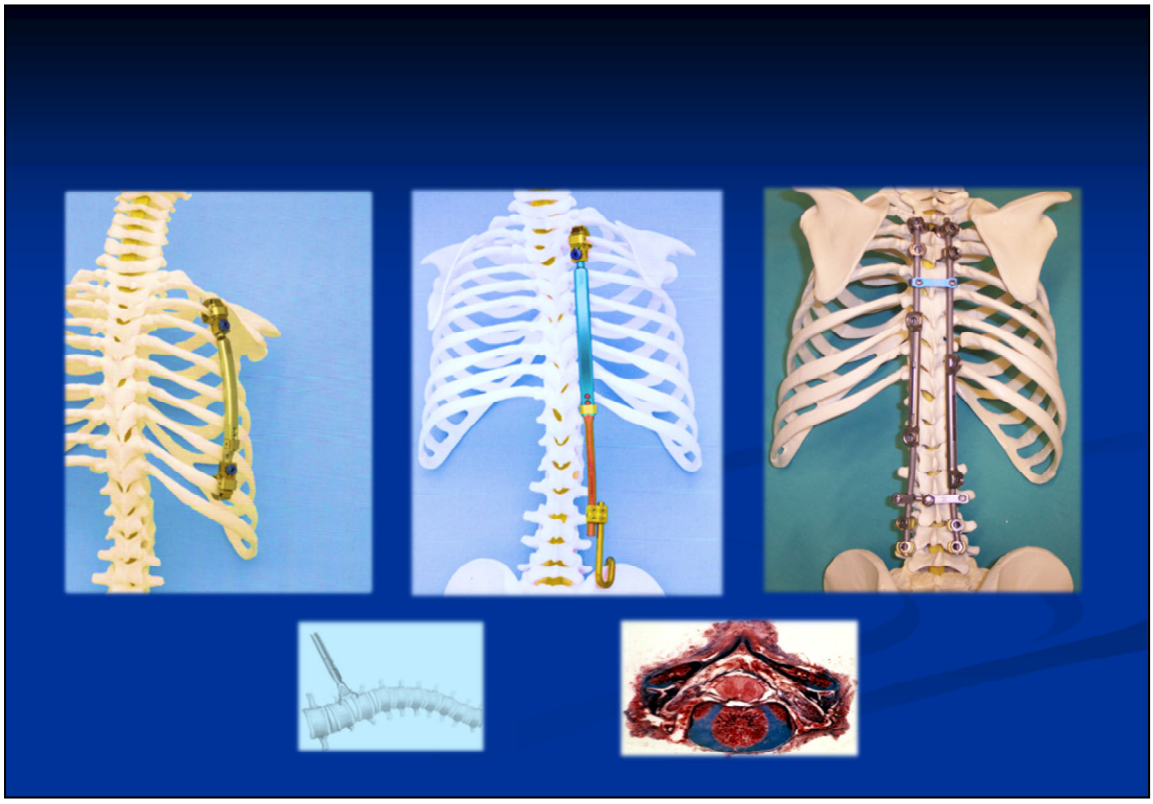
TORONTO

2010

THE IMMATURE SPINE

PROF. A. DIMEGLIO

F. CANAVESE, M.D.



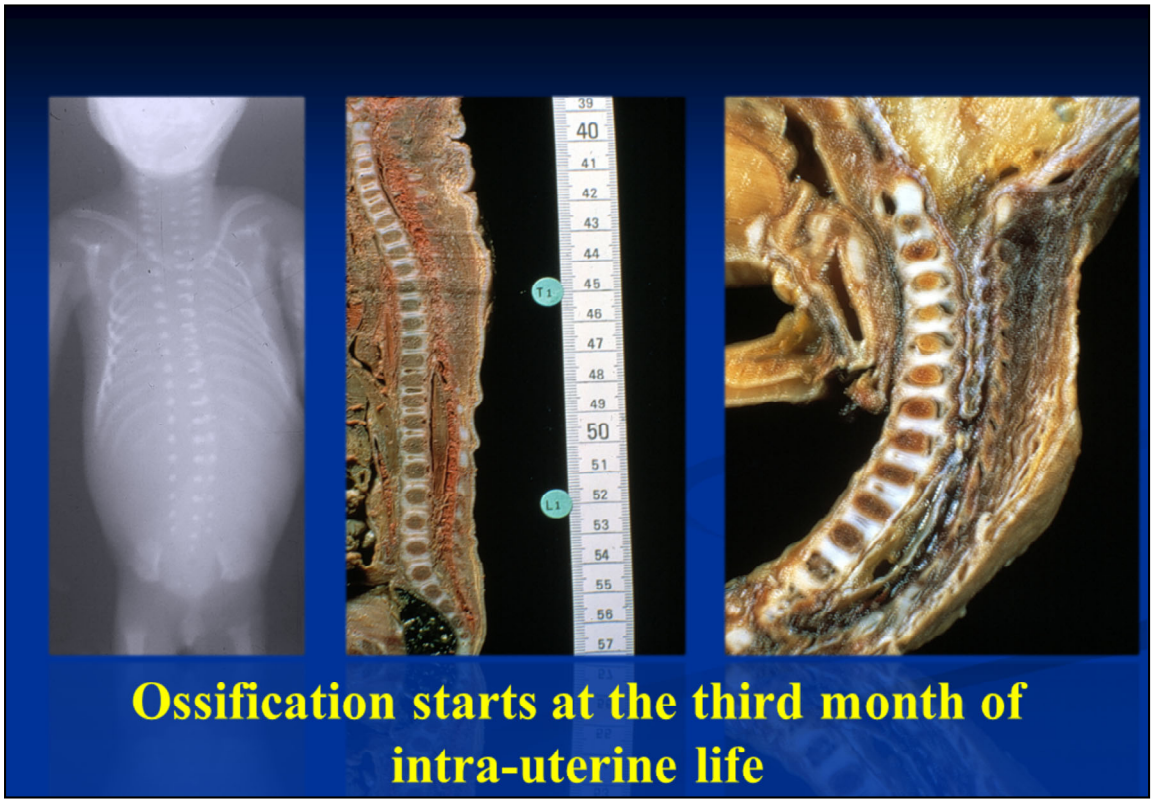
Campbell and Abkarnia have changed by their imagination and audacy the treatment and the philosophy of complex spine deformities, before ten years. To get along with this offensive strategy, many devices can be used: VEPTR, Dual rod distraction, Staples, and screw fixation of the neural central synchondrosis.

- The thorax is the heart of the problem in severe scoliosis
- Growth of the spine, thorax, lung are intricated
- The spine and ribs dictate lung function
- The cranckshaft phenomenon is a determining factor

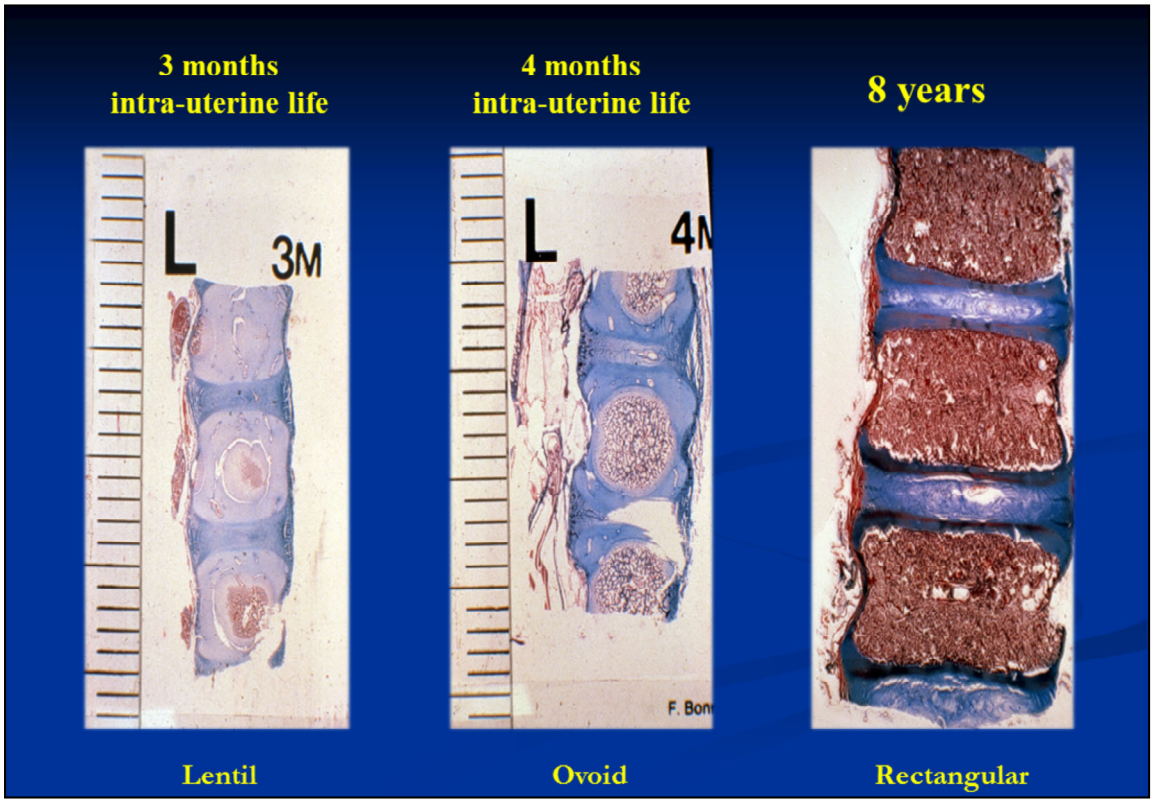
The growing spine

- Mosaic of growth plates
- Changes in rhythm
- All parameters do not progress at the same speed
- The thorax is the fourth dimension

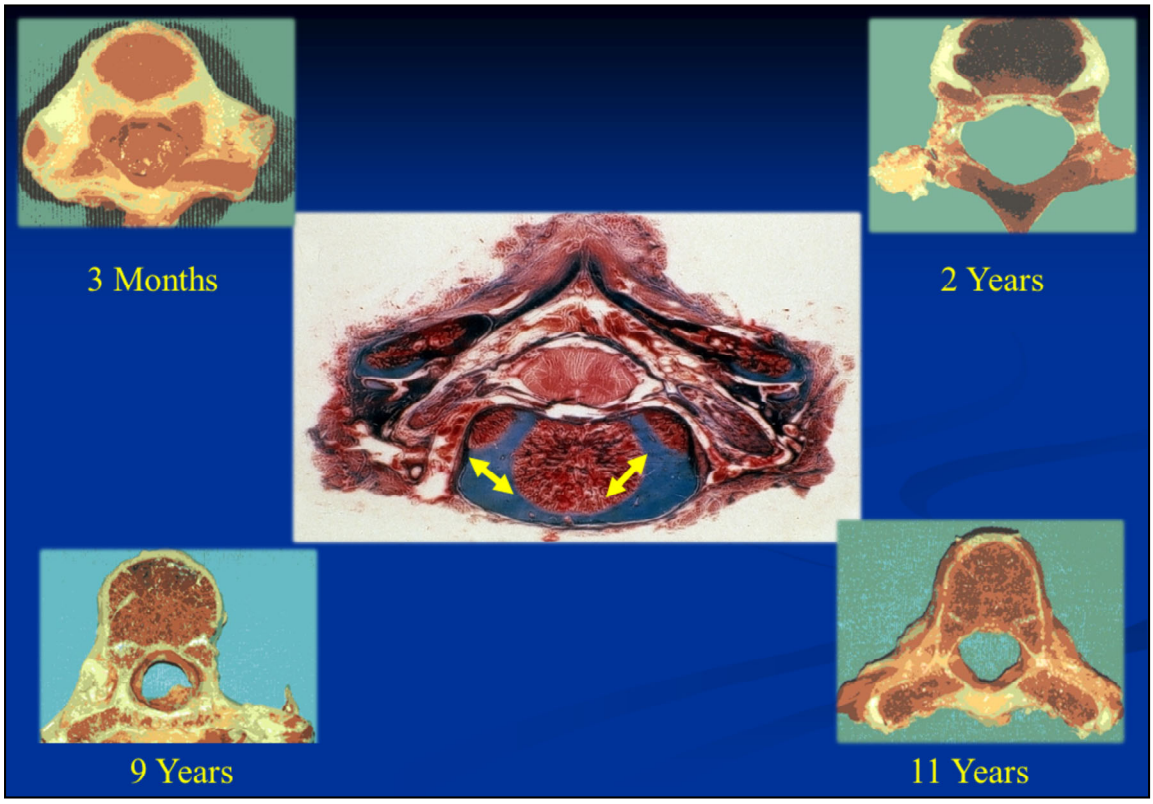
- Challenging the growing spine means how to maintain the spinal growth, the thoracic growth, the lung growth and keep the spine supple



