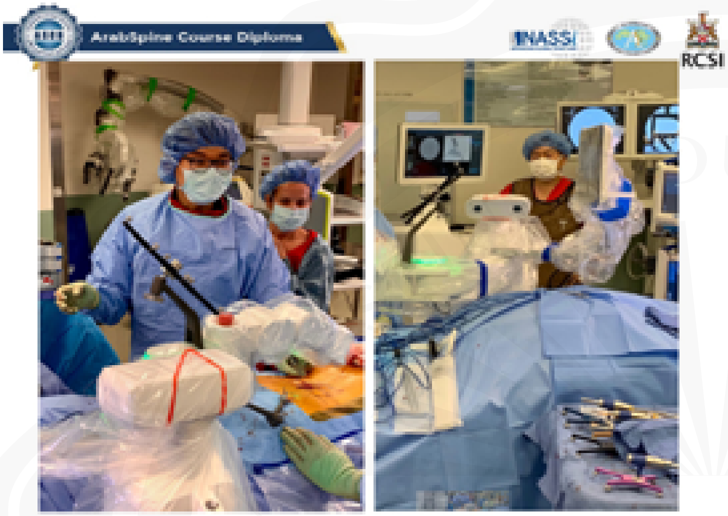
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Robotic Assisted Surgery =
Decreased Cognitive Workload
Drill
Tap
Screw


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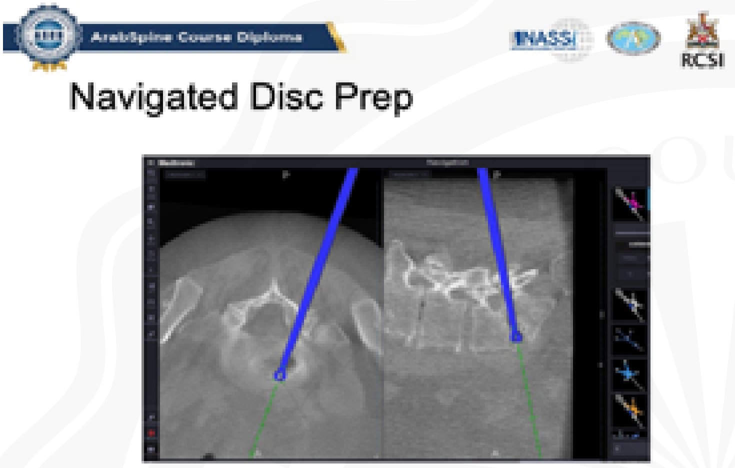
Navigated Disc Prep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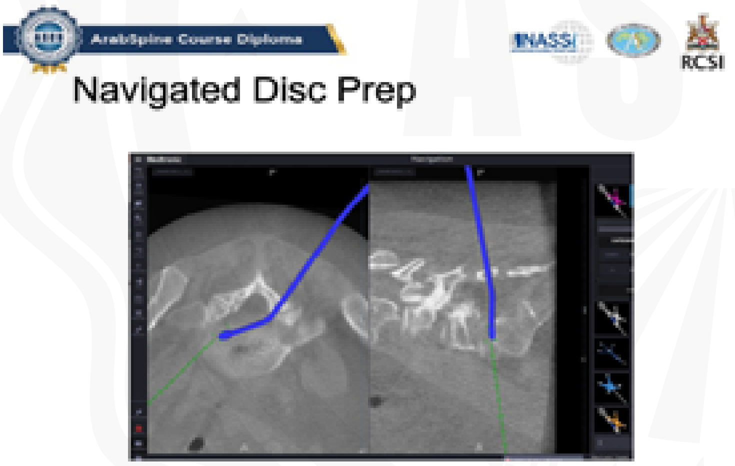
Navigated Disc Prep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Navigated Disc Prep


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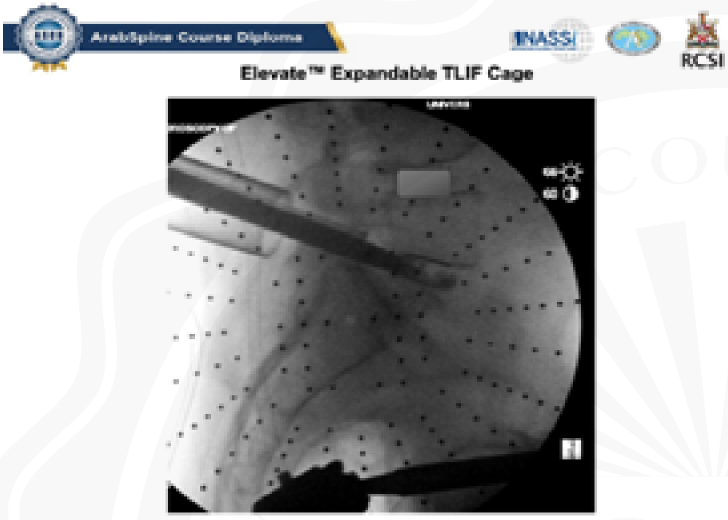
Navigated Disc Prep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Elevate™ Expandable TLIF Cage


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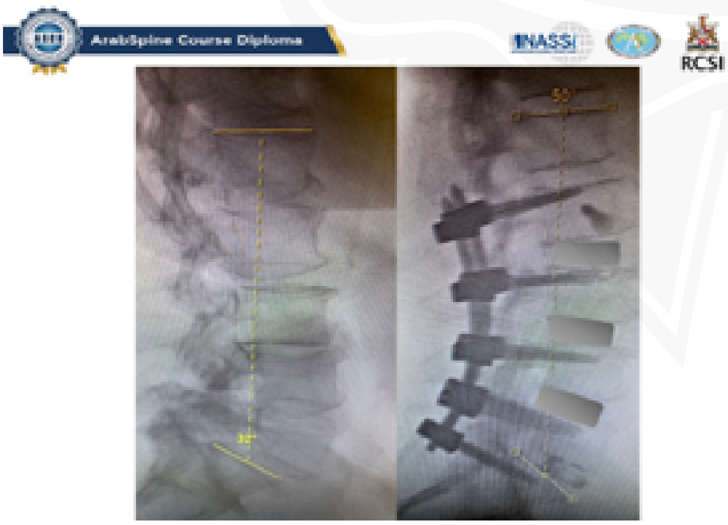
Pre and post op images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Post-op course

AAOx3, MAE 5/5

Discharged home on POD3

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Reasons I Use Navigation/Robotics

- Improves screw accuracy
- Decreases intraoperative stress
- Enables me to focus energy on critical parts of surgery (osteotomy, deformity correction, tumor resection, etc)
- Enables MIS deformity correction
- Facilitates osteotomy in complex revision cases
- Facilitates tumor resection

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Iatrogenic Flatback

HPI: 68F presents with a progressive severe low back and BLE pain (L>R), 10/10 low back pain with radiation into both buttock, hips, and lateral thighs. Could not walk due to pain and inability to stand straight.

PMH/PSH:
- Anxiety
- Spine sx in 2016 at OSH

All: NKDA

SH: negx3

PHYSICAL EXAM
- AAOX3
- BUE 5/5
- BLE 4 to 4+/5 limited by pain
- Unable to stand up straight

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- Takes 5 to 10 pills of 650mg acetaminophen.
- She is also taking gabapentin and using heat.
- She has had multiple ED visits for pain and has tried muscle relaxants, prior opioid therapy, and oral steroids and lumbar ESI.
- Unable to tolerate NSAID therapy due to GI symptoms and investigation of possible IBD.
- Tried physical therapy with severe increase in pain.
- She has tried neurostimulator trial without relief

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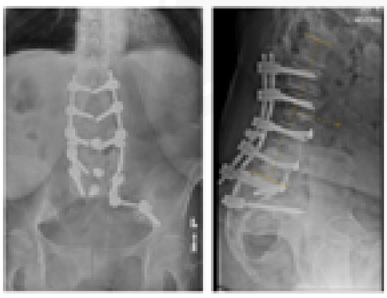
L3-S1 ALIF + L2-S1 PSF at OSH in 2016



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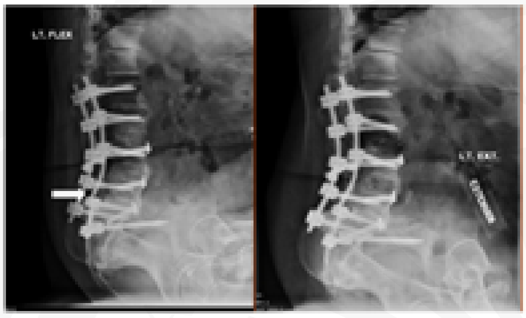

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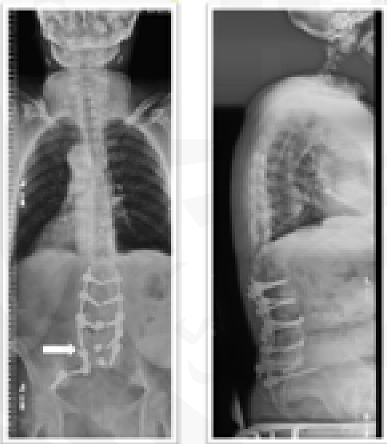

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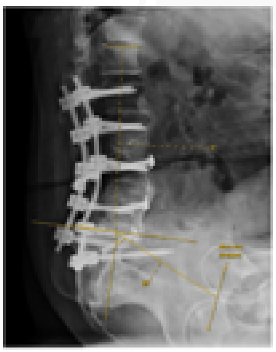

PI = 65 deg
LL = 5 deg

PI-LL = 60 deg

SS=10 deg
PT=55 deg

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Diagnosis?

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Diagnosis?

PJK
L5-S1 pseudarthrosis
Iatrogenic flatback syndrome

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Management plan?

PI = 65 deg
LL = 5 deg

PI-LL = 60 deg

SS=10 deg
PT=55 deg

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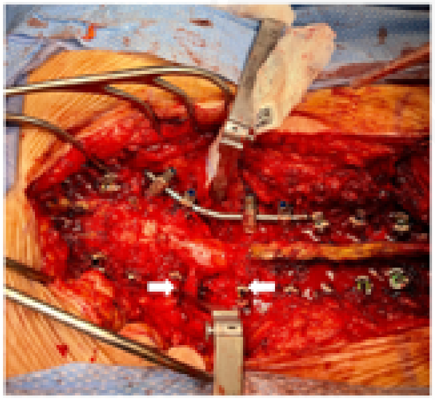
Revision T10-pelvis w/ L3 PSO



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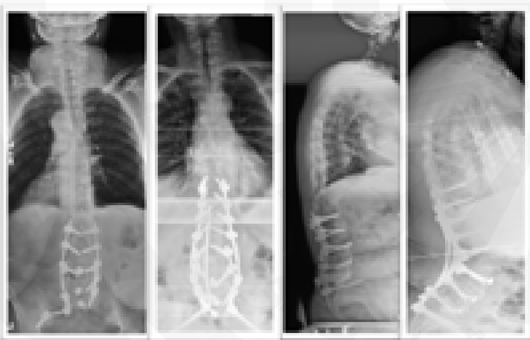

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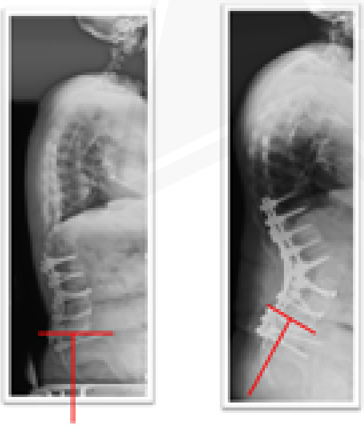

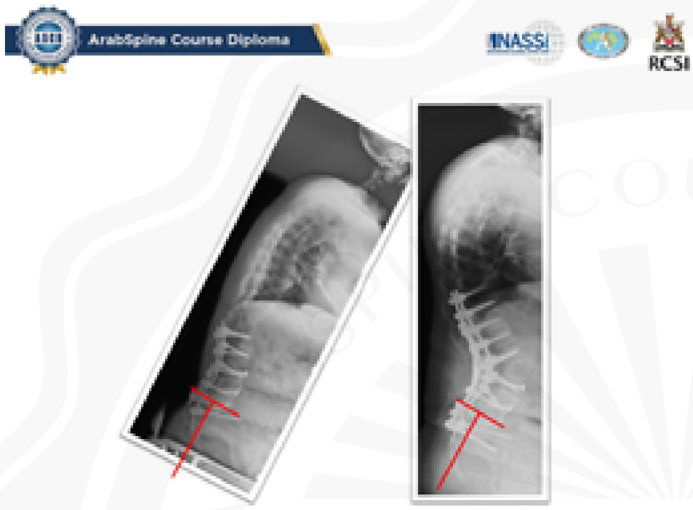
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Rigid Coronal & Sagittal Deformity

HPI: 42F with prior T10-pelvis fusion presents with increasing low back pain and left leg pain

PMH/PSH:

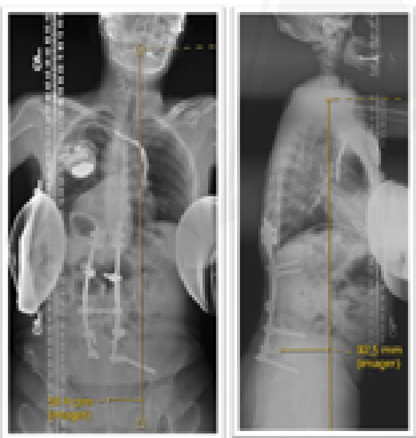
- Cardiac arrhythmia → defibrillator placement
- T10-pelvis fusion as a teenager

All: none

Meds: oxycodone

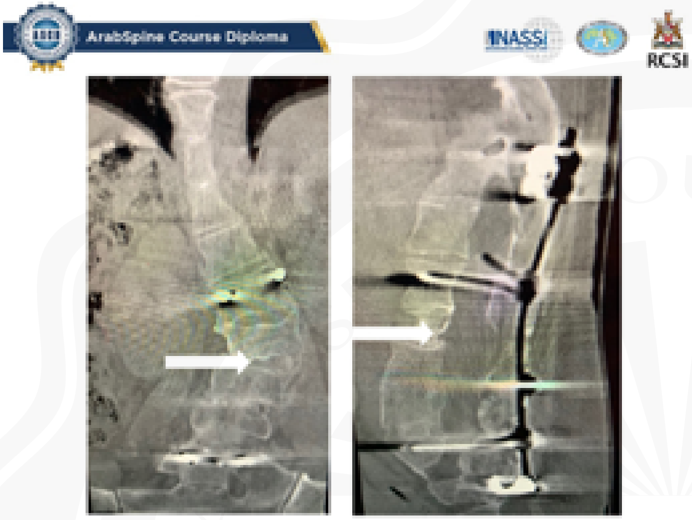
PHYSICAL EXAM:

