Pediatric Upper Extremity Fractures

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SMART SERIES

Children's Wisconsin

Financial Disclosures

- I have no relevant financial disclosures

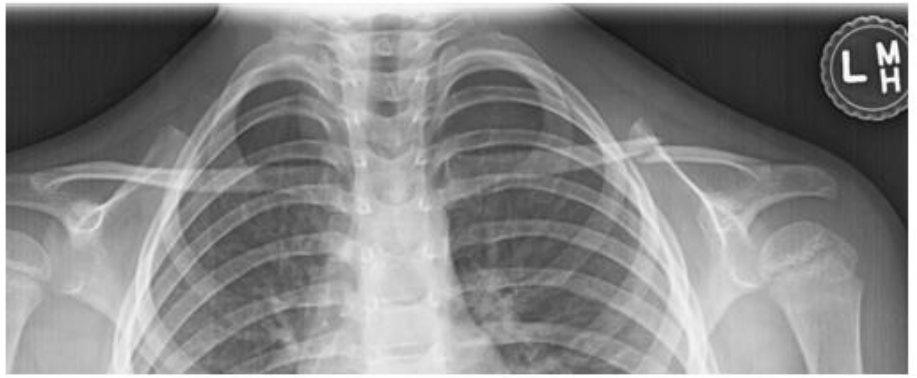
Objectives

- Epidemiology of Pediatric Upper Extremity Fractures
  - Clavicle
  - Proximal Humerus
  - Humeral shaft
  - Supracondylar
  - Forearm
- Common mechanisms of injury
- Key physical exam findings
- Treatment recommendations
- Complications

Clavicle Fractures

Pediatric Clavicle Fractures

- Clavicle fractures represent 5-15% of all pediatric fractures
  - Midshaft is the most common location (80%)
  - 15% lateral, 5% medial



Clavicle Fractures

Anatomy

- Clavicular diaphysis is the first bone to ossify in utero
- Medial epiphysis is one of last centers to fuse

- Highest rates of growth occur by 12 years of age
  - Growth can continue into early 20s
  - Significant remodeling potential

- Thick periosteum leads to decreased nonunion rates

Clavicle Fractures

Mechanism of Injury

- Common in all stages of childhood
  - Lateral compression of shoulder in school age children
  - Athletic injuries
    - High impact
    - Stress fracture secondary to repetitive activities
  - High energy injuries
    - MVC
    - ATV

Clavicle Fractures

Signs and Symptoms

- Neonates
  - Decreased movement of effected extremity
  - Crying with passive movement of arm
  - Swelling, crepitus
  - Decreased Moro reflex

- Child/Adolescent
  - Deformity, swelling, ecchymosis
  - Skin tenting
  - Shoulder drooping/ shortening
  - Pain with range of motion

Clavicle Fractures

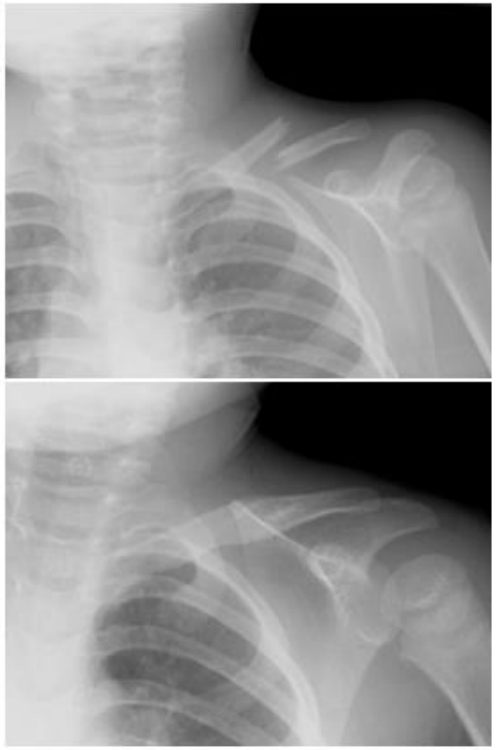
Imaging

- XR
  - AP
  - 45 degree cephalic tilt view
- CT
  - May be warranted in high energy mechanisms to further evaluate for additional injury
  - Allows evaluation of SC and AC joint injuries

