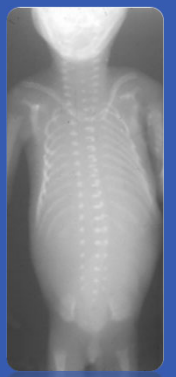


THE GROWING SPINE

The effect of early spine fusion on the thoracic cavity growth

Prof. A. DIMEGLIO

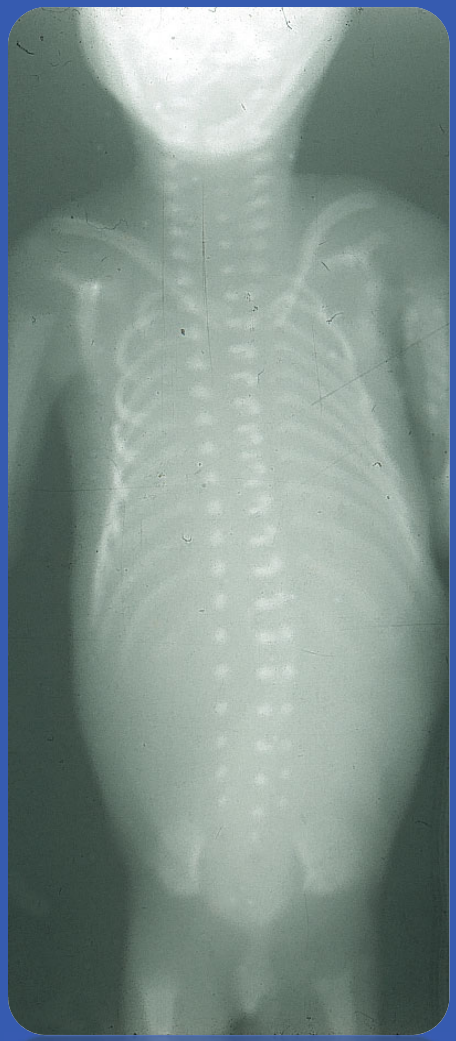
J.HABANBO, M.D.

F. CANAVESE, M.D.

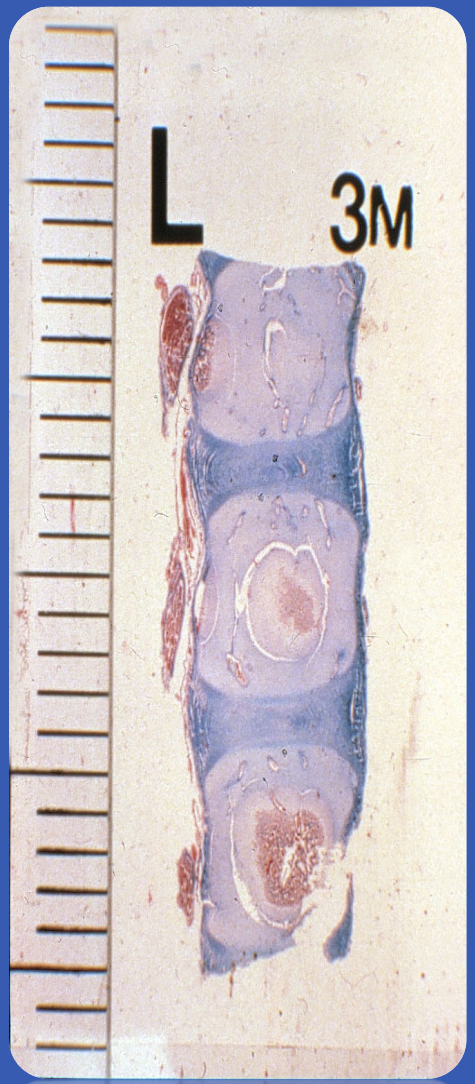
YP, CHARLES,M.D.

- The thorax is the main concern in severe scoliosis
- Growth of the spine, thorax, and lungs are inter- related
- The spine and ribs dictate lung function
- The cranckshaft phenomenon is a determining factor

Ossification starts at the third month of life
Interaction, synchronism, hierarchy

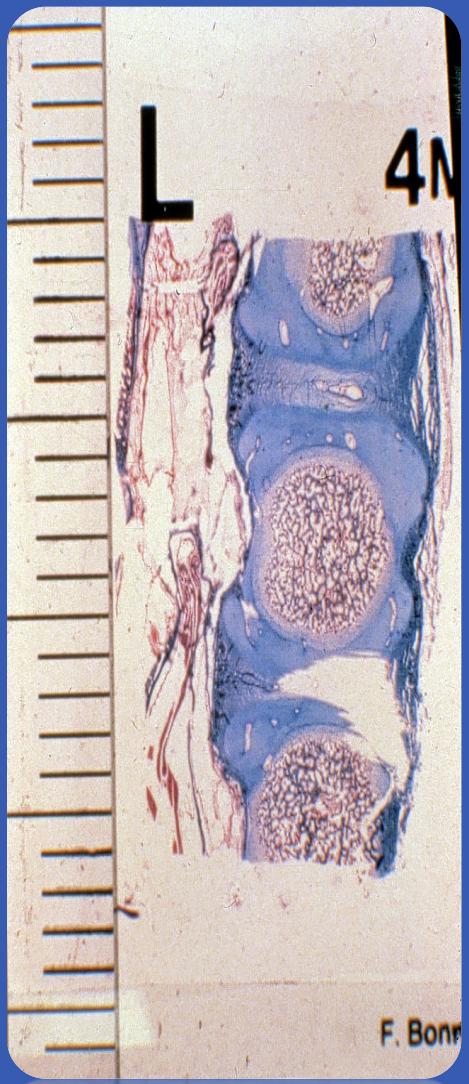


3 months



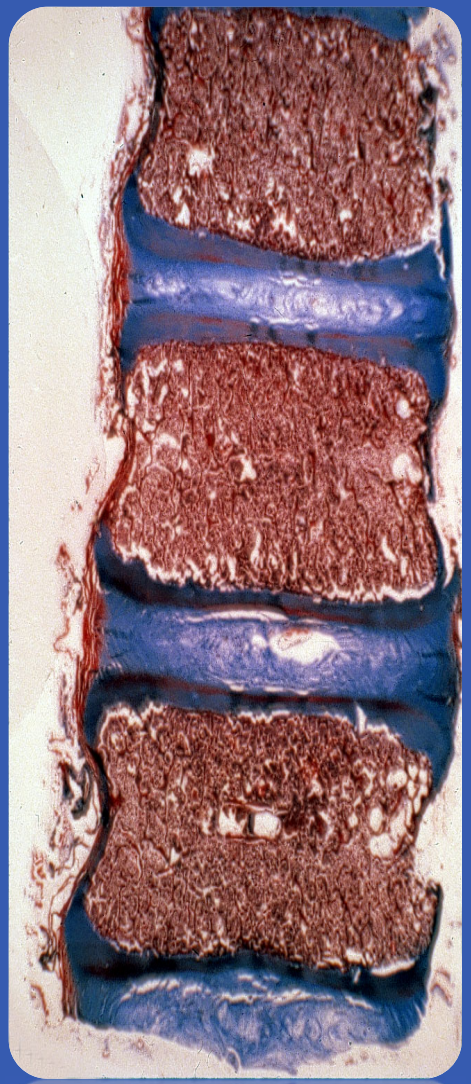
Lentil

4 months



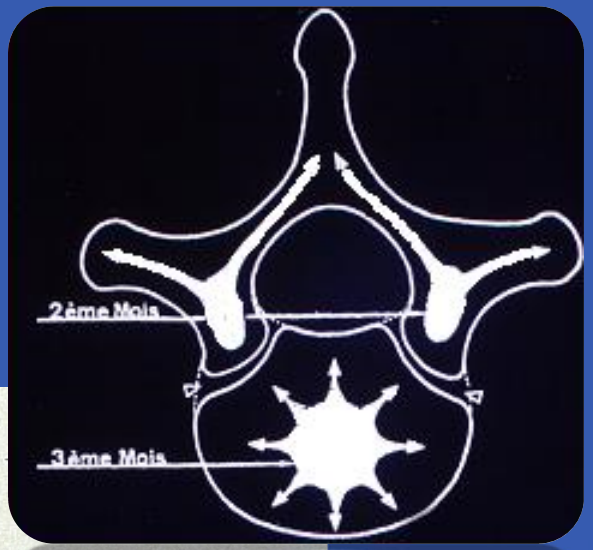
Ovoid

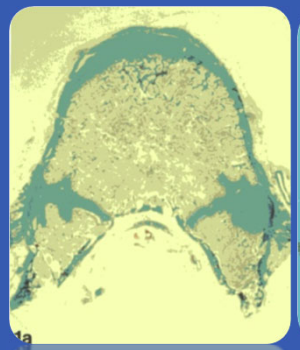
8 years

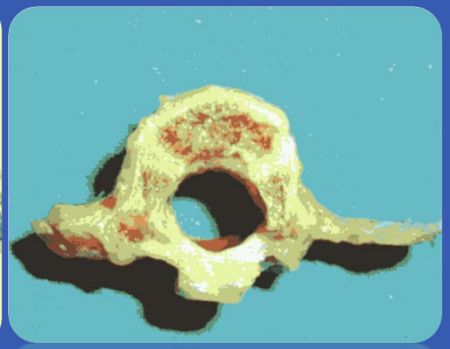


Rectangular

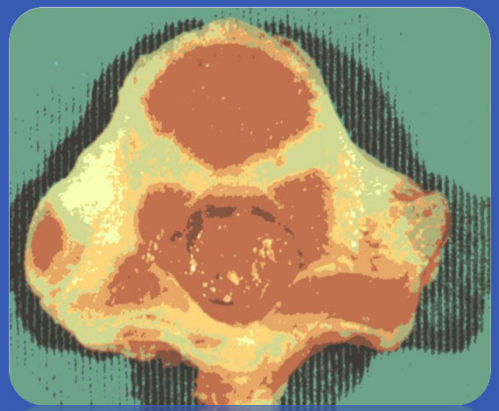
Neurocentral growth plate: Dual activity



