# Growth Plate Injuries

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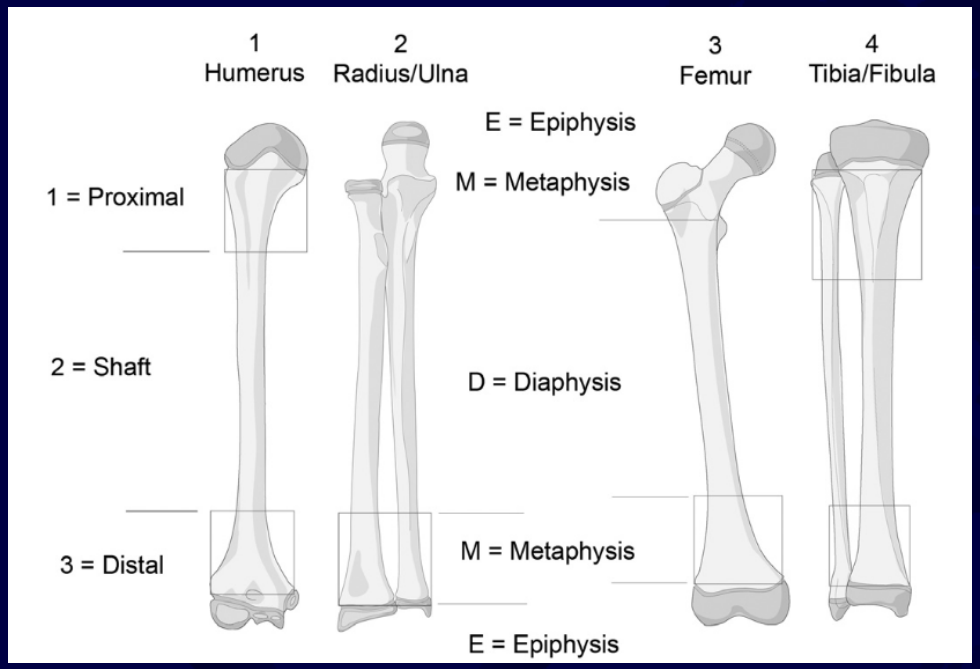
# Outline

