Growing Straight Children

John R. Faust, M.D.

Straight from the bottom to the top
Feet
Legs
Hips
Spine

Down the Garden Path:
Growing Children in the 21st Century

A Gentle Plea for Chaos:
Growing Children in the 21st Century

A Gentle Plea for Chaos

“Mirabel Osler offers a stirring appeal for gardens that have lives of their own, that reflect not so much a compulsion for dominance and regimentation as an intimate understanding of nature’s own designs.”

Learning Objectives

This lecture will review:
1. Normal growth of the feet, legs, and hips
   - Normal growth of the feet, legs, and hips
   - Differentiate conditions which improve with growth from those that require treatment
2. Treatment of scoliosis in the growing child
Disclosure

John Faust, M.D., has no relationships with commercial companies to disclose.

The origin of orthopaedics

The term “orthopaedics” comes from a French medical book: L’Orthopédie
- Title in English: orthopaedia: Or, the Art of Correcting and Preventing Deformities in Children: By such Means, as may easily be put into Practice by Parents themselves, and all such as are employed in Educating Children
- Written in 1741 by Nicholas Andry, a French physician
- Also considered the father of parasitology
- Taught different methods of preventing and correction of deformities in children

2 chief complaints

1. Pain
   - Never normal

2. Deformity
   - What is outside the spectrum of normal?

The challenge

Decisions are difficult
- Must consider growth

Diagnoses may be difficult
- Babies who hide their pathology
- Toddlers who are hard to examine
- Rare syndromes

The difficult parent or patient
- It is not about you, extract your ego
- Anyone sitting on that stool would be getting the same angry diatribe
- Pretend that you are watching a drama
- Life is hard, try to understand the underlying problem
- Your job is to resolve the issue in the best interest of the patient
The challenge

When you come to the fork in the road...

Time is wise

Your bail out

Punt to peds ortho

“Son, there’s talkin’ doctors and there’s doin’ doctors.”
- old Texas general practitioner

Peds Ortho referral

Should I order radiographs before referring?

Are you going to refer anyway?
- No: get x-rays
- Yes: don’t get x-rays

Feet

The normal foot:
- Supple (flexible ankle, subtalar and transverse tarsal joint)
- Flat on the ground (plantigrade)
- No pain
- Arch: wide spectrum of normal
- Shape doesn’t matter if the above are present
- A flatfoot is usually a normal foot
- A cavus (high-arched foot) is more likely to be concerning
  - “The feet are the window to the spine”
- Charcot-Marie-Tooth disease
Feet

**Improve with growth:**
- Metatarsus adductus
- Talipes calcaneovalgus
- Flat feet

**Require treatment:**
- Clubfoot (tarsus equinovalgus)
- Congenital vertical talus (CVT)

Feet: normal growth

**Feet Exam**
- Inspection
  - Arch
  - Standing: may be low, average, or high
  - Sitting (lift big toe) or tip toes: low arches reconstitute
  - Heels
  - Standing: neutral/varus
  - Tip-toes: varus

Flexible flatfoot

Corrective Shoes and Inserts as Treatment for Flexible Flatfoot in Infants and Children

We concluded that wearing corrective shoes or inserts for three years does not influence the course of flexible flatfoot in children.

Terminology

- Talipes: talus (ankle) + pes (foot)
- Equinus: talus/calcaneus are plantarflexed (pointed down)
**Terminology**

**Talipes:** talus (ankle) + pes (foot)

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**Varus:** distal part points **TOWARDS** midline

**Valgus:** distal part points **AWAY** from midline

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**Terminology**

**Genu:** knee

**Varus:** distal part points **TOWARDS** midline

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**Metatarsus adductus Clubfoot**