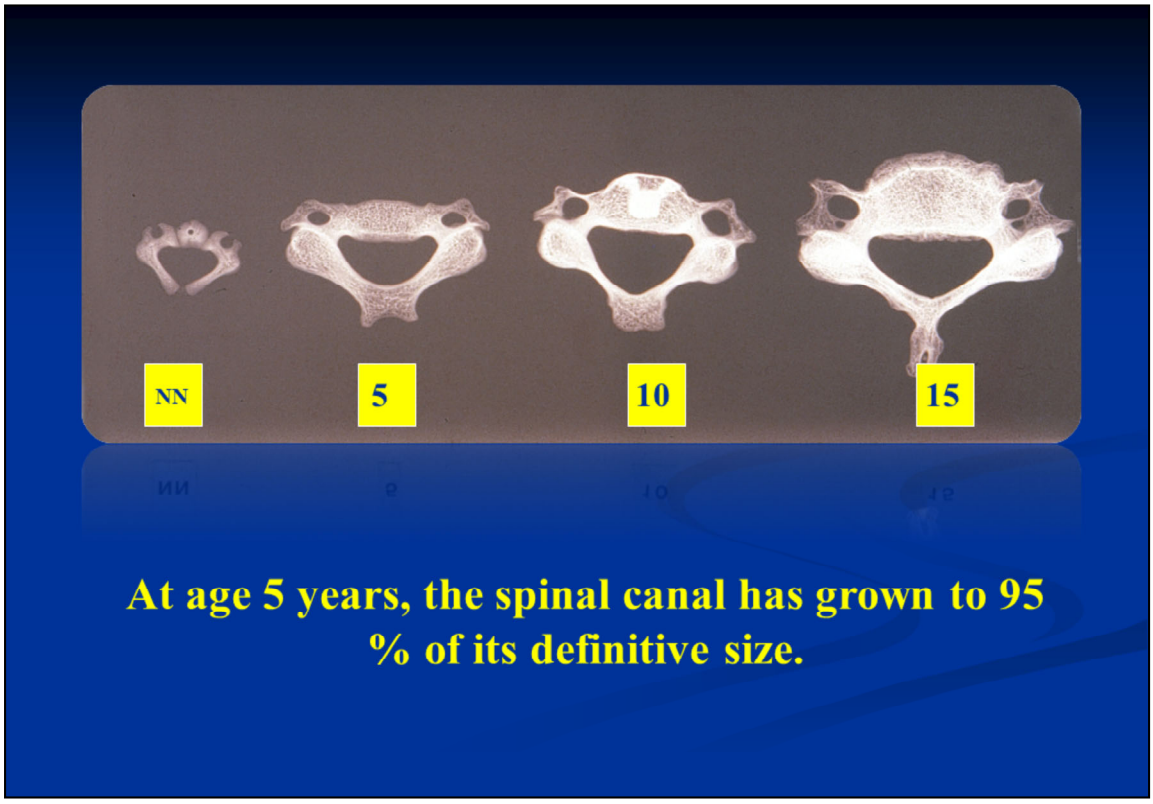
Ossification starts at 3 months of the intra-uterine life: the very beginning of ossification occurs in the posterior part of the vertebrae. The process ossification lasts 15 years up to skeletal maturity.



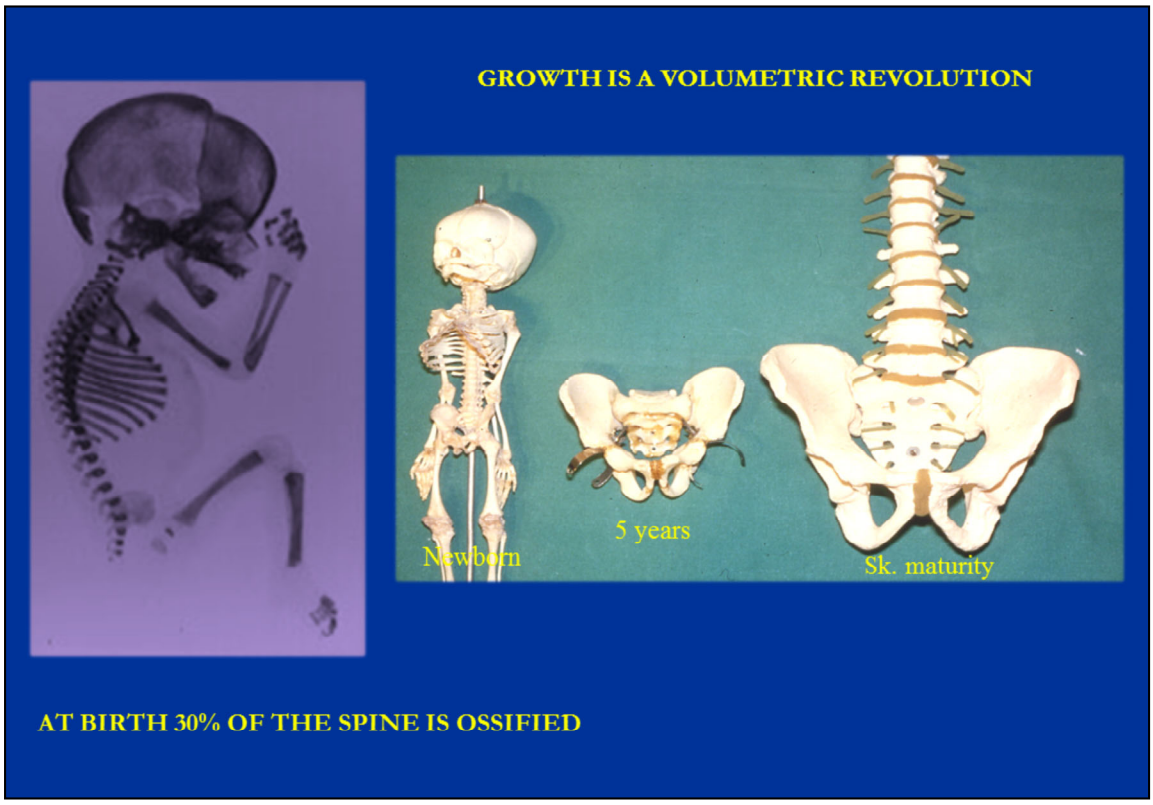
The nucleus center of the vertebrae body undergoes dramatic changes: at 3 months of intrauterine life the nucleus center grows up like a lentil; at 4 months, ossification has progressed and the nucleus center has an ovoid morphoogy; at 8 years the nucleus center has a rectangular morphology.



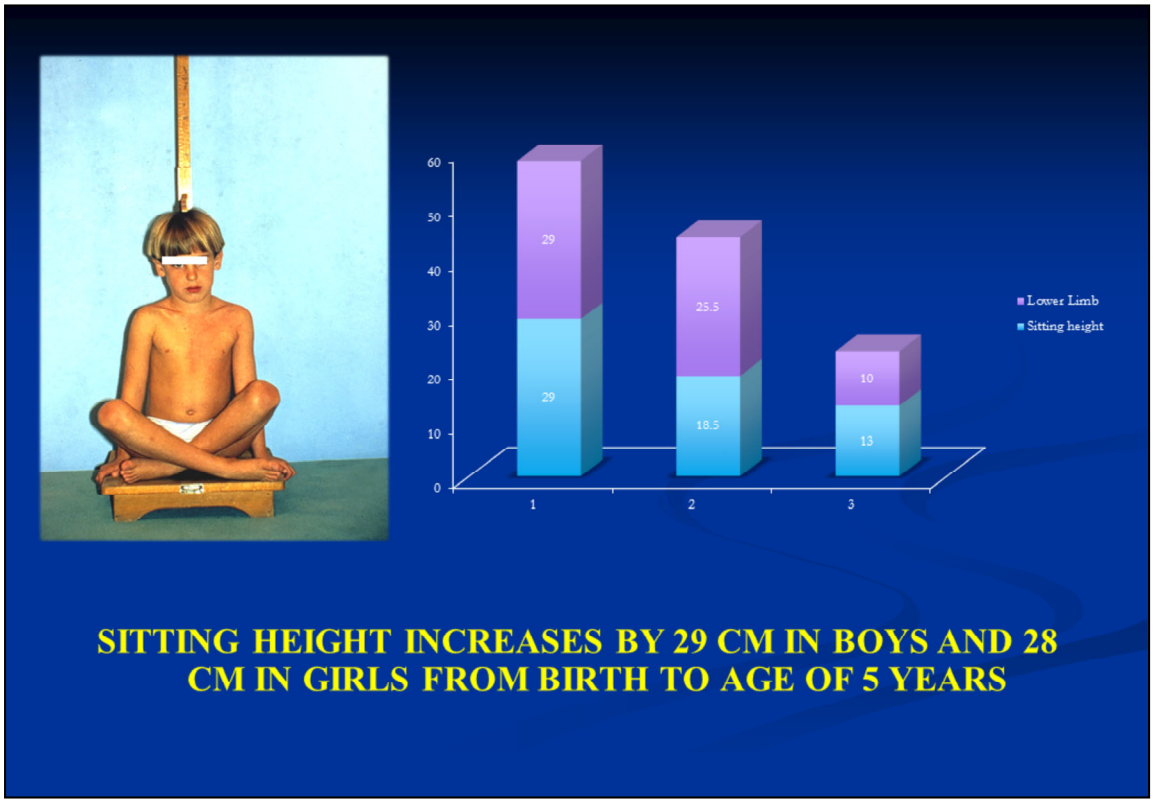
Neuro-central synchondrosis of double activity: the growth plate works in two directions. It contributes to the ossification of the vertebral body and to the posterieur arch. It closes around 11 years.



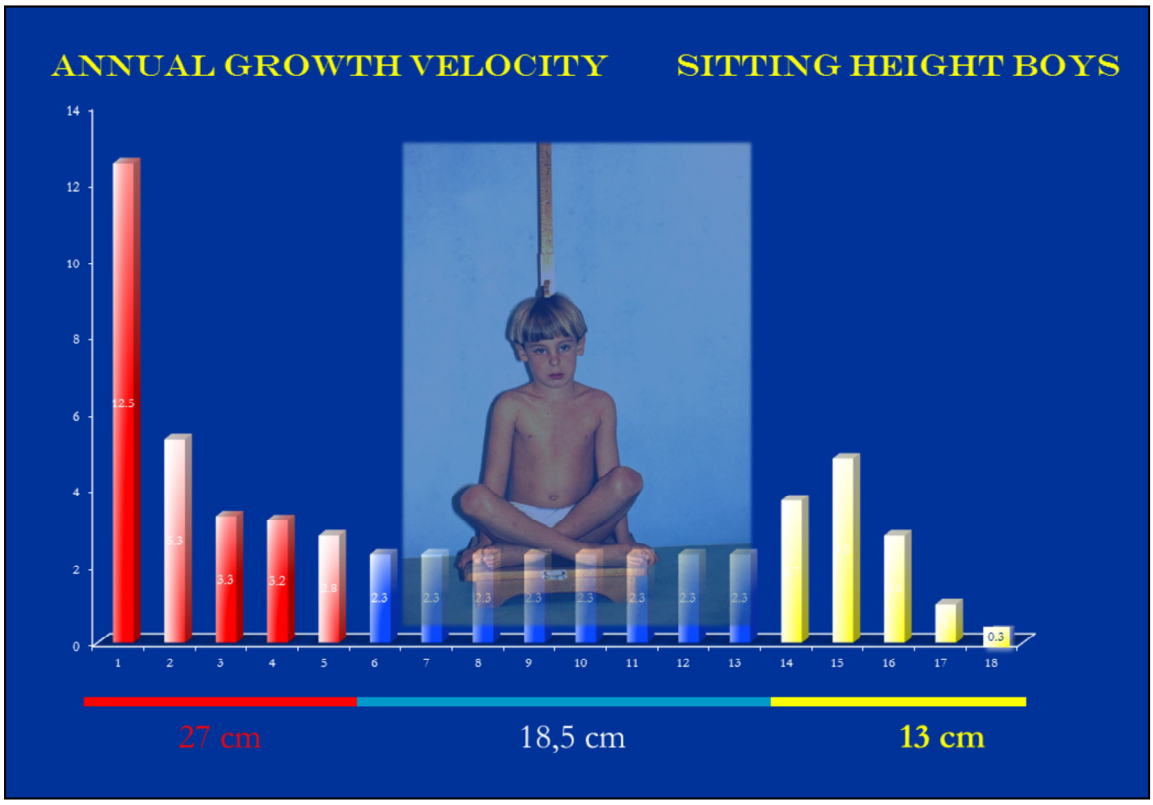
At age five, the spinal canal has reached 95 % of its definitive size. A peri-vertebral arthrodesis is theorically possible at 5 years of age. There will be no influence on the size of the spinal canal.

