



## Scoliosis in children and adolescents Surgical treatment, new concepts, impact for radiologists

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- What is scoliosis?
  - 3-D deformity of the spine
    - Vertebral rotation
    - Coronal deviation
    - Sagittal malalignment (inconstant)
  - Most frequent spinal deformity in children (2-3%)





### What is scoliosis?

- 3-D deformity of the spine
- Most frequent spinal deformity in children (2-3%)
- Scoliosis? Scolioses!
  - Based on etiology

### **Idiopathic scoliosis**

- 75% of scoliosis in children/adolescents
- Girls > Boys
- Family history
- Right Th / Left Lumbar
- No other abnormality



- What is scoliosis?
  - 3-D deformity of the spine
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Cerebral palsy



Trisomy 26





Hemivertebra

Marfan sd

### **Non-Idiopathic scoliosis**

- Congenital / Malformative
- Neuro-muscular
- Syndromic
- Tumor



### What is scoliosis?

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- Most frequent spinal deformity in children (2-3%)
- Scoliosis? Scolioses!
  - Based on etiology / Based on age of onset



### What is scoliosis?

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  - Based on etiology / Based on age of onset

### When is surgical treatment warranted?

- Imbalance
- Neurologic involvement
- Risk of progression
  - With growth
  - During adulthood



- Surgical treatment: What's new?
  - Historically: Harrington rods
    - Distraction based
    - Flattening of the spine, in every plane!
  - 1980's: Multilevel instrumentation (Cotrel-Dubousset)
    - Enhanced sagittal plane correction
    - Technical improvements
  - Early Onset Scoliosis : Advances in growth-friendly techniques
  - Growth modulation (Anterior Vertebral Body Tethering)

# - Part 1 -Early Onset Scoliosis

- Onset before the age of 7
- Largely dominated by congenital scoliosis
  - Bone malformation
    - Hemivertebra
    - Bars / blocks / mosaïc
    - Rib fusions : thoracic insufficiency syndrome
- Problem : worsening with growth

- Early diagnosis on standard X-rays
- Worsening potential depends on the type of HV
  - Presence of growth plate
  - Fully segmented > Hemi-segmented > Fused















**Fused** Symmetric growth : stability

**Fully segmented** Asymmetric growth : worsening

- MRI is of major interest in diagnosis
  - HV type, growth potential
    - Visualization of growth plates, intervertebral disc (nucleus pulposus)



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  - HV type, growth potential
    - Visualization of growth plates, intervertebral disc (nucleus pulposus)
  - Associated spinal cord abnormalities
    - Frequent
      - Tethered spinal cord
      - Chiari
      - Syrinx
      - Diastematomyelia
      - Etc...



- MRI is of major interest in diagnosis
  - HV type, growth potential
    - Visualization of growth plates, intervertebral disc (nucleus pulposus)
  - Associated spinal cord abnormalities
- Other abnormalities frequently associated
  - Urinary tract
  - Heart
  - ⇒ Kidney/bladder and cardiac systematic ultrasonography



## Hemivertebra – Surgical management

- Early surgery (3 years old) if
  - Curve worsening
  - Fully segmented HV
- Complete resection mandatory (HV + growth plates and discs)



6 y.o.

15 y.o.

## Hemivertebra – Surgical management

- Early surgery (3 years old) if
  - Curve worsening
  - Fully segmented HV
- What's new? Technical improvements
  - Preop imaging accuracy
  - Intraop
    - Ultrasonic bone scalpel (reduces bleeding)
    - Hemostatic matrix (thrombin)
  - Intraop imaging not necessary



## Safer and complete resections **Posterior-only approach**

## **Other congenital scoliosis**

- Requires both CT-scan and MRI
  - Only remaining indication for CT-scan
  - Accurate analysis of osseous malformations
    - Block, bars, synostosis, etc...
    - Improvement of image quality and 3-D reconstructions
  - Surgical treatment
    - Growth-friendly-techniques
    - Aggressive surgery in close to skeletal maturity/severe deformity
      - Posterior substraction osteotomies (PSO), vertebral column resection (VCR)
      - Intraop imaging guidance







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  - Possibility of 3D printing
    - Helps for preop planning







## **Growth-friendly techniques**

- Better try not to operate children before the beginning of growth-spurt
  - But sometimes it's impossible
- Growth-friendly techniques allows to preserve spine growth
- What's new? Electromagnetic growing rods
  - No multiple surgeries
  - Distraction every 2-3 months based on a magnet/endless screw (remote)
  - Not perfect...