**Association:**
- DDH
- Torticollis

**Natural history:**
- Spontaneously improves (usually)

**Treatment:**
- Observation
- Stretching by family
- Casting: <6 mo. age (rare)
- Surgery (rare)

**Clubfoot**

**Association:**
- Many syndromes but usually isolated

**Natural history:**
- Lifetime disability

**Treatment:**
- Ponseti method: world-wide
  - Serial casting
  - Peroneus Achillis lengthening
- Boots and bars until age 3-5 yr
- French method: less common
  - Daily stretching and taping
Metarsus Adductus

- Forefoot: adducted
- Midfoot: straight/flat
- Hindfoot: neutral/valgus
- Ankle: neutral, flexible

Clubfoot

- Forefoot: adducted
- Midfoot: cavus
- Heel: varus
- Ankle: equinus, rigid

Metatarsus adductus

Calcaneovalgus

- Association:
  - Posteromedial bowing of the tibia
  - Lower extremity external rotation
  - DDH
- Natural history:
  - Spontaneous resolution
- Treatment:
  - Observation
  - Stretching by family

Vertical talus

- Association:
  - Many syndromes:
    - 11% of arthrogryposis
    - 10% of myelomeningocele
    - Larsen syndrome
- Natural history:
  - Lifelong disability
- Treatment:
  - Reverse Ponseti casting followed by limited surgical reduction and pinning

Calcaneovalgus

- Ankle: hyperextension, usually passively correctible
- Hindfoot: valgus
- Midfoot: straight (flat foot)
- Forefoot: abducted

Vertical talus

- Ankle: fixed equinus
- Hindfoot: valgus
- Midfoot: rockerbottom
  (convex plantar surface from the talar head pointing down)
- Forefoot: abducted/everted
Terminology

Genu: knee

Varus: distal part points **TOWARDS** midline

Valgus: distal part points **AWAY** from midline

Growing pains

- Evenings or nights
- More after busy, active days
- Awakens and they ask to have their legs rubbed
- Parents often try warm baths, etc.
- Parents never see or feel anything
- Not swollen, warm, stiff, etc.
- Back to sleep in 20-30 min and sleeps the rest of the night
- Fine in the morning
- Some days the hurt, some they don’t
- Doctor never sees anything objective
- No fever, weight loss, malaise, school trouble, etc.

Now, not 100% on all of these, but the closer to this story, the more telling.

Lower Extremity

Rotation
- Intoeing (pigeon toes)
- Outtoeing

Alignment
- Genu varum (bow legs)
- Genu valgum (knock knees)

Rule out neurovascular disorders

Don’t confuse in-toeing with genu varum

Hip development

Born with a lot of valgus

Growing pains

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Hip development

Born with a lot of valgus
Hip development

CCD 124°–130°
Coxa vara <126°
Coxa valga >139°

Terminology

Femoral anteversion

Thigh-foot angle

Wide range of normal

Terminology

Femoral anteversion

Excessive Femoral Anteversion

Position of the Femoral Head with the Foot Length

Most patients with excessive femoral anteversion "tip" the pelvis and lose the Femoral Head

Anteverted Hip

"Tying in" due to anteverted Hip

Femoral neck anteversion (°)

Wide range of normal

Age (years)
Foot progression angle

Wide range of normal

Hip development

Angle of anteversion (AT angle)
- Between the neck axis and condylar axis
  - 5°-25° (average 12°)

Angle between the axis of the greater trochanter and the neck axis: 25°-30°
- To put a blade plate center in the femoral neck don’t put the plate on the flat part of the trochanter

Intoeing

3 anatomic sources:
- Feet: metatarsus adductus
  - Will be most common in infants
  - Infants tend to outtoe due to hip muscle contractures so intoeing is usually from the foot
- Tibias: internal tibial torsion
  - “Tibial rotation, or torsion, is the most common cause of intoeing and outtoeing up to the age of 4 years.” Tachdjian’s Pediatric Orthopaedics, 5th Edition, Chapter 22 Disorders of the Leg
  - In my experience femoral anteversion is the most common
- Femur (hips): femoral anteversion (antetorsion)
  - Greatest in infancy and gradually decreases as skeletal maturity is approached

Internal tibial torsion or bowlegs?