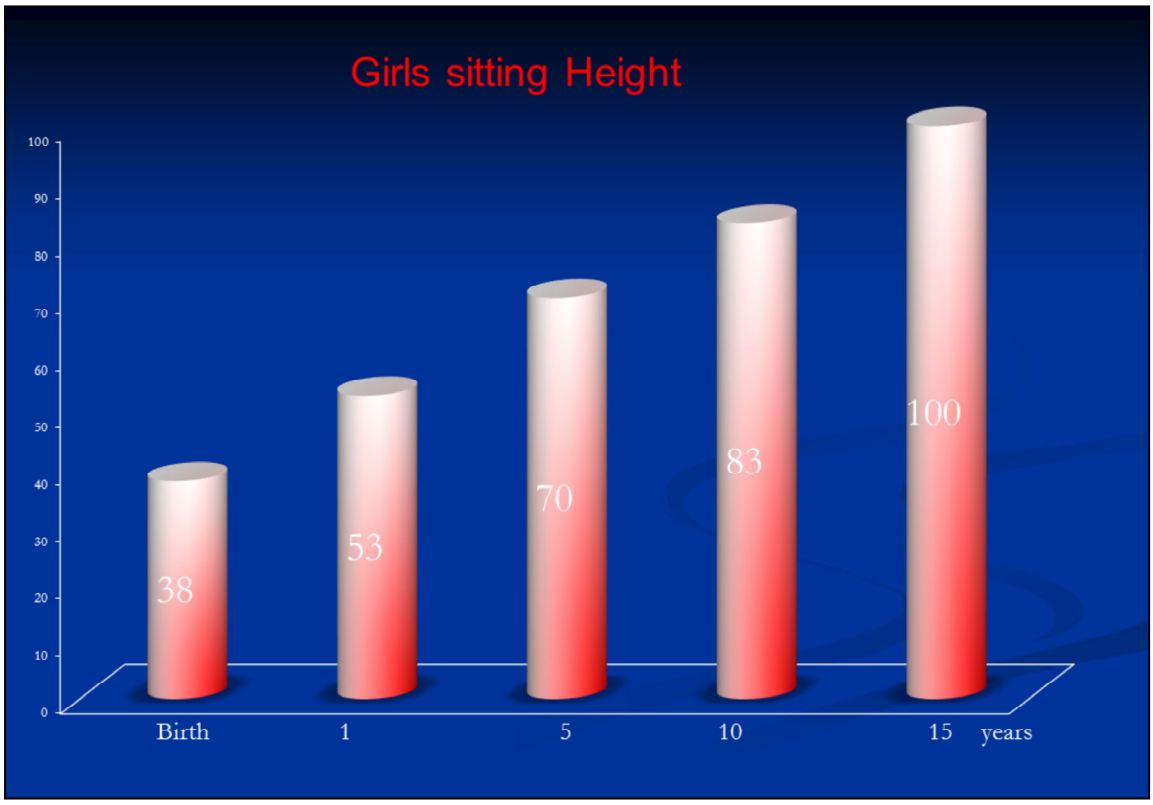


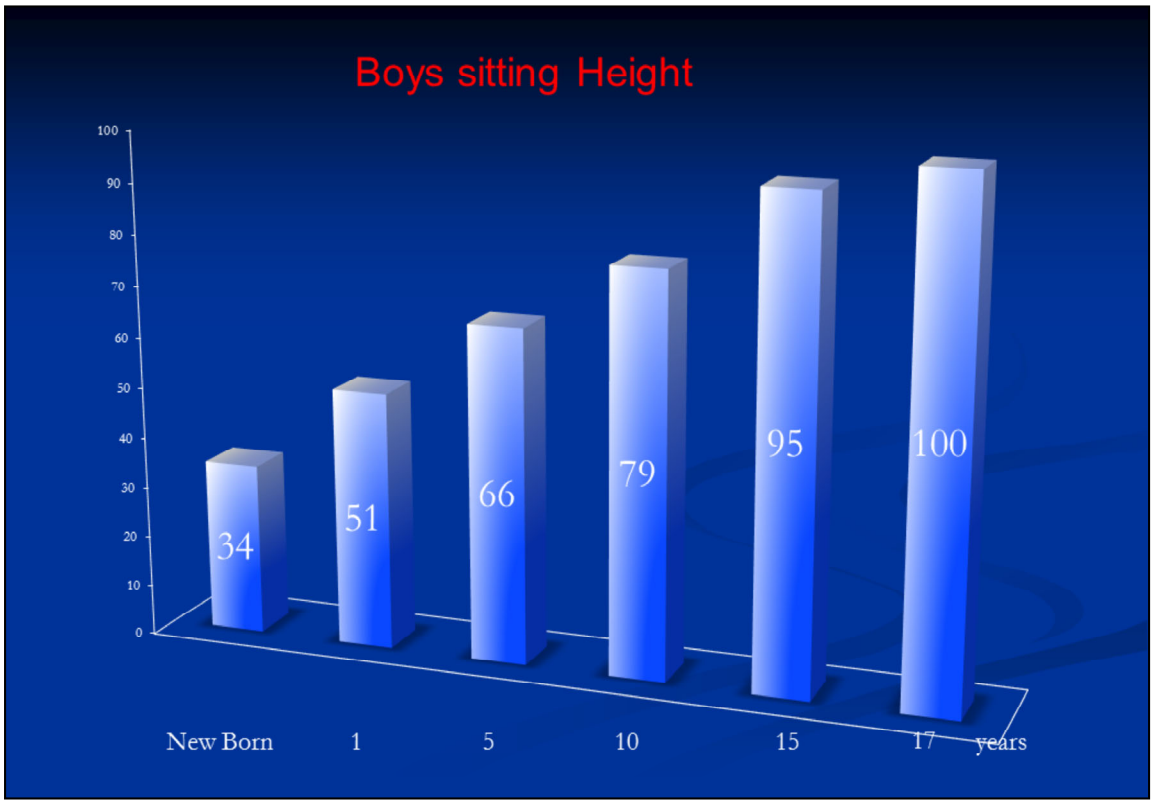
The pelvis undergoes spectacular changes from birth to five years. At five years, the vertebra volume makes up 17% of its final volume.

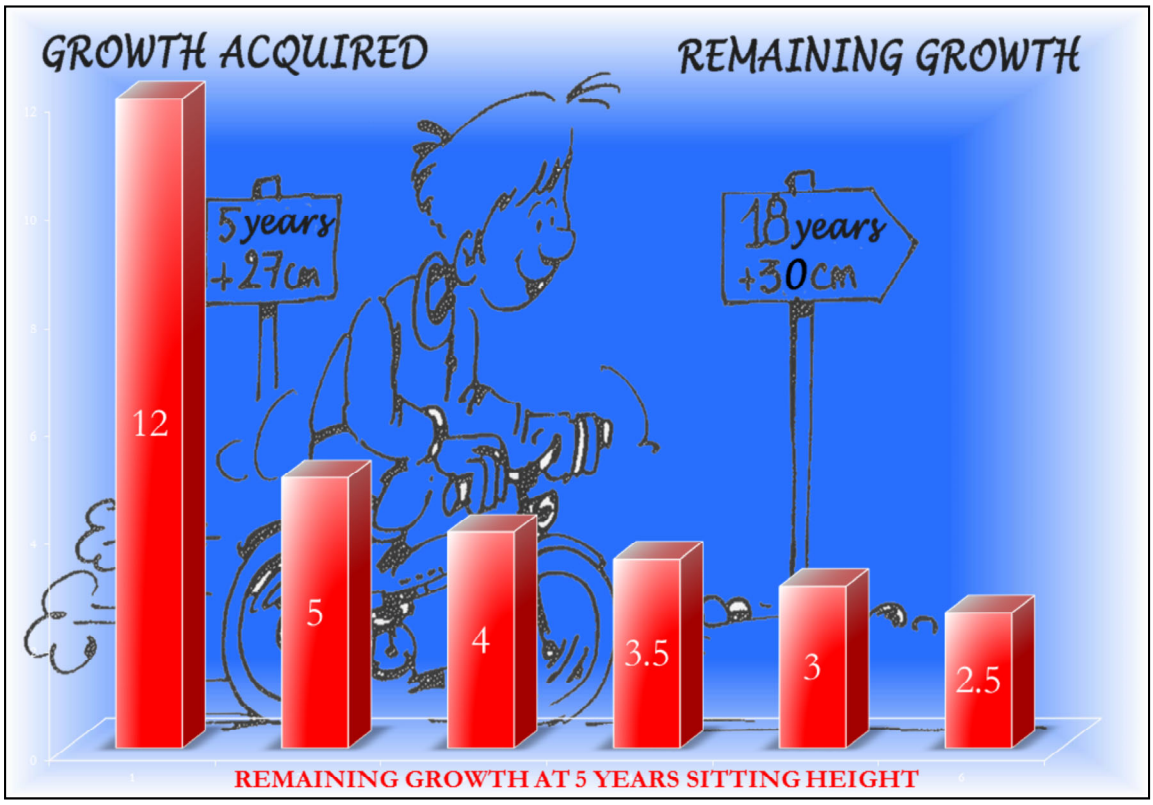


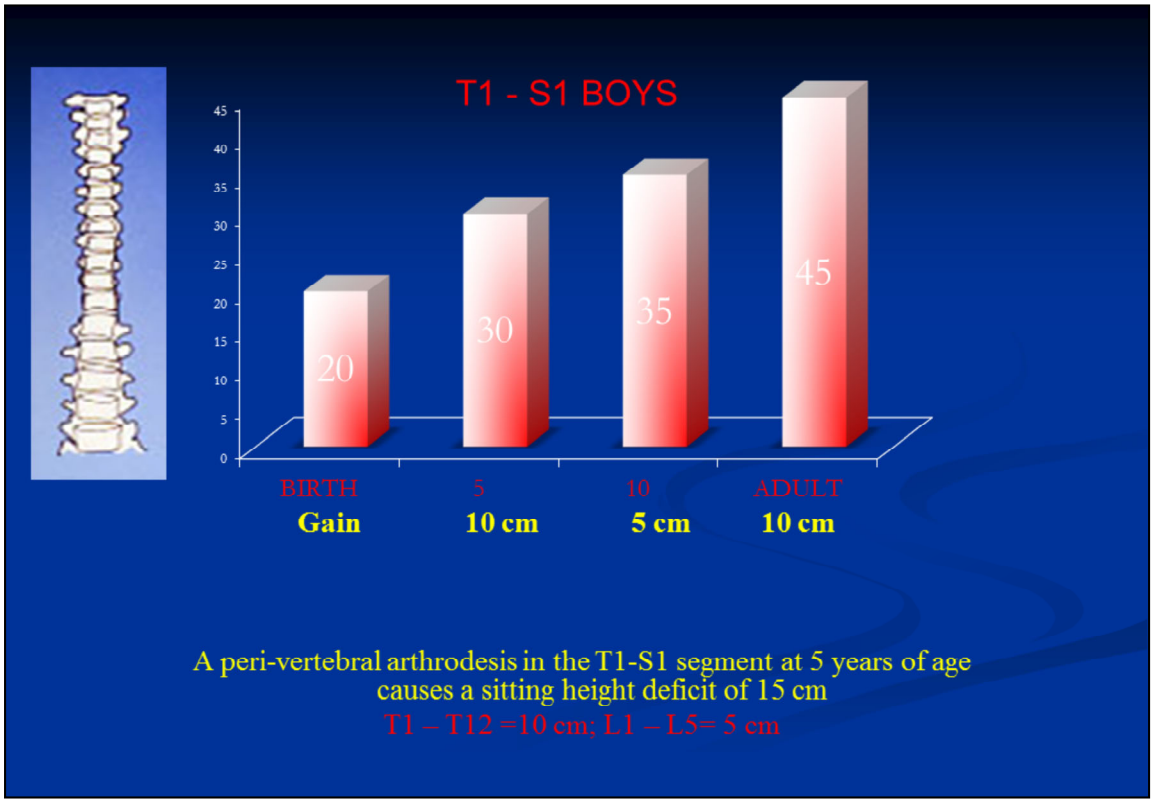
In five years there will be a dramatic change in proportions. A dramatic increase from birth to five. All parameters do not progress at the same speed, at the same pace; at 5 years of age the increase weight and thoracic volume remain offset relative to the other indications. At five years the weight is only 20 kg, it has reached only 20 % of his final volume. Age five is a turning point between fast spine growth and slow spine growth. The trunk grows as much as the lower limb. The sitting height in five years increases about 28 cm. 2/3 of the final sitting height is achieved at five years. The standing height will increase by 56 cm: 28 cm for the sitting height and 28 cm for the lower limbs.