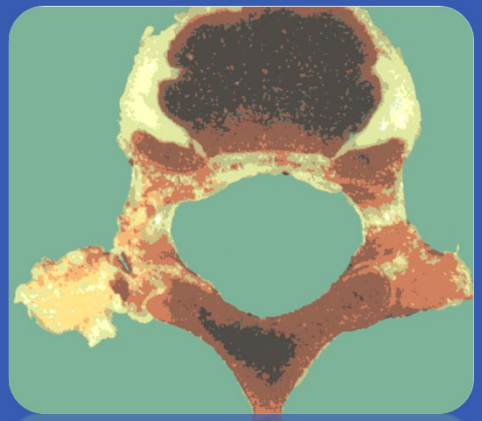




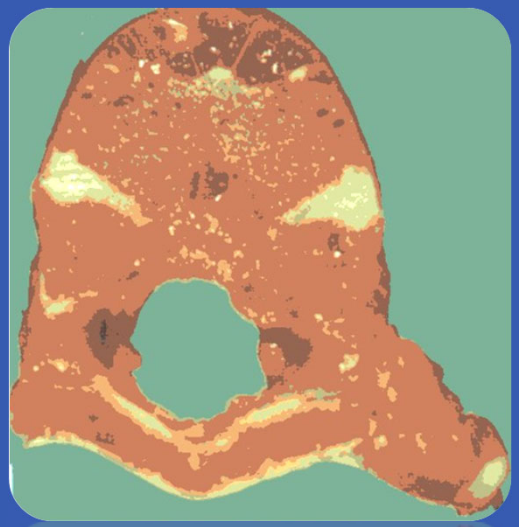
2 days



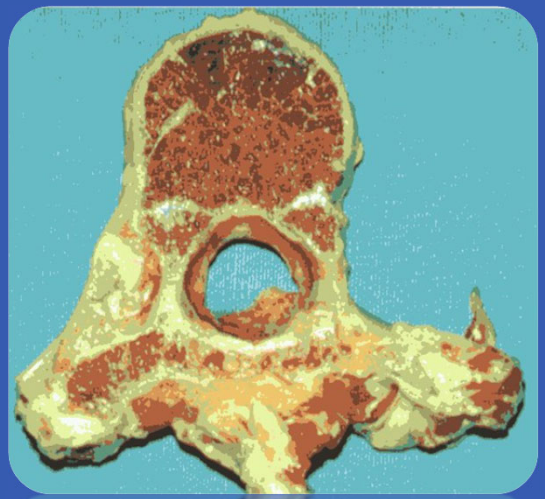
3 Months



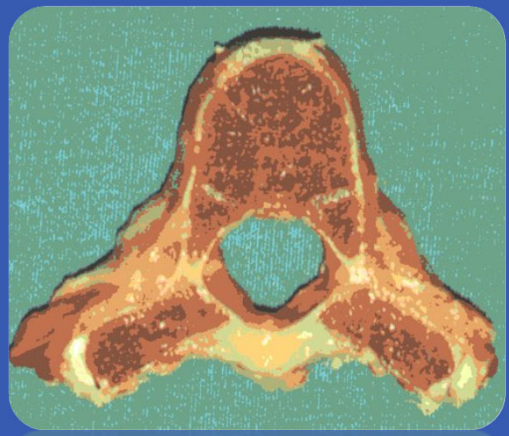
2 Years



3 Years

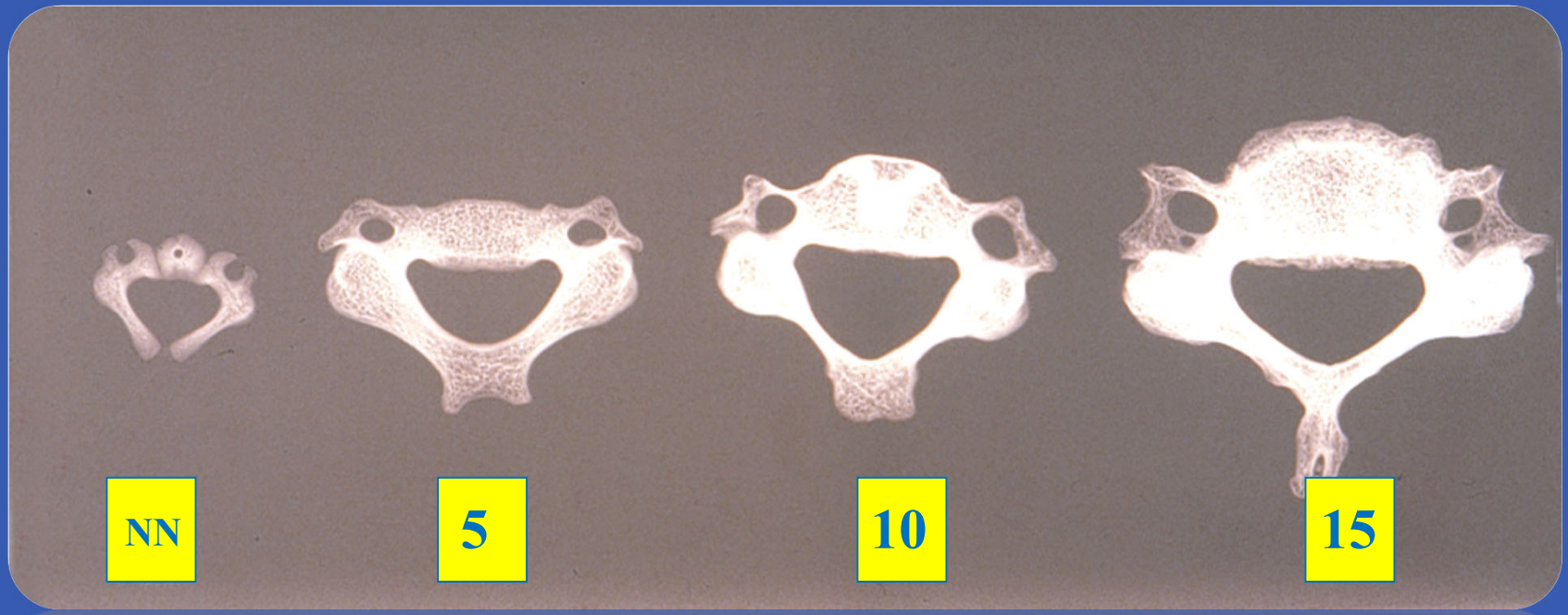


9 Years



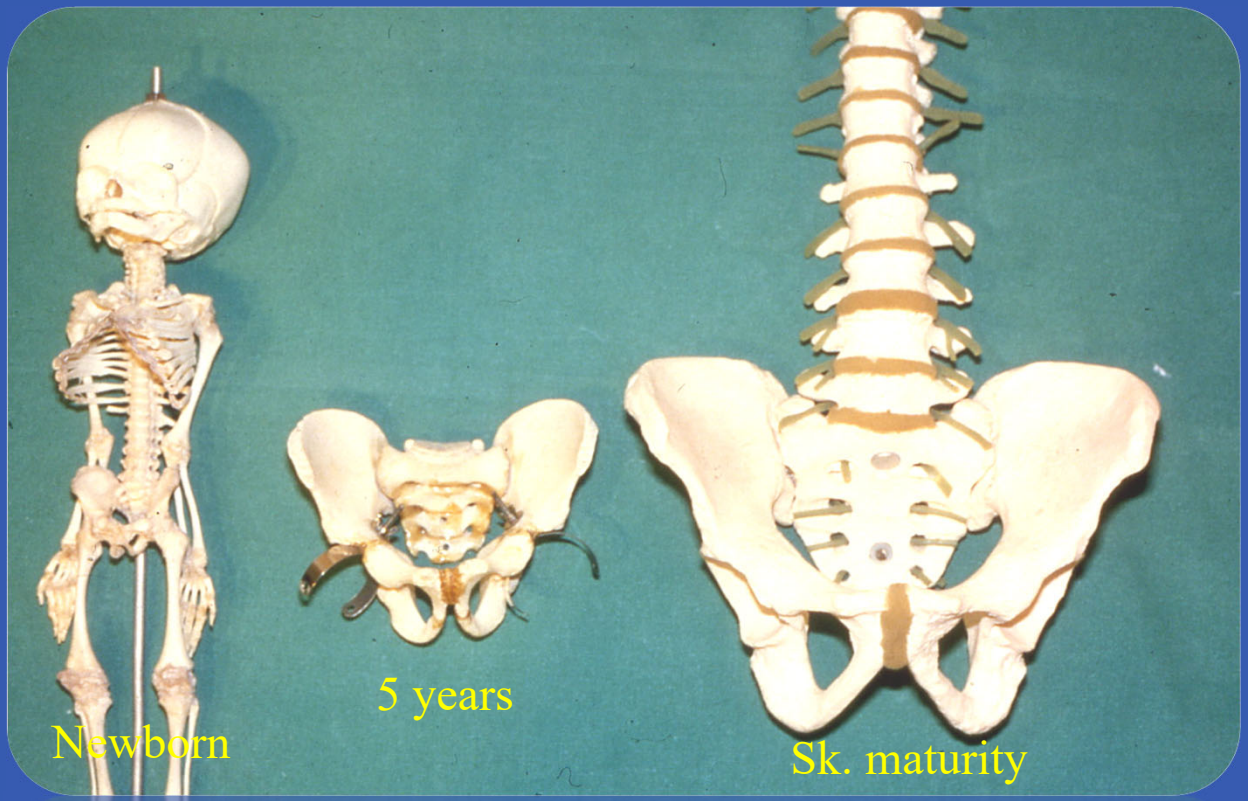
11 Years

Almost closed at 9 years of age



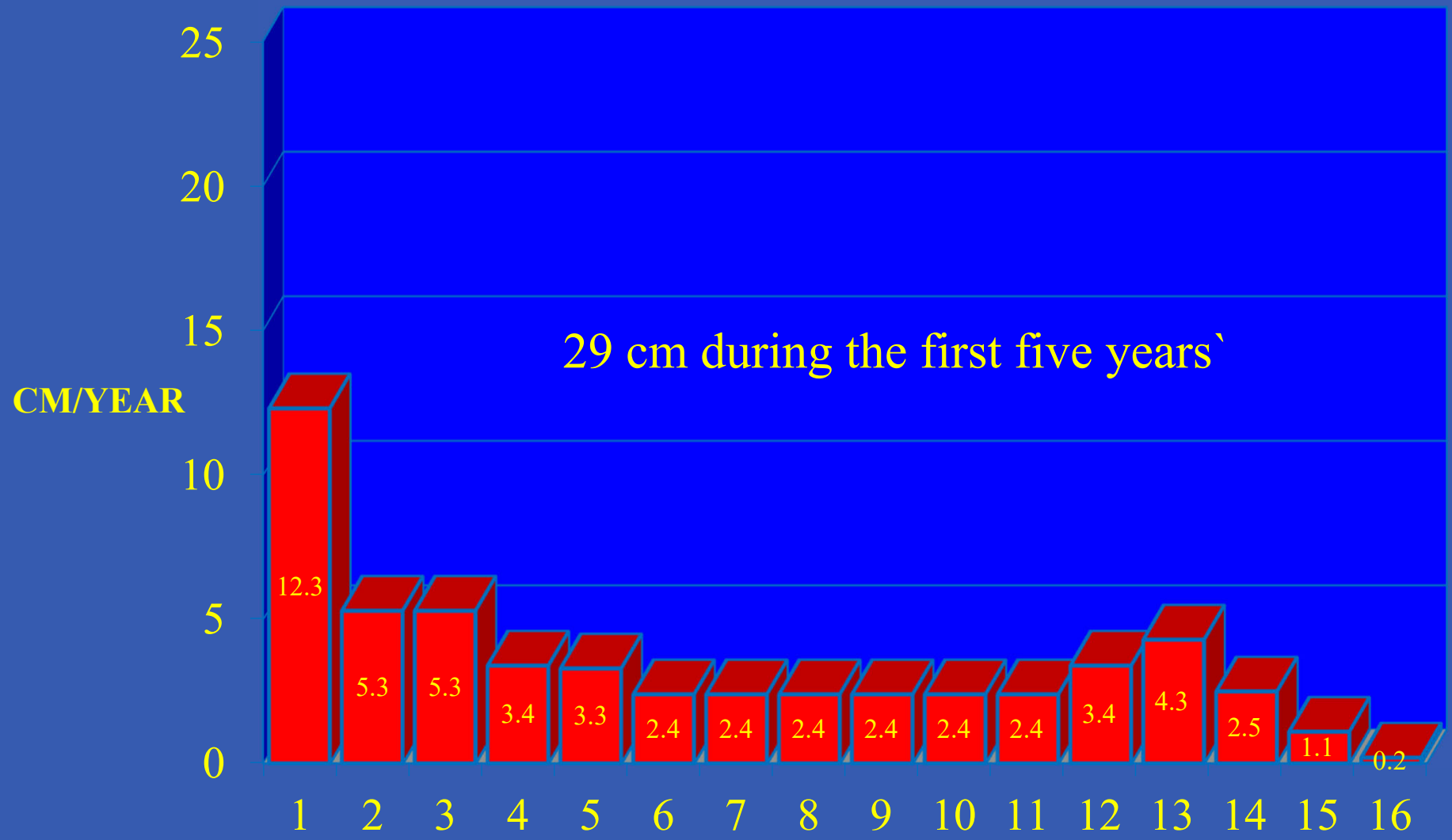
At age 5 years, the spinal canal has grown to 95 % of its definitive size