Internal tibial torsion
- Knees look straight
- There is a subtle twist in the lower portion of the legs
- Cover-up test
  - Cover the distal half of the legs
  - Do the knees look straight?

Bowlegs
- Usually a gradual bowing through the thigh and leg centered at the knee

In-toeing: femoral anteversion

Normal Femoral Neck Anteversion (anteversion: 10°)

Excessive Femoral Anteversion
- Position of the femoral head with the foot straight.
- Most patients with excessive femoral anteversion “toe in” to better position the femoral head
Pediatric Grand Rounds - University of TX
Health Science Center at San Antonio

**Tibial torsion**
15 mo. old
In-toeing

**Femoral anteversion**
11 yo male
Slight in-toeing on exam
Straight bones on x-ray

**Intoing**
Ultimately the way the feet point is the sum of:
- Bony anatomy:
  - Feet: metatarsus adductus
  - Legs: tibial torsion
  - Hips: femoral torsion/version
- AMK: Muscle control

Rule out a neuromuscular disorder (Cerebral palsy):
- Birth history
- Early hand dominance
- Spasticity – arms, legs
- Clonus
- Abnormal gait
- Arm posturing when running

**Legs**
Rotation
- Intoing (pigeon toes)
- Outtoeing

**Alignment**
- Genu varum (bow legs)
- Genu valgum (knock knees)

Can be normal depending upon age
- Follows a normal physiologic pattern of development
- Or may represent severe local or systemic disorders
- Important to know what normal is

**Alignment during growth**
Varus up to 2 yo
Neutral by age 2
**Alignment during growth**

- **Valgus:** after 2 y

  - Tibiofemoral angle

  ![Diagram showing alignment during growth](image)

**Tibiofemoral angle during growth**

1. Varus
   - Newborns 10–15°
5. Physiologic valgus: 6 yrs
   - Mean of 6° to 15 y


**Normal LE alignment during growth**

- **Physiologic genu varums (and internal tibial torsion) - complete series**

  - 1 y 5 mo 1 y 11 mo 2 y 7 mo 3 y 4 y 4 mo

1 yr 5 mo 1 yr 11 mo 2 yr 7 mo 3 years 4 yr 4 mo

![Physiologic genu varums](image)

Physiologic bowing is part of normal growth

- 1 y 5 mo 1 y 11 mo 2 y 7 mo 3 years 4 yr 4 mo

Genu varum (bowlegs)

- Physiologic bowing is part of normal growth

1 yr 5 mo 1 yr 11 mo 2 yr 7 mo 3 years 4 yr 4 mo

- Physiologic genu varums

1 yr 5 mo 1 yr 11 mo 2 yr 7 mo 3 y 4 y 4 mo
Genu varum (bowlegs)

Physiologic genu varum is part of normal growth

Differential diagnosis:

**Physiologic**
- Physiologic genu varum (physiologic bowed legs): <2 yo
- Persistent physiologic varus
- Children >2 yo
- Adolescent genu varum: mild genu varum accentuated by rapid growth

**Pathologic**
- Tibia vara (Blount disease)
  - Most frequent pathologic case
- Metabolic bone disease
- Renal osteodystrophy
- Rickets
- Skeletal dysplasia (osteochondrodysplasia) – dwarfs
- Tumor
- Focal fibrocartilaginous defect
- Physeal injury
- Infection, fracture, irradiation

Genu varum (bowlegs)

Physiologic

- Gradual bowing (entire limb)
- Normal physes
- Corrects spontaneously

Pathologic

- Abrupt angulation
- Abnormal physes
- Doesn’t correct spontaneously

Mild infantile Blount disease is an exception

Newborns typically bowed (10-15° varus)

Bowing more prominent when begin to stand/walk

Concomitant internal tibial torsion exacerbates the deformity

Can be physiologic up to 20 mo. old (18–24 mo.)