# - Part 2 -Adolescent Idiopathic Scoliosis

- Most frequent etiology
- Different curve patterns: Lenke classification



1 Th curve



Lenke 2 2 Th curves



Lenke 3 1 Th curve (major) 1 ThL/L curve



Lenke 4 2 Th curves 1 ThL/L curve



Lenke 5 1 ThL/L curve



Lenke 6 1 Th curve 1 ThL/L curve (major)

### Surgery : improvements



### Harrington distraction rods







# Cotrel-Dubousset multi-level instrumentation

- Multiple anchors
- 3D-correction

## Surgery : improvements toward shorter fusions



### **Modern instrumentations**

Better coronal reduction





### Surgery : improvements toward shorter fusions



### **Modern instrumentations**

- Better coronal reduction
- Sagittal profile restoration



## Surgery : improvements toward shorter fusions





### **Modern instrumentations**

- Better coronal reduction
- Sagittal profile restoration
- Derotation





- What has changed? Sagittal plane considerations
  - Functional results, mechanical complications
  - ⇒ Radiologists must be aware!

### From the bottom to the top: slope-to-slope concept

- Pelvic incidence
  - Sacrum orientation: take-off of the spine
- Lumbar lordosis
  - No normal values
  - Depends on PI (LL ≈ PI +/- 10°)
- Thoracic Kyphosis
  - No normal values
  - Depends on LL (TK  $\approx \frac{3}{4} \times LL$ )



## Measurement of sagittal curves: fixed landmarks or spline concept?

- With PI increase, "lengthening" of the LL
- Creation of a spline
  - Requires dedicated software
    - Semi-automated reconstruction of the spline
    - Based on visual recognition of the vertebral endplates
  - ⇒ Fancy! Useful?
- In a normative population
  - T1T12 represents 97% of the spline-based TK measurement
  - L1S1 represents 98% of the spline-based LL measurement
    Don't bother...



#### Pesenti et al, SFCR, 2022

- Global alignment assessment
  - SVA
  - Compensatory mechanisms
    - Over or underlying curves
    - Positional pelvic parameters
      - Pelvic tilt +++ (pelvic retroversion)



- Growth modulation (AVBT): revolution?
  - Principle: hemi-epiphysiodesis
  - VB screws + Polyethylene cable (tether) / anterior approach
  - Slow growth on the concave side
  - + flexible fixation: keeps spine mobility





## Growth modulation (AVBT): revolution?

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- Slow growth on the concave side
- + flexible fixation: keeps spine mobility





- Growth modulation (AVBT): revolution?
  - Does it work?
  - Yes, but only if realized at the very beginning of growth spurt!
    - Risser 0 ++





Bernard et al, Bone Joint J, 2022

- Growth modulation (AVBT): revolution?
  - Does it work?
  - Yes, but only if realized at the very beginning of growth spurt!
    - Risser 0 ++
    - Triradiate cartilage closed
      - Risk of over-correction
  - Too young or too old
    - 25% complication rate at 5 years
    - 25% return to the OR





- Growth modulation : what does it change for radiologists ?
  - Accurate assessment of bone age / skeletal maturity
    - Risser test? Probably not enough
    - Sanders hand score: correlates with scoliosis progression





## Growth modulation : what does it change for radiologists ?

- Accurate assessment of bone age / skeletal maturity
  - Risser test? Probably not enough
  - Sanders hand score: correlates with scoliosis progression