- AAOx3
- MAE 5/5 except LLE 4+/5
- Sensation grossly full
- Reflexes 2+



Trunk shift: 5.84cm Rt

SVA = +9.25cm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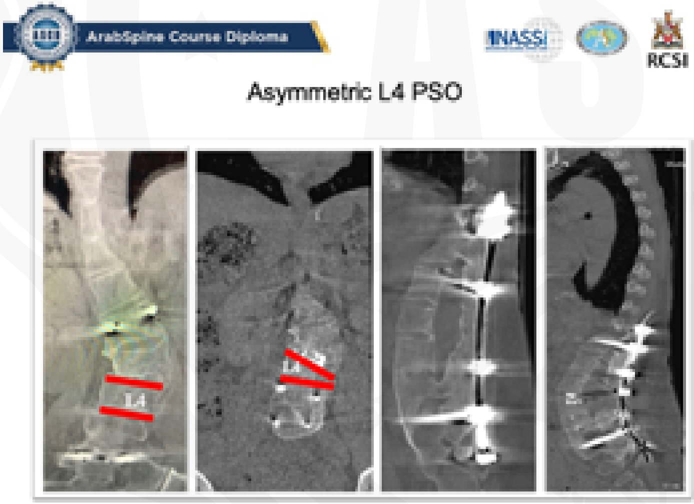
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Asymmetric L4 PSO
L4


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Asymmetric L4 PSO

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Rigid Sagittal deformity due to PJF

HPI: 73F with multiple prior spinal surgeries presented with fever, bacteremia, severe cervicothraocic kyphosis and skin erosion with exposed hardware

PMH/PSH:

- Anxiety, Depression, SVT, Hypothyroidism, Psoriatic Arthritis, osteoporosis (T-score = -2.9)
- multiple spinal surgeries, with last T4 to S1 with L3 PSO in 2015 at OSH
- bowel perforation with multiple bowel resections

All: amoxicillin, allopurinol

Meds: Vancomyacin, bupropion, diltiazem, neurotin, dilaudid, synthroid

PHYSICAL EXAM

- MAE 4+/5
- Sensation grossly full
- Reflexes 2+
- Able to ambulate
- Open wound in the upper thoracic region

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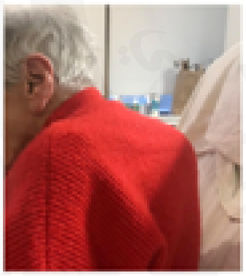

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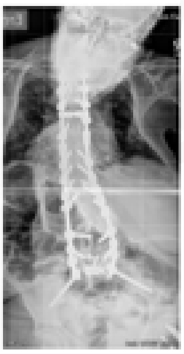

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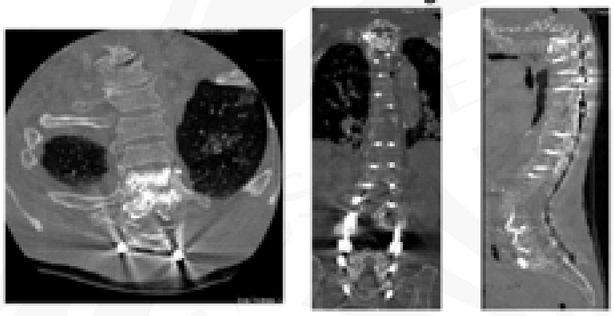
Axial/Coronal/Sagittal



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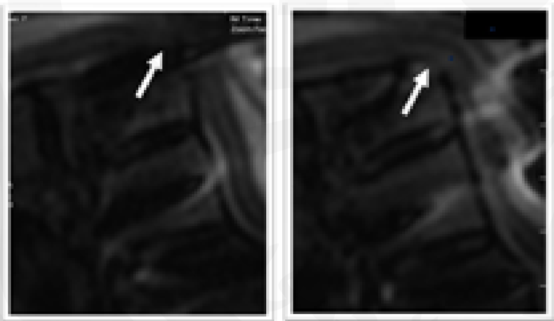

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Treatment options?


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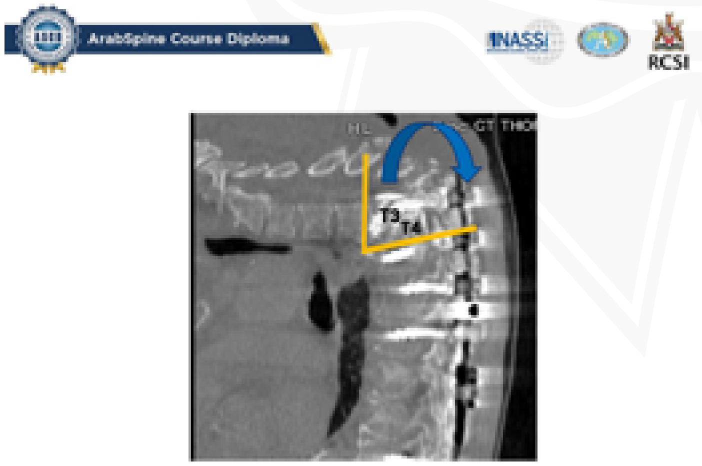
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T3
T4

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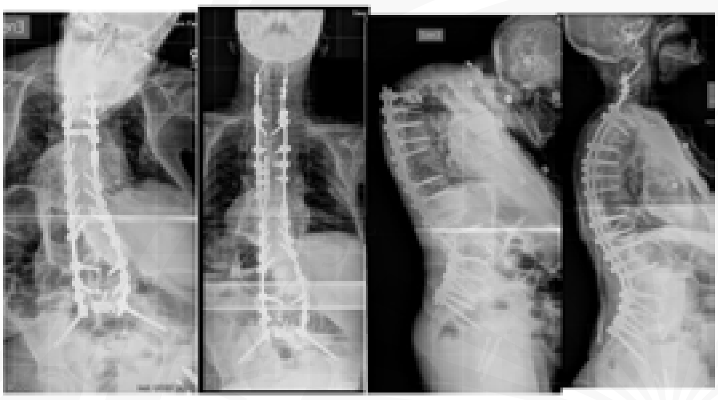

"Wound debridement prior to device implantation

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Severe Kyphoscoliosis

HPI: 28F with progressive back pain, lack of appetite, and difficulty with ambulation.

PMH/PSH:

- Marfanoid syndrome
- "Squished visceral syndrome"

All: NKDA

Meds: Tylenol, norco, NSAIDS

PHYSICAL EXAM

- MAE 4+/5
- Sensation grossly full
- Reflexes 3+
- Able to ambulate

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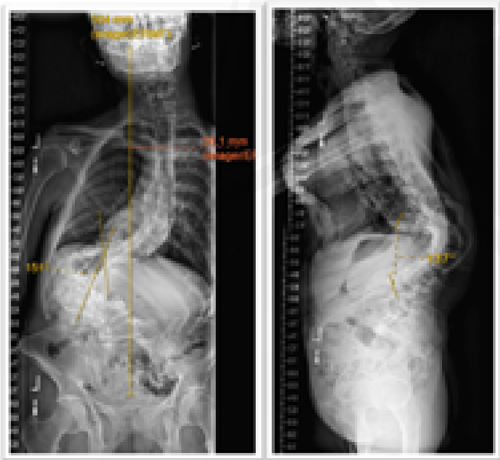


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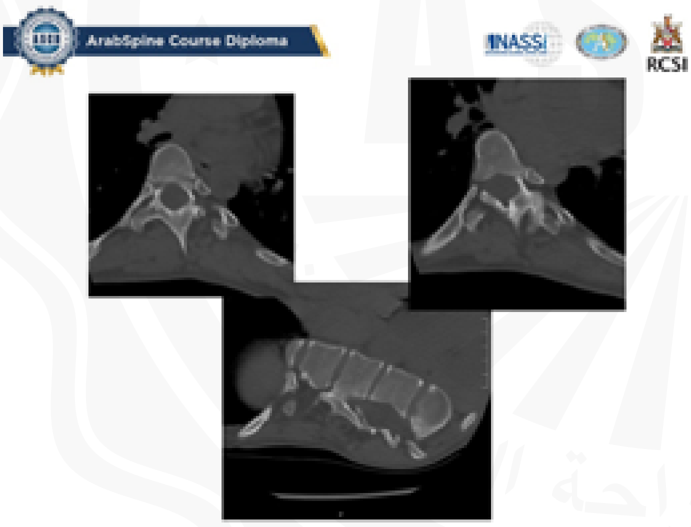
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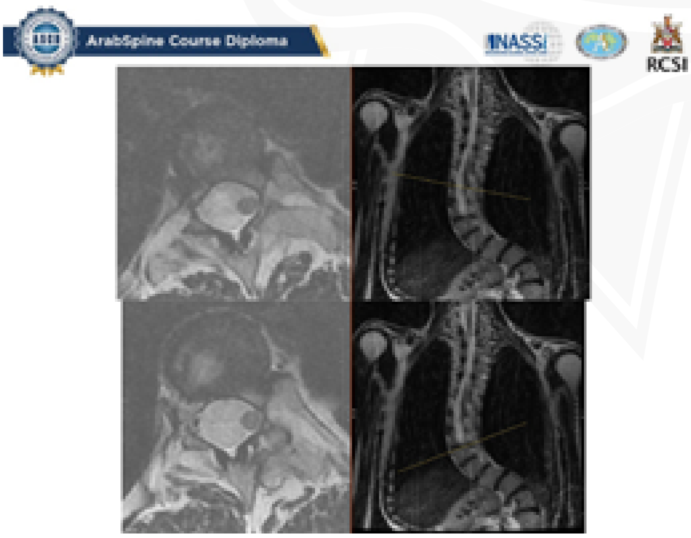
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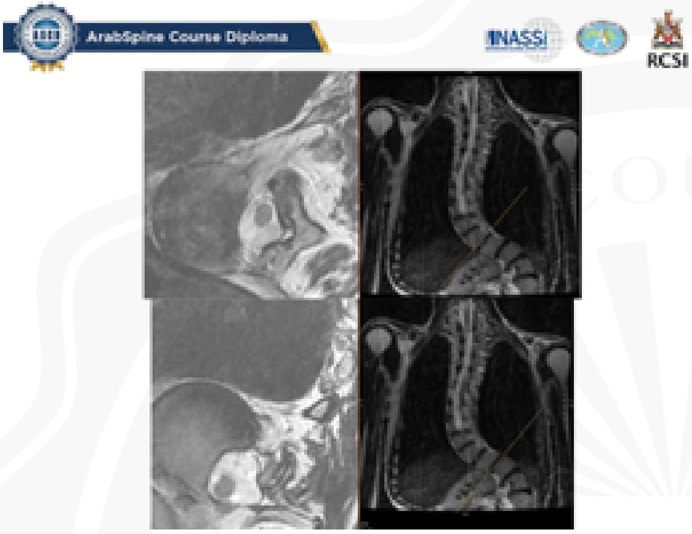
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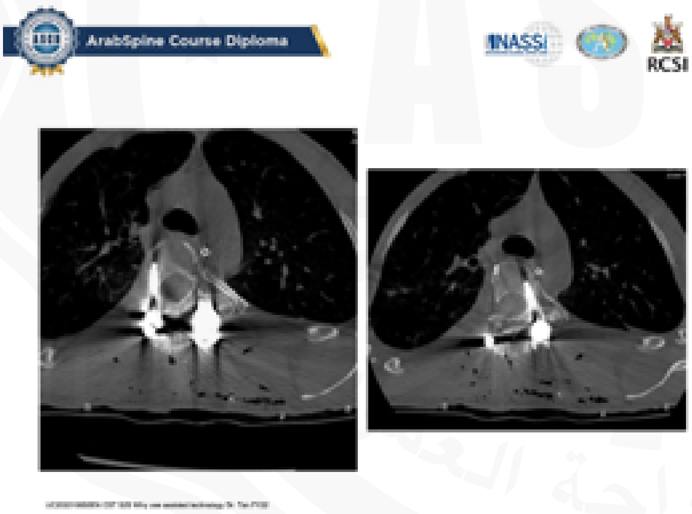
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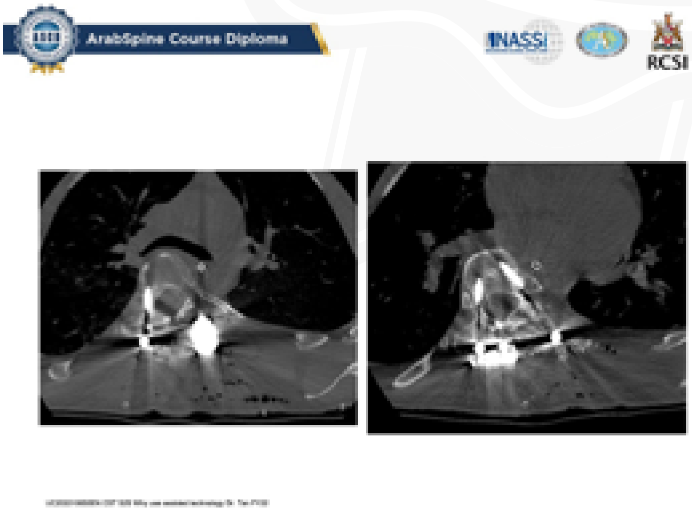
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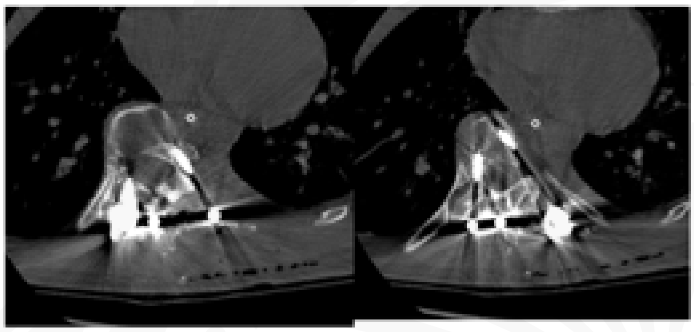