Radiographs unnecessary if all the following are present:

- <24 mo. old
- Normal stature
- Watch for short stature
- Symmetric deformity
- Normal gait/clinical exam

Genu varum (bowlegs)

Physiologic bowing – clinical findings

- Generally < 24 mo. old
- Normal stature
- Watch for short stature
- No skeletal deformities
- Facies, spine, limb shortening
- Rib, wrist flaring
- No lateral thrust with weight bearing
- Symmetric bowing
- Mild, gradual deformity of the entire limb
- Cover-up test
  - Cover lower half of tibia
  - Valgus alignment indicates physiologic bowing
  - Neutral or varus alignment suggests infantile Blount
  - Can follow with clinical photographs

Genu varum (bowlegs)

Physiologic genu varum – definition:

- Tibiofemoral angle >10° varus
- Not sure up to what age
- Normal growth plates
- Apex lateral bowing of the proximal tibia and often the distal femur
Genu varum (bowlegs)

Physiologic genu varum – radiographs:
- Normal physes
- Delayed ossification:
  - Medial distal femoral epiphysis
  - Medial proximal tibial epiphysis
- Flared medial distal femoral metaphysis

Physiologic genu varum – treatment:
- Parent education

When to worry

Genu varum (bowlegs)

Pathologic genu varum – clinical findings
- Many benign findings:
  - No tenderness
  - No knee effusion
  - Normal knee range of motion
  - Radiographic procurvatum deformity not apparent clinically
  - Varus deformity most prominent at the proximal tibia
  - Siffert-Katz sign: posteromedial instability
  - Varus deformity accentuates with single leg stance
  - Lateral thrust during gait:
    - Brief, dynamic, lateral knee joint protrusion during stance phase
    - Lateral subluxation of the femur on the depressed medial tibia
    - Accentuated by ligamentous laxity

Pathologic genu varum – clinical findings
- Abnormal clinical findings not always present
- Radiographs confirm the diagnosis

References:
- Bradway, J Pediatr Orthop, 1987;7
- Johnston, Clin Orthop, 1990;255
- Kling, Orthop Clin North America, 1987;18
Genu varum (bowlegs)

When to order radiographs (red flags)
- Age 2 or older
- Pain
- Asymmetry
- Limb disproportion
- Lateral thrust, knee instability
- Short stature
- Other skeletal deformities
- Marked deformity (> 20° tibiofemoral angle)

Radiographs – what to order
- Standing AP of bilateral lower extremities
- Hips to ankles
- Patellae forward
- Mark the patellae on the skin
- Radiographic marker

When to refer:
- After 24 mo. old
- Or any of the following:
  - Nonresolving
  - Asymmetric
  - Lateral thrust on stance phase
  - Postero-lateral instability
  - Metaphyseal-diaphyseal angle not improving or ≥10–16°

Evaluating the radiographs
- Note the deformity
- Physiologic bowing affects the distal femur and proximal tibia equally
- Mechanical axis
- Metaphyseal-diaphyseal angle
- Langenskiöld stage

Metaphyseal-Diaphyseal Angle

A.k.a.
- Tibial metaphyseal-diaphyseal angle (TMDA)
- Drennan’s angle
- Metaphyseal-diaphyseal angle of Levin and Drennan

Draw 2 lines:
- “Line through the transverse plane of the proximal tibial metaphysis”
- “Most distal ossified peak of the medial and lateral beaks of the tibial metaphysis”
- “Line perpendicular to the long axis of the tibial diaphysis”
- “A line along the lateral part of the cortex”

Levin and Drennan, JBJS, 1982;64(8)

Infantile Blount Disease

Genu varum (bowlegs)