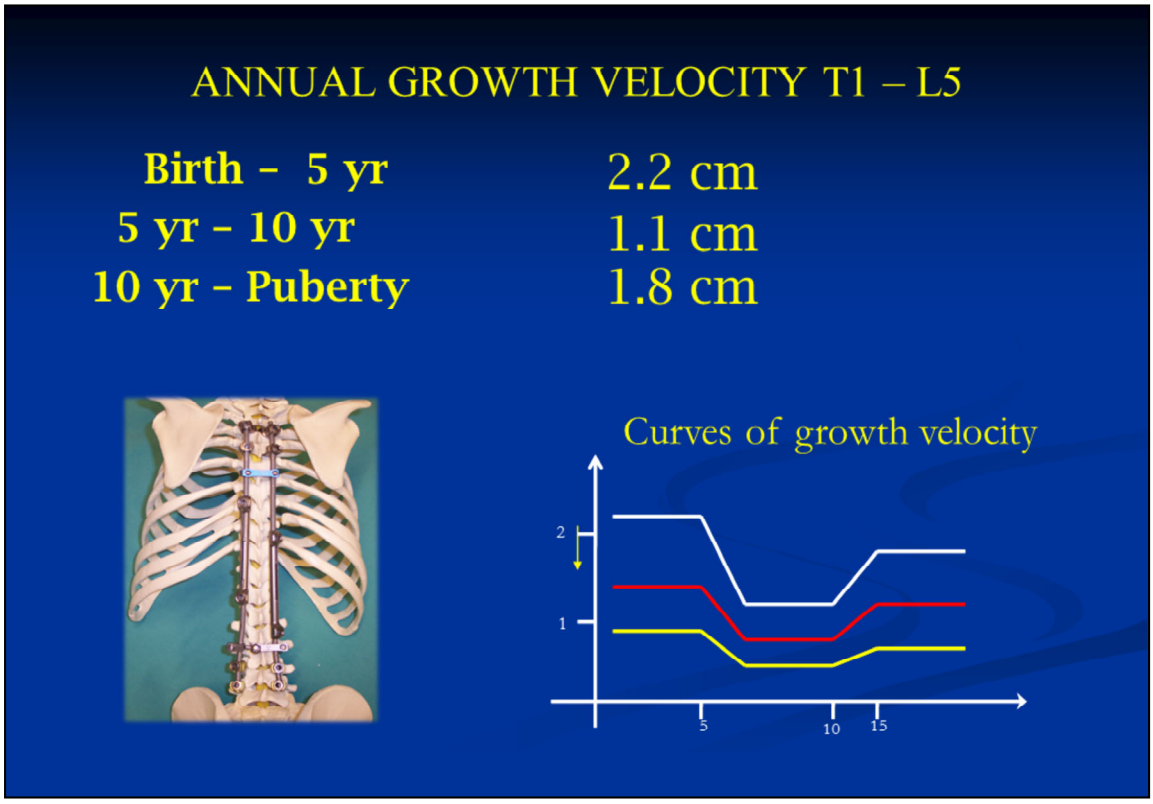

ANNUAL GROWTH VELOCITY
SITTING HEIGHT BOYS
14
12
10
8
6
4
2
0
12.5
5.3
3.3
3.2
2.8
2.3
2.3
2.3
2.3
2.3
2.3
2.3
2.3
0.3
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
27 cm
18,5 cm
13 cm


Girls sitting Height
100
90
80
70
60
50
40
30
20
10
0
38
53
70
83
100
Birth
1
5
10
15
years

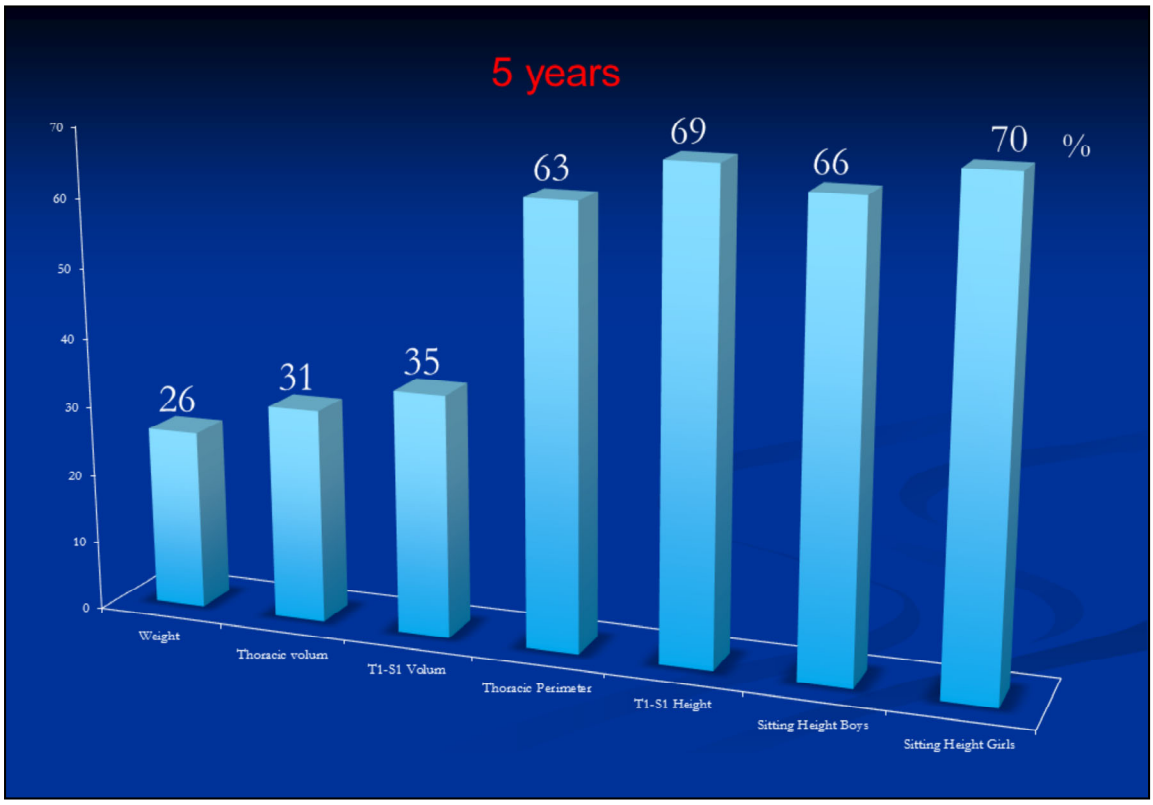

Boys sitting Height
100
90
80
70
60
50
40
30
20
10
0
34
51
66
79
95
100
New Born
1
5
10
15
17
years


GROWTH ACQUIRED
REMAINING GROWTH
5 years
+27cm
18 years
+30cm
12
5
4
3.5
3
2.5
REMAINING GROWTH AT 5 YEARS SITTING HEIGHT


T1 - S1 BOYS
45
40
35
30
25
20
15
10
5
0
20
30
35
45
BIRTH
5
10
ADULT
Gain
10 cm
5 cm
10 cm
A peri-vertebral arthrodesis in the T1-S1 segment at 5 years of age causes a sitting height deficit of 15 cm
T1 – T12 =10 cm; L1 – L5= 5 cm

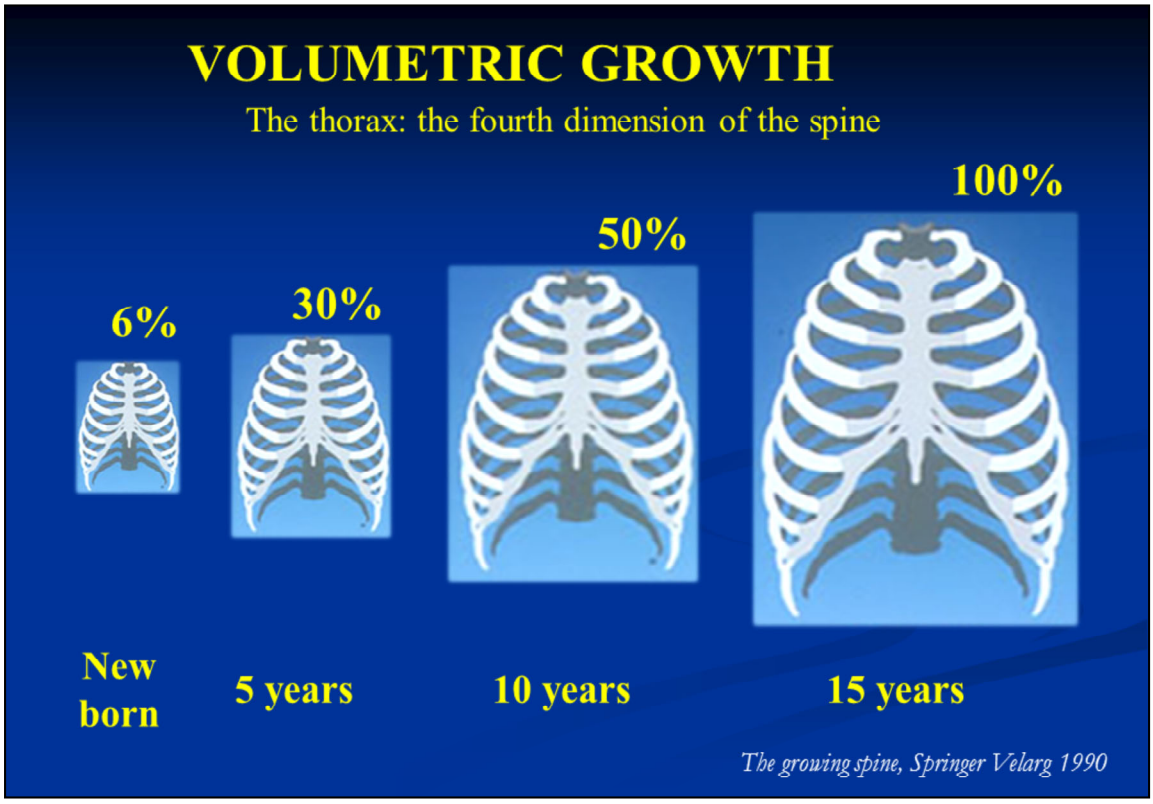


Annual growth velocity T1-L5. Distraction of the spine must take into consideration this figures.

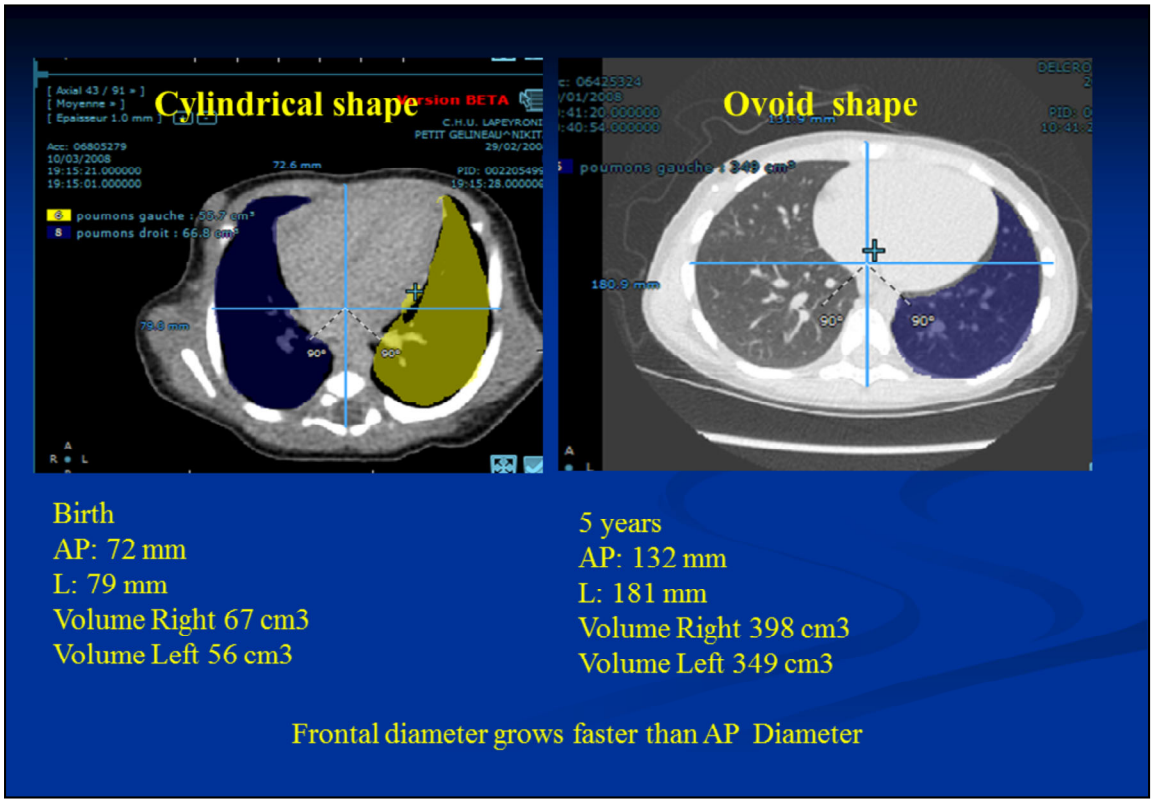

5 years
70
60
50
40
30
20
10
0
26
31
35
63
69
66
70
%
Weight
Thoracic volum
T1-S1 Volum
Thoracic Perimeter
T1-S1 Height
Sitting Height Boys
Sitting Height Girls