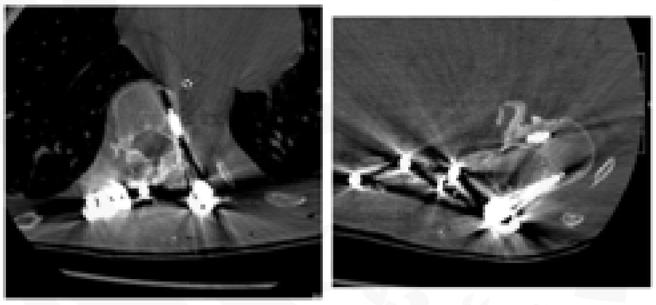

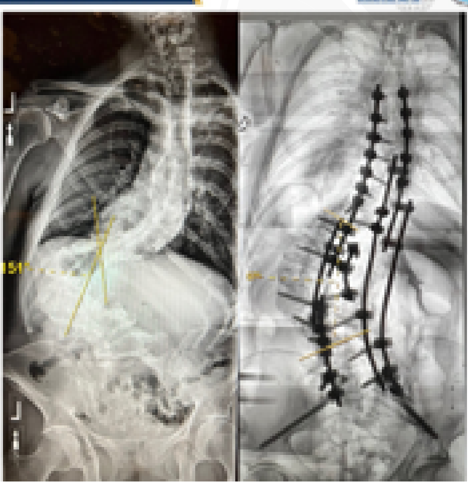


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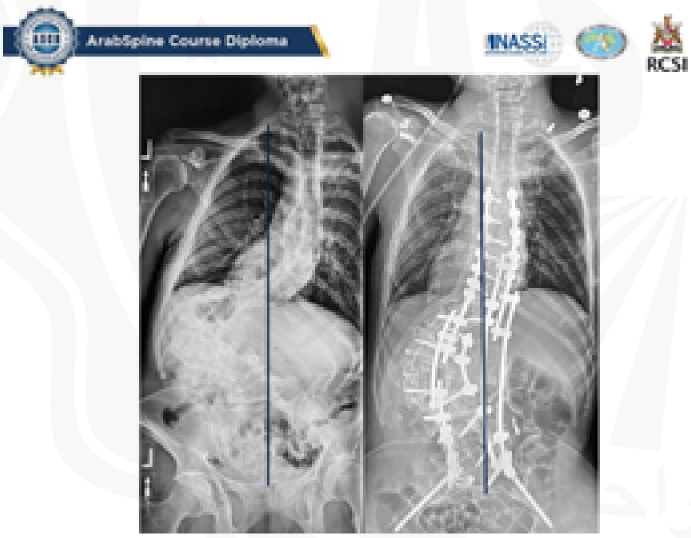
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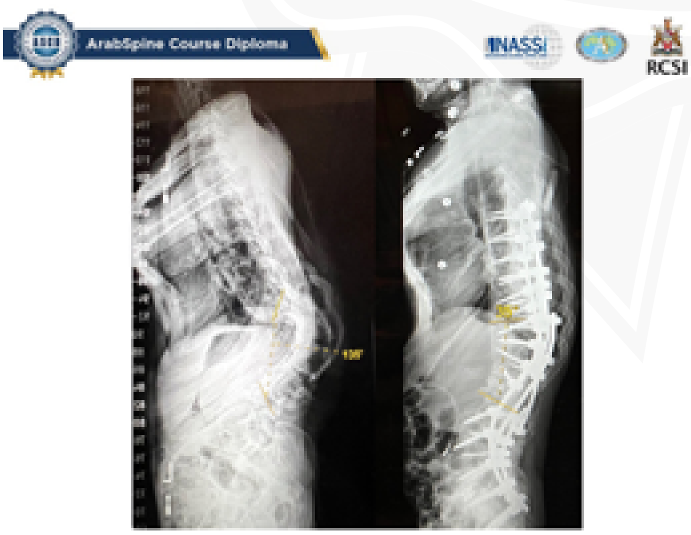
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Reasons I Use Navigation/Robotics

- Improves screw accuracy
- Decreases intraoperative stress
- Enables me to focus energy on critical parts of surgery (osteotomy, deformity correction, tumor resection, etc)
- Enables MIS deformity correction
- Facilitates osteotomy in complex revision cases
- Facilitates tumor resection

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Giant Thoracic Spine Tumor

HPI: 48M transferred from OSH for 6 weeks of thoracic back pain and 2 weeks of bilateral leg weakness.

PMH/PSH:

NONE

All: NKDA

SH: negx3

PHYSICAL EXAM

AAOX3

BUE 5/5

BLE 4 to 4+/5

Unsteady gait

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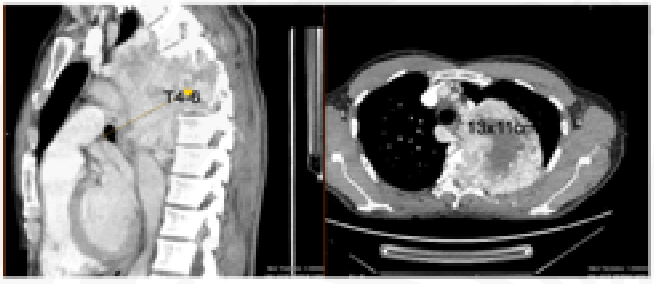
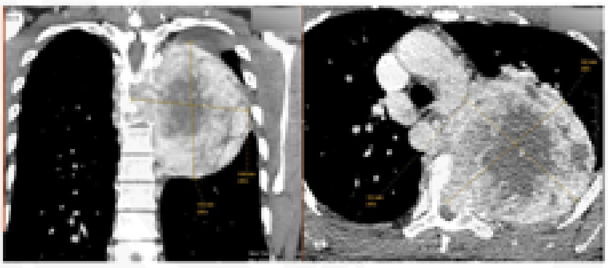
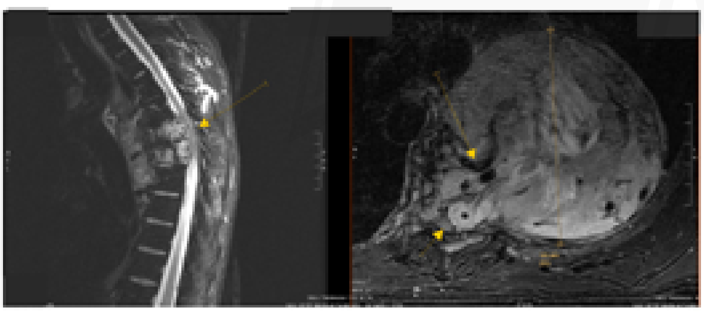


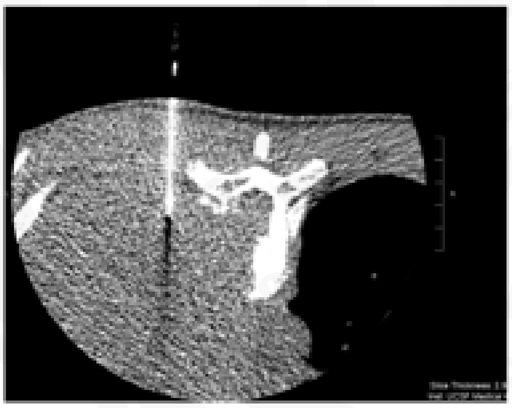
CT chest showing 13x11cm mass with cord compression and T4-6 vertebral destruction





Differential dx?

Additional work-up?



CT-guided bx prelim path =

Paraganglioma vs. schwannoma vs. MPNST

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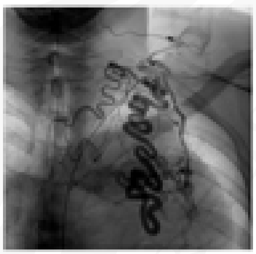
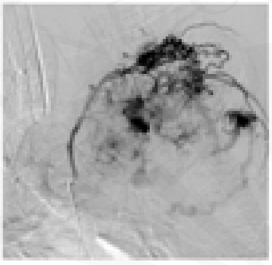
Angio showed extremely hyper-vascular tumor →
Pre-op embolization performed by IR





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Surgical plan?

Anterior?
Posterior?
Anterior/Posterior?
Posterior/Anterior?

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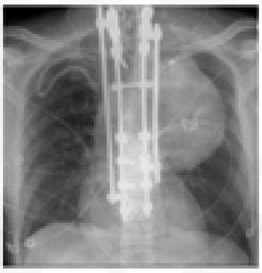
Surgical plan?

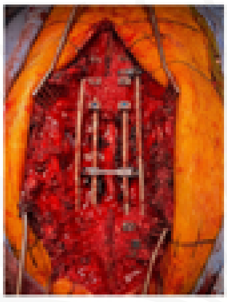
Two-stage en-bloc resection was planned:

1) Posterior decompression/tumor separation + spinal stabilization

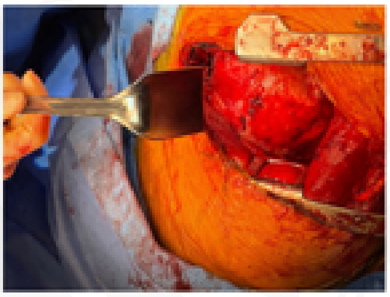
2) Anterior thoracotomy for tumor resection and anterior spinal column reconstruction

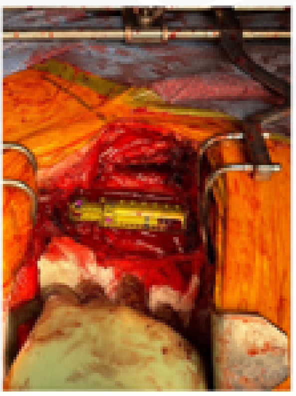
Stage 1 – Posterior decompression/tumor separation + stabilization





Stage 2 – thoracotomy for tumor rsxn & T4-6 VCR with anterior spinal reconstruction



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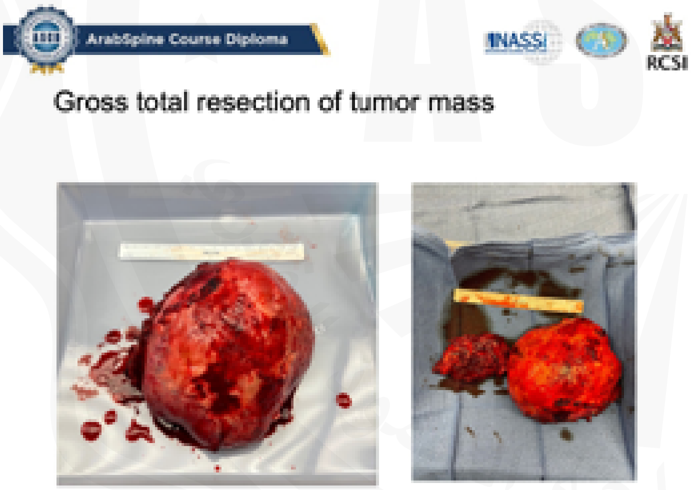
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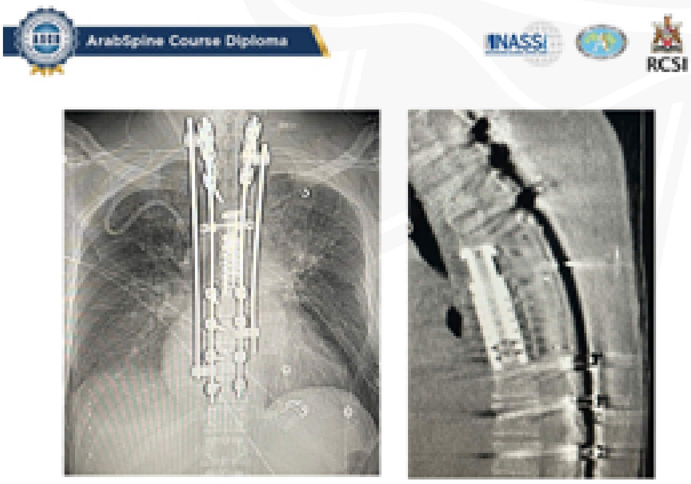
Gross total resection of tumor mass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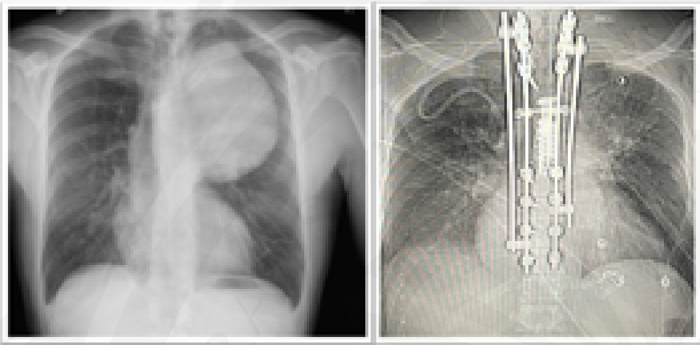

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Post-op

Neurologically stable post-op.

Doing well at 1 year follow-up visit.

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Reasons I Use Navigation/Robotics

Improves screw accuracy

Maximized screw size and bony purchase

Decreases intraoperative stress

Enables me to focus energy on critical parts of surgery (osteotomy, deformity correction, tumor resection, etc)

Enables MIS surgery/ MIS deformity correction

Facilitates osteotomy in complex revision cases

Facilitates tumor resection

→ **Better Patient Outcome, Less Complications, Less Revisions In My Practice**

MIS Techniques in Adult Deformity

Open Procedure

- Maneuvers to destabilize the spine
  - Removal of posterior osteo-ligamentous structures
  - Facet osteotomies, PSO
  - IB Cages,
- Large Grafting site
- LS Junction Fixation

Treatment of adult spinal deformity Complications

Complication rates 41.2 %

- Excessive blood loss
- Deep wound infection
- Pseudarthrosis

MIS & Adult Deformity

MIS for adult spinal deformity surgery have been developed to address the high perioperative morbidity of traditional open approaches....