Clavicle Fractures

Treatment

- Non-operative
  - Nondisplaced fractures
  - <2cm displacement
  - 95-100% union rate
    - ***Almost all fractures unite and result in minimal to no residual disability***



Clavicle Fractures

Treatment

- Treatment
  - Sling immobilization for 2 weeks
    - Sling when out of home for an additional 2-4 weeks
  - No proven benefit to figure-8 brace

  - XR obtained at 4 week intervals until union occurs
  - Noncontact activities typically resume at 6 weeks
  - Contact activities resume at 3 months if healing is present
    - *Must discuss refracture risk with early return to sports*

Clavicle Fractures

Surgical Treatment

- Operative Indications
  - Absolute
    - Open fractures
    - Fractures with impending skin compromise
    - Fractures associated with neurovascular injury
  - Relative
    - Floating shoulder injuries
    - Polytrauma
    - “Severely displaced” ??

Clavicle Fractures

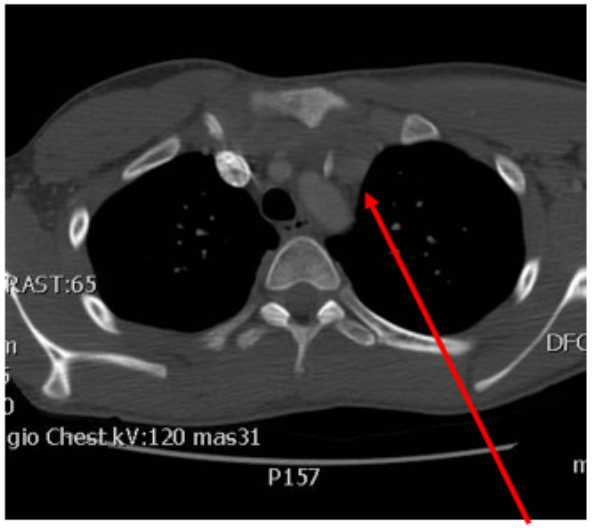
Complications

- Non-operative treatment
  - Nonunion
  - Malunion
  - Bony prominence
- Operative Treatment
  - Hardware prominence / pain
  - Re-fracture
  - Infection

Clavicle Fractures

Medial Clavicular Injuries

- Pseudo-sternoclavicular dislocation
  - Anterior displacement
    - Metaphyseal fragment lies in subcutaneous position
  - Posterior displacement
    - Puts innominate artery/vein, trachea, and esophagus at risk
    - Patients can present with dysphagia, hoarseness, pneumothorax, respiratory distress, brachial plexus injury, and vascular compromise
  - Critical to perform thorough neurovascular exam of extremity and assess respiratory status



Notice: Medial tip of clavicle adjacent to aortic arch!

Clavicle Fractures

Treatment

- Non-operative
  - Anterior fractures or dislocations
  - Can be considered for asymptomatic posterior dislocations
  - Significant remodeling potential, some deformity acceptable
    - Physeal fractures remodel
    - Dislocations DO NOT REMODEL
  - Treat symptomatically in sling or figure-of-eight brace
  - Recurrent instability is uncommon

Clavicle Fractures

Treatment

- Operative
  - Closed reduction can be considered for displaced injuries
  - Emergent reduction in OR indicated for posterior displacement with dyspnea or dysphagia
    - Consider having general or thoracic surgery on standby
  - Closed reduction with traction and manual manipulation
  - Open reduction utilized for posterior dislocations
    - Heavy sutures are used to stabilize the reduction

Clavicle Fractures

Lateral (Distal) Clavicle Injuries

- Coracoclavicular ligaments (conoid and trapezoid) usually remain attached to periosteal sleeve and the lateral epiphyseal fragment
- When medial metaphyseal fragment is significantly displaced, intact periosteal sleeve may form new metaphysis resulting in duplicate lateral clavicle