WEIGHT

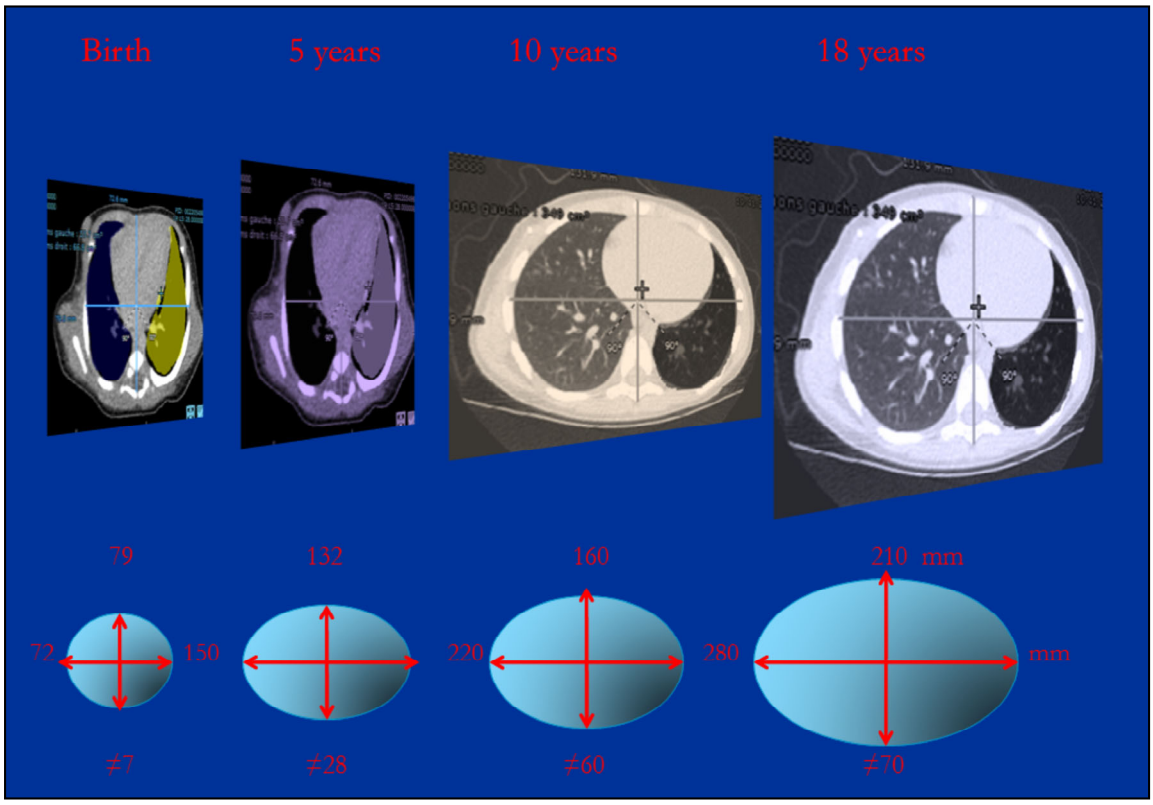
BIRTH:	**3.5 Kg**
5 y:	**20 Kg**
10 y:	**30 Kg**



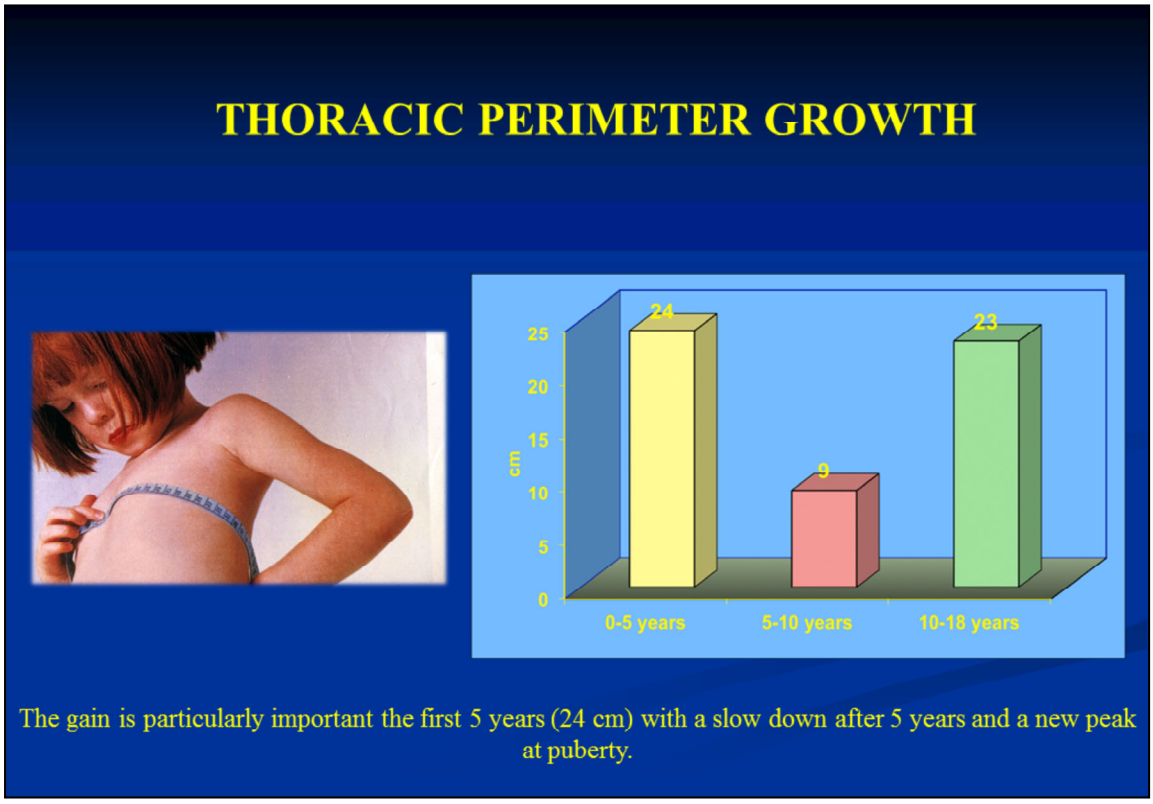
At birth, the thoracic volume is about 6,7 % of the final volume. At 5 years the remaining thoracic volume is about 70 %. At 10 years, the remaining thoracic volume is about 50%. At age 5 the remaining sitting height is about 35 % and the remaining growth of the thorax is about 70 %.



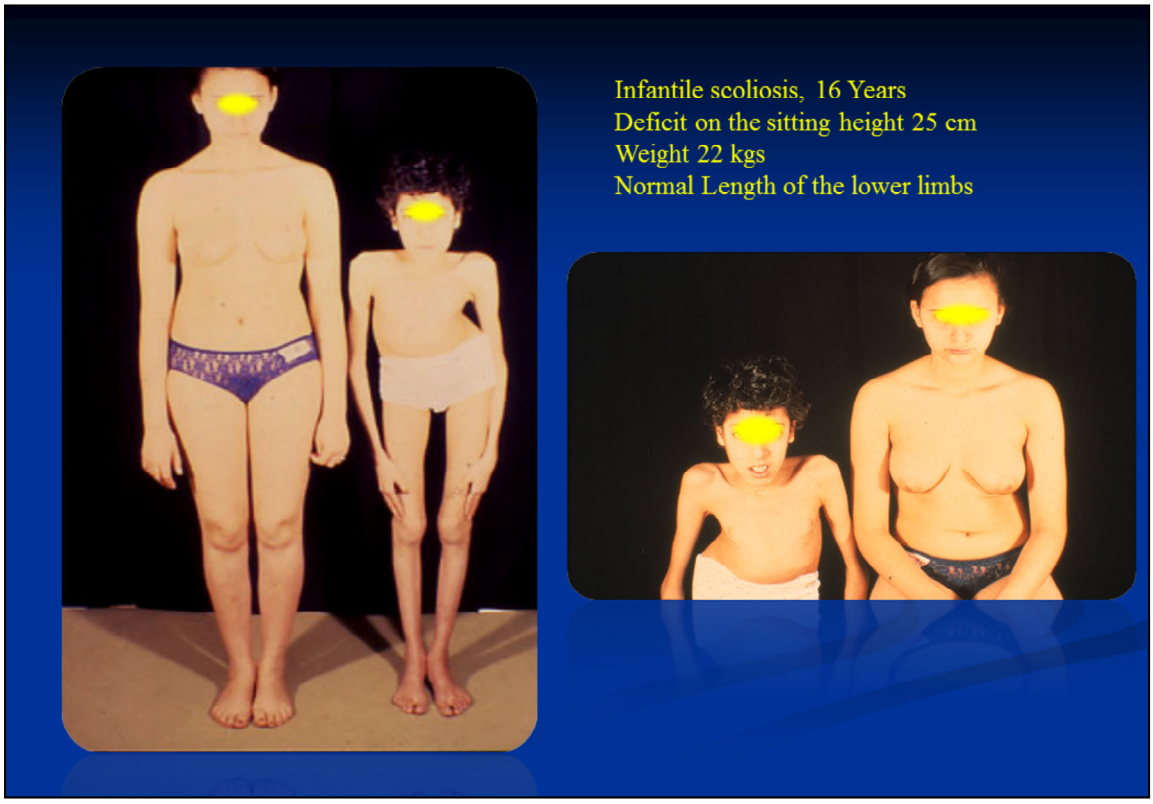
The morphology of the thorax changes with growth. At birth there is no difference between AP and frontal diameter: differential 7 mm. The thorax has a cylindrical shape. At five years, the differential between AP and frontal diameter is 49 mm. The volume of the lung is multiply by 6 (average).



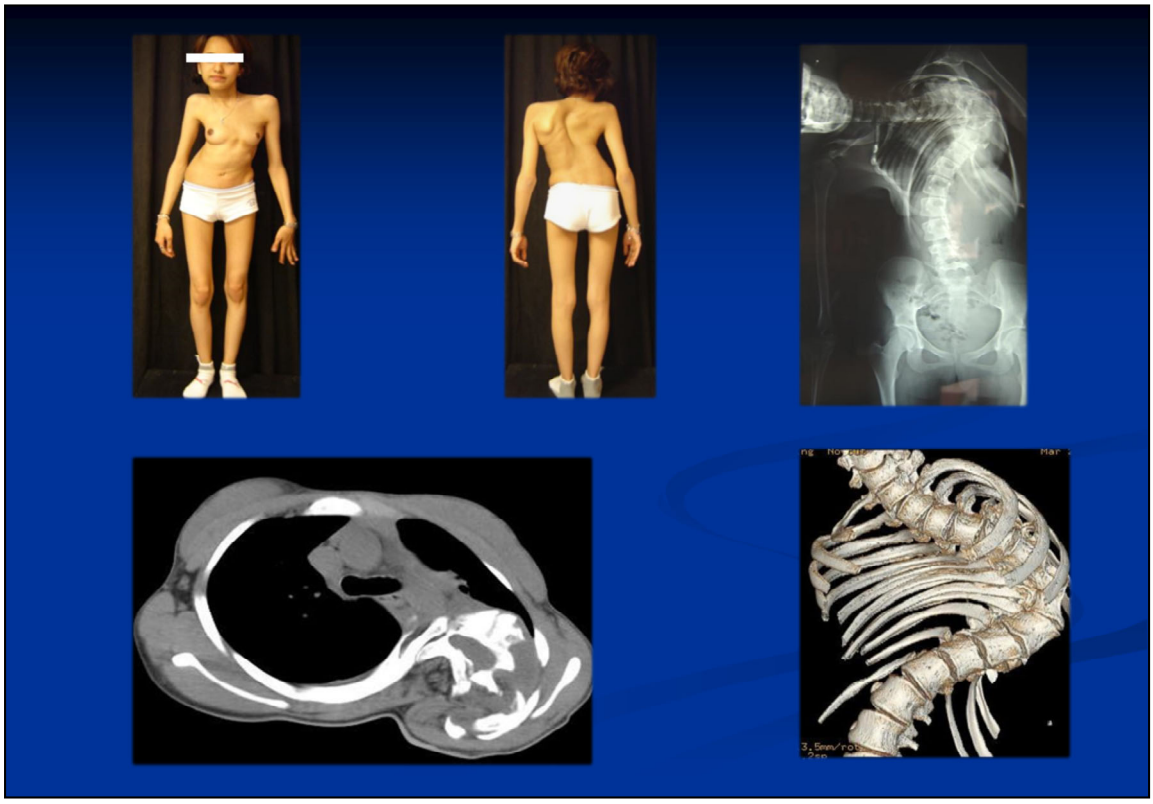
The morphology of the thorax changes with growth. At birth there is no difference between AP and frontal diameter: differential 7 mm. The thorax has a cylindrical shape. At five years, the differential between AP and frontal diameter is 49 mm. The volume of the lung is multiply by 6 (average).



