Growth Plate Injuries

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Adapted from work by
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Outline

• Osseous Anatomy and Biology
• Analyzing Growth Remaining
• Fracture Classification
• Imaging Studies
• Operative Indications
• Potential Complications
• Treatment of Complications
Basic Osseous Anatomy

- **Epiphysis**
  - Secondary Ossification Center
  - The epiphysis is the bone located between the articular surface and the physis

- **Epiphyseal Plate = Growth Plate = Physis**

- **Metaphysis**
  - Bone adjacent to the physis on the opposite side of the epiphysis.

- **Diaphysis**
  - The shaft of the bone
Growth Plate Histology

- **Zones of the Physis**
  - **Germinal Zone**
    - Minimally active, scattered chondrocytes
  - **Proliferative Zone**
    - Columns of chondrocytes actively dividing
  - **Hypertrophic Zone**
    - Chondrocytes accumulate and release calcium
    - Weakest zone of physis
  - Zone of endochondral ossification
Other Important Growth Factors

<table>
<thead>
<tr>
<th>Location</th>
<th>Average Growth (mm/yr)</th>
<th>Percentage of bone Longitudinal Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximal Humerus</td>
<td>7mm</td>
<td>80%</td>
</tr>
<tr>
<td>Distal Humerus</td>
<td>2mm</td>
<td>20%</td>
</tr>
<tr>
<td>Proximal Radius</td>
<td>1.75mm</td>
<td>25%</td>
</tr>
<tr>
<td>Distal Radius</td>
<td>5.25mm</td>
<td>75%</td>
</tr>
<tr>
<td>Proximal Ulna</td>
<td>5.5mm</td>
<td>80%</td>
</tr>
<tr>
<td>Distal Ulna</td>
<td>1.5mm</td>
<td>20%</td>
</tr>
<tr>
<td>Proximal Femur</td>
<td>3.5mm</td>
<td>30%</td>
</tr>
<tr>
<td>Distal Femur</td>
<td>9mm</td>
<td>70%</td>
</tr>
<tr>
<td>Proximal Tibia</td>
<td>6mm</td>
<td>60%</td>
</tr>
<tr>
<td>Distal Tibia</td>
<td>3-5mm</td>
<td>40%</td>
</tr>
</tbody>
</table>
Epidemiology

- 18% to 30% of children’s fractures involve the physis
- Male-to-female ratio is about 2:1
- Most common site is phalanges of the fingers (approximately 40%)
  - Distal radius (18%)
  - Distal Tibia (11%)
  - Distal Fibula (7%)
Mechanism of Injury

More Common:
- Direct Trauma
- Infection
- Overuse
- Tumor
- Iatrogenic Injury
- Metabolic abnormality

Less Common:
- Vascular Injury
- Radiation
- Frostbite
- Burns
- Electrical Injury
Fracture Classification

- Salter-Harris most commonly used
- Multiple historical classification systems
  - Poland
  - Bergenfeldt
  - Aitken
  - Peterson
Salter-Harris Classification
Salter-Harris General Frequency

13%  54%  11%  6%  16%
Imaging

• Plain radiographs
• Concerning radiographs or history:
  – Comparison x-rays
  – CT Scan
  – MRI
Importance of Prior X-ray Views

- Child with knee pain
- Difficult to see fracture displacement

Courtesy of Dr Klatt
Oblique Xray

- Shows significantly displaced fracture

Courtesy of Dr Klatt
Advanced Imaging

• Fracture displacement difficult to assess and measure

Courtesy of Dr Klatt
Advanced Imaging

- CT scan shows a Salter Harris III fracture of the distal tibia
- Displacement can be measured easily

Courtesy of Dr. Klatt
Principles of Treatment

- Fracture healing with maintenance of growth potential
- Acceptable reduction and alignment
- Limit iatrogenic injury to physis
  - Repeated, forceful reduction attempts
  - Hardware across physis
- Maintenance of reduction/alignment
Salter-Harris 1

- Physis only injured
- Fracture through zone of hypertrophy
Salter-Harris 1

• Subtle, non-displaced SH1
  – Exam with tenderness, swelling at physis
  – Normal radiographs
  – Casting/immobilization

• Severe, displaced SH1
  – Exam with obvious deformity and pain
  – Displacement seen on radiographs
  – Closed reduction and casting favored
    • Reduces risk of iatrogenic physeal injury
Salter-Harris 2

- Physis + metaphysis
- Thurston-Holland metaphyseal fragment
- Zones of endochondral ossification and hypertrophy fractured
Salter-Harris 2