GROWTH IS A VOLUMETRIC REVOLUTION



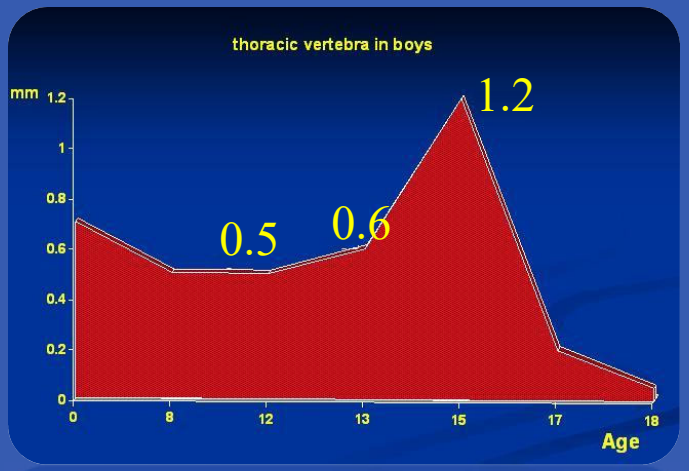
AT BIRTH 30% OF THE SPINE IS OSSIFIED

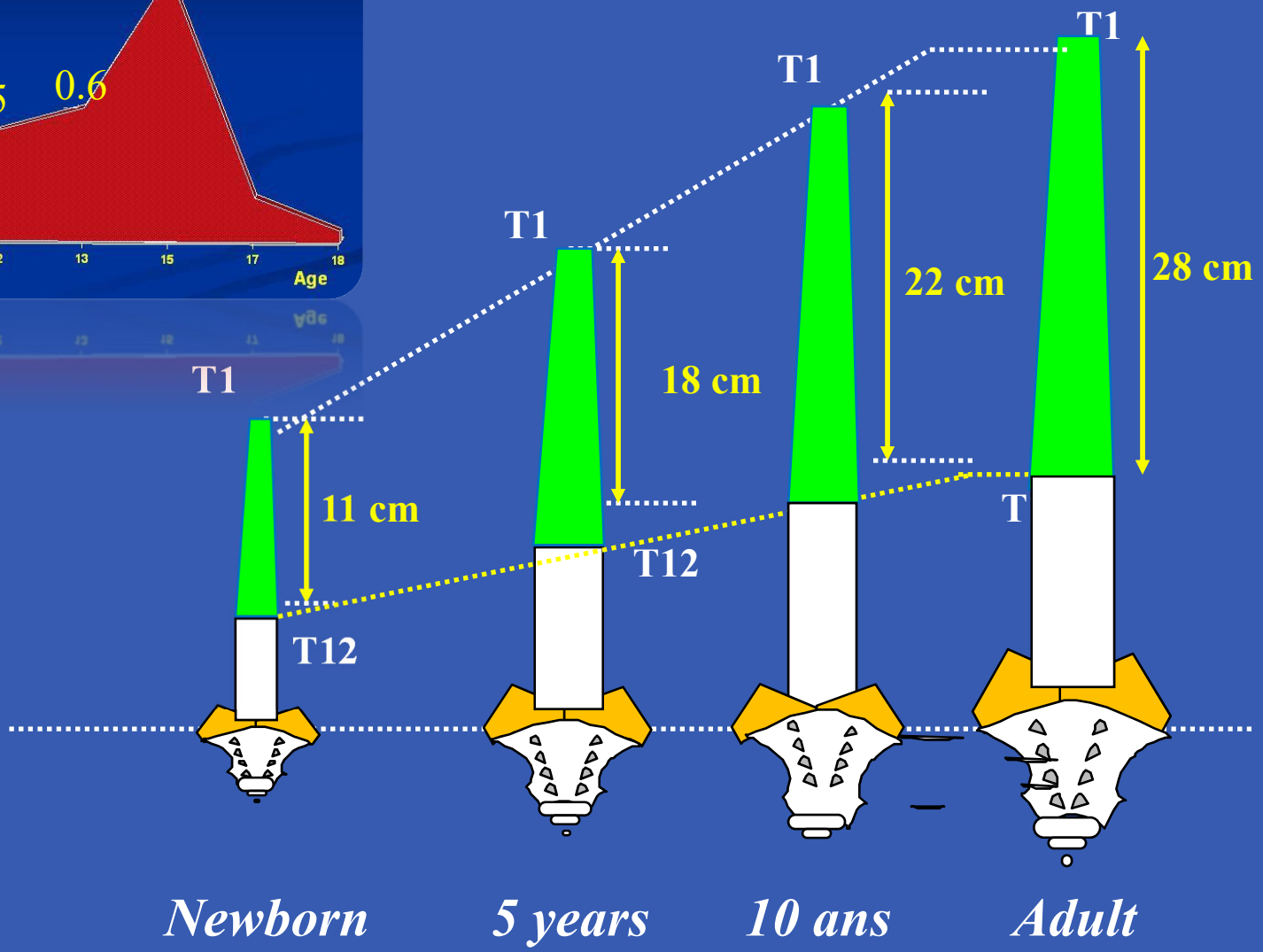
GROWTH VELOCITY ON THE SITTING HEIGHT



same profile for boys and girls

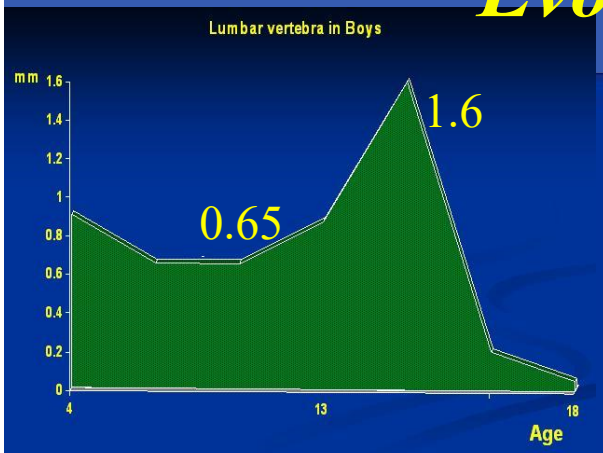
Evolution of T1-T12 Segment





The growing spine, springer Verlarg 1990

Evolution of L1-L5 Segment

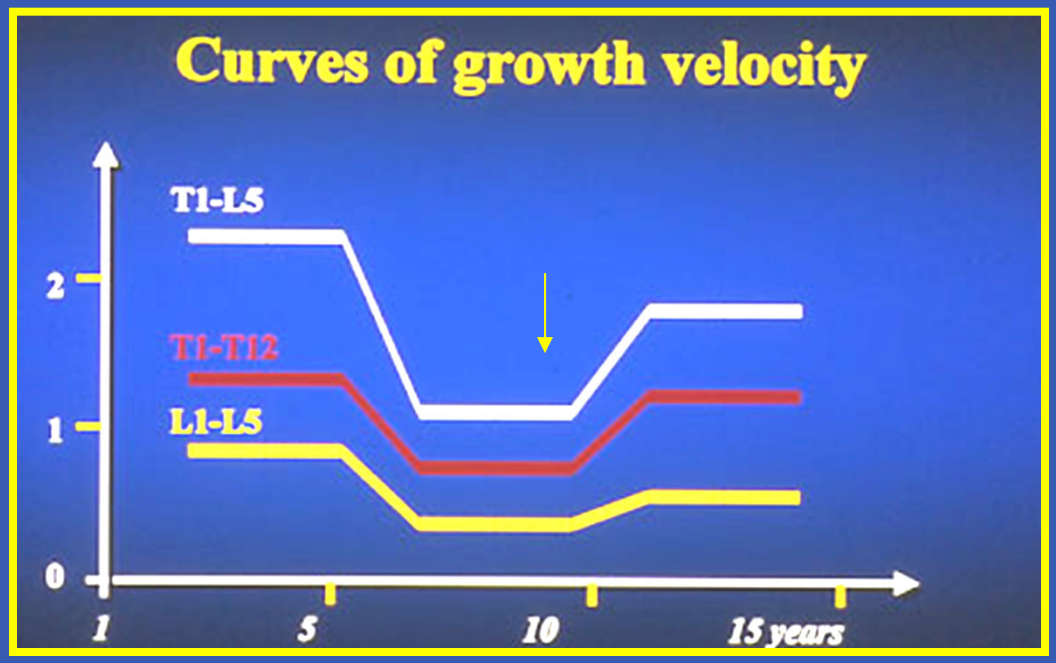


Newborn 5 years 10 years Adult

The growing spine, springer Verlarg 1990

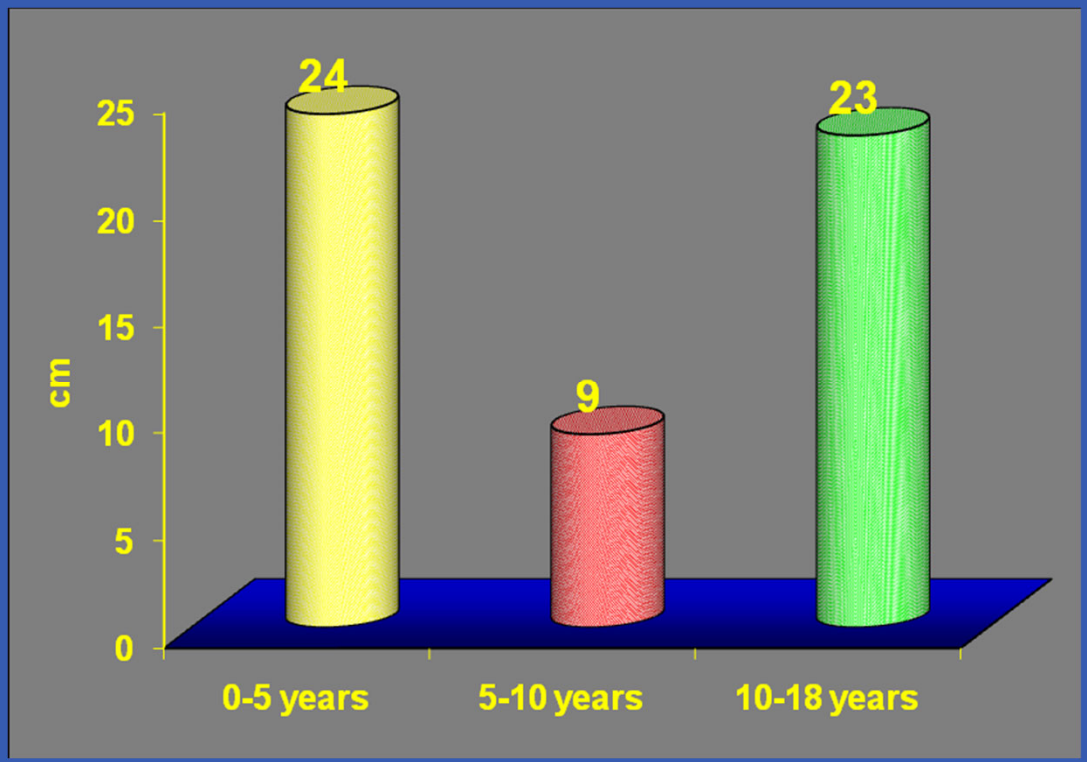
ANNUAL GROWTH VELOCITY T1 –L5

BIRTH – 5 y.	2.2 cm
5 y – 10 y.:	1.1 cm
10 y. – PUBERTY:	1.8 cm



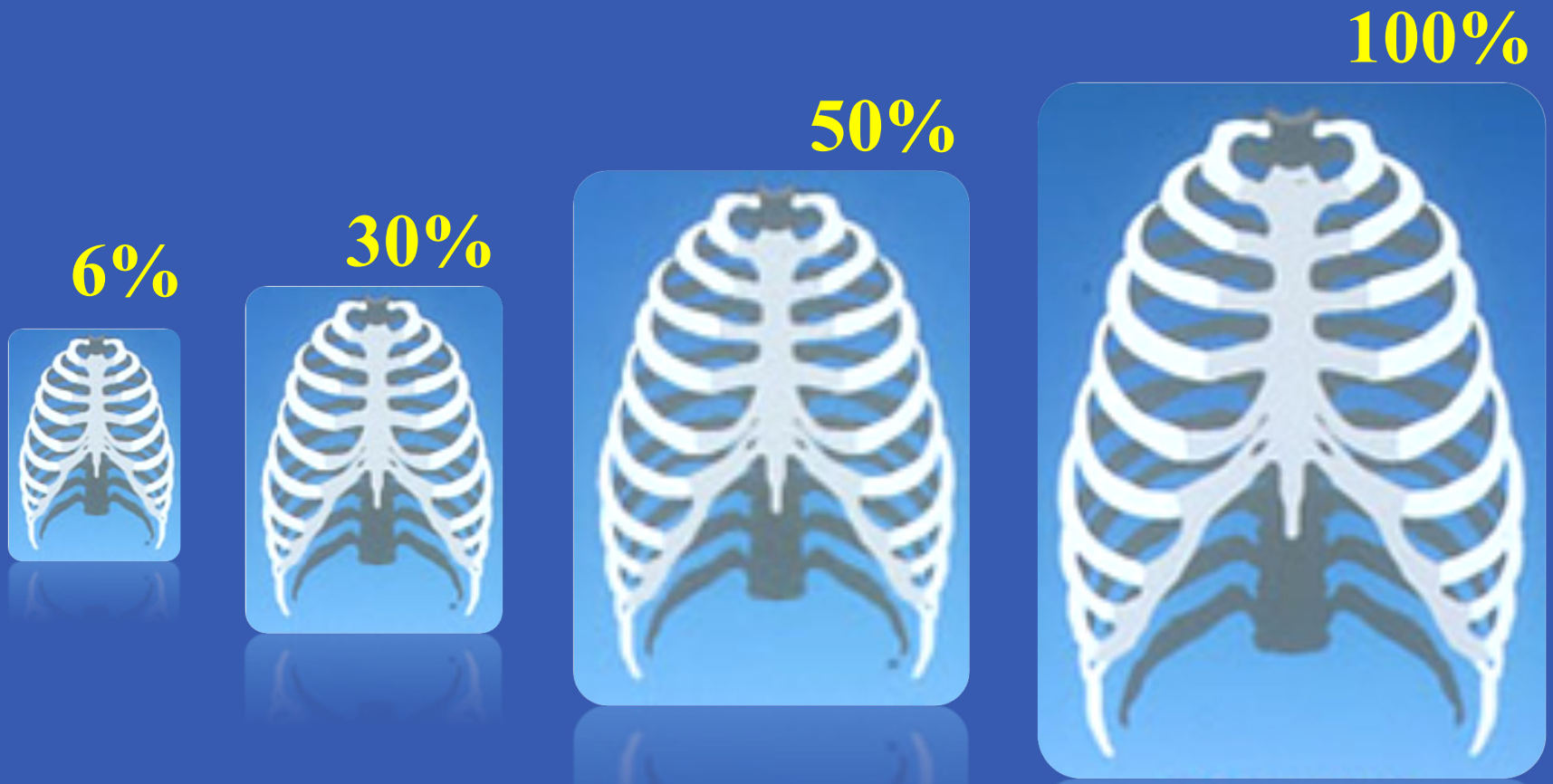
