Growth changes of the musculoskeletal system
Children fracture healing and remodeling

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Agenda

• Basic Principles in Fracture Healing and Remodeling

• Non Accidental Injury

• Principles of Treatment Options
### Epidemiology of children fracture

<table>
<thead>
<tr>
<th>Fracture Type</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Distal radius fracture</td>
<td>20.2%</td>
</tr>
<tr>
<td>2 Supracondylar humeral</td>
<td>17.9%</td>
</tr>
<tr>
<td>3 Forearm shaft</td>
<td>14.9%</td>
</tr>
<tr>
<td>4 Tibial Shaft</td>
<td>11.9%</td>
</tr>
<tr>
<td>5 Fingers &amp; hand</td>
<td>4.9%</td>
</tr>
<tr>
<td>6 Lateral condyle</td>
<td>4.8%</td>
</tr>
<tr>
<td>7 Femoral shaft</td>
<td>4.6%</td>
</tr>
<tr>
<td>8 Ankle</td>
<td>3.1%</td>
</tr>
<tr>
<td>9 Proximal radius (head &amp; neck)</td>
<td>2.9%</td>
</tr>
<tr>
<td>10 Humeral shaft</td>
<td>2.8%</td>
</tr>
<tr>
<td>11 Medial Condyle humeral</td>
<td>2.5%</td>
</tr>
<tr>
<td>12 Olecranon</td>
<td>1.7%</td>
</tr>
<tr>
<td>13 Distal radius epiphyseal</td>
<td>1.7%</td>
</tr>
<tr>
<td>14 Elbow dislocation</td>
<td>0.8%</td>
</tr>
<tr>
<td>15 Rarities</td>
<td>5.4%</td>
</tr>
</tbody>
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Paediatric Fracture Patterns

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<th>% of Total</th>
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<tr>
<td>Fingers &amp; Hand</td>
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</tr>
<tr>
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<tr>
<td>Elbow dislocation</td>
<td></td>
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</table>

65% 

Fracture types
Children ≠ Small adult
Children ≠
Small adult

• Bone quality
• Periosteum
• Ligament
• Growth plate
Bone

Higher collagen to bone ratio in paediatric bone

- Lower modulus of elasticity (less brittle) and higher ultimate strain to failure ratio than adult.
Plastic Deformation

- Fixed bending remains when bone deformed past elastic limit
- Most commonly in forearm, fibula
- Periosteum intact and thus usually no periosteal callus
- Permanent deformity can result
(A) direct impact perpendicular to the axis of the long bone:

-periosteal stripping on convex side of the fracture:

**greenstick fracture**
Plastic Deformation

(B) longitudinal compression – impact parallel to the axis of the long bone results in incomplete fractures

(1) bowing (plastic deformity)
Plastic Deformation

- Remodeling not as reliable
- Significant curvature should be corrected
- General anesthesia
- Considerable force
- Slowly applied over a padded fulcrum
Comminuted fracture uncommon

– Higher cellular and porous
  • Reduce tensile strength
  • Reduce the tendency of fractures to propagate
Bone

– Bone fails in both tension and compression

• Mechanism of buckle fracture in children
Bone transitions

- Between the metaphysis and diaphysis cause a mechanical discontinuity leading to certain fracture types
Buckle or Torus Fracture

- Compression failure
- Stable
- Usually at metaphyseal / diaphyseal junction
Bone-Blood Supply

– The blood supply is different
  • a rich metaphyseal circulation with fine capillary loops ending at the physis
  
  • In neonate, small vessels may transverse the physis and end in epiphysis
Periosteum

- Periosteum in children is thicker and stronger
  - Offer additional resistance to shear force
  - Little displacement, help in reduction
Greenstick Fractures

- Bending mechanism
- Failure on tension side
- Incomplete fracture, plastic deformation on compression side
- May need to complete fracture to realign
Ligaments

• Ligaments in children are functionally stronger than bone
  – Force that procedure sprains in adults result in fracture in children
Physeal Fractures

• Traditionally believed to occur primarily through **zone of hypertrophy**

• Some fractures may traverse more than one zone
Growth plate

- The physis is weaker than bone in torsion, shear and bending
- Potential for remodeling
- Growth plate injury causes deformity
Physeal fractures

• Salter-Harris classification
  – I - # across physis
  – II - # across physis and metaphysis
  – III - # across part of physis & epiphysis
  – IV - # across metaphysis, physis & epiphysis
  – V - crush injury of physis without fracture
  – VI - Perichondral ring injury
Physeal fracture