Treatment options include:
- Closed reduction and casting
- Closed reduction and percutaneous screw or wire fixation
  - Screw for larger metaphyseal fragment
  - Wires crossing physis for smaller metaphyseal fragment
Salter-Harris 3

- Physis + Epiphysis Injured
- Hypertrophic, proliferative, and germinal zones fractured
- Advanced imaging may be needed to evaluate articular displacement
Salter-Harris 3

- Treatment options include:
  - Closed reduction and casting
  - Closed vs open reduction, screw fixation
    - Screw along width of epiphysis avoiding physis
    - Screws in epiphysis may increase pressure on adjacent articular cartilage and are often removed quickly after fracture healing

Courtesy of Dr Klatt
Salter-Harris 4

- Epiphysis, physis, metaphysis injured
- All four zones of physis involved
- Anatomic reduction of physis required to minimize risk of physeal bar
Salter-Harris IV: Triplane Fracture

• Triplane Ankle Fx
  – Usually near end of growth as asymmetric closure of distal tibia physis occurs
  – Anterior epiphyseal fracture with large posterior medial fragment
    • Combination SH2 and SH3
Salter-Harris IV: Triplane Fracture

- CT gives 3D visualization of fracture patterns
- Essential for surgical planning
Salter-Harris IV Triplane Fracture

- Fixation best accomplished from epiphysis to epiphysis and/or metaphysis to metaphysis
- As with SH3, epiphyseal hardware should be removed to decrease pressure on adjacent articular cartilage
Salter-Harris 5

- Crush injury to entire physis
- Very difficult initial diagnosis as minimal displacement
- Initial nonoperative treatment
- Late diagnosis after complication of physeal arrest and deformity has occurred
Growth Plate Injuries

• When an entire physis arrests (SH1,2,5)
  – Longitudinal bone growth ceases completely at that physis

• When only part of physis arrests (SH 3,4)
  – Angular deformity associated with shortening
  – Often a much more difficult problem to address
What to look for?

• Loss of abnormal physeal contour
• Sharply defined connection between epiphysis and metaphysis
• Tapering of harris growth arrest line towards area of growth arrest
• Obvious angular deformity or segment shortening
Prognosis and Treatment

- Prognosis and treatment depends on these factors
  - Severity of injury
    - Displacement, comminution, open vs. closed
  - Radiographic type of fracture
  - Patient age, growth remaining
  - Which physis injured: linear vs undulating
  - Where physis injured: Central vs Peripheral
  - What percentage of physis is injured
- Advanced imaging (CT or MRI) often warranted
Treatment: Know Your Options

• Surgical Physeal Arrest Resection
  – Removal of arrest with continuation of physeal growth

• Complete Physis Arrest
  – Ablation of growth in physis on one or both sides
    • Hemi-epiphysiodesis (angular) vs epiphysiodesis (growth correction of affected and/or unaffected side)

• Treatment of angular or growth deformities
  – Guided growth
  – Osteotomies
  – Fixators
Treatment Considerations:

• Affected Leg:
  – Physis with remaining growth potential?
    • How much?
  – Longitudinal deformity
    • End LLD?
  – Angular deformity
    • Acceptable?
    • No: Hemi-epiphysiodesis vs osteotomy?

• Uaffected Leg:
  – Limb length discrepancy that may require treatment
    • Epiphysiodesis
Physeal Arrest Resection Considerations

- Etiology of arrest may affect outcome
- Central versus peripheral
- Extent of arrest
- Exposure and access to arrest
- Amount of growth remaining
Prognosis
Distal Femur Fractures

• Meta-analysis of 564 fx's
• Risk of arrest based on type
  – I – 36%
  – II – 58%
  – III – 49%
  – IV – 65%
• Based on displacement
  – Non-displaced – 31%
  – Displaced – 65%
• 22% developed length discrepancy > 1.5 cm

Prognosis
Distal Tibia Fractures

• Risk of arrest based on type
  – I – 3 to 5%
  – II – 17 to 36%
  – III – 13 to 50%
  – IV – 13 to 50%
  – Tillaux – low risk
    • Unique fracture occurring at time of physeal closure
  – Triplane – 7 to 21%
    • Unique fracture occurring at time of physeal closure
Prognosis
Distal Tibia Fractures

- Mechanism of injury likely very important
  - MVA – 86%
  - Sports – 8%
  - Falls – 6%

- Displacement
  - Increased risk of 15% with each additional mm of displacement

- Residual displacement*
  - Gap > 3 mm associated with 60% risk (vs 17%)

- Attempts at reduction (not signif.)
  - 1 attempt – 11%
  - 2 attempts – 24%
  - 3 attempts – 50%

Summary

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Thank You

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