The gain is particularly important the first 5 years (24 cm) with a slow down after 10 years and a new peak at puberty.



Severe infantlle scoliosis leads to severe retraction of the thorax, with massive deficit of the trunk and the weight.



Severe infantile scoliosis with penetration of the vertebrae, inside the thorax with crushing of the lung.

Thoracic deformity in severe scoliosis

- Thoracic insufficiency Syndrome

  Congenital scoliosis and fused ribs

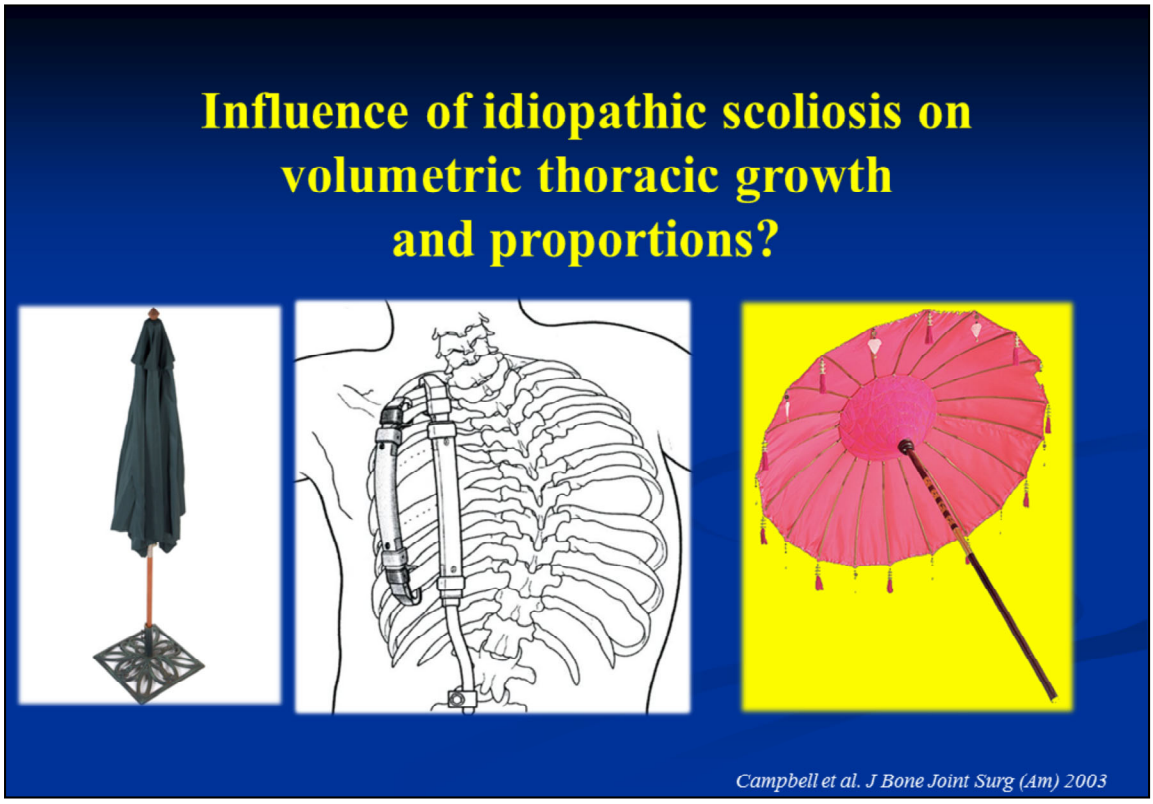
  Campbell et al.
  J Bone Joint Surg (Am) 2003

- Spinal penetration index

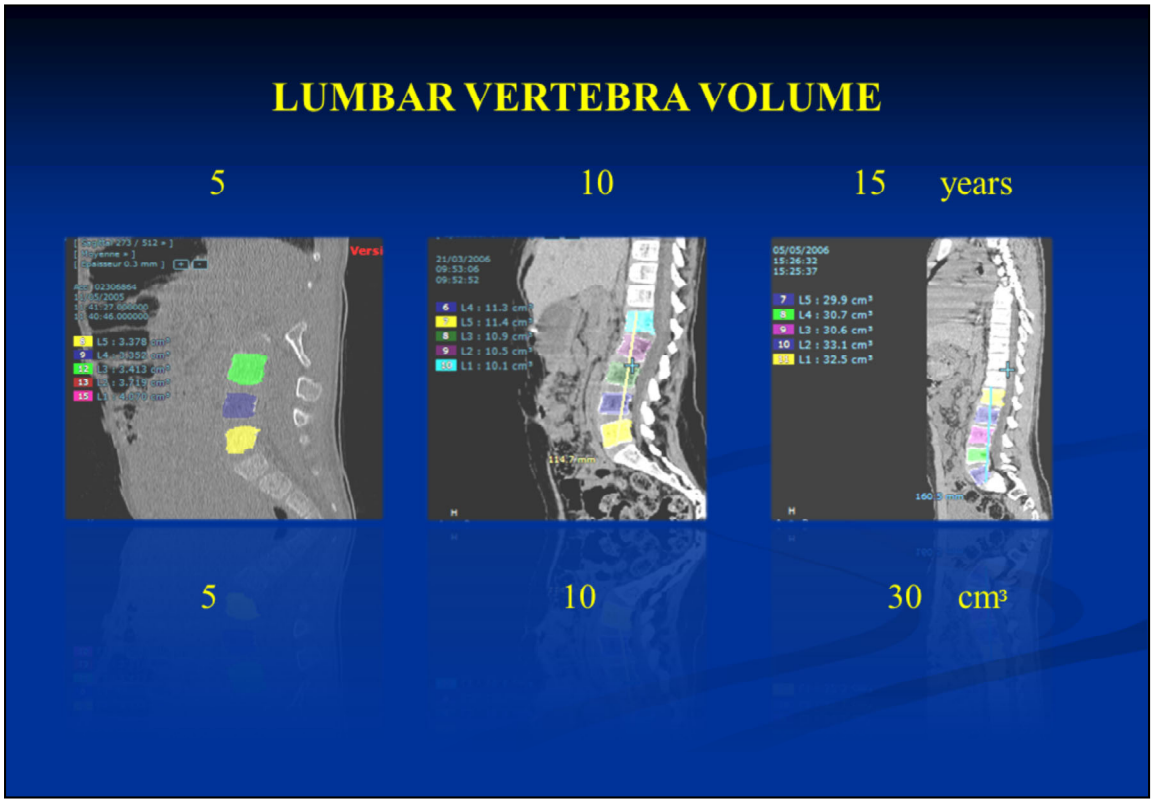
  Neuromuscular scoliosis
  Syndromes

  Dubousset et al.
  J Orthop Sci 2003

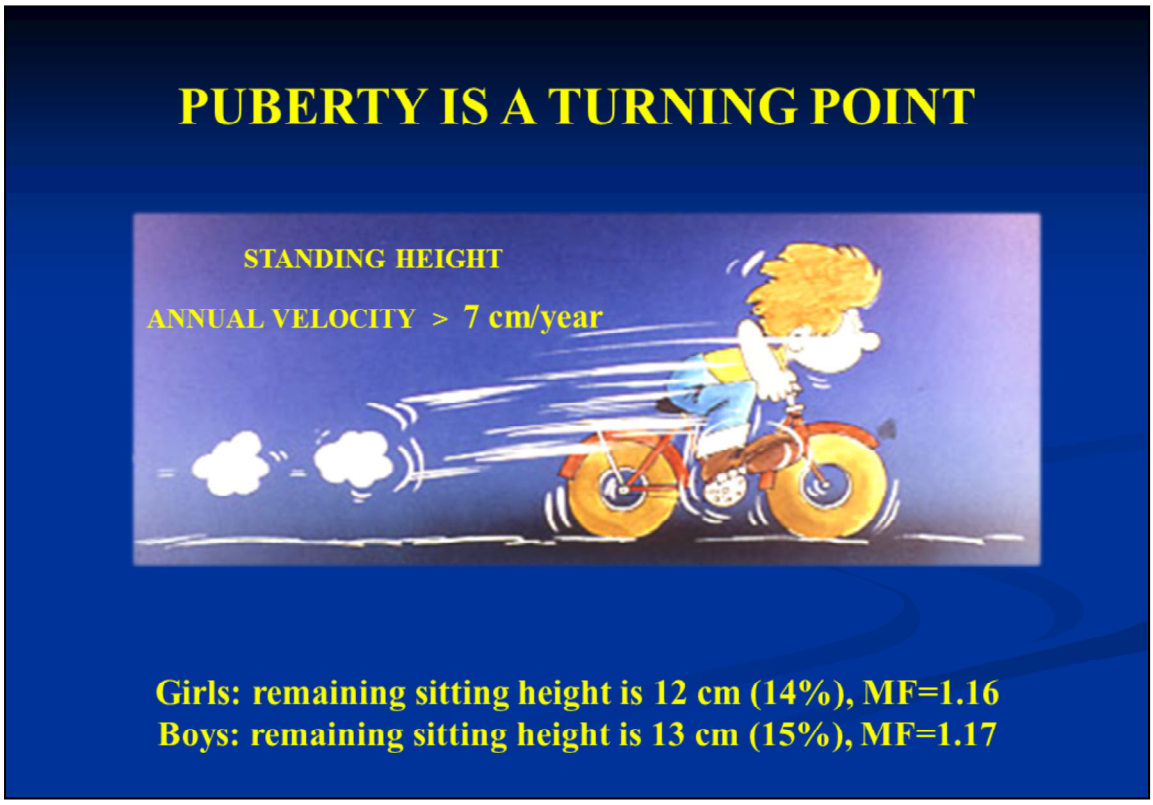
Campbell has described the thoracic insufficiency syndrome and Dubousset the spinal penetration index.



Campbell has understood the negative role of the thorax deformity. The main principle is to open the thorax: the parasol philosophy.



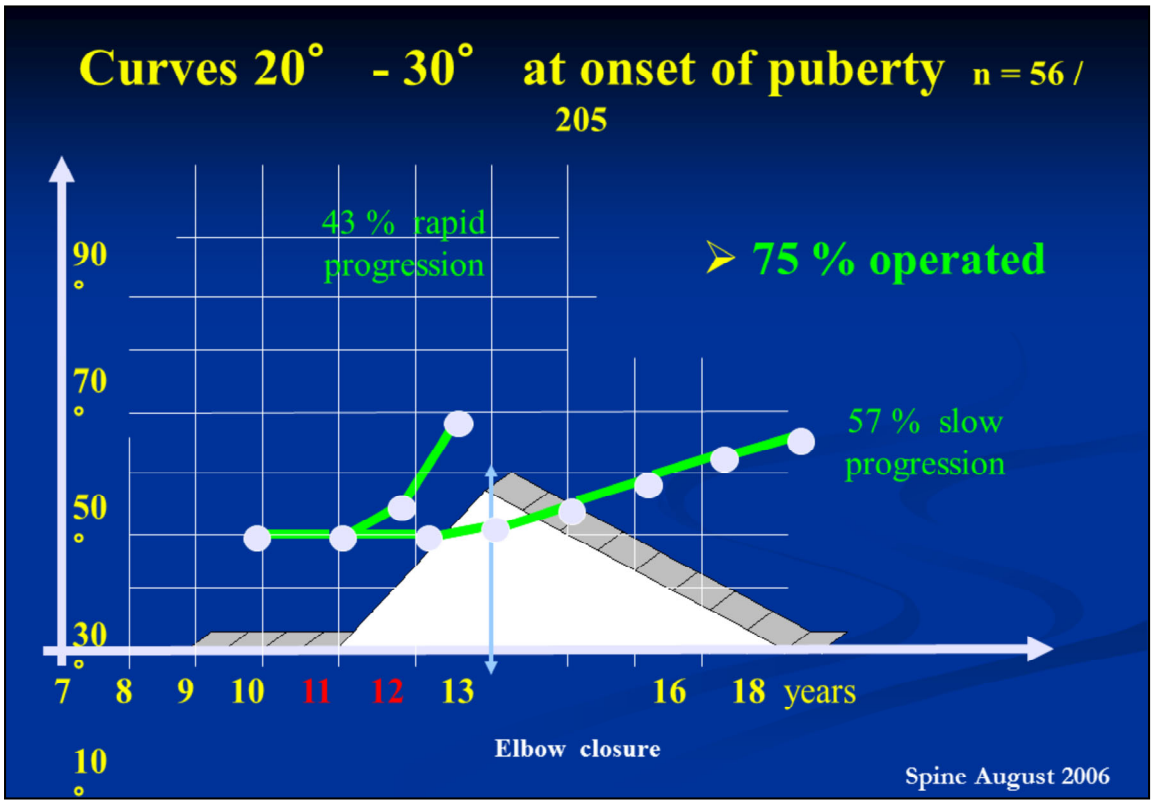
The volume of the vertebra is multiplied by 6 from 5 to skeletal maturity.