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MIS Today

- reduced blood loss
- lower narcotic consumption
- faster mobilization
- Reduced infection rates

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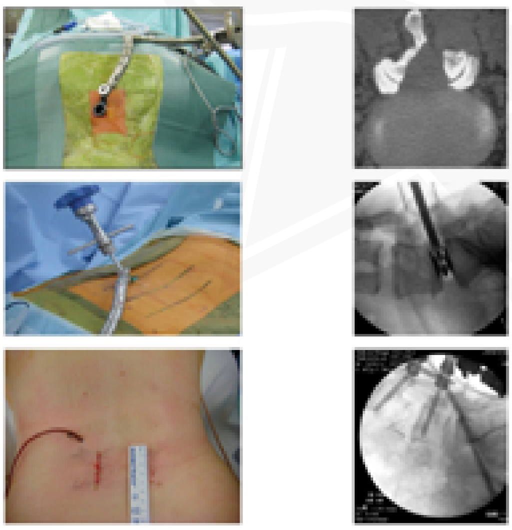
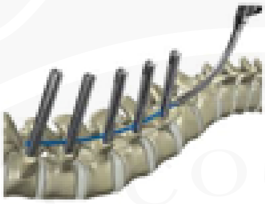
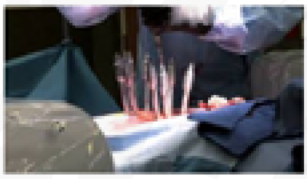
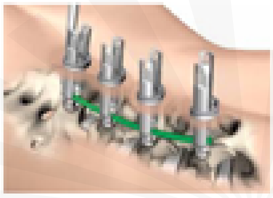
Standard Applications for MIS

Decompression
Short Segment arthrodesis
ALIF, DLIF, OLIF
Deformity correction










2/3
3/4
4/5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Adult deformity

Surgical considerations

- **Adequate decompression (direct & undirect)**
- **Implants should be accurately placed**
- **Solid fusion should be established**
- **Sagittal balance should be restored**

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Deficiencies with MIS Surgery

- Curve under correction (**MI osteotomies)**
- Multisegmental **fusion**
- Management of **fractional curves**
- **Lumbosacral Junction**

Limitations

- Learning curve
- Reduction capabilities (deformity)
- Radiation exposure

Surgical MI options

- Multilevel MI 360° correction and fusion
- Anterior realignment posterior MI screws & rods
- MI Pedicle osteotomy

Surgical MI options

- Multilevel MI 360° correction and fusion
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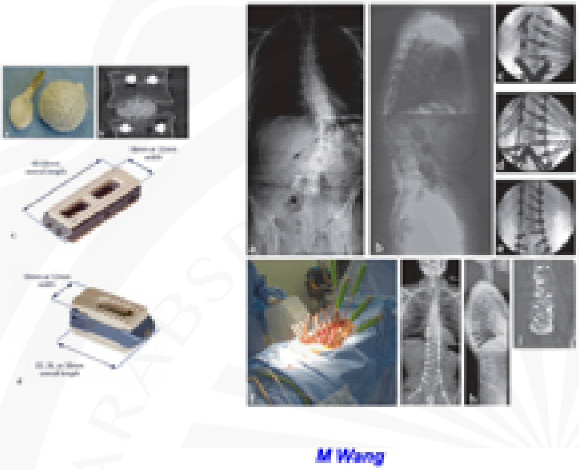

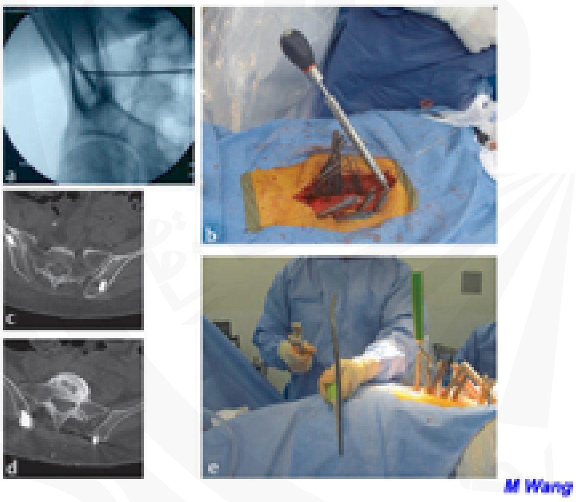

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Surgical MI options

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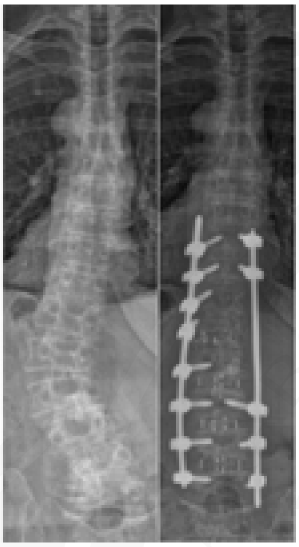

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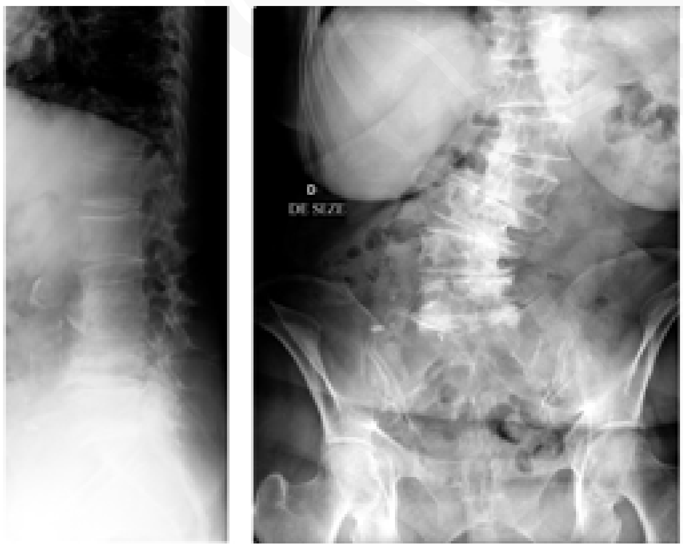
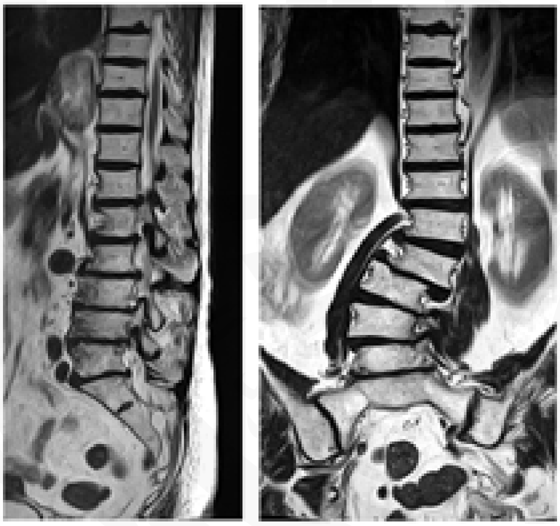
- 83 y old F
- L3/L5 Laminectomy
- Back pain
- Neurogenic claudication. Permanent L4 radiculopathy (VAS 6)
- Failure of conservative treatments
- Asking for surgery
- ODI 56



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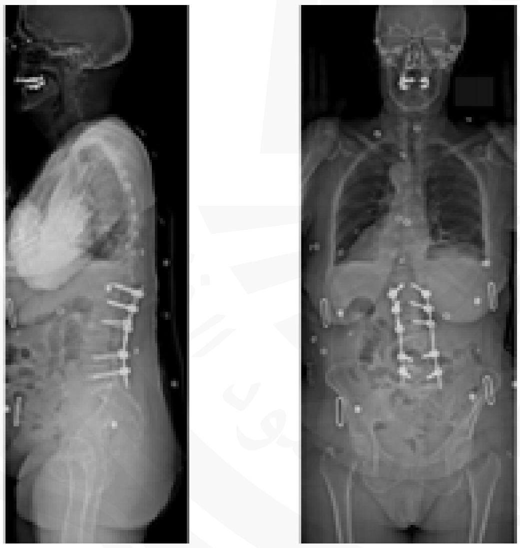
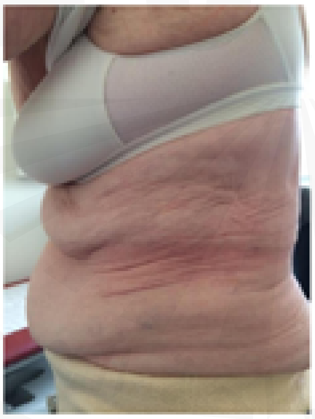
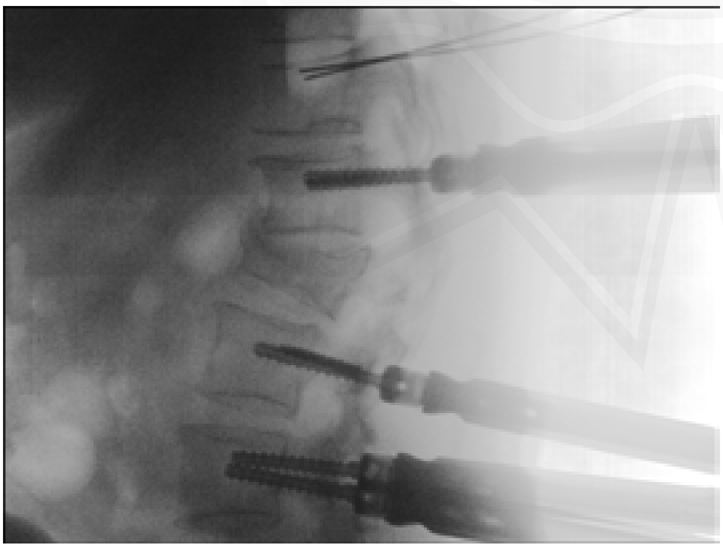


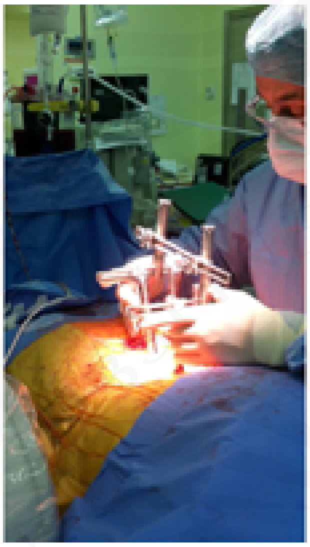


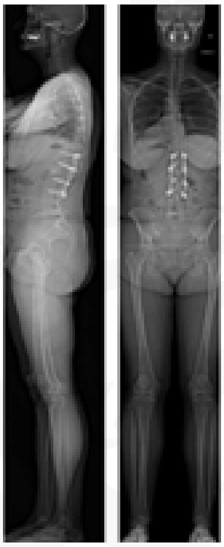
Surgical MI options

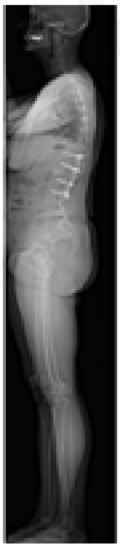
- Multilevel MI 360° correction and fusion
- Anterior realignment posterior MI screws & rods
- MI Pedicle osteotomy

- 54 y Old F
- L1 Fracture
- Pseudarthrosis, Hardware fracture
- Removal of the hardware
- Post operative kyphosis (4y)
- Back pain: ODI 46%



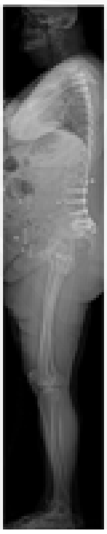






perspectives

Bipolar instrumentation



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In summary

- MI technologies are applicable to ASD
- Fundamentals of deformity surgery are not negotiable
- Be aware of limitations
- On going technologies

Sacro-Iliac Fixation Principle and Technical Options

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Biomechanical Considerations

- Lumbosacral junction is at a mechanical disadvantage
- The spine above the pelvis acts as a lever
- Stress concentration at the lumbosacral junction
- The sacrum is a thin cortical shell with weak cancellous bone
- Poor site for fixation

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Early Surgical Techniques

- Harrington instrumentation
  - Sacral bar and hook
  - High pseudarthrosis rate (17-25%)
  - Bar migration
  - Hook dislodgement

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Early Surgical Techniques

- Segmental fixation with L-rod and sublaminar wires developed by Luque in 1976
  - Return of pelvic obliquity due to vertical dissociation of rods
  - High pseudarthrosis rate
  - S1 nerve root injury from sublaminar wire

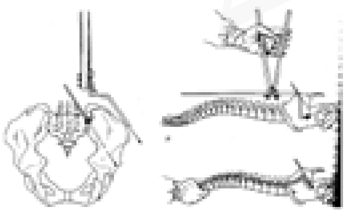
The Galveston technique for L-rod instrumentation of the scoliotic spine

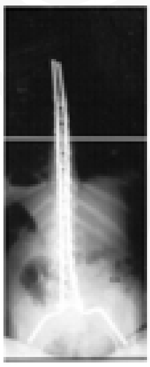
Allen BL Jr, Ferguson RL: Spine 7, 1982

The Galveston Technique

- Rods anchored between inner and outer tables
- Secure fixation
- Stable base to correct pelvic obliquity

Luque Galveston for Pelvic fixation





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Disadvantages of the Galveston Technique

- 3-D bending of the rods
- Extensive exposure of the Ilium
- Prominent hardware

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Other Techniques

- Iliosacral screws
  - Dubousset
- Jackson intrasacral fixation
- S-rod fixation
  - McCarthy
- Chopin block

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Spinal Fusion to the Sacrum in Adults with Scoliosis

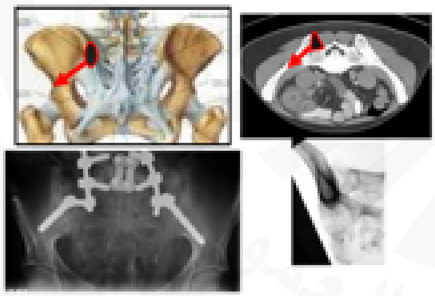
Kostuik et al: Spine 8 No5, 1983

- 78% complication rate
- 22 patients with loss of lordosis
  - 13 required osteotomy
- 10 out of 45 patients with pseudarthrosis

Modified Galveston Technique

- Pedical screws in ilium
- Screws attached to rods directly or with transverse connector
- Avoids need for 3-D bend

Technique of Iliac fixation



Interbody Fusion

- Combined anterior and posterior procedures
- Improved construct stiffness
- Improved fusion rates

Biomechanical Testing of the Lumbosacral Spine

Kostuik et al: Spine 23 No16, 1998

- Increased stiffness with anterior fixation
- Failure to use L5 screws decreased torsional rigidity