- Medial mechanical axis deviation
- Distal femoral varus
- Proximal tibial varus

\[ \text{mLDFA} = 92° \]
\[ \text{MPTA} = 78° \]

Genu valgum (knock-knees)

**Normal**: 2-8 years old

**Maximum physiologic valgus**: 2-4 years old

Knee alignment won’t change much after age 8

**Genu valgum (knock-knees)**

**Differential diagnosis:**
- Idiopathic – most common
- Fracture with growth plate injury of femur or tibia
- Cozen phenomenon after proximal tibia fracture
- Rickets
- Skeletal dysplasia (spondyloepiphyseal, metaphyseal)
- Tumors:
  - Osteochondroma / Multiple hereditary exostosis
  - Fibrous dysplasia
  - Endromatosis (Ollier disease)
  - Focal fibrocartilaginous dysplasia

**Indication for radiographs:**
- Short stature
- History of trauma
- History of infection
- Metabolic bone disease
- Significant asymmetry

**Indications for surgery:**
- Greater than 8 years old
- Gait disturbance or difficulty running
- Knee pain
- Patellar malalignment
- Ligamentous instability
- Excessive affect on appearance

**Genu valgum (knock-knees)**

12 yo 11 mo

**Genu valgum (knock-knees)**

Pre-op 1yr later
**Genu valgum**

Before

After

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**Guided growth**

Blount staple

Tension band hemiepiphysiodesis

Peter Stevens, MD

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**Tension band hemiepiphysiodesis**

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**Guided growth**

Epiphysiodesis with tension band physeal plating

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**Guided growth**

Epiphysiodesis with tension band physeal plating

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**Guided growth**

Overcorrection
- Family needs to follow-up reliably
Scoliosis and thoracic deformity

“The trunk under goes in severe skoliosis
+ not only a considerable shortening in the vertical direction
+ and a considerable deformation in the other
directions,
+ but is also altered as a whole
+ in that it is displaced laterally
+ while its whole structure is twisted.”

“The lungs, being
+ must accordingly adapt
+ both in position and shape,
+ to the thoracic walls
+ and so may assume
conformations.”

Adolf Lorenz, Die Orthopädie in der inneren Medizin, 1911 (1913 English translation: Orthopaedics in Medical Practice) 2004

Scoliosis terminology

Idiopathic
+ No underlying cause
+ Lateral curvature ≥10° Cobb with rotation
+ James 1954, SRS:
  - Infantile idiopathic
  - Juvenile idiopathic
  - Adolescent idiopathic
+ Dickson, 1994:
  - Early-onset
  - Late-onset

Congenital:
+ Malformed bones
+ Failure of formation or/and segmentation
  - Spine
  - ribs

Neuromuscular
+ Due to either a neurologic or muscular disorder

Idiopathic scoliosis classification

“Three peak periods of onset”

- Infantile idiopathic:
  - Spontaneous correction noted by 1030
  - Harrington & Jebsen (orthopedics) 1933,1.1
  - Term defined as progression in SRS
    - Scott IC: before age 7 years
      - SRS diagnosed before age 10 yrs.
    - Originally described as age of onset "under the age of three"
  - Males, left thoracic curves
- Juvenile idiopathic:
  - SRS diagnosed 4-10 yrs.
  - Originally described as age of onset "from five to eight"
- Adolescent idiopathic:
  - SRS diagnosed 10 yrs to skeletal maturity
  - Originally described as onset "from ten until the end of growth"
  - Females, right thoracic curves

Scoliosis mortality

Any scoliosis (>10 degrees) is abnormal and requires observation or treatment

- May spontaneously resolve
  - Only infantile scoliosis
  - But can also progress

- May remain stable or progress, but will not resolve
  - All other scoliosis:
    - Juvenile scoliosis
    - Adolescent scoliosis
    - Congenital scoliosis
    - Neuromuscular scoliosis