The growing spine, springer Velarg 1990

THORACIC PERIMETER GROWTH



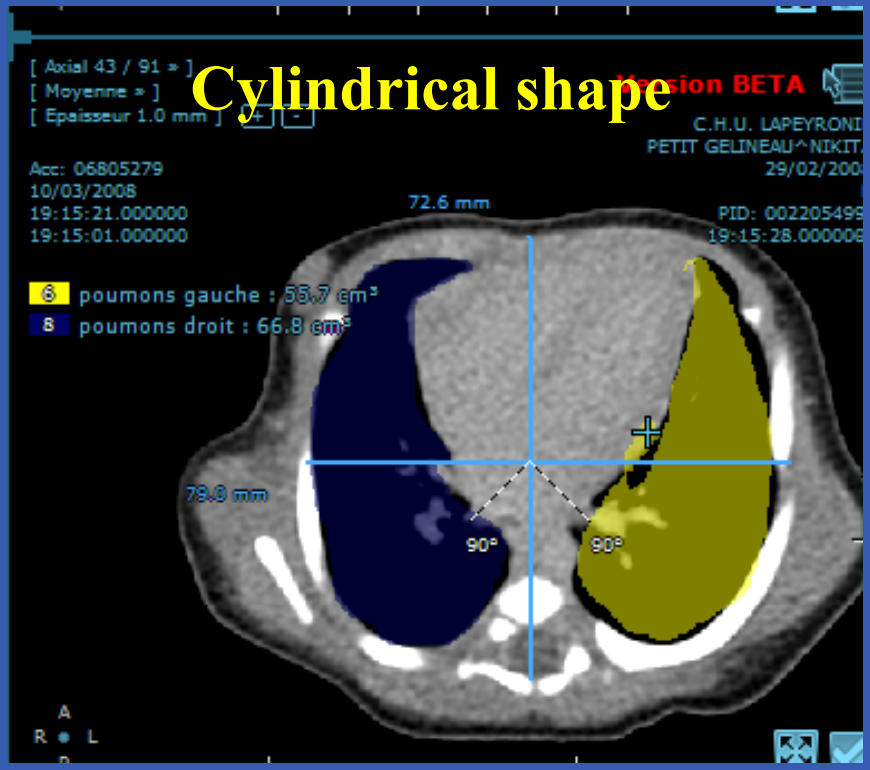
The gain is particularly important the first 5 years (24 cm) with a slow down after 5 years and a new peak at puberty.

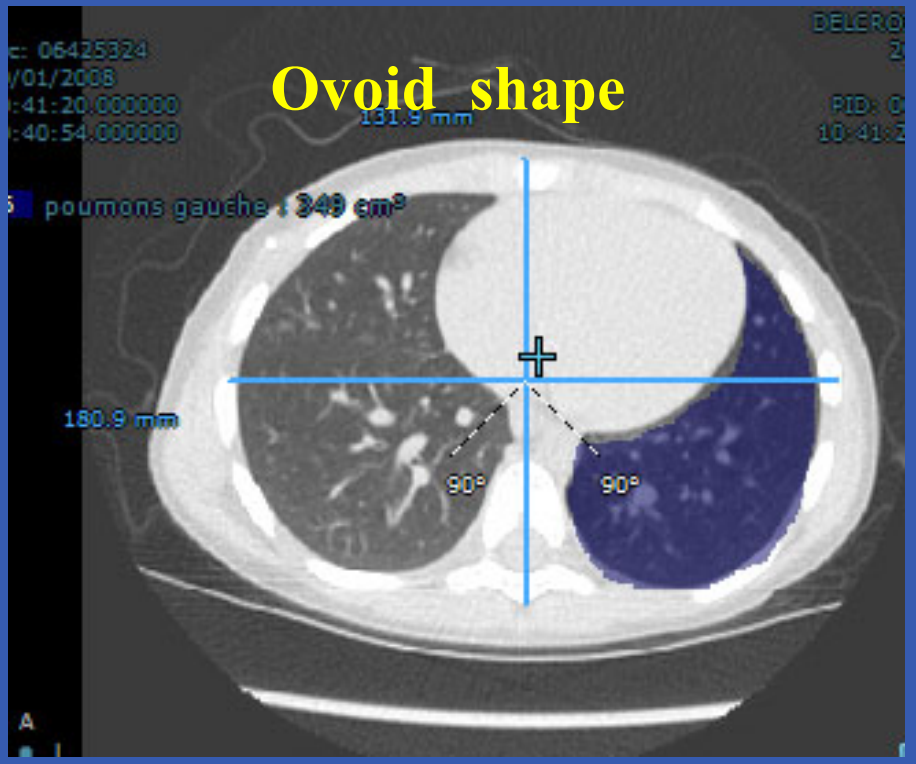
VOLUMETRIC GROWTH



The growing spine, springer Velarg 1990

Remaining thoracic growth: 70%
Remaining sitting height: 35%





Birth

AP: 72 mm
L: 79 mm
Diff: 6 mm
Volume Right 67 cm^3
Volume Left 56 cm^3

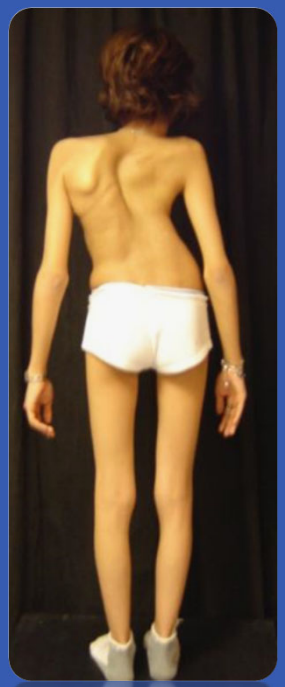
5 years

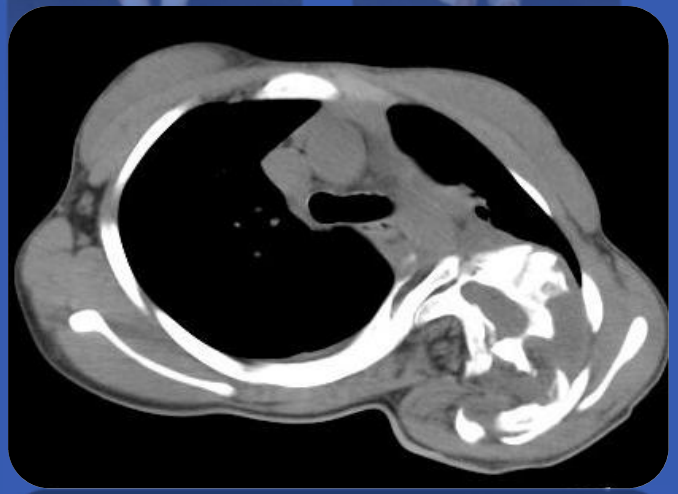
AP: 132 mm
L: 182 mm
Diff: 50 mm
Volume Right 398 cm^3 (6x)
Volume Left 349 cm^3 (6x)