• Type I
  – Transphyseal fracture involving the hypertrophic and calcified zones
  – Prognosis is excellent, although complete or partial growth arrest may occur in displaced fracture
• Type II
  – Transphyseal fracture that exits the metaphysis
  – The metaphyseal fragment is called Thurston Holland fragment
  – The periosteal hinge is intact on the side with metaphyseal fragment
  – Prognosis is excellent, although complete or partial growth arrest may occur in displaced fracture
• Type III
  – Exits the epiphysis, causing intra-articular disruption
  – anatomic reduction and fixation without violating the physis are essential
  – Prognosis is guarded, partial growth arrest and angular deformity are common
• Type IV
  – Transverse epiphysis, physis and metaphysis
  – anatomic reduction and fixation without violating the physis are essential
  – Prognosis is guarded, partial growth arrest and angular deformity are common
• Type V
  – Diagnosis is generally made retrospectively
  – Prognosis is poor
  – growth arrest and partial physeal closure common
Growth Arrest Secondary to Physeal Injury

• Complete cessation → limb length discrepancy

• Partial cessation
  → angular deformity if peripheral
  → progressive shortening if central
Epiphysis or Apophysis?

- Epiphysis - forces are compressive on physeal plate
- Apophysis - forces are tensile
- Histologically distinct
Apophyseal Injuries

- Tibial tubercle
- Medial Epicondyle
- May be preceded by chronic injury/repetitive processes
Non-accidental injury
Radiographic Findings in NAI
Radiographic Findings in NAI

- Fracture pattern not specific (spiral, transverse, etc.)
- Metaphyseal Corner # or Bucket Handle #
- Multiple fractures at different stages of healing highly specific
• Humerus diaphyseal # < 3 yo are almost always associated with NAI

• Femur # < 1 yo are usually due to NAI

• Risk or re-abuse is 35% and risk of death 5-10%
Metaphyseal Corner # or Bucket Handle #

- Pathognomonic of NAI
- Traction/rotation mechanism of injury
- Planar fracture through primary spongiosa
DDX: NAI #

- Accidental trauma/Birth trauma
- Osteogenesis Imperfecta
- Metabolic Bone Disease (rickets, etc.)
- Physiologic periostitis
Management
General Principles

• Acute Fracture Care
  – immobilization of joints above and below
    • provides comfort, reduces deformity, reduces risk of additional injury
    • cast or splint depending on anticipated swelling & compartment syndrome
Post-fracture care

• Post-fracture Care
  – F/U to ensure union & restoration of alignment and length
Special Considerations

- Open fracture
- Compartment Syndrome
- Pathologic Fracture
  - tumors e.g. osteosarcoma
  - hereditary diseases e.g. osteogenesis imperfecta
  - metabolic diseases e.g. rickets
  - neuromuscular diseases e.g. Muscular Dystrophy
  - infectious diseases e.g. osteomyelitis
Treatment options
Most upper limb # - 90/90 elevation
Most Lower limb #
Back slab
Treatment of minimal / Un-displaced #
Completely Displaced Fractures

Closed/Open Reduction + K-wire Fixation + Casting
Excellent remodelling power
Forearm shaft
Tibial Shaft, Wedging Works Beautifully!
Traction Principle

- Traction produces a reduction through the surrounding soft parts which align the fragments by their tension.
Purpose

* Regain normal length and alignment of involved bone
* Reduce and immobilize a fractured bone
* Lessen or eliminate muscle spasms
* Relieve pressure on nerves, especially spinal
* Prevent or reduce skeletal deformities or muscle contractures
Mechanism of traction

- Every force has an equal and opposite force
- Applied in different ways
  - Fixed traction with a splint
  - Fixed traction using gravity
  - Sliding traction
  - Balanced traction
Classification

- Defined by force
  - Traction by gravity
  - Skin traction
  - Skeletal traction

- Defined by configuration
  - Fixed traction
  - Balance traction
  - Combined traction
A: Traction by Gravity
B: Fixed skin traction
C: Balanced skin traction
D: Russell skin traction
E: Skeletal traction with splint + knee flexion piece
Skin traction

• 12 lb (5kg) is the upper limit
Skeletal Traction

- Max. 18kg (40lb) can be used
- Allow joint motion exercise
- Useful for femur fracture in paediatric
TIBIAL TRACTION – RIGHT AND WRONG

A  Yes!

B  pin clear of skin and horizontal

C  No!
pin skew

D  pin touches

E  the cord less easily slips off a cork

F

G  No!

H  too far anteriorly

skew

easily slips off
External fixation
Flexible and Rigid Intramedullary Nail
Compression plating
Children $\not\equiv$ Small Adult
Thankyou