Scoliosis progression

Risk factors for progression with type of scoliosis:
- Infantile scoliosis
  - Older age: the curve less likely to resolve with increasing age
  - Associated syndrome
- Juvenile and adolescent idiopathic scoliosis
  - Younger age (premenarche): more growth remaining
- Congenital scoliosis
  - Type of bone abnormality
  - Larger curve
- Neuromuscular scoliosis
  - Younger age: more growth remaining
  - GMFCS level: scoliosis more common if nonambulatory
  - Larger curve

Infantile scoliosis: natural history

Resolving

Progressive

Infantile scoliosis: resolution

Reported rates of spontaneous resolution:
- 12% – James, 1951
- 17% – James, 1954
- 20% – Scott, Morgan, 1955
- 36% – James, Lloyd-Roberts, Pilcher, 1959
- 92%* – Lloyd-Roberts, Pilcher, 1965

*These children were younger than in the other studies (all <1 year old)
Progression: infantile idiopathic

4 criteria distinguish progressive from resolving curves

- RVAD (Rib-vertebra angle difference)
- Apical vertebra
- Concave RV angle minus convex RV angle
- Initial radiographs:
  - RVAD <20°: 80% of cases resolve
  - RVAD ≥20°: 80% of cases progress
- After 3 months:
  - Resolving: RVAD reduced (even if curve increased)
  - Progressive: RVAD same or greater

- Phase 2 is the hallmark of progressive scoliosis
  - 100% progression

- Curved rib "droops" downward
- RVAD at T12 always negative
- Lumbar rotation opposite the thoracic rotation
  - Lumbar rotation present even before the curve apparent radiographically


Treatment: fuse the curve

- 11 yo premenarchal female with juvenile idiopathic scoliosis

- Posterior spinal instrumentation and fusion T4-L1
  - Selective thoracic fusion (Lenke III curve)
  - Residual curves left balanced
Scoliosis in growing children


- Patients with thoracic spine fusions before 9 yo underwent PFTs
- Results by thoracic height:
  - T1-T12: <28 cm
    - Averaged predicted FVC 48.2% (range 27-86%)
    - 63% (10/16 patients) had severe restrictive lung disease (FVC <50%)
  - T1-T1: 18-22 cm
    - Averaged predicted FVC 63% (range 42-99%)
    - 25% (2/8 patients) had an FVC <50%
  - T1-T12: 22-28 cm
    - Average predicted FVC 85.2% (range 80-91%)
    - None had an FVC <50%

Thoracic spine and lung development

When is “early” fusion safe?

“Early” meaning before skeletal maturity

Current thoughts on safe early fusion:
- Age 10 yo
- 22 cm

Real answer: We don’t know.
Mike Schmitz answer: Depends.
- How many levels?
- What age?
- Functional demand

When fusion is not an option

Challenge:

- Keep the spine growing
- Control the curve

What were the dark ages like for scoliosis treatment?

Insert picture of Dr. Willey-Courand crying here

Barbaric things

like... traction and casting

Insert picture of traction and casting here
Fortunately, now we have modern treatments like... traction and casting.

When fusion is not an option
- Bracing
- Casting
- Traction
- “Growth friendly” surgery

Why not brace instead of casting?
**Bracing benefits:** you can remove it
- Bathing
- Swimming

**Bracing deficits:** you can remove it
- Because it can be removed, it will be removed
- Possibly less correction because brace if flexible enough to remove

Cast vs. brace: level V evidence
- Unfortunately there is little evidence:
**Gary Larson approach to scoliosis**

**Problem:**
- Severe curve...
- Bad kyphosis...
- Poor nutrition...
- Poor lung function...
- Young age...
- Dystrophic neurofibromatosis...
- Complex social situation...
- Need lots of consults you can’t get...
- Can’t figure out what to do...