Proximal Humerus Fractures

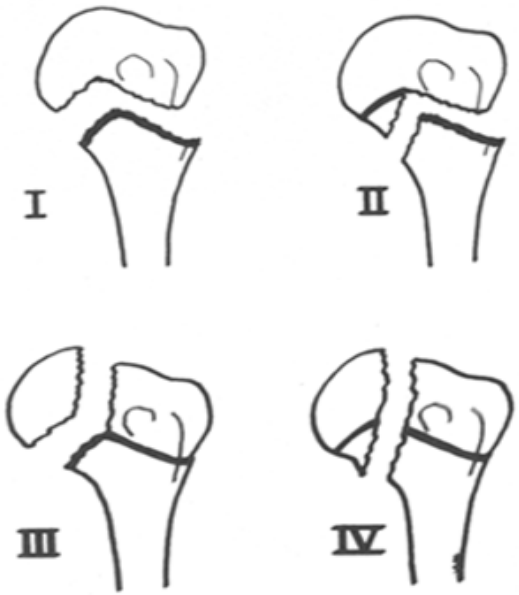
Proximal Humerus Fractures

- 3% of all physeal injuries
- More common in adolescents
- Most commonly Salter-Harris I or II injuries
- 80% of humeral growth comes from proximal physis
- Can be associated with glenohumeral dislocation

Proximal Humerus Fractures

Proximal Humerus Fractures

- Birth injuries → SH 1
- 0-5 yo → SH 1
- 5-11 yo → metaphyseal
- 11 to maturity → Salter II
- Others rare (III, IV)



Proximal Humerus Fractures

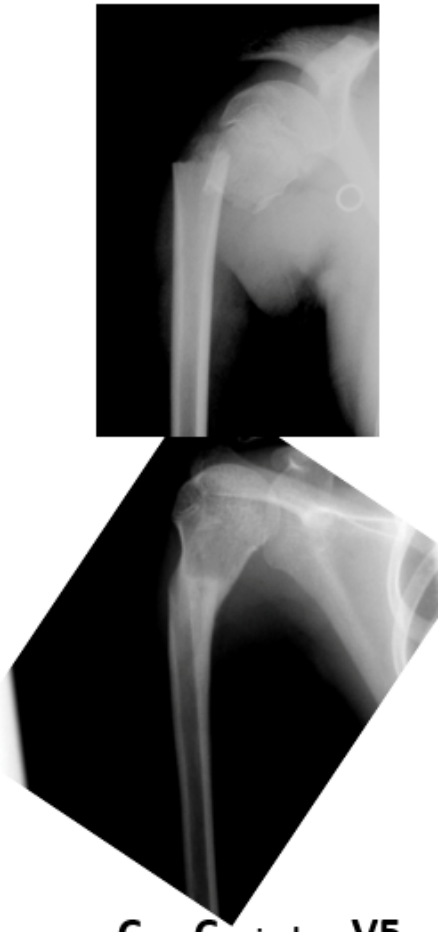
Mechanism of Injury

- Birth trauma
  - Hyperextension and rotation
- Child abuse
- Direct blow
- Indirect forced extension during a fall
- Pathological fractures through tumor or cyst
  - Unicameral bone cyst (shown)
  - Aneurysmal bone cyst

Proximal Humerus Fractures

Treatment

- Most can be treated non-operatively
  - Most children under 10y have sufficient growth remaining to remodel severely displaced fractures
- Consider surgical management in adolescent patients >13y with over 30 deg angulation or more than 50% displacement
- Surgical treatment
  - Open fractures
  - Polytrauma
  - Vascular injuries



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Proximal Humerus Fractures

Acceptable Alignment

- <5y- 70 deg angulation, 100% displacement
- 5-11y- 40 - 70 deg angulation, 50-100% displacement
- >12y- <40 deg angulation, <50% displacement

Proximal Humerus Fractures

Shoulder Immobilization

- Sling and swathe
- Hanging arm cast
- Cuff and Collar
- Start gentle pendulum at 2 weeks
- Can begin overhead activities 4-6 weeks

Proximal Humerus Fractures

Complications

- Pain, weakness, loss of ROM
- Physeal arrest
  - Shortening of the humerus
    - 11% in Salter Harris I or II
    - 33% in Salter Harris III or IV
- Varus malalignment
- Neurovascular injury