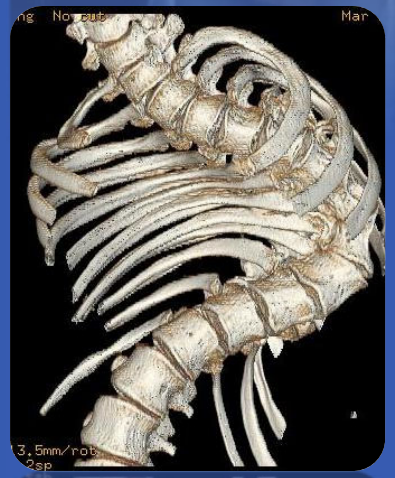
Frontal diameter grows faster than AP Diameter

The thorax is the fourth dimension of the spine

Infantile scoliosis, 16 Years
Deficit on the sitting height 25 cm
Weight 22 kgs
Normal Length of the lower limbs







- RESTRICTIVE RESPIRATORY MECHANICS
- LOSS OF CHEST WALL EXCURSION
- ASSYMETRICAL LOSS OF LUNG FUNCTION
- INEFFICIENT DIAPHRAGM FUNCTION

Thoracic deformity in severe scoliosis

- THORACIC INSUFFICIENCY SYNDROME

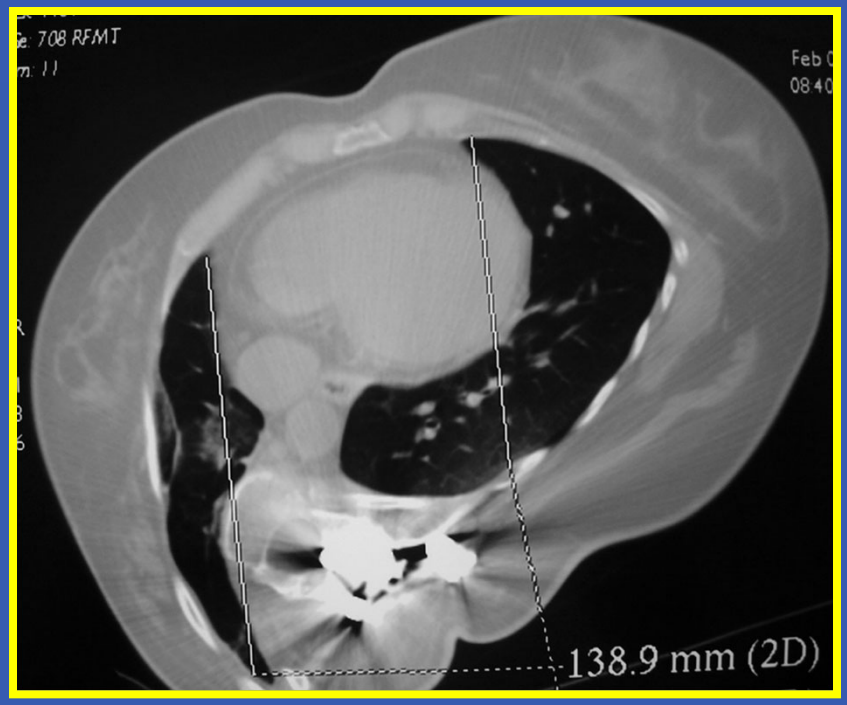
  CONGENITAL SCOLIOSIS AND FUSED RIBS

  CAMPBELL ET AL.
  J BONE JOINT SURG (AM) 2003

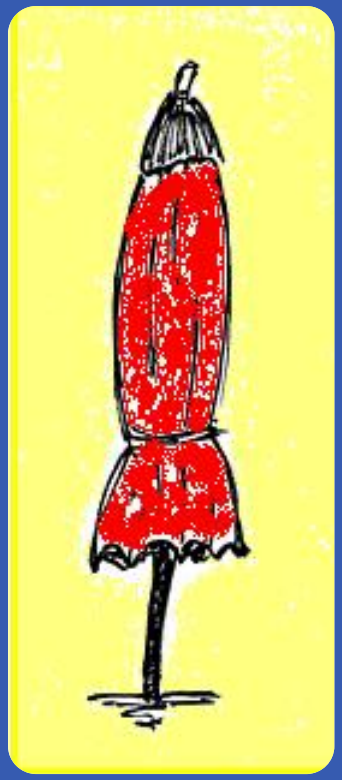
- Spinal penetration index

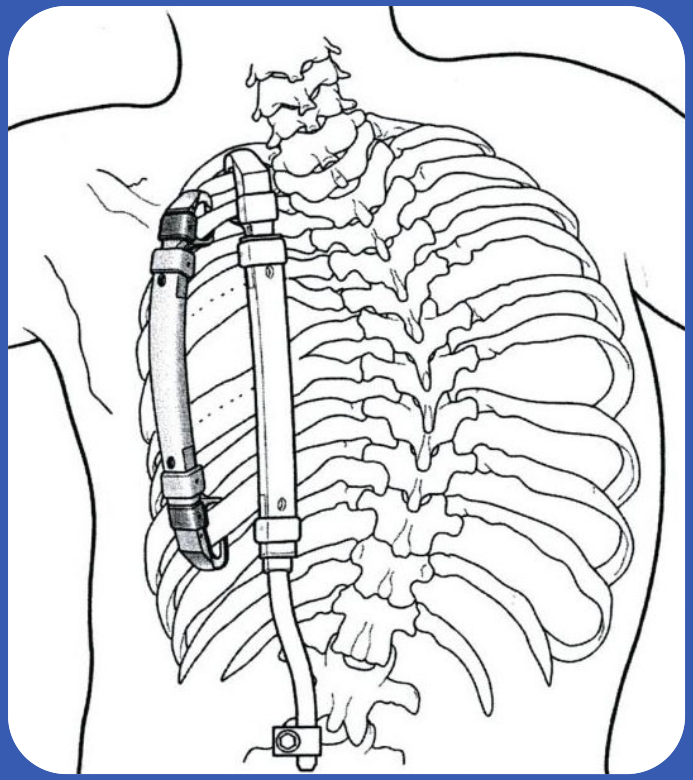
  Neuromuscular scoliosis
  Syndromes

  Dubousset et al.
  J Orthop Sci 2003



Influence of early onset scoliosis on volumetric thoracic growth and proportions?





Early expansion of the chest wall and VEPTR promote lung function

Campbell et al. J Bone Joint Surg (Am) 2003

POSTERIOR ARTHRODESIS OF THE THORACIC SPINE IN PRE-PUBERTAL RABBITS: EFFECTS ON THORACIC GROWTH

Does a posterior arthrodesis influence the thoracic growth patterns, the length of the sternum and the thoracic volume?

. Montpellier

Canavese et al. Spine, 2007

MATERIAL AND METHODS

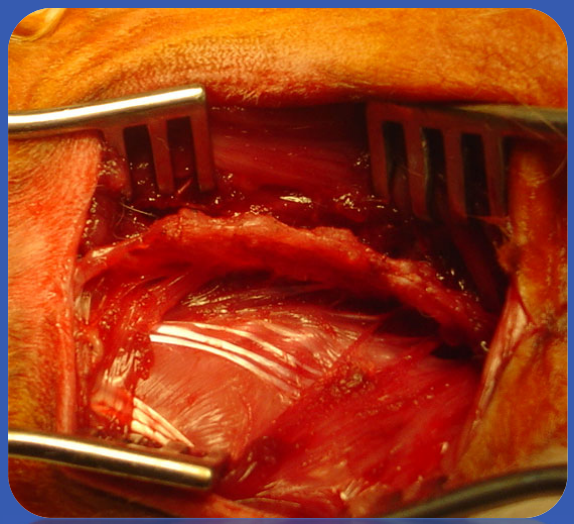
- 12 female White New Zeland pre pubertal rabbits 9 weeks old

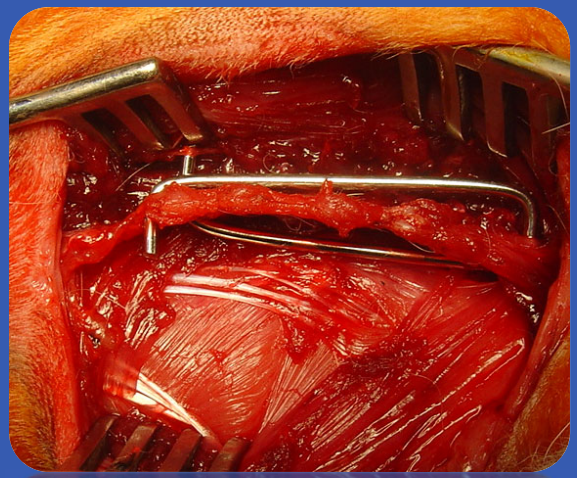
- Implant of 2 “C” shaped titanium bars placed beside the spinous processes of the first 6 thoracic vertebrae

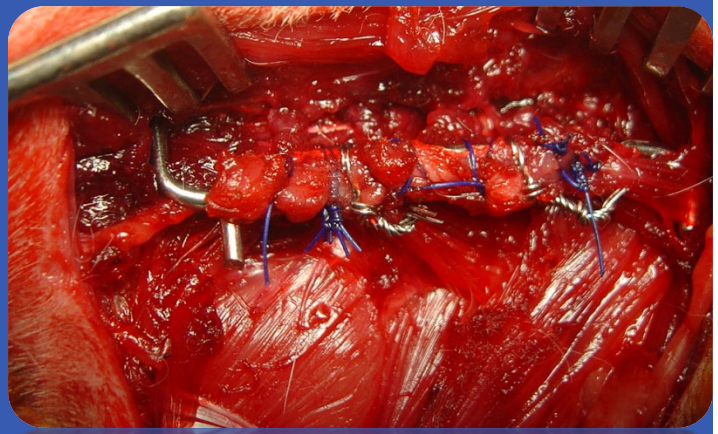
- 3 CT SCAN: day 10 (T1)
  day 55 (T2)
  day 139 (T3)