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

# Basic Osseous Anatomy




OTA Compendium

- 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

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

# 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 (~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





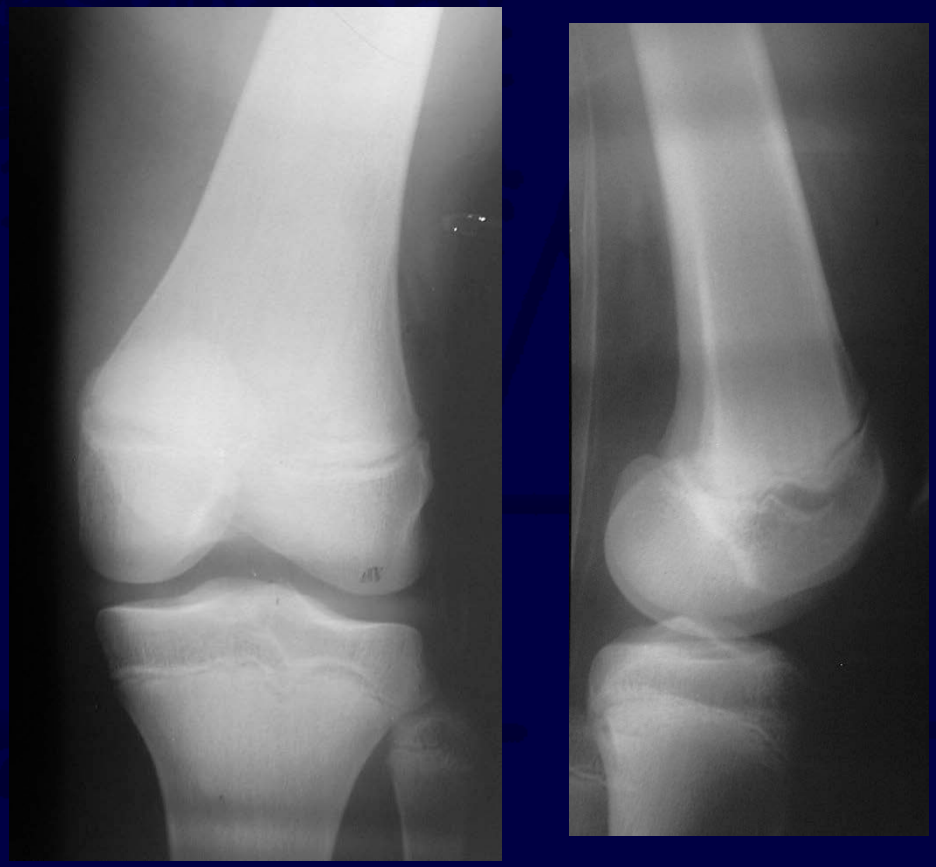
13% 54% 11% 6% 16%

# Imaging

- Plain radiographs
- Concerning radiographs or history:
  - Comparison xrays
  - CT Scan
  - MRI

# Importance of Prior Xray Views

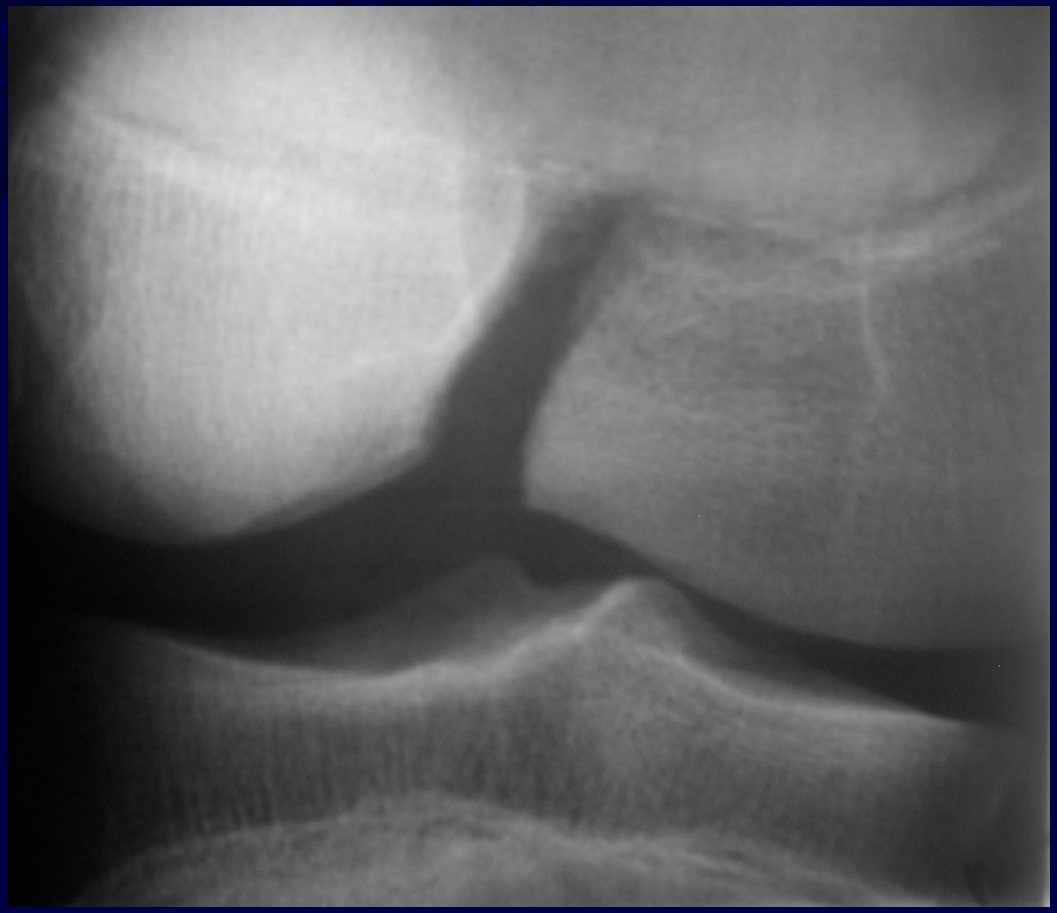
- Child with knee pain
- Difficult to see fracture displacement