Indications for Extension to the Pelvis

- Paralytic or neuromuscular curves with pelvic obliquity
- Idiopathic scoliosis with a painful L5S1 disc
- Oblique lumbosacral take-off
- Sagital malalignment (flat-back)
- Failed prior lumbosacral fusion
- Long fusion above L2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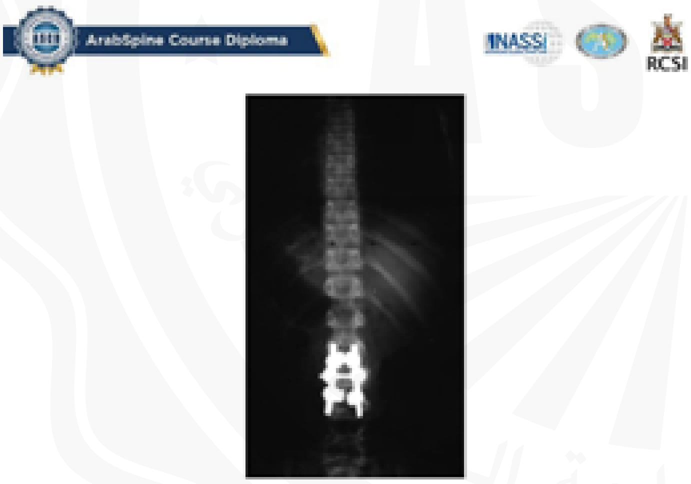
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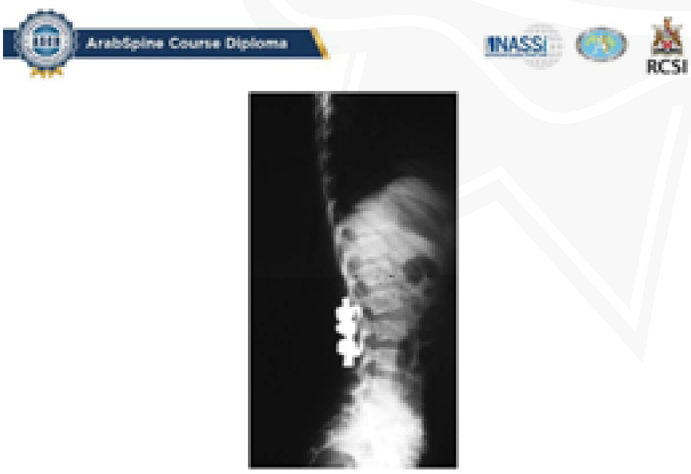
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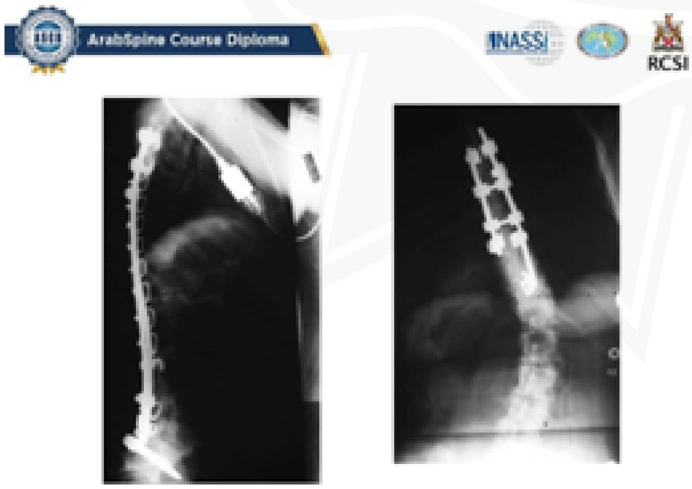
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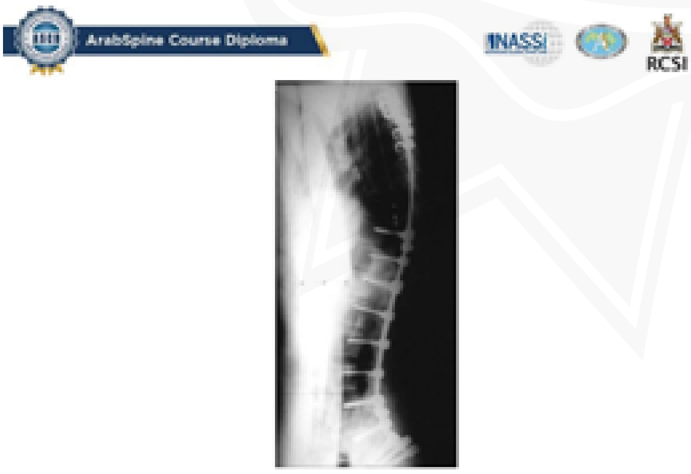
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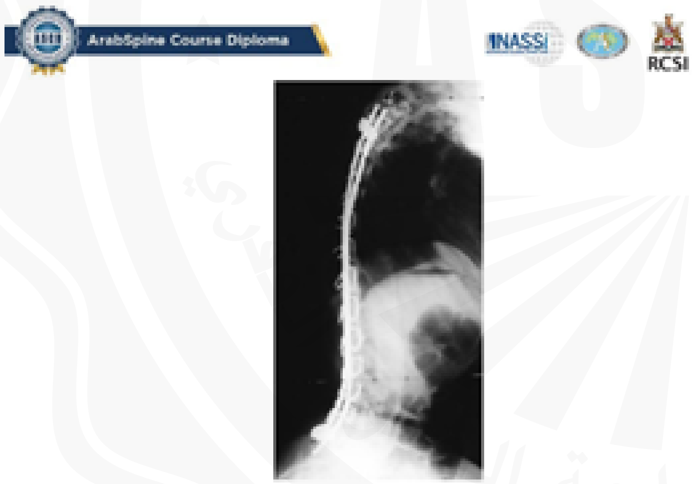
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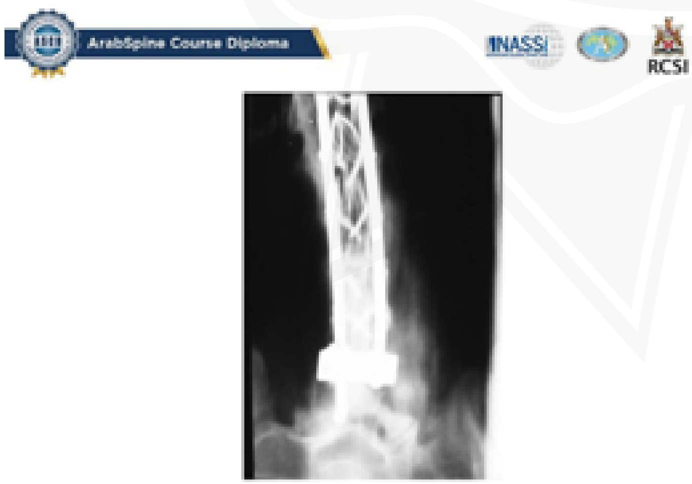
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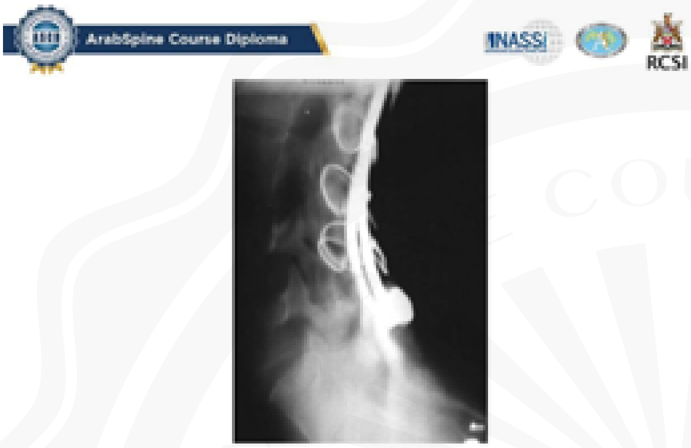
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S2AI Screws

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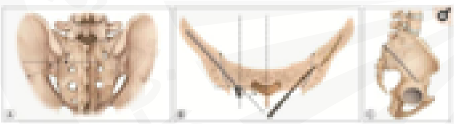

A / The entry point of the S2 alar-iliac (S2AI) screw is located at the midpoint between the S1 and S2 foramen and 2 mm medial to the lateral sacral crest. Caudal angle in the sagittal plane is marked (*). B / Left, horizontal angle in the coronal plane connecting the posterior superior iliac spine is marked (*). Right, the gearshift is initially pointed dorsally as a safety measure to avoid anterior wall perforation of the iliac crest. After crossing the sacro-iliac joint, the tip of the gearshift turned to face ventrally. C / On the lateral plane radiograph, the S2AI screws should be placed above the superior rim of the sciatic notch.

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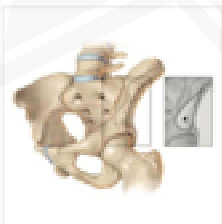
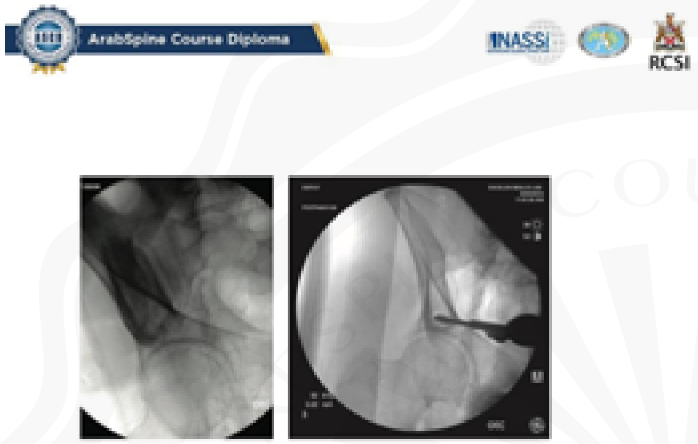
Fluoroscopy can be helpful identifying the appropriate trajectory. The C-Arm should be oriented in the intended trajectory of the implant. Position the C-Arm above the starting point. Next, angle the C-Arm 20–30° caudal (Fig. 4) and 40–50° to the vertical plane (Fig. 5), aiming for the anterior inferior iliac spine (AIIS). With this trajectory, the iliac teardrop should be visible on your AP fluoroscopic image (Fig. 7 and 8). Also note the anterior view of the pelvis and iliac teardrop in figure 6.

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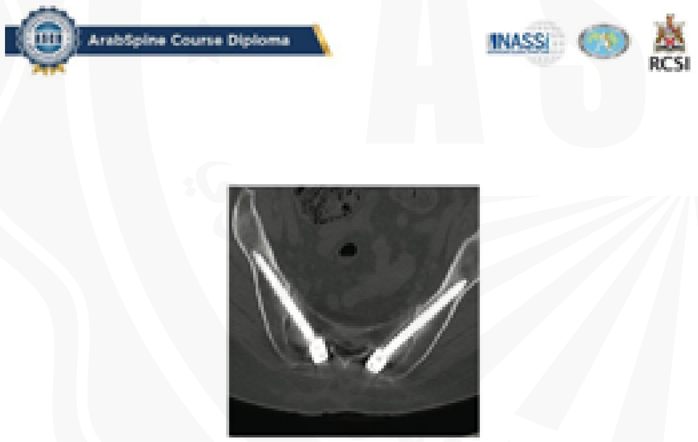
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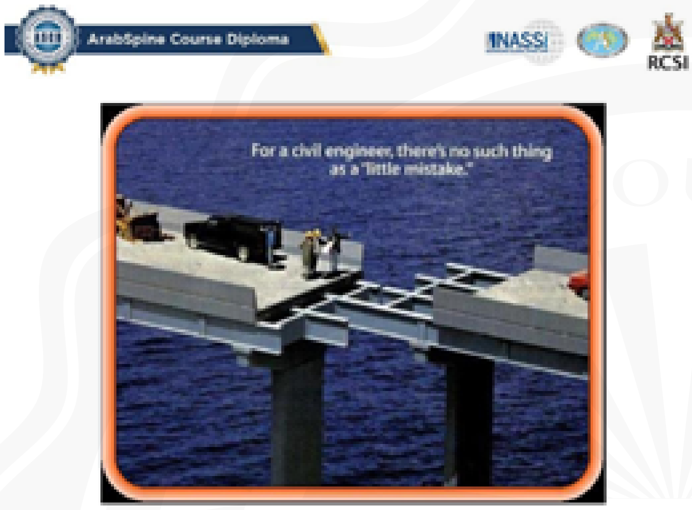
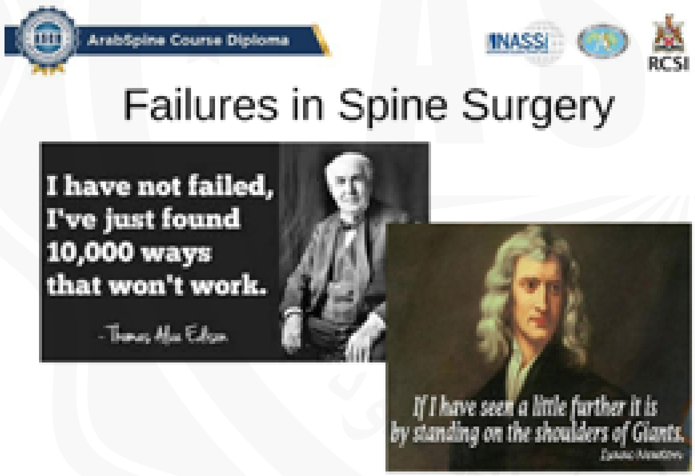
Revising Failed Adult Deformity Surgery





Failures in Spine Surgery

Causes of Failure

- Malalignment
- Nonunion
- Proximal junctional kyphosis
- Distal failure

Optimal Alignment

- Importance of Preoperative Planning
- Understanding surgical goals
  - PI:LL
  - Pelvic tilt
  - Distribution of Lordosis

Spectrum of Post-operative Spinal Deformity:

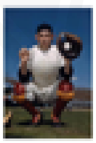
1) Immediate post-op
   a) Fixation of the spine in malalignment
      i) Flatback Syndrome
      ii) Acquired Kyphotic Deformity
      iii) Coronal malalignment
2) Delayed decompensation
   a) Developmental
      i) Crankshaft
      ii) Progressive deformity of a non-structural curve
   b) Degenerative
      i) Junctional Pathology

Avoidance

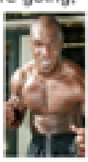
- Pre-operative Planning
  - Choice of Levels
  - Choice of Strategy and Techniques
- Intraoperative Mindfulness
  - Radiographic Assessment
  - Flexibility to change a plan
- Post-operative Recognition

Surgical Planning

- Have a plan. Follow the plan, and you'll be surprised how successful you can be. Most people don't have a plan. That's why it's is easy to beat most folks.
  - Paul "Bear" Bryant



- You got to be careful if you don't know where you're going, because you might not get there.
  - Yogi Berra



- Everyone has a plan until I hit them in the head.
  - Mike Tyson

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Surgical Planning

- By failing to prepare, you are preparing to fail.
  - **- Benjamin Franklin**

- Forewarned, forearmed; to be prepared is half the victory.
  - Miguel de Cervantes Saavedra

- Those who plan do better than those who do not plan even thou they rarely stick to their plan.
  - Winston Churchill

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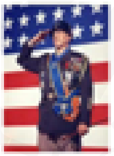
Surgical Planning

- In preparing for battle I have always found that plans are useless, but planning is indispensable.
  - Dwight D. Eisenhower

- A good plan today is better than a perfect plan tomorrow.
  - George S. Patton (1947)



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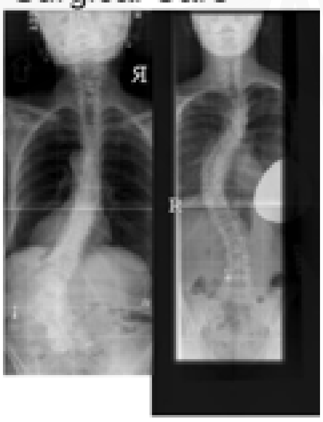
Defining the Goals of Surgical Care