- Myran Pro® program : Thoracic Diameters
  Lung Volume
  Vertebral Body Size

Canavese et al. Spine 2007



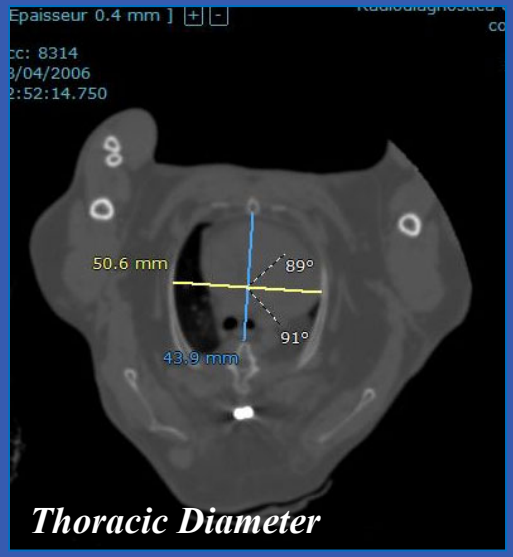




Canavese et al. Spine 2007

MATERIAL AND METHODS

Dorsal Fusion assessment



Thoracic Diameter

Lung Volume

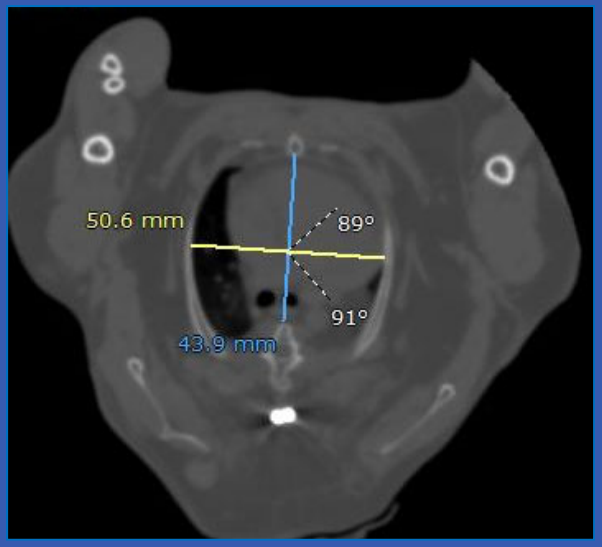
Vertebral Body Size

Canavese et al. Spine 2007

RESULTS

Group 1: **Complete fusion, 6 rabbits**
Group 2: **Incomplete fusion, 3 rabbits**
Group 3: **Control group (shams), 3 rabbits**

Average AP/L Thoracic Diameter ratio at fused levels



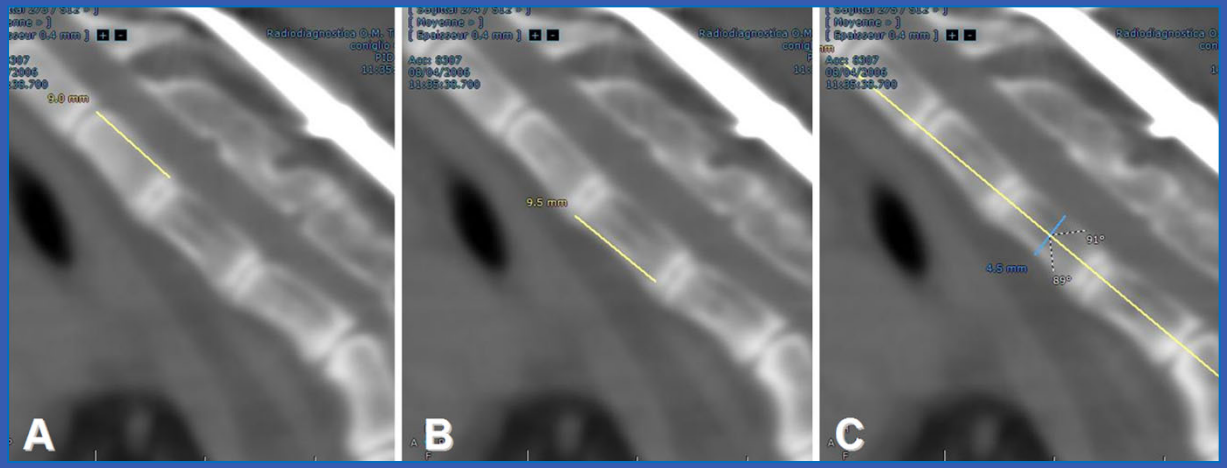
AP Thoracic Diameter grows slower than the L Thoracic Diameter and leads to an asymmetrical growth of the thorax

Canavese et al. Spine 2007

RESULTS

Group 1: **Complete fusion, 6 rabbits**
Group 2: **Incomplete fusion, 3 rabbits**
Group 3: **Control group (shams), 3 rabbits**

Vertebral Body Size



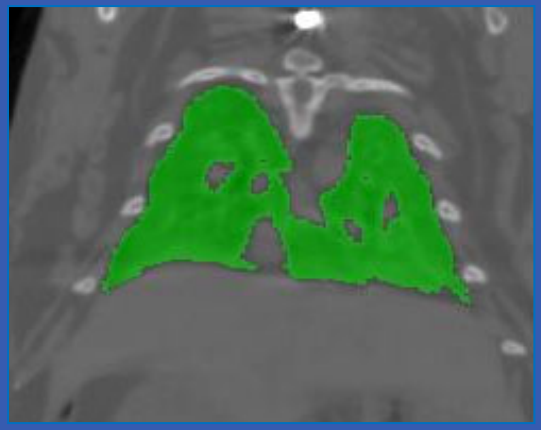
In the complete fusion group there was a decrease in the length and the volume of the vertebral body
There is reduction of thoracic kyphosis due to Crankshaft Phenomenon

Canavese et al. Spine 2007
Canavese et al. Rev Chir Orthop 2008

RESULTS

Group 1: **Complete fusion, 6 rabbits**
Group 2: **Incomplete fusion, 3 rabbits**
Group 3: **Control group (shams), 3 rabbits**

Average Lung Volume ↓
Average Growth of the Sternum ↓



The asymmetrical growth of the thorax which become almost elliptical influences and reduces the growth of the sternum and the lung development (-13%)

Canavese et al. Spine 2007

RABBIT	Vol. (cm^3) 28-11-05	Vol. (cm^3) 14-1-06	Vol. (cm^3) 8-4-06	
632942	47,8	55,5	58,7	GROUP 1 posterior instrument. with arthrodesis
650880	44,4	59,7	59,7	
656488	37,1	51,5	52,8	
866965	39,9	50,4	51,3	
650449	48,9	66,1	68,9	
742549	37,6	55,1	56,9	
747364	45,6	57,2	89,9	GROUP 2 posterior instrument. without arthrodesis)
724398	47,7	53,4	58,7	
725847	47,5	50,9	57,6	
sh 633171	50,1	61,3	71,1	GROUP 3 control group: shams
sh 653104	47,1	58	67,4	
sh 700025	46,9	54,7	60,3	

Canavese et al. Spine 2007

Metha et al. *Spine* 2006, vol. 31, n°23, pp. 2654-2664

In a growing rabbit model, there is an interaction between growth of the spine and thorax: a unilateral deformity of the spine or the thorax induces both scoliosis and thoracic cage deformity with asymmetric lung volumes

Karol et al. *JBJS Am* 2008; 90:1272-81

Early arthrodesis reduces the AP diameter and shortens the T1 - T12 index

Fusion is a cause of respiratory insufficiency and adds to the spinal deformity the loss of pulmonary function

What we know, where we are, which way to follow …

- There is a normal interaction between the spine, the thoracic cage and the lungs.
- Deformities of the spine adversely affect the development of the thorax by changing its shape and reducing its normal mobility.
- The **rib-vertebral-lung complex** should be considered as a whole, it constitutes an elastic structural model that in the presence of scoliosis it becomes rigid thus preventing the from normal development lungs.

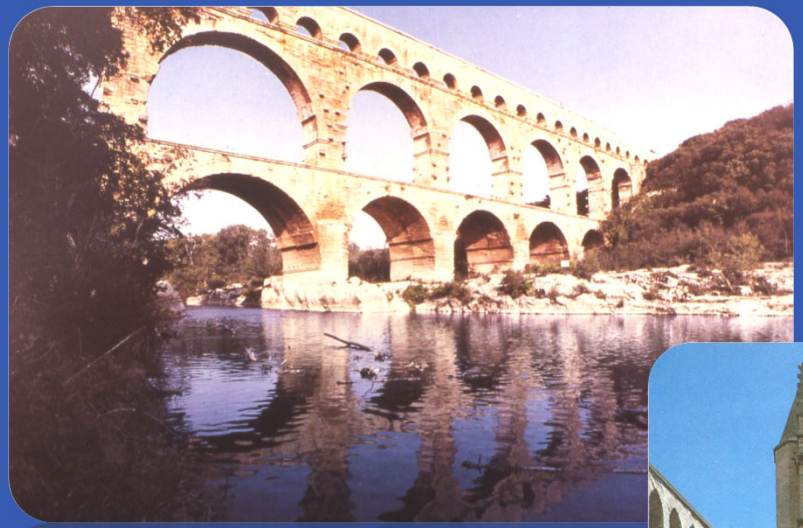
- Early posterior arthrodesis in the proximal portion of the spine disturbs significantly the morphology of the thorax and blocks the thoracic volume.

- Before the age of five years, treat the deformities of the thorax to preserve the pulmonary growth.

- Innovative techniques such as expansion thoracoplasty and dual rod distraction offer the possibility of preventing thoracic insufficiency for spinal deformity.

- The principle that a short spine produced by early fusion is better than a long curved spine is no longer generally accepted (Charles Johnston).

- Challenging the growing spine means how to maintain the spinal growth, the thoracic growth , the lung growth and to keep the spine supple.




Montpellier

Chest wall/spine/lung interactions

- The spine dictates rib function
  - Kyphoscoliosis after rib malalignment and mobility
  - Early arthrodesis has a negative effect
- The ribs dictate spine function
  - Fused ribs lead to scoliosis
- The lungs dictate rib and spine functions
  - Corrected congenital diaphragmatic hernia produced scoliosis (18% of patients)