Courtesy of Dr Klatt

# Oblique Xray

- Shows significantly displaced fracture



Courtesy of Dr Klatt

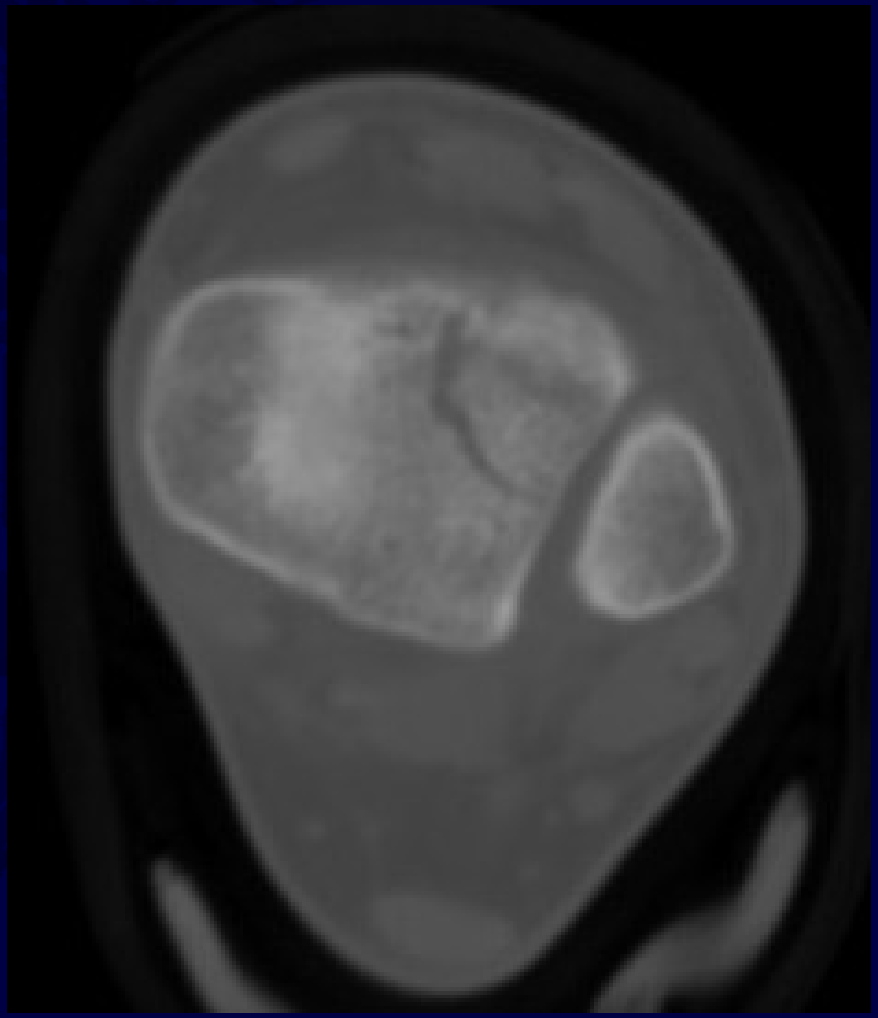
# Advanced Imaging

- 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

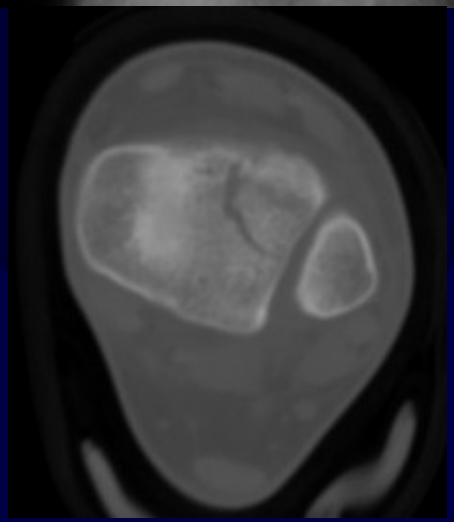
Treatment options include:

- 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

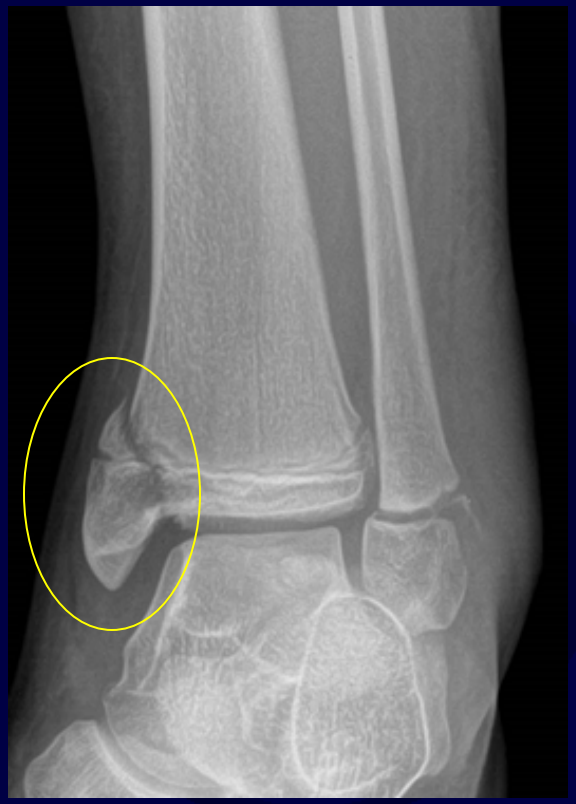
# Salter-Harris 3



- 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

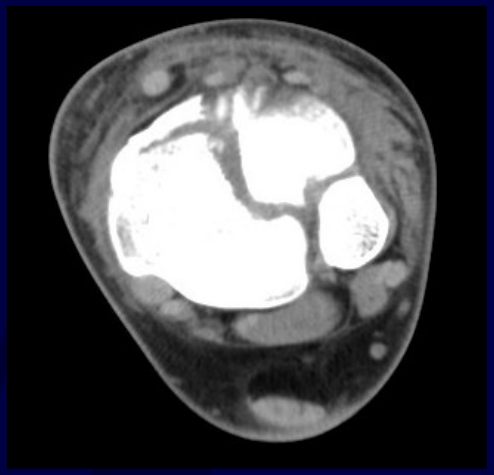
# Salter-Harris IV: Triplane Fracture

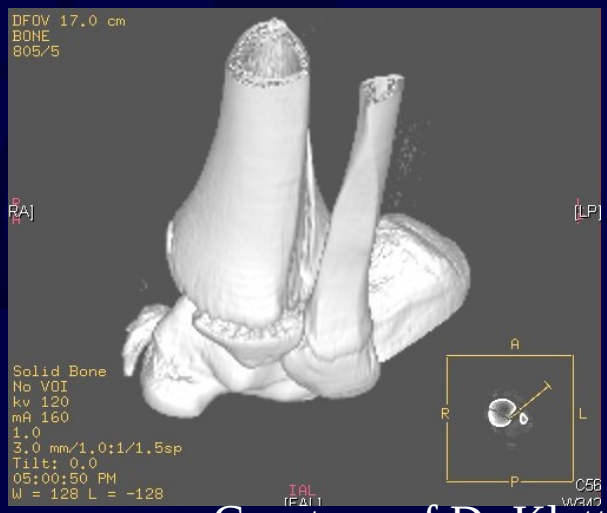
- Triplane Ankle Fx
  - Usually near end of growth as asymmetric closure of distal tibia physis occurs
  - Anterior epiphyseal fracture with large posterior medial fragment
    - Combination SH2 and SH3

Courtesy of Dr Klatt

# Salter-Harris IV: Triplane Fracture

- CT gives 3D visualization of fracture patterns
- Essential for surgical planning




Courtesy of Dr Klatt

# 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


Courtesy of Dr Klatt

# 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 occured

# 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 betweeen 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-ephiphysiodesis (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 discrepany 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 fxs
- 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

Arkader et al. Predicting the outcome of physeal fractures of the distal femur. *J Pediatr Orthop*. 2007;27:703.
Basener et al. Growth disturbance after distal femoral growth plate fractures in children: a meta-analysis. *J Orthop Trauma*. 2009;23:663.

# 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 occuring at time of physeal closure

Leary et al. Physeal fractures of the distal tibia: predictive factors of premature physeal closure and growth arrest. *J Pediatr Orthop*. 2009;29:356.

# 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%

Leary et al. Physeal fractures of the distal tibia: predictive factors of premature physeal closure and growth arrest. *J Pediatr Orthop*. 2009;29:356.
*Barmada et al. Premature physeal closure following distal tibia physeal fractures: a new radiographic predictor. *J Pediatr Orthop*. 2003;23:733.

# Summary

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- Imaging Studies
- Operative Indications
- Potential Complications and Treatment

# Thank You

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