- Safety
- Neural decompression
- Alignment of the spine
  - Correction of deformity
- Prevention of Progression
- Improvement of health-related quality of life
  - General health status
  - Disease-specific health status



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Goals of Realignment Determine Choice of Procedure

- Measurable Goals
  1) Segmental Realignment
     - Restoration of trapezoidal intervertebral disc space
  2) Restoration of Regional Alignment
     - Lumbar Lordosis matching Pelvic Incidence
     - Realignment of chin-brow angle
  3) Restoration of Global Sagittal Balance
     - Shift C7 plumb line to within 3cm of sacral promentory
     - Correction of Pelvic Tilt
  4) Coronal Plane Correction
     - Truncal Translation

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Spine

HEALTH SERVICES RESEARCH

Scoliosis Research Society—Schwab Adult Spinal Deformity Classification

A Validation Study

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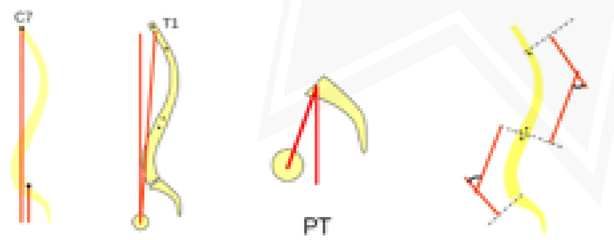
Sagittal Plane Alignment Objectives



SVA	T1 Tilt	PT	Proportional:
<5cm	$<0^0$	$<25^0$	LL=PI $+/- 9^0$

Frank Schwab

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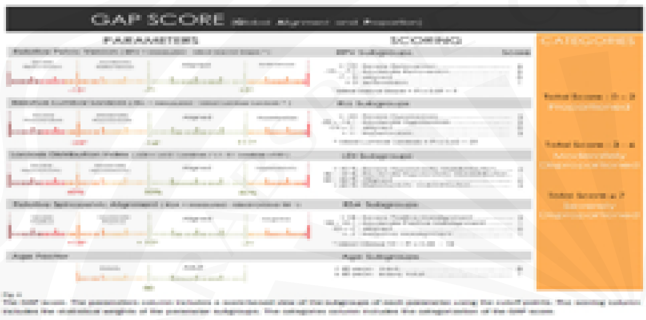
Global Alignment and Proportion (GAP) Score

Development and Validation of a New Method of Analyzing Spinopelvic Alignment to Predict Mechanical Complications After Adult Spinal Deformity Surgery

Caglar Yilgor, MD, Nuray Sogunmez, MSc, Louis Boissiere, MD, Yasemin Yavuz, PhD, Ibrahim Obeid, MD, Frank Kleinstück, Francisco Javier Sánchez Pérez-Grueso, MD, Emre Acaroglu, MD, Sleiman Haddad, MD, Anne F. Mannion, PhD, Ferran Pellisé, MD, and Ahmet Alanay, MD, on behalf of the European Spine Study Group (ESSG)



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Implications of Pseudarthrosis

- Completely asymptomatic
- Radiographic finding
  - Hardware failure
    - Breakage
    - Loosening
- Axial pain
- Deformity
  - Loss of alignment
  - Prominence or skin erosion

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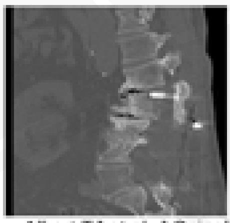
Diagnosis



- Radiographs
  - Hardware failure
    - Can go on to fusion after failure
    - Can't deform without this
  - Dynamic films
- Bone scan50% specificity and sensitivity Albert TJ et al. J Spinal Disord. 1998
- CT scan
  - Coronal in plain of fusion, esp. L5-S1
  - Can see subtle HW failure by adjust contrast
- Surgical exploration
  - Smooth vs difficult to strip

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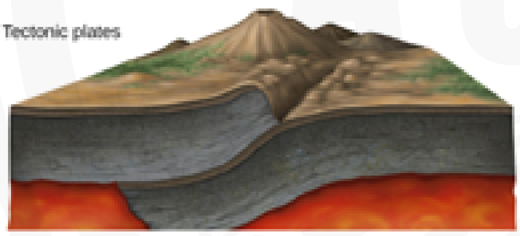

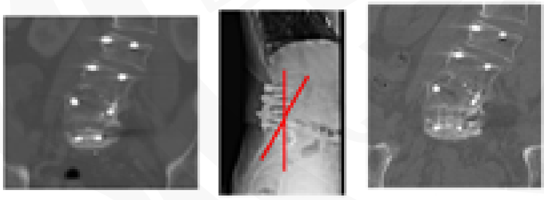

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Who's at risk?
Patient factors

- Smokers
- Low Vitamin D
  - Ravindra et al Spine 2015
- Medications
  - Steroids, bisphosphonates
- Osteotomies
- Parkinsons
- Patient's that pick the wrong surgeon

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Who's at risk?

Procedure/ technique factors

- Osteotomies
- Multilevel
- Long fusions to pelvis
- Junction zones
  - Lumbosacral
  - Thoracolumbar
- Infection
- Fusion bed exposure, preparation, grafting

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Type of bone graft or substitute does not affect outcome of spine fusion with instrumentation for adolescent idiopathic scoliosis.

Theologis et al Spine (Phila Pa 1976). 2015 Sep 1;40(17):1345-51

- Outcomes after primary posterior spinal fusion with instrumentation are not influenced by type of bone graft or substitute.

Why?

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How to Prevent?

- Address the risk factors
  - Biology
- Expose bone surface area
- Create environment for healing
  - Decortication
- Graft selection & placement
- Mechanical stability
  - Overcome instability you created
  - Create better biology/ stability junction zones

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rhBMP-2 protects against reoperation for pseudoarthrosis and/or instrumentation failure: A matched case-control study of 448 patients.

Macki et al J Clin Neurosci. 2016 Oct;32:99-103.

- "instrumented fusion constructs supplemented with rhBMP-2 plus autograft and/or allograft had a 73% lower odds of developing pseudoarthrosis and/or instrumentation failure compared to autograft and/or allograft alone"

7.5 fold decrease reoperation for nonunion in deformity cases

Paul et al Spine 2016

Not found to be true with posterior subaxial cervical fusions

Guppy et al J Neurosurg Spine

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Use of Recombinant Bone Morphogenetic Protein Is Associated With Reduced Risk of Reoperation After Spine Fusion for Adult Spinal Deformity.

Paul et al Spine. 2016 Jan;41(1):E15-21

- 2008-2011 New York State Inpatient Database
  - 3751 patients 2008
  - BMP used in 37.6% @ index procedure
- Reoperation rate within 3 years for fusion >8 levels
  - 23.4% overall
  - 5% with BMP and 33.9% without BMP
  - No difference wound complications
- Mean total hospital charges $196,464 vs $214,551 p<0.001

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"Very Rough Estimate"

- Extra cost $20,000/case
- Estimate 100,00 cost nonunion repair
- 5/100 with bmp vs 34/100 without bmp
- 29 less nonunion repairs
  - Spend $2,000,000 on BMP to Save $2,900,000 on nonunion repair
- Saving $900,000 per 100 patients
  - $9,000/patient

RCSI

. RhBMP-2 is superior to iliac crest bone graft for long fusions to the sacrum in adult spinal deformity: 4- to 14-year follow-up.

Kim HJ, Buchowski JM, Zebala LP, Dickson DD, Koester L, Bridwell KH. Spine. 2013 Jun 15;38(14):1209-15

- 31 BMP (8 posterior only) vs 32 ICBG (all A/P fusion)
- f/u 4-14 years
- Ave bmp/level 11.1 mg (3-36)
- Pseudarthrosis 6.4% BMP vs 28.1% ICBG group (P = 0.04)
- Possible dose dependency
  - no detected pseudarthrosis if > 5 mg per level (n = 20/20).

RCSI

Added stability of pelvic fixation

- low dose of BMP-2 (approx 2mg) @ L5-S1 level posterolateral with sacropelvic fixation 96% fusion rates in adult deformity surgery
- No additional benefit by adding an interbody cage

Annis et al Spine 2015

RCSI

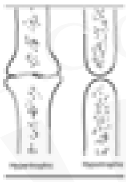
Who to Treat?

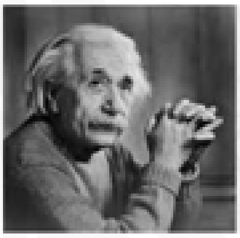
- Follow revision surgery principles
  - Would I have expected success with index procedure?
  - Was there an interval of relief?
- At risk to progress deformity
  - Eg.parkinsons

March 2016 June 2016

How to treat?

- Simply achieve solid fusion
- Decompression
- Adjacent segments
- Original HW position OK to use?
- Alignment
- Stability vs biology
- Change the game
  - Add something, do it differently, up the game



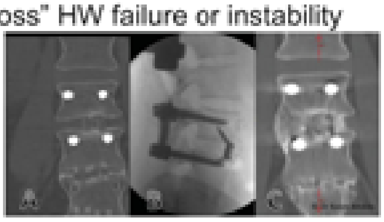


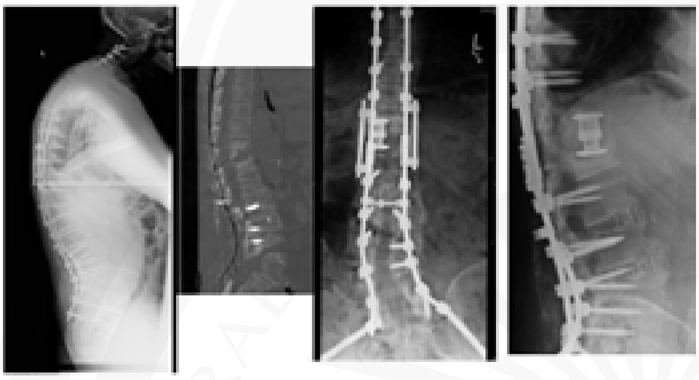
The definition of insanity is repeating the same behaviors and expecting a different outcome.

Albert Einstein

ALIF after Posterolateral Nonunion

- Symptomatic radiographic nonunion
- ? Adjacent issues
  - Prior to or subsequent to index procedure
- No "gross" HW failure or instability





Added anterior support and dual rods

Summary

- You will have nonunions
- You can take steps to minimize nonunion
- Additional cost analysis warranted
- Think about the problem for that patient and situation
- Don't repeat the same procedure

Junctional Failure

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Define Proximal Junctional Failure

- Proximal junctional kyphosis
  - >10° cobb & 10° increase from preop
  - Approx 20-40% incidence
  - 66% in first 3 months
  - Can progress over long time
  - Can eventually result PJF
- Proximal junctional failure
  - Kyphosis with structural failure boney or ligamentous

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Define Proximal Junctional Failure

- Location
  - Upper cervical
  - Cervicothoracic junction
    - More boney failure
  - Thoracolumbar junction
    - More ligamentous failure
- Manifestation
  - Radiographic
  - Prominence
  - Pain
  - Neurologic
  - Social stigma of kyphosis
    - "I don't want to look like my mother"
  - Horizontal gaze

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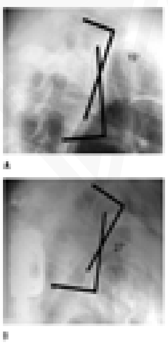
Definitions of PJK

Radiographic

- Proximal junctional sagittal Cobb angle between the lower end plate of the upper instrumented vertebra (UIV) and the upper end plate of the two supra-adjacent vertebrae of ≥ 10° and at least 10° greater than the preoperative measurement
  - Glattes et al, *Spine*, 2005



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Definitions of Proximal Junctional Failure

Proximal junctional failure (Hostin et al, *Spine* 2012)

- ≥ 15° post-operative increase in PJK
- Vertebral fracture of UIV or UIV+1
- Failure of UIV fixation
- Neural symptoms/Myelopathy
- Or need for proximal extension of fusion within 6 months of surgery

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Proximal Junctional Kyphosis

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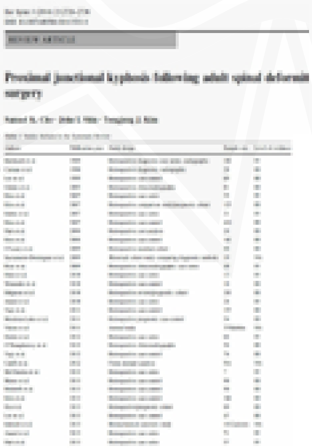
The Definition of PJK

Authors	Publication year	Study population	Definition	Remark
Lee et al.	1999	AIS	Kyphosis from T2 to the UIV ≥5° above the normal angular segments	
Glattes et al.	2005	Adult spinal deformity	Cobb angle between the UIV and two supra-adjacent vertebrae ≥10°	Most commonly used definition
Helgeson et al.	2010	AIS	Cobb angle between the UIV and one supra-adjacent vertebra >15°	
Hostin et al.	2012	Adult spinal deformity	Cobb angle between the UIV and two supra-adjacent vertebrae ≥15°	
O'Shaughnessy et al.	2012	Adult spinal deformity	Cobb angle between the UIV and two supra-adjacent vertebrae ≥20°	



REVIEW ARTICLE

Proximal junctional kyphosis following adult spinal deformity surgery

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Definitions of PJK

Radiographic

- Proximal junctional sagittal Cobb angle between the lower end plate of the upper instrumented vertebra (UIV) and the upper end plate of the two supra-adjacent vertebrae of ≥ 10° and at least 10° greater than the preoperative measurement
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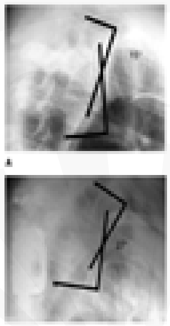

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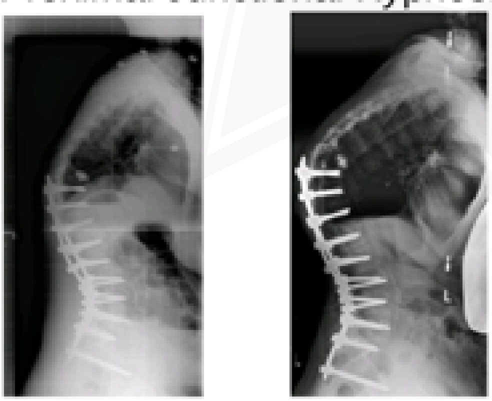
Proximal Junctional Kyphosis



