What To Know About Growth Plate Injuries

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Disclosure

• I have nothing to disclose
Growth Plate 101

- Preservation of structure and function is essential for normal growth

- Growth plates are prone to injury as they may be weaker than surrounding bone in tension or shear

- Different growth plates respond differently to injury

- Long-term complications include growth arrest and progressive angular deformity
Growth Plate 101

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

Growth Plate = Physis

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

Diaphysis
- The shaft of the bone

OTA Compendium
Growth Plate 101

• Physeal Zones

- **Resting Zone**
  - Minimally active, scattered chondrocytes

- **Proliferative Zone**
  - Columns of chondrocytes actively dividing

- **Zone of enchondral ossification**

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*Weakest zone of physis*
Growth Plate 101

- Three sources of blood supply
## How Much Does Bone Grow?

<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 all pediatric fractures
- Male-to-female ratio is about 2:1
- Upper limbs tend to be more commonly injured than lower limbs
- Most common sites:
  - Phalanges of the fingers (~40%)
  - Distal radius (18%)
  - Distal Tibia (11%)
  - Distal Fibula (7%)
Mechanism Of Injury

• Depends on the age of the child
  – Physis is relatively thick in infancy and childhood
  – Injury secondary to shear or tensile forces
  – Fracture separation due to combination of shear and compressive forces more common in older children

• Repetitive microtrauma
  – Little League elbow and shoulder
  – Growth disturbances of the wrist in gymnasts

• Other causes
  – Iatrogenic, infection, neoplasm, vascular insult, thermal injuries
Consequences of Injury

• Disruption or cessation of longitudinal bone growth most characteristic
  – Complete growth arrest can result in significant limb length inequality with functional impairment.
  – Partial growth arrest can lead to angular deformity

• Nonunion
• Malunion
• AVN
Consequences of Injury

• Prognosis for future growth depends in part on the location of the injury within the physis
  – If fracture is limited to the hypertrophic layer healing is usually uncomplicated
  – If fracture involves the resting zone or affects multiple zones of the physis, growth disturbance is far more likely
  – Physeal bar formation may occur when the layers of the physis are not realigned
Associated Injuries

- **Neurovascular**: Popliteal artery in knee fractures

- **Ligamentous**: most common about the knee, e.g. tibial spine and ACL

- **Compartment syndrome**: Uncommon but has been reported with proximal and distal tibia fractures
Classification

- Salter-Harris most widely used
- Based on
  - Mechanism
  - relationship of the fracture line to physis
  - prognosis
Salter-Harris I

Fracture through the zone of hypertrophy with no fracture through surrounding bone

Growth is undisturbed unless blood supply is damaged
Salter-Harris II

Similar to type I but with metaphyseal fragment (Thurston-Holland)

Periosteum remains intact on metaphyseal side, growth disturbance low
Salter-Harris III

Physeal separation with fracture through the epiphysis into the joint

Advanced imaging may be needed to evaluate articular displacement
Salter-Harris III: Tillaux Fracture

- Caused by an avulsion of the anterior inferior tibiofibular ligament

- Typically occur within one year of complete distal tibia physeal closure

- Mechanism of injury due to an external rotation force
Salter-Harris IV

Fracture through the metaphysis, physis and epiphysis, all four zones of physis involved

Anatomic reduction of physis required to minimize risk of physeal bar
Salter-Harris IV: Triplane Fracture

- A complex SH IV fracture pattern with components in all three planes
- Combination of SH II and III
- Triplane fractures may be 2, 3, or 4 part fractures
  - epiphysis fractured in sagittal plane (AP radiograph)
  - physis separated in axial plane
  - metaphysis fractured in coronal plane (lateral radiograph)
Salter-Harris IV: Triplane Fracture

- CT gives 3D visualization of fracture patterns
Salter-Harris V

- Compression or crushing injury to the physis
- Rare and difficult if not impossible to diagnose acutely due to the lack of radiographic signs
- These fractures are generally diagnosed only after growth disturbance is recognized
Epiphyseal Fractures Not Involving The Growth Plate
Failure to Image Joint Above/Below

⚠️ Missing the “second injury”
No Fracture Line in an Undisplaced Growth Plate Fracture