Curve	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7, 8
10°	2%	0%	0%	0%	0%	0%	0%
	(0% to 40%)	(0% to 15%)	(0% to 0%)	(0% to 0%)	(0% to 0%)	(0% to 0%)	(0% to 1%)
15°	23%	11%	0%	0%	0%	0%	0%
	(4% to 69%)	(1% to 58%)	(0% to 2%)	(0% to 0%)	(0% to 0%)	(0% to 0%)	(0% to 7%)
20°	84%	92%	0%	0%	0%	0%	0%
	(40% to 98%)	(56% to 99%)	(0% to 14%)	(0% to 1%)	(0% to 1%)	(0% to 1%)	(0% to 26%)
25°	99%	100%	29%	0%	0%	0%	0%
	(68% to 100%)	(92% to 100%)	(3% to 84%)	(0% to 5%)	(0% to 5%)	(0% to 2%)	(0% to 64%)
30°	100%	100%	100%	0%	0%	0%	0%
	(83% to 100%)	(98% to 100%)	(47% to 100%)	(0% to 27%)	(0% to 22%)	(0% to 11%)	(0% to 91%)
35°	100%	100%	100%	0%	0%	0%	0%
	(91% to 100%)	(100% to 100%)	(89% to 100%)	(0% to 79%)	(0% to 65%)	(0% to 41%)	(0% to 98%)
40°	100%	100%	100%	15%	0%	0%	0%
	(95% to 100%)	(100% to 100%)	(98% to 100%)	(0% to 99%)	(0% to 94%)	(0% to 83%)	(0% to 100%)
45°	100%	100%	100%	88%	1%	0%	0%
	(98% to 100%)	(100% to 100%)	(100% to 100%)	(2% to 100%)	(0% to 99%)	(0% to 98%)	(0% to 100%)

\*Unshaded cells correspond with combinations of curve size and maturity stage for which surgery would be a plausible treatment if >50° at maturity is accepted as the threshold for surgical treatment. Shaded cells correspond with combinations for which surgery would not be a plausible treatment. †Cells with wide 95% confidence intervals (shown in parentheses) correspond with groups that had too few patients for accurate estimates (or groups that had no patients) and should be interpreted with caution.

- Growth modulation : what does it change for radiologists ?
  - Accurate assessment of bone age / skeletal maturity
  - Assessment of tether breakage
    - Tether: radioluscent
    - Indirect signs
      - Change in screw angulation
      - Loss of correction
    - Imaging?
      - CT-scan? MRI?
      - Challenging...





### DiBiasio et al, Pediatr Radiol, 2022

# - Part 3 -Neuromuscular Scoliosis

## Many etiologies

- Myopathy, cerebral palsy
- Surgical indications
  - Depends on ambulatory status
    - Walking patient: "same" principles as in AIS patients
    - Non-walking patients : pelvic obliquity is the challenge



## Many etiologies

- Myopathy, cerebral palsy
- Surgical indications
  - Depends on ambulatory status
    - Walking patient: "same" principles as in AIS patients
    - Non-walking patients : pelvic obliquity is the challenge
  - Problem
    - Frailty
      - Risk of complication (infection, mechanical, death)
    - Need for less invasive surgery
      - Bipolar instrumentation







- Distraction based
  - Multiple surgeries to follow growth
  - No definitive fusion needed



Courtesy L Miladi

- Ilio-sacral screws
  - Possible misplacement
  - CT for control?



- But multiple surgeries are at-risk for these patients
  - To avoid them, creation of notched rods
    - "Automated" growth
    - Not ideal...



- **Cobb 1** 66°
- Cobb 2 67°
- T1S1 length
  33 cm



**Cobb 1** 44°

- **Cobb 2** 45°
- T1S1 length 36 cm





- **Cobb 1** 64°
- **Cobb 2** 64°
- **T1S1 length** 36 cm

## **Conclusion - 1**

- Many types of scoliosis, surgical management will depend on age and etiology
  - No major paradigm shift during the last 20 years

### Early onset scoliosis

- Hemivertebra
  - Early surgery (before 8 y.o.)
  - Preop MRI mandatory
    - HV type (discs (NP), growth plates)
- Other malformative scoliosis : complex surgeries
  - Only remaining indication of CT-scan
- Growth-friendly instrumentation: electromagnetic rods

## **Conclusion - 2**

- Many types of scoliosis, surgical management will depend on age and etiology
  - No major paradigm shift during the last 20 years
- Adolescent Idiopathic Scoliosis
  - Multilevel instrumentations
    - 3D-correction, shorter fusions
    - Importance of sagittal plane assessment / restoration
  - Anterior Vertebral Body Tethering is not a revolution
    - Remaining growth assessment is crucial
    - To be evaluated in the long-run

## **Conclusion - 3**

- Many types of scoliosis, surgical management will depend on age and etiology
  - No major paradigm shift during the last 20 years
- Neuromuscular scoliosis
  - Pelvic obliquity is the challenge
  - Multilevel instrumentation possible but frail patients
    - Bipolar instrumentation is an interesting alternative
    - *"Automated" growth does not always work*





Hôpitaux Universitaires de Marseille