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Etiology and Pathogenesis

- Proximal Junctional Kyphosis
  - Choice of Levels
    - First lordotic vertebra
  - Radiographic Factors
    - PJA
  - Biomechanics
    - Rigidity of Fixation
  - Patient-specific Factors
    - Bone Quality
    - Age
    - Neuromuscular Pathology

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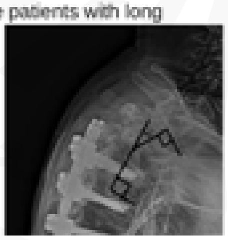
Spine

DEFORMITY

Incidence, Risk Factors and Classification of Proximal Junctional Kyphosis: Surgical Outcomes Review of Adult Idiopathic Scoliosis

- Restrospective study of 157 consecutive patients with long fusion for deformity
- PJK observed in 32 (20%)
  - Posterior instrumentation
  - Fusion to sacrum
  - Significant sagittal imbalance
    - TK+LL+PI>45 degrees
    - SVA change more than 5cm
- No association with age, BMI, BMD



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Proximal Junctional Kyphosis in Adult Spinal Deformity After Segmental Posterior Spinal Instrumentation and Fusion

Minimum Five-Year Follow-up

Yongjung J. Kim, MD, Keith H. Bridwell, MD, Lawrence G. Lenke, MD, Chris R. Glattes, MD Seungchul Rhim, MD, and Gene Cheh, MD

- Defining PJK:
  1. Proximal junction sagittal Cobb angle ≥10° and
  2. Proximal junction sagittal Cobb angle at least 10° greater than the preoperative measurement.
- 62/161 pts with adult deformity and fusions >5 levels (
- 59% within 8 weeks
- Risk factors:
  - Older age (>55yo)
  - Combined A/P surgery
  - Pedicle screws (age non-adjusted)
  - UIV at S1 (age non-adjusted)
- Outcome worst with kyphosis >20 degrees
- Rate not dependent upon proximal level

Table 1. Risk Factors for PJK Patients

Risk Factors	Total Patients	PJK Patients	P
Age at operation			
Approach			
Lowest instrumented vertebra			
Construct			
Upper instrumented vertebra			
Comorbidity			
Any osteotomies			
[illegible]	[illegible]	[illegible]	[illegible]

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Incidence, Mode, and Location of Acute Proximal Junctional Failures Following Surgical Treatment for Adult Spinal Deformity.

Hostin R et al; International Spine Study Group.
Spine 2012

- thoracolumbar region 66%
  - Fracture failure more common
  - Tend to be older
  - Worse postop SVA
- upper thoracic region 34%
  - Soft tissue failure more common

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Is the T9, T11, or L1 the More Reliable Proximal Level After Adult Lumbar or Lumbosacral Instrumented Fusion to L5 or S1?

Yongjung J. Kim, MD, Keith H. Bridwell, MD, Lawrence G. Lenke, MD, Seungchul Rhim, MD, and Young-Woo, Kim, MD

- 125 adults with proximal fusions T9-L2
  - Average 7.1 levels fused
- 3 groups sorted by PIV

	PJK	Revision
– T9-10	51%	24%
– T11-12	55%	24%
– L1-L2	36%	26%

- Recommendation: Choose lowest neutral and stable proximal vertebra

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Deformity

Predictive Factors for Proximal Junctional Kyphosis in Long Fusions to the Sacrum in Adult Spinal Deformity

- 90 consecutive patients fused from T9-L1 to pelvis
- Average Age- 64.5
- Minimum Follow-up 2 years (2.9 years average)
- Radiographic PJK observed in 37 patients (41%)
- Reoperation in 12 patients (12%)
- Purpose:
  - Defined Risk Factors for PJK
  - Identify Protective Strategies

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Deformity

Predictive Factors for Proximal Junctional Kyphosis in Long Fusions to the Sacrum in Adult Spinal Deformity

- 90 consecutive patients fused from T9-L1 to pelvis
- Radiographic PJK observed in 37 patients (41%)
- Reoperation in 12 patients (12%)
- Risk factors:
  - Change in Lumbar Lordosis >30 degrees
  - Pre-operative thoracic kyphosis >30 degrees
  - Preoperative PJA >10 degrees
  - Pelvic incidence >55 degrees
- Protective strategy
  - Post-op SVA<50mm, PT<20 degrees, and PI-LL<+/-10 degrees

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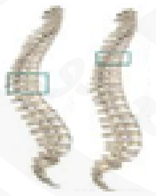
Cervicothoracic Junctional Pathology

- Upper Thoracic vs Thoracolumbar End Vertebra



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Proximal Junctional Kyphosis

Ha Y, UCSF Spine Service: J Neurosurg Spine August, 2013

162 consecutive adults with long fusions to the sacrum
127 distal thoracic (T9 to L1)
35 proximal thoracic (T2 to T5)
Radiographic PJK
31% distal thoracic
25% proximal thoracic
Kyphotic decompensation disease
6.3% distal thoracic
5.7% proximal thoracic
Mechanism of distal thoracic decompensation was fracture at UIV
Mechanism of proximal thoracic decompensation was subluxation- 2 cases with neural injury

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Evidence-based Approach to Choosing a Level

Indications for Extending Arthrodesis to the Upper Thoracic Spine

- Extension of measured curve to the structural thoracic spine
- Segmental kyphosis at the thoracolumbar junction
  - >5 degrees
- Thoracic Kyphosis >30 degrees
- Osteoporosis
- Neuromuscular Disease

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Classifications of PJK

TABLE 3. Modified Boachie-Adjei Classification of Proximal Junctional Kyphosis

Types	Definition
1	Ligamentous failure
2	Bone failure
3	Implant and bone interface failure
Grades	**Definition**
A	Proximal junctional increase 10°–19°
B	Proximal junctional increase 20°–29°
C	Proximal junctional increase ≥30°
Spondylolisthesis	**Definition**
N	No obvious spondylolisthesis above UIV
S	Spondylolisthesis above UIV

UIV indicates uppermost instrumented vertebrae.

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Risk Factors for PJK

Adult deformity

Table 4 Risk factors

Authors	Publication year	Risk factors	Remark
[illegible]	2008	[illegible]	
[illegible]	2011, 2012	[illegible]	
[illegible]	2012	[illegible]	
[illegible]	2013	[illegible]	
[illegible]	2013	[illegible]	
[illegible]	2013	[illegible]	[illegible]
[illegible]	2013	[illegible]	[illegible]

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Risk Factors for PJK

- Osteoporosis
- Fusion to the sacrum
- Choice of proximal levels
- Supralaminar fixation
- Correction of lordosis >30 degrees with or w/o PSO
- Mismatch of Lumbar Lordosis and PI
- Pre-operative thoracic kyphosis >30 degrees
  - Pre-op PJA >10 degrees
- Rigidity of construct

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Promising solutions?

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Possible solutions

- Minimize cantilever forces at cephalad end of construct
- Optimize post-operative alignment
  - PI+LL+TK<45⁰
- Augmentation of proximal fixation
- Augmentation of level above proximal fixation
- Interspinous augmentation/stabilization
- Dynamic stabilization/tethering

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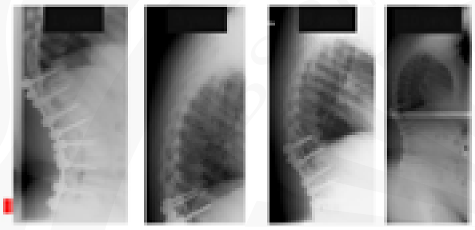
How to treat it

- PJK can be observed
  - Pain and deformity drive treatment
  - Sometimes HW prominence



- – Above plus neurological issues and risk

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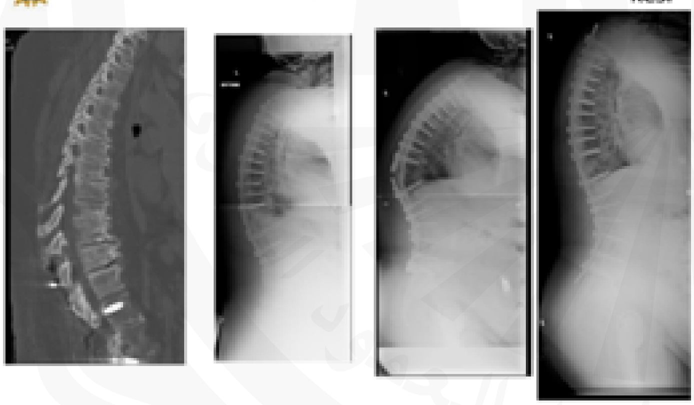
5 years later



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Junctional Failure

Proximal Thoracolumbar


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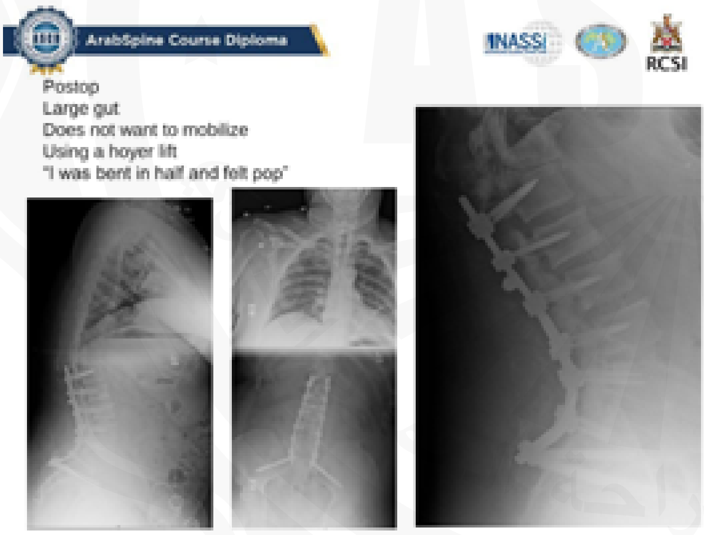
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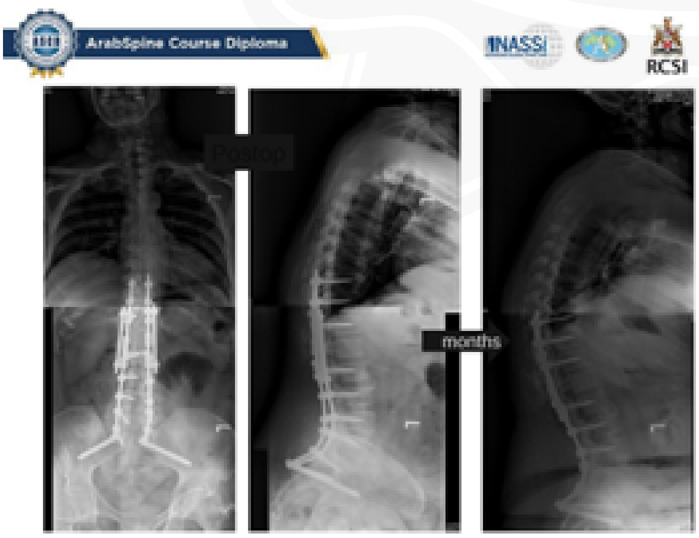
RCSI
Postop
Large gut
Does not want to mobilize
Using a hoyer lift
"I was bent in half and felt pop"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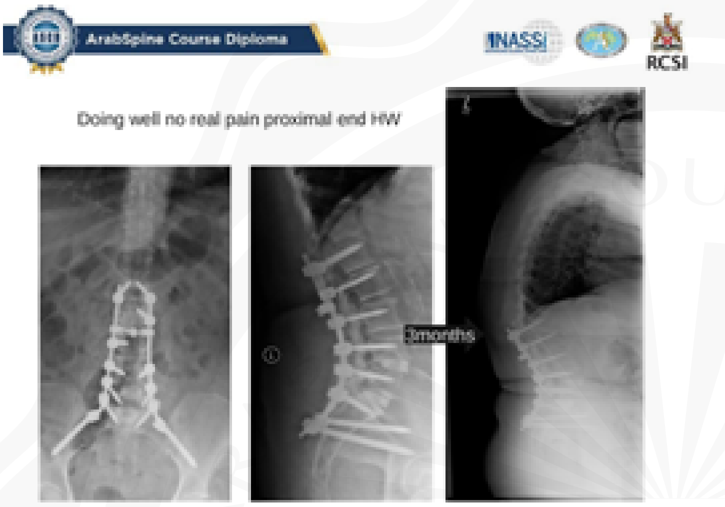
NASS
RCSI
Postop
months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NASS
RCSI
Doing well no real pain proximal end HW


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NASS
RCSI
Having pain & encouraged to address surgically
6 months


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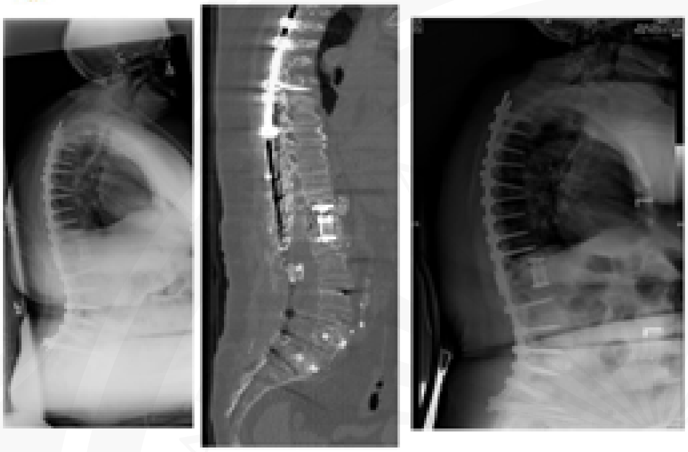
1 year

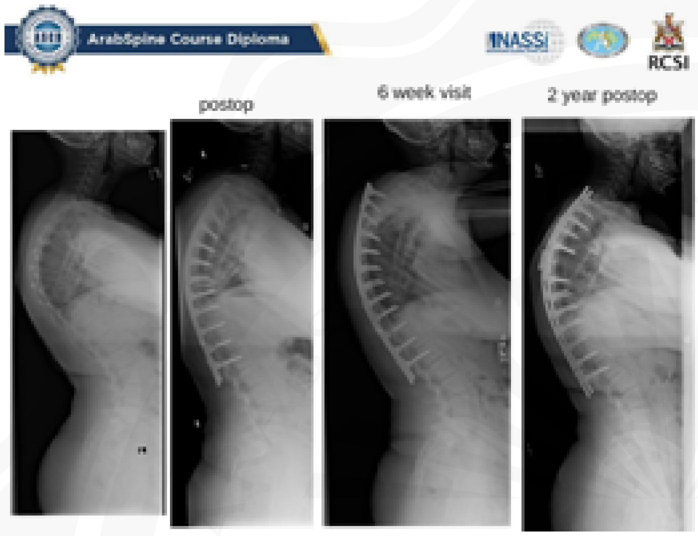


Does a long-fusion "T3-sacrum" portend a worse outcome than a short-fusion "T10-sacrum" in primary surgery for adult scoliosis?