**Treatment:**
- Traction
- Traction
- Traction
- Traction
- Traction
- Traction
- Traction
- Traction

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**Scoliosis casting**

**Yves Cotrel**
- French orthopaedic surgeon
- Developed the EDF technique for scoliosis casting:
  - E = elongation
  - D = derotation
  - F = flexion
- Differed from the localizer cast with a lateral push/bend technique used by the famous American surgeon, Joseph Risser
- Published in 1964


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**Scoliosis casting**

**Min Mehta**
- She herself has scoliosis
- 1972: published her landmark paper on the RVAD
  - Did not describe any treatment for infantile scoliosis in that paper
- Began treating infantile idiopathic scoliosis with EDF casting
- Continued her work in Great Britain largely in isolation

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**Scoliosis casting**

**Min Mehta**
- In Great Britain, she was considered far outside the mainstream and ignored or derided
- Outside Great Britain, no one knew she was doing this work
- 2005: published her casting results for 136 children with 9 year follow-up
  - Was initially rejected and then only accepted after high level persuasion from the government health system


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**Scoliosis casting**

**Sanders and D’Astous began publishing their technique:**

D’Astous JL, Sanders JD, Orthop Clin N Am, 2007;38:477-484

- Sanders JD, D’Astous JL, J Pediatr Orthop, 2009;29:S51-87

Derotational Casting for Progressive Infantile Scoliosis

James O. Sanders, MD*; Jacques D’Astous, MD*; Mario Perseigneal, P.A.C.*; Joseph G. Kliony, R.R.T. Sh arry Kihon, M.T.1 and Peter F. Swan, M.D.*

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EDF casting technique

General anesthesia and intubation
- Protect the airway during rotation of the chest wall

Traction: Elongation
Legs suspended: Flexion

EDF casting technique

Manual rotational correction: Derotation
- Mirror helpful

Scoliosis casting: results

<table>
<thead>
<tr>
<th>Curve response</th>
<th>Definition</th>
<th>No. patients (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolved</td>
<td>Final Cobb 10° or less</td>
<td>19 (27%)</td>
</tr>
<tr>
<td>Improved</td>
<td>Final Cobb improved ±10°</td>
<td>40 (1%)</td>
</tr>
<tr>
<td>Stable</td>
<td>Final Cobb within 9° of initial Cobb</td>
<td>9 (1%)</td>
</tr>
<tr>
<td>Progressed</td>
<td>Final Cobb worse ±10°</td>
<td>2 (3%)</td>
</tr>
<tr>
<td>All patients</td>
<td></td>
<td>70 (100%)</td>
</tr>
</tbody>
</table>

97% (68 pts.) had no curve progression at short-term f/u
- 3% (2 pts.) had curve progression
  - Both subsequently had surgery

Largest initial curve that resolved with casting was 49°

Overall, 11% (8 of 70 pts.) underwent surgery
- 2.7 years after the start of casting, on average

Natural history vs. Scoliosis casting

<table>
<thead>
<tr>
<th></th>
<th>Single Curve, initial RVAD ≥20°, Rib phase 1</th>
<th>Rib phase 2 (single or double curves)</th>
<th>Double curve (rib phase 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution:</td>
<td>Historic Cohort 18/85 (21%)</td>
<td>0/12 (0%)</td>
<td>1/84 (1%)</td>
</tr>
<tr>
<td></td>
<td>EDF Casting Cohort 10/19 (57%)</td>
<td>6/41 (14.6%)</td>
<td>1/4 (25%)</td>
</tr>
<tr>
<td>Progression:</td>
<td>Historic Cohort 67/85 (79%)</td>
<td>12/12 (100%)</td>
<td>83/84 (99%)</td>
</tr>
<tr>
<td></td>
<td>EDF Casting Cohort 0/19 (0%)</td>
<td>1/41 (2.4%)</td>
<td>0/4 (0%)</td>
</tr>
</tbody>
</table>

Casting is better than the natural history
- Higher resolution
- Lower progression