- Stress views may help but cruel
- Diagnosis clinical exam
8 y/o male, soccer player
Failure to Appreciate Injury Severity
Failure to Recognize Associated Injuries
osteoCHONDRAL Fractures

sliver of bone often attached to a significant piece of cartilage
Principles of Treatment

• Fracture healing with maintenance of growth potential

• Reduce physeal/epiphyseal injuries within 24 hours

• Acceptable reduction and alignment
  – Alignment articular surface/physis equally important
Principles of Treatment

- Limit iatrogenic injury to physis
  - Repeated, forceful reduction attempts
  - Avoid repeat manipulation >5-7 days
  - Hardware across physis

- Maintenance of reduction/alignment
Principles of Treatment

- Fixation should be inserted parallel to the physis in the epiphysis and metaphysis.
- Smooth rather than threaded pins should be used if the physis is to be crossed.
- Check at about 1 week postreduction to ensure no loss of reduction has occurred.
Salter-Harris I

- Closed reduction and immobilization without internal fixation
- Healing is rapid and is usually within 3 to 4 weeks
- Complications are rare
Salter-Harris II

Closed reduction and immobilization usually stable due to presence of metaphyseal fragment and its associated intact periosteum.

If reduction is unstable, pins or screws may be used to fix the metaphyseal fragment to the metaphysis, avoiding the physis.
Salter-Harris III

- Anatomic reduction essential
- Often requires ORIF
- Pinning of epiphyseal fragment to epiphysis or across fracture parallel to physis
Salter-Harris IV Triplane Fracture

Fixation best accomplished from epiphysis to epiphysis and/or metaphysis to metaphysis

As with SH III epiphyseal HW should be removed to decrease cartilage pressure

Follow up needed for at least a year due to risk of growth arrest
Complications

- Malunion
- Growth Disturbance
- Residual Displacement
- Angulation
DISTAL FEMORAL PHYSEAL SEPARATION
Distal Femoral Physeal Separation

**Mechanism:**

- Medial/lateral collateral ligaments transfer forces to physis
- Common sports injury (American football)
- Most are SH I or II injuries
  - but higher energy b/c of size and geometry of physis
Distal Femoral Physeal Separation

- Plain radiographs usually sufficient
- Knee effusion/instability w/o obvious fx stress views
- High incidence of osteochondral fx
Distal Femoral Physeal Separation

Potential Problems

Physeal arrest

- higher incidence even with SH I and II injuries (up to 40 %)
  Riseborough JBJS 65A, 1983

- more likely if non anatomic reduction
  Graham, CORR 255, 1990; Roberts Ortho Clin N Am 21, 1983
Distal Femoral Physeal Separation

Potential Problems

- Vascular injury
  - Rare
  - more likely with extension mechanism
Distal Femoral Physeal Separation

Treatment Goals

→ Stable anatomic reduction
→ Resumption normal physeal growth
**Distal Femoral Physeal Separation Treatment**

- **Open reduction/internal fixation**
  - All SH III and IV injuries → anatomic reduction physis and joint surface
  - Unreducible SH I and II injuries
  - Minimal internal fixation → cannulated screws → avoid crossing physis
Distal Femoral Physeal Separation

- Follow for minimum of 1 year to rule out growth disturbance

Physeal arrest, angular deformity

LLD
PROXIMAL TIBIAL PHYSEAL FRACTURES
Proximal Tibial Physeal Fractures

Mechanism:

• Hyperextension is most common similar to knee dislocation

• Most are SH I or II injuries

• SH III injuries, if unrecognized, can cause premature physeal closure

• SH I or II injuries with posterior displacement can compromise the popliteal vessels
Proximal Tibial Physeal Fractures

Treatment

- Needs anatomic reduction and stability first

- Avoid vascular catastrophe
  - Serial evaluation if pulses present
  - Arteriogram if pulses diminished or absent
  - Monitor for compartment syndrome
Proximal Tibial Physeal Fractures
Complications

• Vascular compromise
  – SH I may spontaneously reduce

• Physeal Arrest

• Don’t be fooled by minimally displaced fractures
Prognosis Distal Femur Fractures

- Meta-analysis of 564 fx
- 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
  - Triplane – 7 to 21%

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%

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Summary

• Preservation of structure and function is essential for normal growth

• Different growth plates respond differently to injury

• Salter-Harris classification most commonly used

• Long-term complications include growth arrest and progressive angular deformity
THANK YOU