O'Shaughnessy et al
Spine 2012 May 1;37(10):884-90

- Fifty-eight patients (UT = 20, LT = 38)
- With long fusions to the sacrum
  - more perioperative complications
  - higher pseudarthrosis rate
  - perhaps more revision surgery
- Short fusions
  - more proximal junctional kyphosis, only rarely requiring revision surgery.

Junctional Failure
Proximal Upper thoracic/Cervical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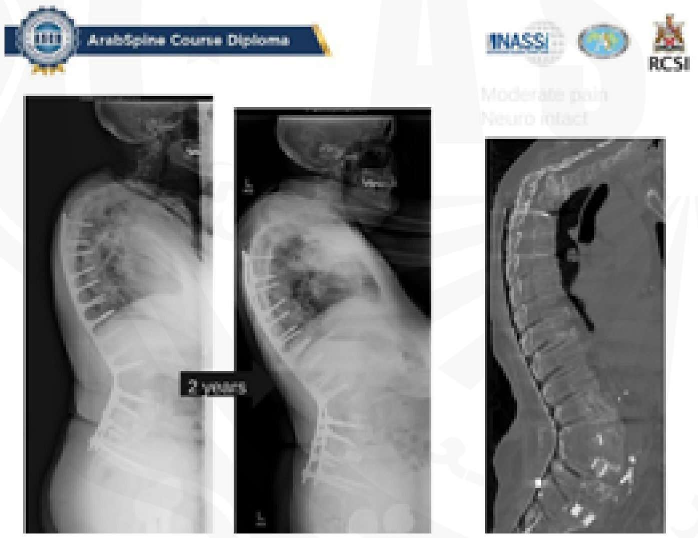
NASS
RCSI
postop
6 week visit
2 year postop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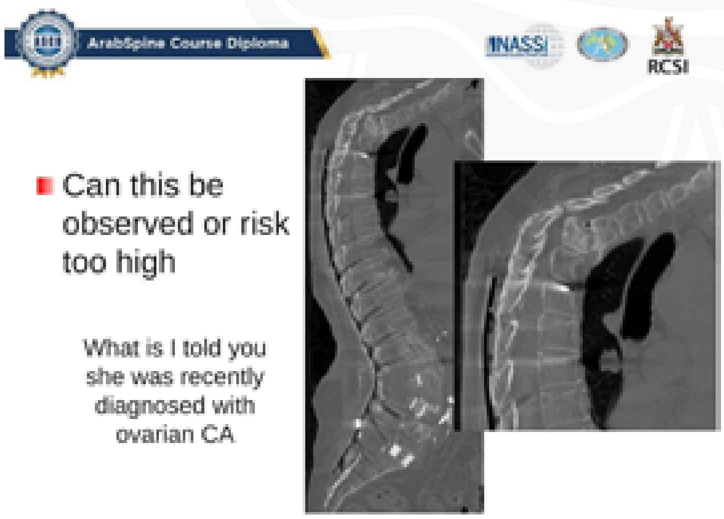
NASS
RCSI
Moderate pain
Neuro intact
2 years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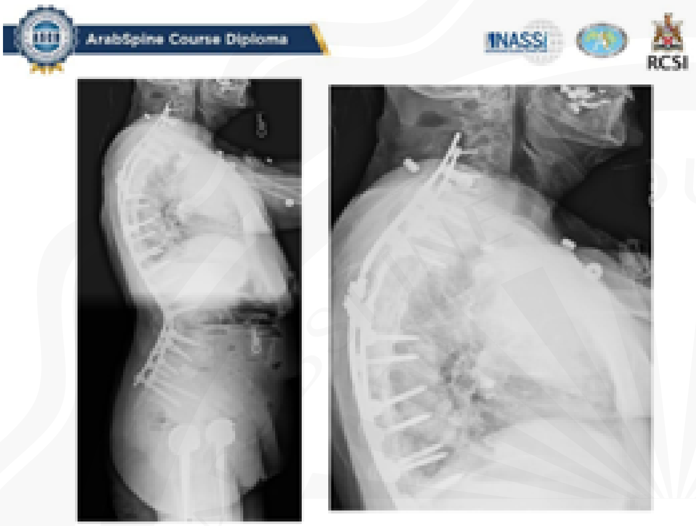
NASS
RCSI
Can this be observed or risk too high
What is I told you she was recently diagnosed with ovarian CA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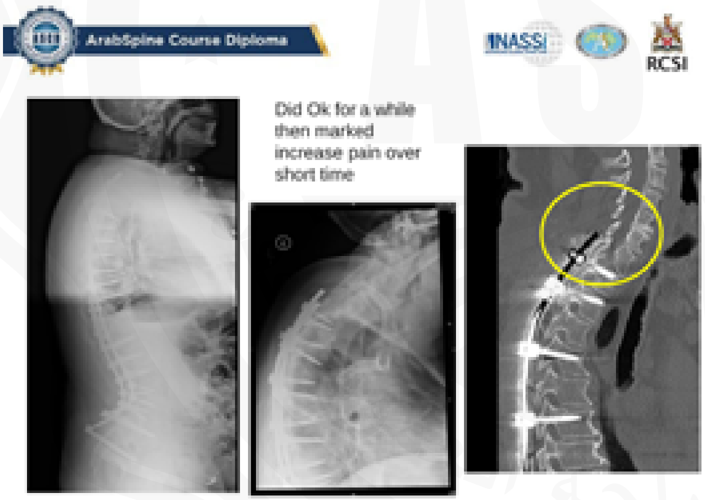
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INASS
RCSI
Did Ok for a while then marked increase pain over short time


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RCSI
Tried to avoid fusing too much of neck

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- 21 male s/p resection low grade astrocytoma at age 16 & 18
- Increased spasticity and leg weakness
- Ambulatory without aids
- Deformity progressive

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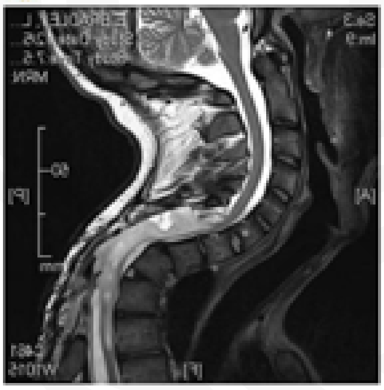

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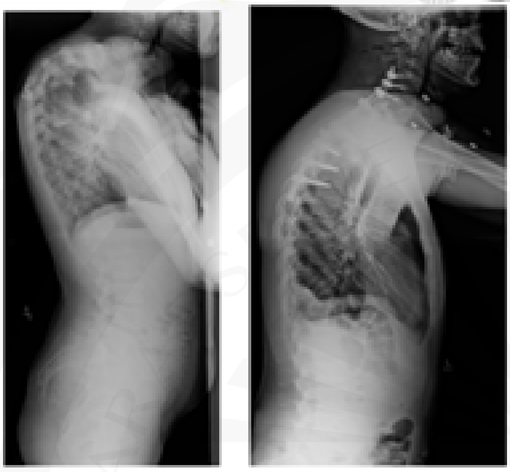
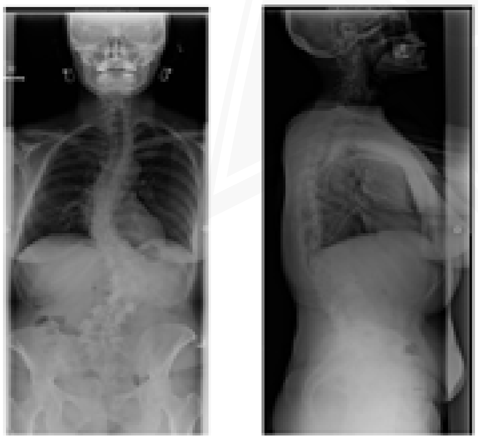
Attempted T1-4 Pontes and anterior osteoclasis
C4-T6 fusion, ICBG



Junctional Failure

Distal

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NASS
RCSI
Good L5-S1
disc
Minimal stenosis


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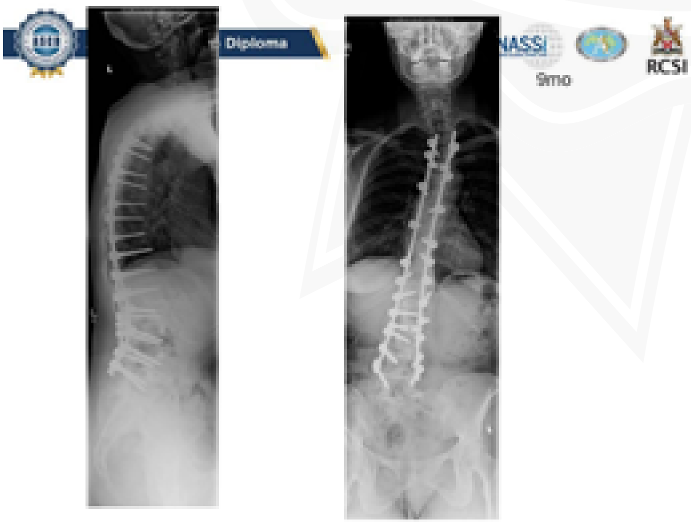
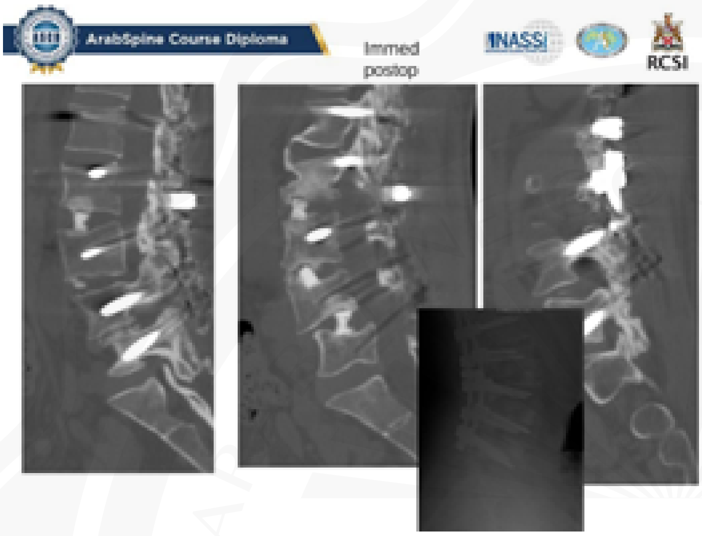
NASS
RCSI


Diploma
NASS
RCSI
9mo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Immed
postop
INASS
RCSI


ArabSpine Course Diploma
INASS
RCSI


ArabSpine Course Diploma
6 mo
INASS
RCSI

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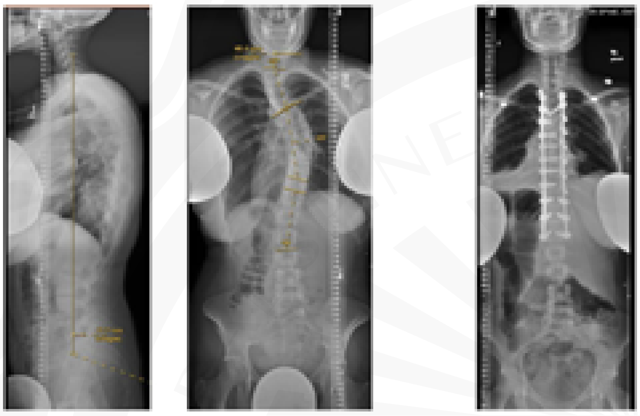
INASS

RCSI



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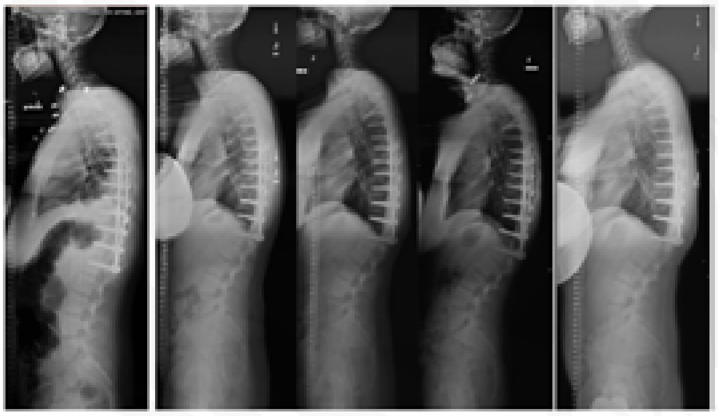

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Distal junctional kyphosis in patients with Scheuermann's disease: a retrospective radiographic analysis

European Spine Journal
March 2017, Volume 26, Issue 3, pp 913–920

Amir Ghasemi, Timo Stubig, Luigi A. Nasto, Malik Ahmed, Hossein Mehdian

Purpose: To investigate the relationship between preoperative and postoperative spinopelvic alignment and occurrence of DJK/DJF.

40 patients who underwent posterior correction of Scheuermann Kyphosis

15% DJK

Risk Factors:

- Lower post-operative thoracic kyphosis
- More negative LIV (posterior to posterior-sacral line)
- Younger age

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Distal Fusion Level Selection in Scheuermann's Kyphosis: A Comparison of Lordotic Disc Segment Versus the Sagittal Stable Vertebrae

Global Spine Journal
2017, Vol. 7(3) 254-259

Han Jo Kim, MD[1], Venu Nemani, MD[1], Oheneba Boachie-Adjei, MD[2], Matthew E. Cunningham, MD, PhD[2], Justin A. Iorio, MD[1], Kevin O'Neill, MD[2], Brian J. Neuman, MD[1], and Lawrence G. Lenke, MD[3]

- Sagitally stable vertebra is the most cephalad vertebra touched by the posterior sacral line
- Extension of fusion to the SSV results in a lower rate of distal junctional pathology
  - 5% vs 36.3%

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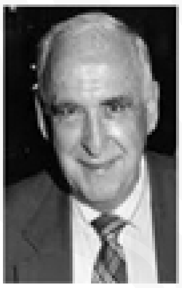
Surgical Strategies

- Cephalad to neutral or lordotic segment
- Instrument to First Lordotic Vertebra



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Junctional Failures Summary

- Reoperations are common in adult deformity
- Beware risk factors for adjacent breakdown
- Achieve physiological balance, not necessarily spot on SVA (SVA behind the femoral heads)
- Not all junctional failure require treatment
  - Pain, neuro sxs, progressive loss correction

Please refer to Book of

DAY- 2 (MODULE 4)

for continuation...

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