The puberty spurt: a turning point. The puberty starts at 11 bone age years for girls and 13 bone years for boys. Acceleration of the growth velocity more than 6 cm/year is the best sign to detect the beginning of puberty.

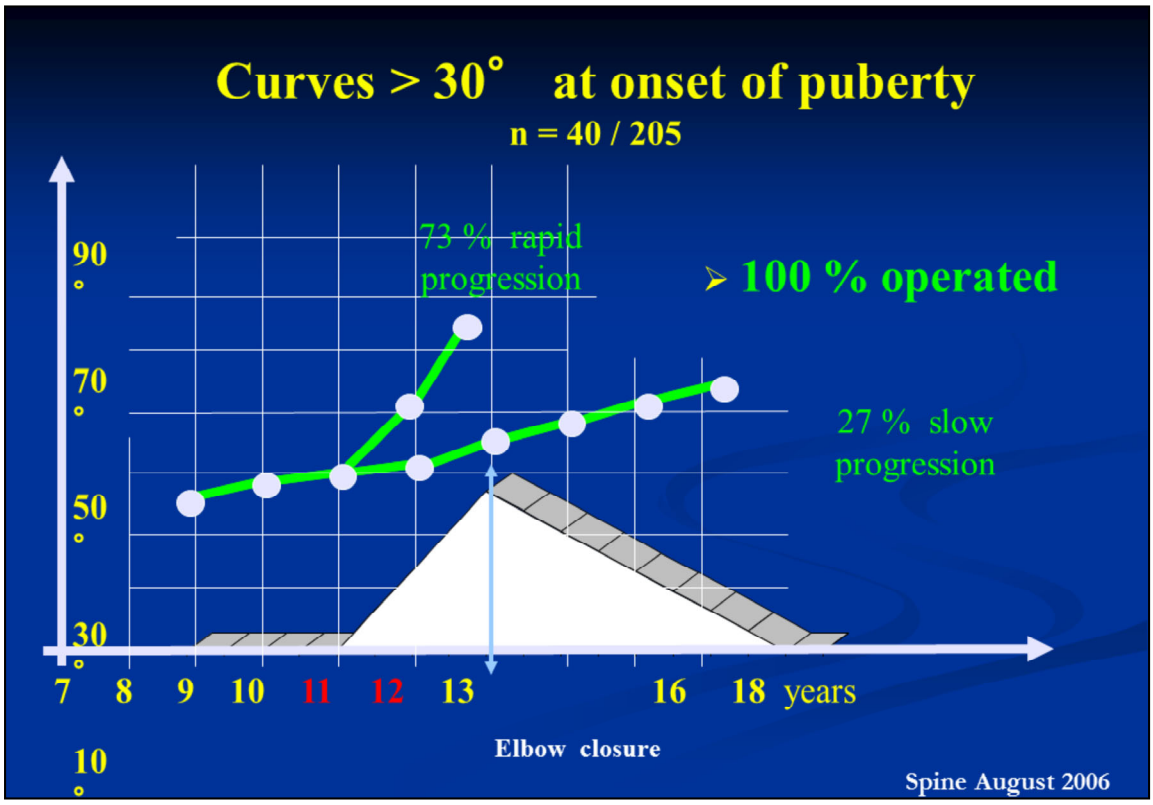
The challenge is to control the spine up to skeletal maturity. Managing the spine before ten years is only one stage in a long way. MF= multiplying factor.

Acceleration of the growth velocity on the standing height more 6 cm/year marks the begining of puberty (look also of the Tanner sign).



In scoliosis with a primary curve between 20° and 30° :

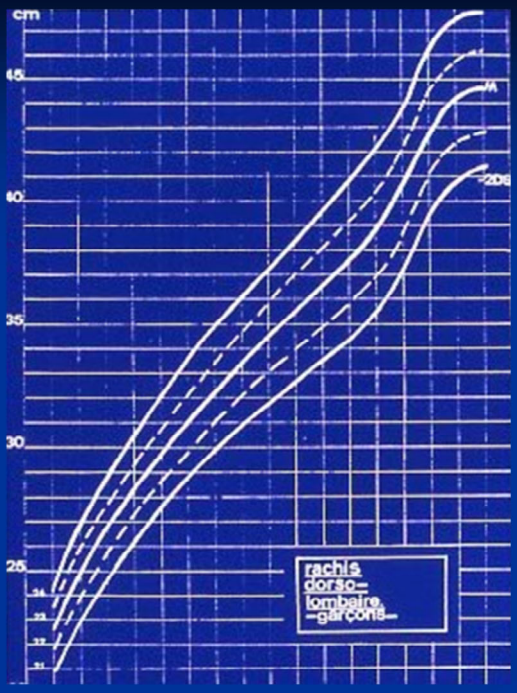
- 75% were operated
- 43% had a rapid curve progression
- 57% showed a slow progression.



In scoliosis with a primary over 30° :

- 100% were operated
- 73% had a rapid curve progression
- 27% progressed at a slower velocity.

•At the beginning of puberty, for the scoliosis of 30° the surgical risk is 100%.