CONCLUSIONS

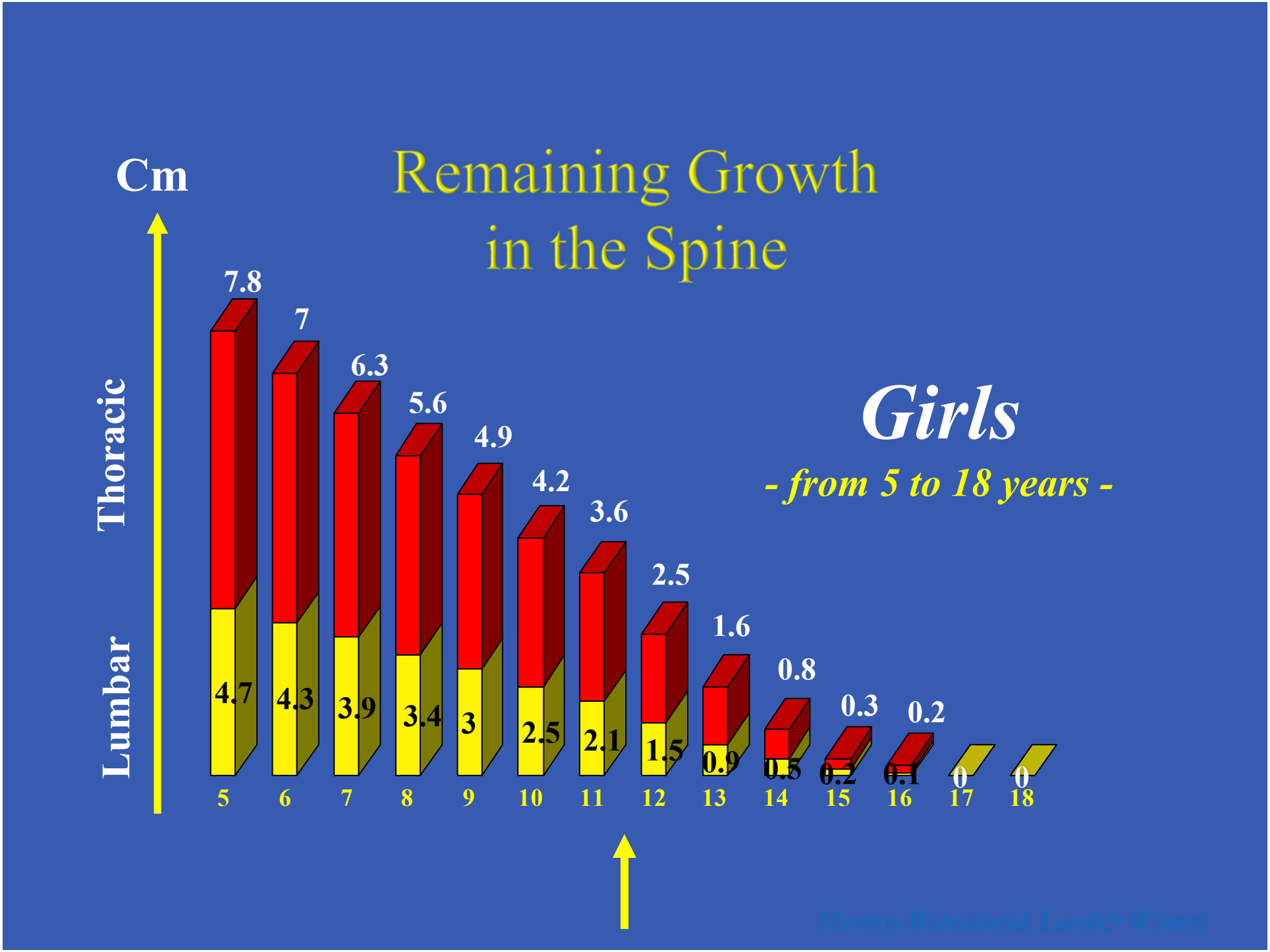
The thorax grows as a whole and a substantial modification of the upper part have effects on the lower one

Posterior surgery directly influences the growth pattern of the ribs which are connected posteriorly to the fused vertebral bodies (D2-D6) and to the sternum in the front (*sternal ribs*)

Lower ribs which are not directly connected to the sternum nor to the fused vertebral bodies (*non-sternal ribs*) grow less under the influence of the upper sternal ribs reduced growth

Posterior surgery can directly influence *sternal ribs* growth and indirectly *non-sternal* ribs growth but has no influence on the underlying vertebral bodies growth

Canavese Spine. 32(16):E443-E450, July 15, 2007.


Cm
Remaining Growth
in the Spine
Thoracic
Lumbar
7.8
7
6.3
5.6
4.9
4.2
3.6
2.5
1.6
0.8
0.3
0.2
4.7
4.3
3.9
3.4
3
2.5
2.1
1.5
0.9
0.5
0.2
0.1
0
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5
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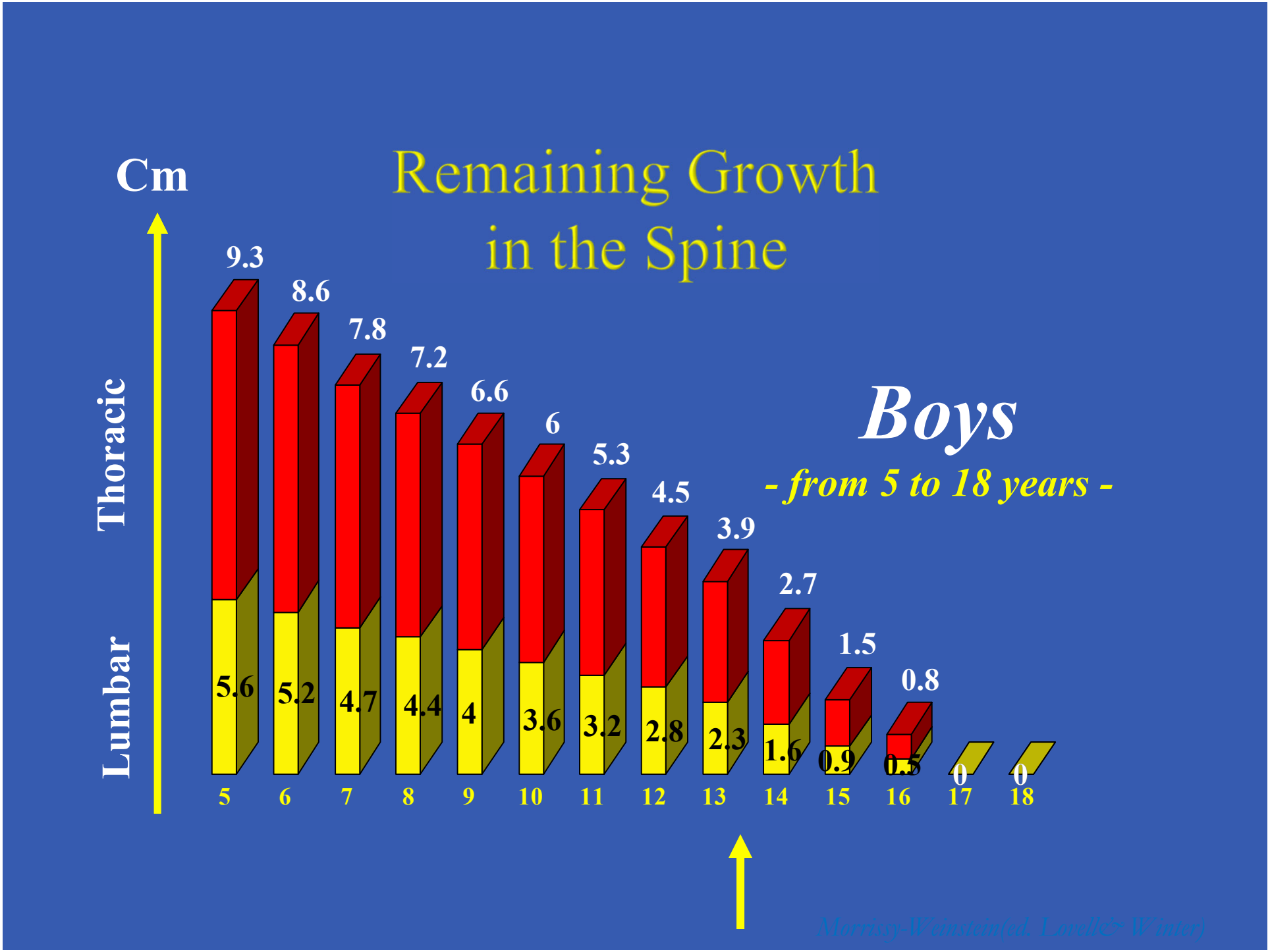
18
Girls
- from 5 to 18 years -
Morrissy-Weinstein(ed. Lovell& Winter)


Cm
Remaining Growth
in the Spine
Thoracic
Lumbar
Boys
- from 5 to 18 years -
9.3
8.6
7.8
7.2
6.6
6
5.3
4.5
3.9
2.7
1.5
0.8
0
0
5.6
5.2
4.7
4.4
4
3.6
3.2
2.8
2.3
1.6
0.9
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18
Murrisy-Weinstein(ed. Lovell& Winter)

Early onset scoliosis

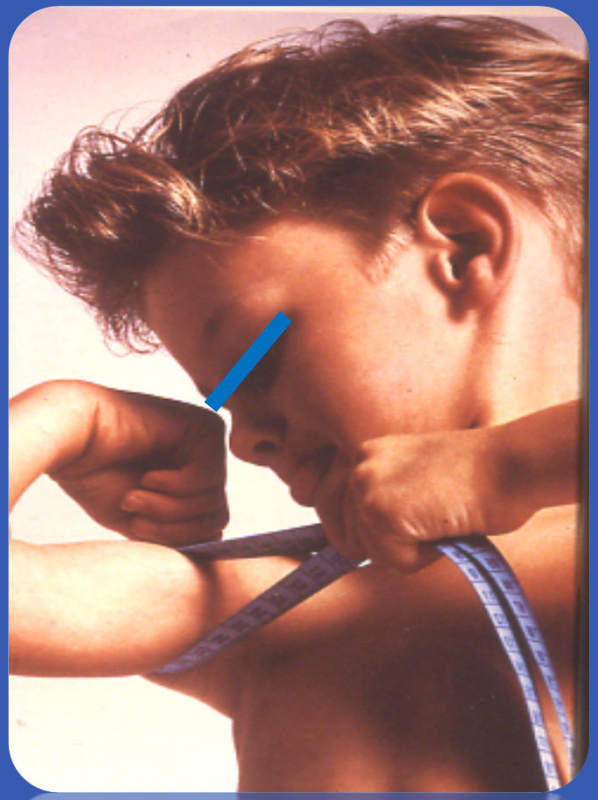
Dorsal arthrodesis has a negative effect on the morphology of the thorax and influences the development of the lung

Spine. 32(16):E443-E450, 2007 - JBJS A. 2008;90:1272-1281.

AT AGE 5 YEARS THE SPINAL CANAL HAS ALREADY REACHED 95 % OF ITS FINAL DIAMETER

AFTER EARLY PERI-VERTEBRAL ARTHRODESIS AT THE BEGINNING OF PUBERTY THE DEFICIT ON THE SITTING HEIGHT IS OUTBALANCED BY THE CORRECTION OF THE CURVE