Scoliosis casting results

Summary:
- Patients tolerate it well (up to about age 5)
- Results of casting are better than the natural history
- Casting prevents progression of most curves
  - Many curves resolve that otherwise wouldn't without treatment
  - For the rest you are buying time before surgery
- 3 predictors of curve size after casting:
  - Age at initiation of casting (best <24 months old)
  - Cast young
  - Cobb angle at initiation of casting (best <50° and rib phase 1)
  - Cast early
  - “Syndromic” etiology
  - Early detection and referral essential
- Chest wall deformity not an issue with proper casting
- Spine remains flexible

Casts are well tolerated
Casts are well tolerated
Cast customization by families

“Growth friendly” implants

“Growth friendly” surgery
The challenges are formidable:
- Keep rods attached without a fusion
- Prevent fatigue failure of implants
- Prevent infection despite:
  - Poor skin coverage
  - Multiple surgeries

“Growth friendly” surgery
The most common techniques involve repeat surgeries every 6 months for implant lengthening
- Additional surgeries/patient after initial implantation:
  - Growing rods: average of 6.6
  - VEPTR: average of 7.1
- VEPTR and growing rods eventually create a stiff non-compliant chest wall
**“Growth friendly” implant complications**

- Small kids
- Poor nutrition
- Large implants
- Prominent implants
- Skin breakdown
- Exposed implants
- Infection

**“Growth friendly” surgery complications**

**Complication rate:**

- “Complication” defined as:
  - Any neurologic injury
  - Any unplanned surgery for implant failure or infection
  - Spine-spine growing rods: 3.3 complications/pt. (23 pts.)
  - Spine-rib growing rods: 1.86 complications/pt. (7 pts.)
  - VEPTR: 2.57 complications/pt. (19 pts.)

- Other studies report 0.38-1.19 complications/patient

**“Growth friendly” implants**

- A FRIEND IS JUST AN ENEMY
- WHO HASN’T ATTACKED YET

**“Growth friendly” implants**

- VEPTR → rib based distraction
- Growing rods → spine based distraction
“Growth friendly” implants

- VEPTR → rib based distraction
  - Hybrid growing rods
    - Biomet Polaris® 4.75
  - Hybrid growing rods
- Growing rods → spine based distraction
  - Traditional growing rods
  - Magnetically controlled growing rods (MCGR) MAGEC®

Magnetically Controlled Growing Rod (MCGR)

S10K clearance from FDA on 2/27/2014

Avoids repeated surgery for lengthening

Can it avoid:
- Infection?
- Pullout?
- Fusion?

Other “Growth friendly” implants

Guided growth
- Shilla
  - Apical fusion with sliding instrumentation
  - Short term data
  - 510(k) FDA approval in 2014


The Future

Other “Growth friendly” implants

Guided growth
- Luque trolley
  - Tried in the 1980’s, abandoned in the 90’s
  - Modern version hasn’t gained traction


Other “Growth friendly” implants

Compression-based
- Vertebral body staples
  - Only works in curve < 35°
  - Braces work up to 45°


Other “Growth friendly” implants

Compression-based
- Anterior tether
  - Under early investigation


Anterior tether

10 year old boy

42° PreOp
28° Post-op
26° 6 mo. post-op
20° 1 yr. post-op
Other “Growth friendly” implants

Compression-based
- Vertebral body staples
- Not great in AIS
- Anterior tether
- Unilateral epiphysiodesis of the neurocentral synchondrosis
  - Animal models

Foot arch development

Thigh-foot angle

Foot progression angle

Femoral anteversion development
Leg alignment during growth

Resource for family education

Global Help: global-help.org
- Free book: "What Parents Should Know About Flatfeet, InToeing, Bent Legs and Shoes for Children"

global-help.org/products/what_parents_should_know_about_flatfeet_intoeing_bent_legs_and_shoes_for_children

Thank you

Angie, Sydney (9), Holden (8), Adelaide (5), Everett (3)