GROWTH CURVE T1 – S1

BOYS

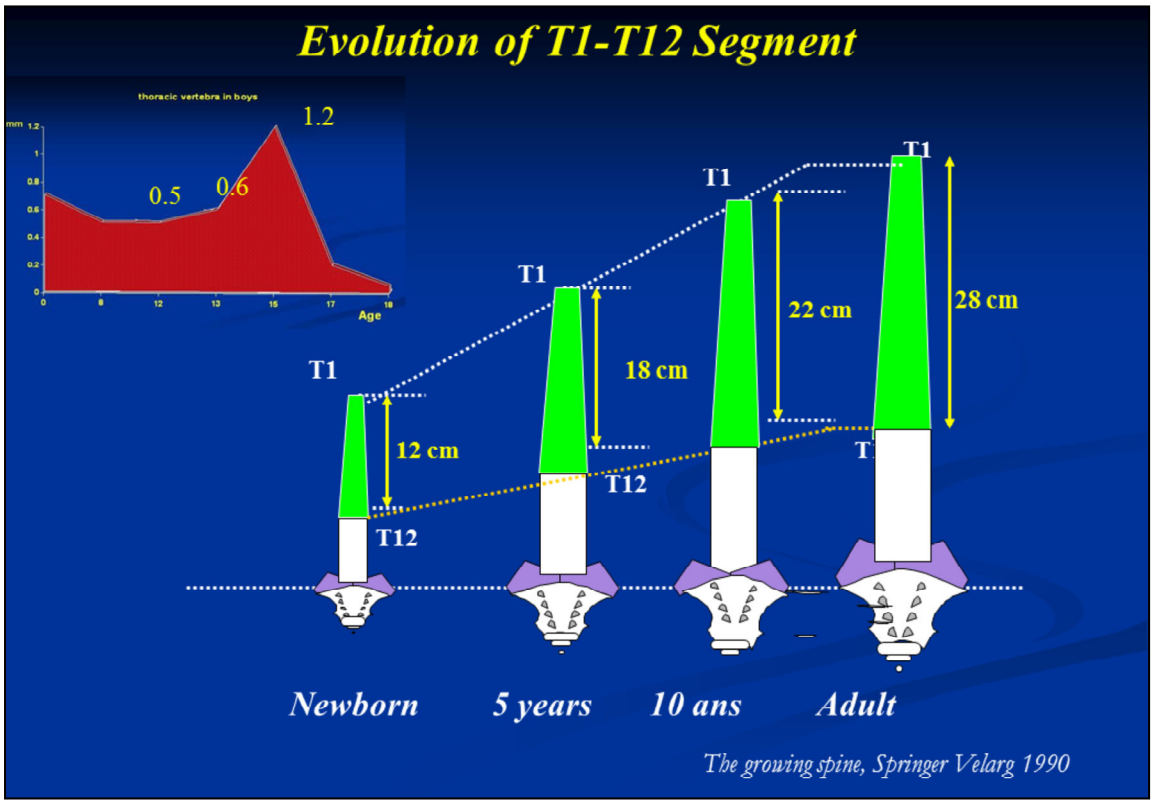
GAIN

T1 – S1 : 25 cm

T1 – T12 : 16 cm

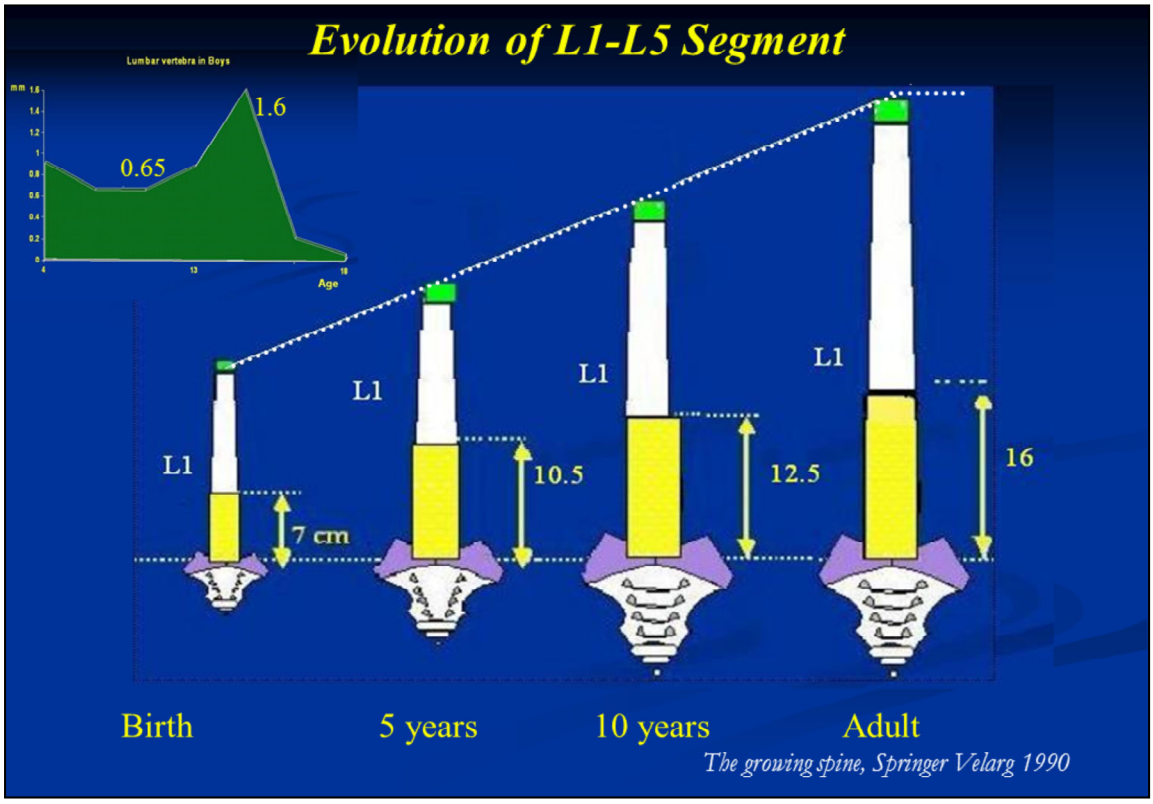
L1 – L5 : 9 cm

From birth to skeletal maturity

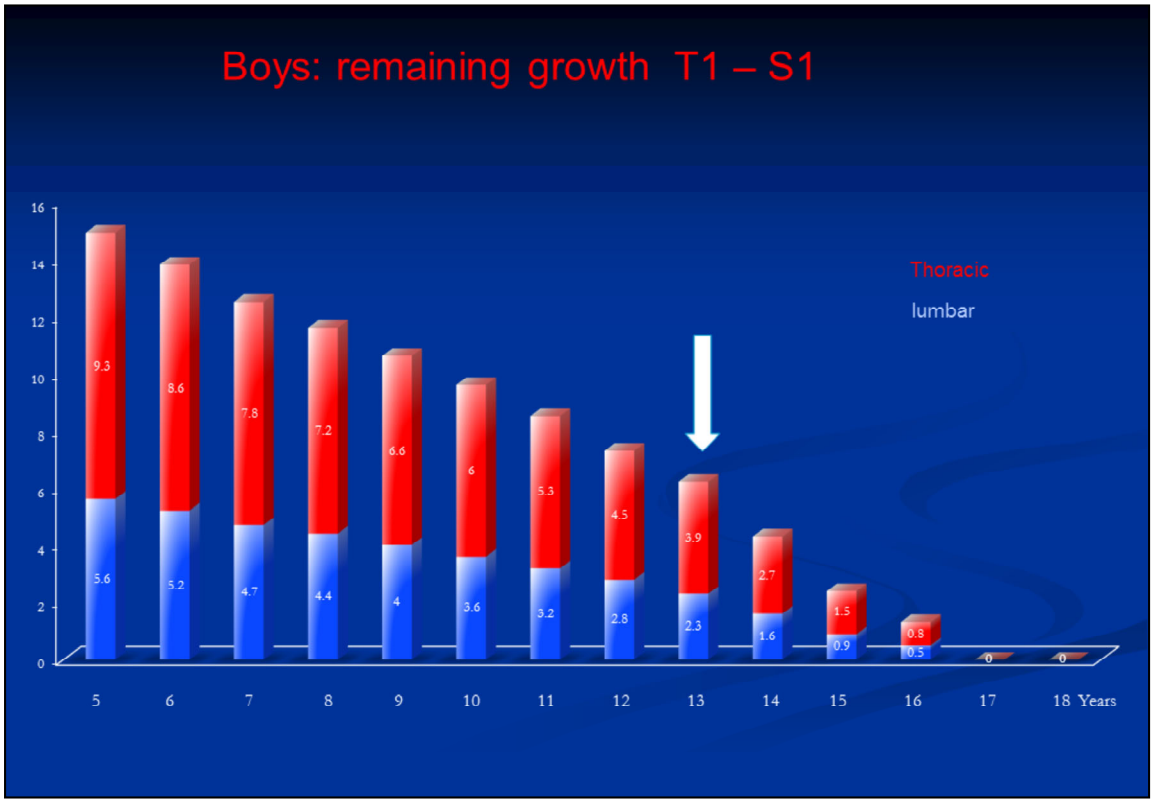


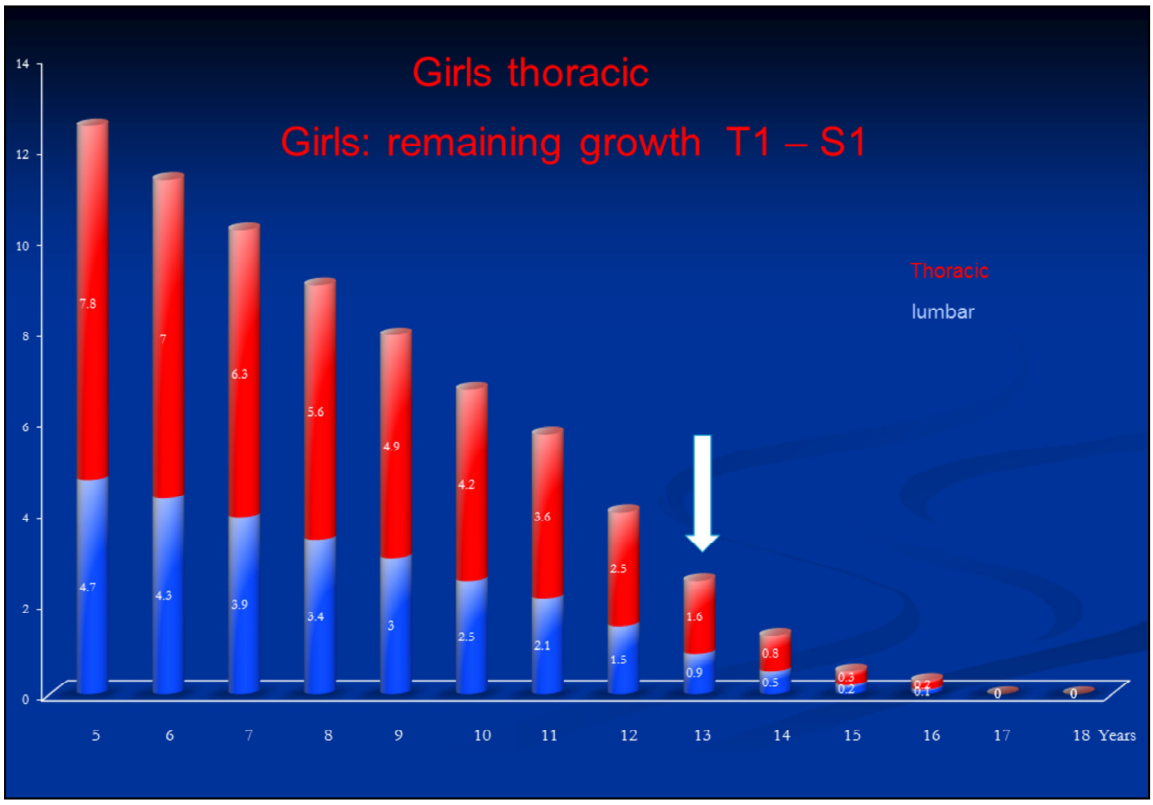
T1-T12 makes up about 35 % of the sitting height. During growth T1-T12 will increase about 16 cm. The remaining growth of T1-T12 at 5 years is about 10 cm.

Karol has shown that the minimum length of the thoracic spine is 18 cm to avoid severe deficit of the vital capacity. Which is the value at 5 years.



Length of the L1-L5 segment from birth to skeletal maturity gain 9 cm.


Boys: remaining growth T1 – S1
Thoracic
lumbar
16
14
12
10
8
6
4
2
0
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
0.5
5
6
7
8
9
10
11
12
13
14
15
16
17
18 Years


Girls thoracic
Girls: remaining growth T1 – S1
Thoracic
lumbar
14
12
10
8
6
4
2
0
7.8
7
6.3
5.6
4.9
4.2
3.6
2.5
1.6
0.8
0.3
0.2
0.1
0
0
4.7
4.3
3.9
3.4
3
2.5
2.1
1.5
0.9
0.5
5
6
7
8
9
10
11
12
13
14
15
16
17
18 Years

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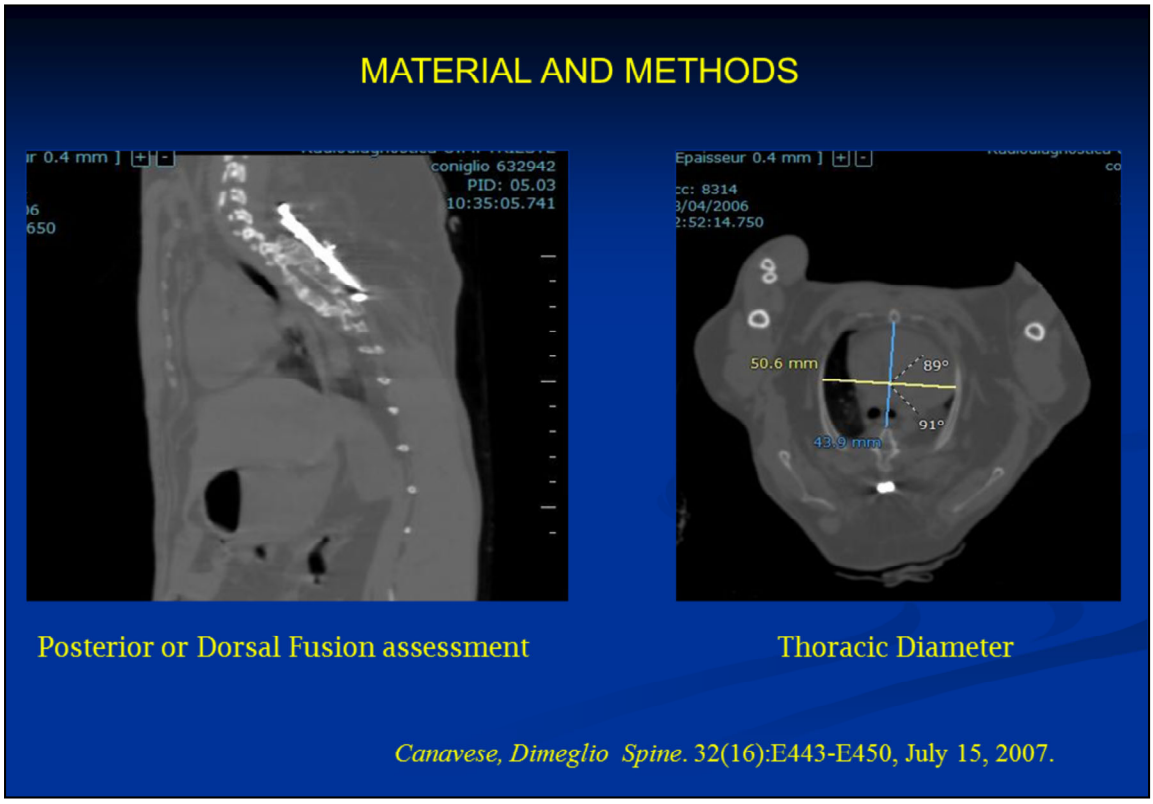


After posterior arthrodesis of immature spine rabbits, measurements of the thorax (AP and frontal diameter).

Length of the vertebrae, of the sternum of the ribs of the lung have been performed.

MATERIAL AND METHODS

Lung Volume

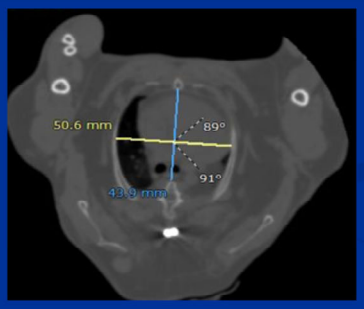
Vertebral Body Size

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

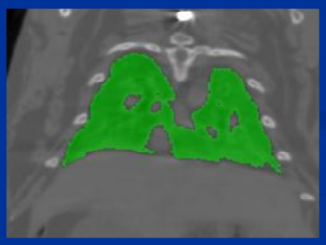
Canavese, Dimeglio Spine. 32(16):E443-E450, July 15, 2007.

After complete arthrodesis, many effects are observed first: AP thoracic diameter grows slower than the frontal diameter….

RESULTS

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

Average Lung Volume at T1 and T3
Average Growth of the Sternum between T1 and T3



The asymmetrical growth of the thorax which become almost elliptical reduces the growth of the sternum and the lung development

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

Second: the growth of the sternum is reduced.

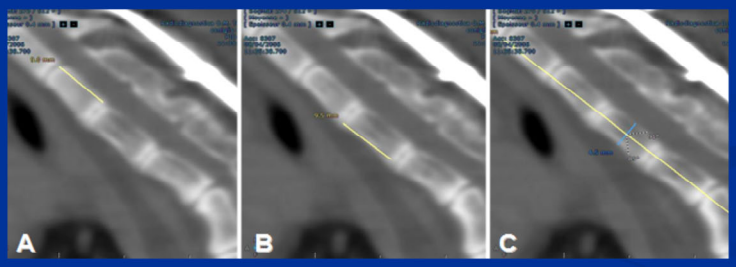
Third: the lung development is reduced

Early arthrodesis has severe consequences on the growing spine.

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:
- decrease in the length of the vertebral body.
- reduction of thoracic kyphosis due to Crankshaft Phenomenon

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

THORACIC VOLUME RABBIT

	Birth	2 months later	5 months later
ARTHRODESIS	47	55	59
CONTROL GROUP	47	58	68

Canavese, Dimeglio Spine. July 2007.

Metha spine 2006

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 JBJS A. 2008 *and Emans (Boston)*

Early arthrodesis reduces the AP diameter and shortens the T1 -T12 index. Fusion is a cause of respiratory insufficiency

Metha spine 2006, vol. 31, nº23, 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 JBJS A. 2008;90:1272-1281

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.

Message

- 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.

WHERE ARE WE GOING ?

- 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.

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

- 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).

The final dream

Avoid arthrodesis.