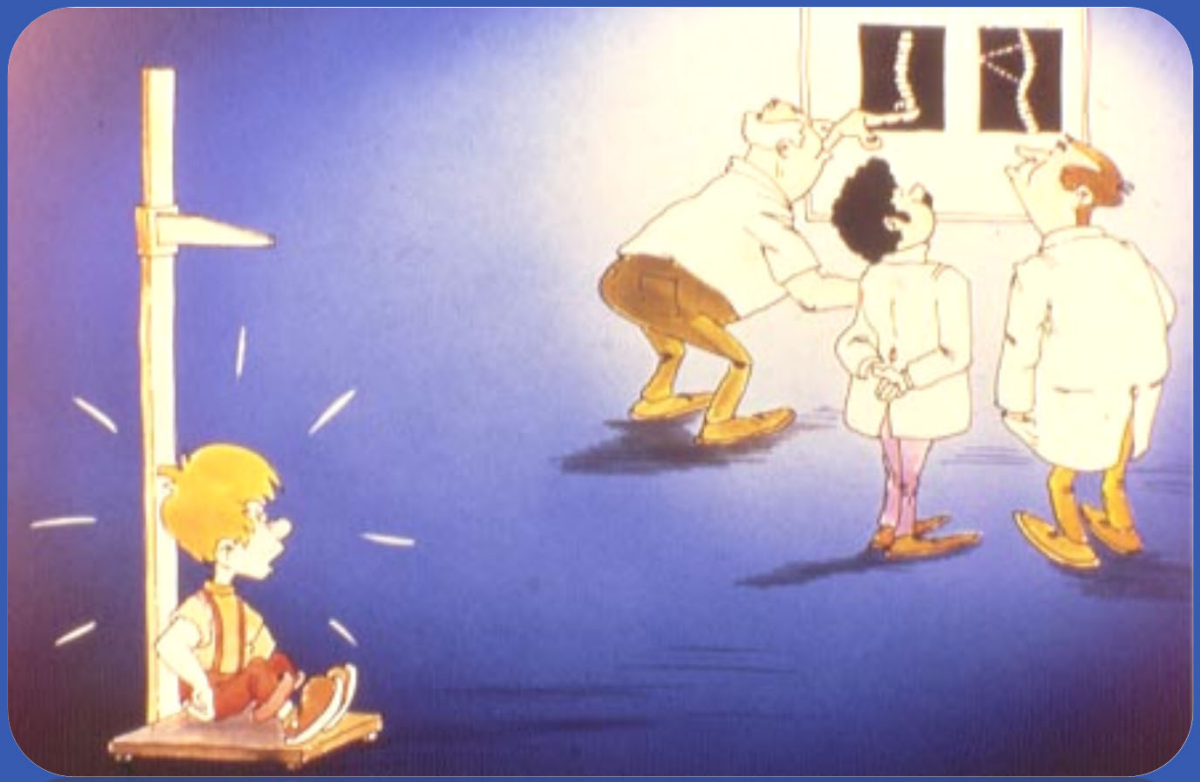
TREAT EARLY



Don’t stick to one parameter

To control growth,Consider:

- Annual Velocity on the trunk
- Skeletal maturation (elbow, and pelvis)
- Tanner signs



Message

- Challenging the growing spine means how to maintain the spinal growth, the thoracic growth , the lung growth and keep the spine supple.

- The thorax is the fourth dimension of the spine. Before the age of 5 years, treat the retraction of the thorax to preserve the pulmonary growth and avoid spinal arthrodesis.

- Between the age of 5 years and the beginning of the puberty, preserve spinal mobility by avoiding arthrodesis and using the dual rod instead (Abkarnia) .

- Treat by anticipation and detect soon aggressive scoliosis.

  Consider the surgical risk; at the beginning of puberty a curve of 30 degrees has a 100% surgical risk.

Message

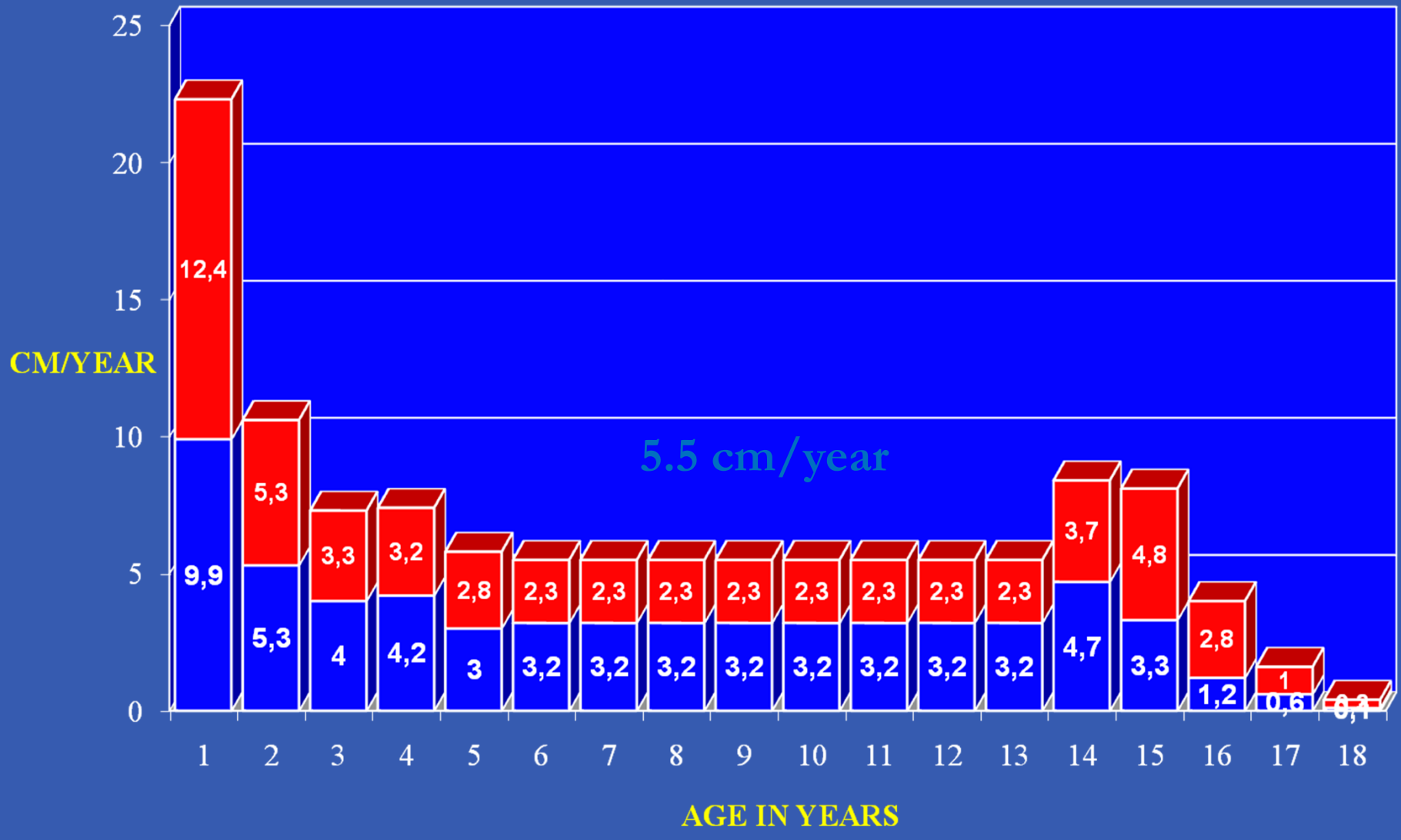
- To control growth, consider:
  - o Annual velocity on the trunk
  - o Skeletal maturation
  - o Tanner signs
  - o Do not stick to one parameter

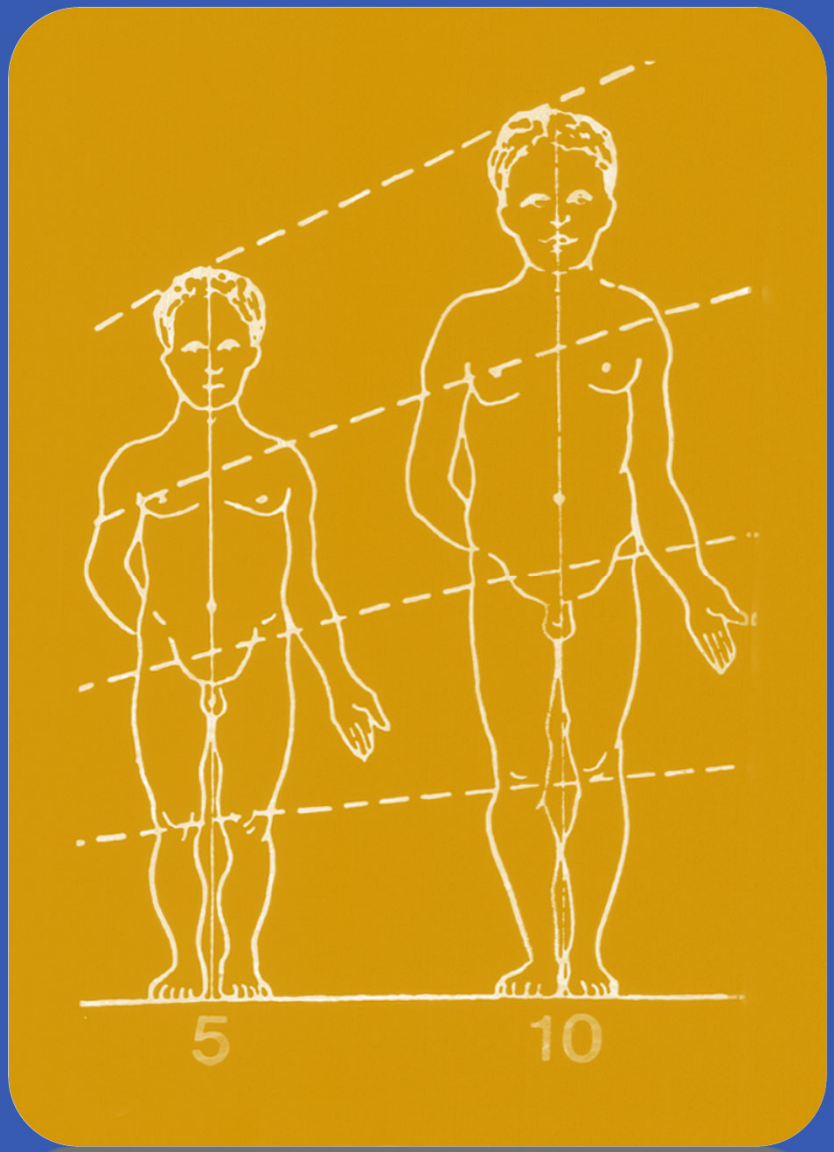
Message

- - The goal of management must be to control spinal deformity without impending spinal growth
- - Innovative techniques such as expansion thoracoplasty offer the possibility of preventing thoracic insufficiency for spinal deformity.
- - The principle that a short spine produced by early fusion is better than a long curved
- - spine is no longer generally accepted.

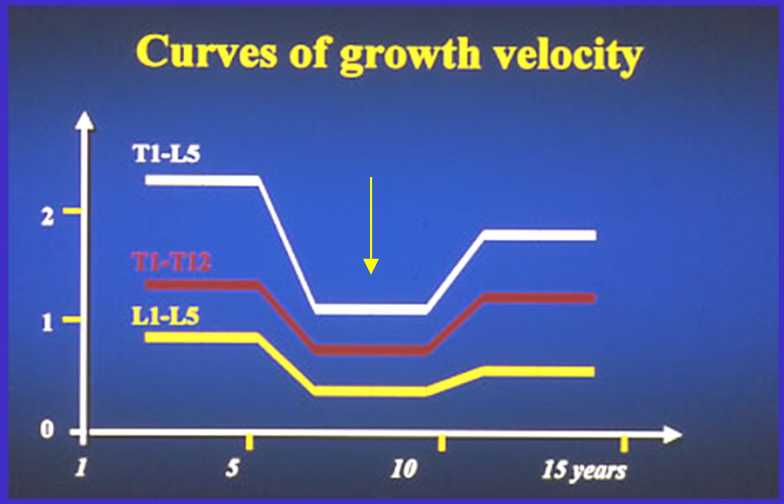
Study performed at the Universities of MONTPELLIER (France), TRIESTE (Italy) and UDINE (Italy)

GROWTH VELOCITY IN BOYS





AFTER 5 YEARS GROWTH SPINE VELOCITY DECREASES STRONGLY



After five T1-S1 increases by 1.1 cm / year