Humeral Shaft Fractures

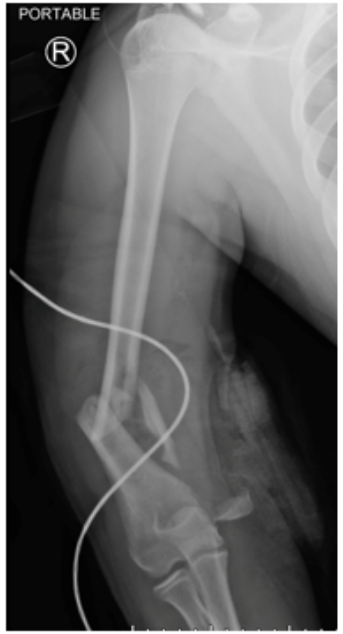
Humeral Shaft Fractures

- Second most common birth fracture
- **MUST consider NAT in those <3y**
- Pathologic fractures can occur through benign bone tumor or cyst
- Fractures can be associated with radial nerve palsy
  - 5% of pediatric humeral shaft fractures
    - High rates of spontaneous recovery

Humeral Shaft Fractures

Mechanism of Injury

- Birth trauma
- Direct high energy forces
  - More likely to be open or proximal humeral shaft
  - Transverse, comminuted, segmental patterns
- Indirect forces
  - Oblique or spiral fractures
- Low-energy mechanisms should raise possibility of pathologic fx

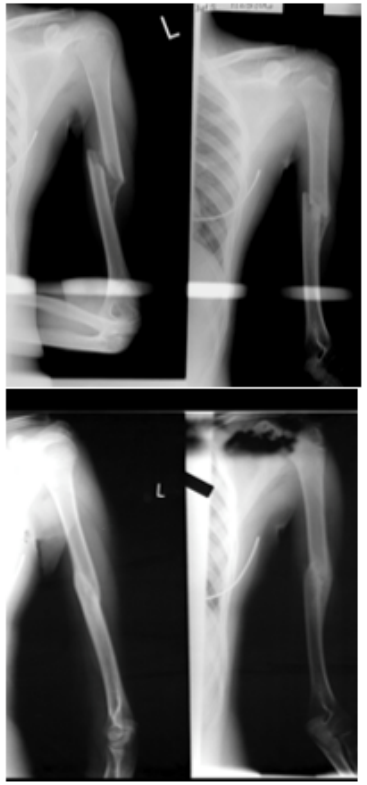


Humeral Shaft Fractures

Treatment

- Most common treatment option
  - Birth-related fractures
  - Stress fractures
  - Benign pathological fractures
  - Closed diaphyseal fractures with acceptable alignment

- Acceptable Alignment
  - 1 to 2 cm of shortening
  - ≤ 20 deg of varus or valgus angulation
  - ≤ 20 deg of anterior-posterior angulation
  - ≤ 15 deg of malrotation



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Humeral Shaft Fractures

Complications

- Malunion
  - Can occur, but rarely cause functional problem
- Nonunion
  - Uncommon
- Radial nerve palsy
  - Most commonly neuropraxia
  - Typically resolves with observation
  - Apply wrist splint to maintain wrist motion in extension
  - EMG and radial nerve exploration at 3-4 months if activity is not present

Supracondylar Fractures (SCH)

- Most common elbow fracture in children
- Most commonly occurs in 5-7yo children
- Most common mechanism of injury is from a low energy fall
- FOOSH for extension types (common)
- Fall on flexed elbow for flexion types (uncommon)

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Supracondylar Fractures

PEDIATRIC SCHF

- Most common surgical pediatric fracture
  - Frequently require surgical treatment to avoid complications due to:
    - Limited contribution of growth of distal humerus = limited remodeling potential
  - Displaced SCHF are unstable and require reduction and stabilization to heal in appropriate alignment

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Supracondylar Fractures

PHYSICAL EXAM

- Pain
- Refusal/inability to move the elbow
- Deformity proportional to displacement
- Swelling & bruising
- Skin integrity
  - Tenting/compromise
  - Open fractures

Supracondylar Fractures

PHYSICAL EXAM

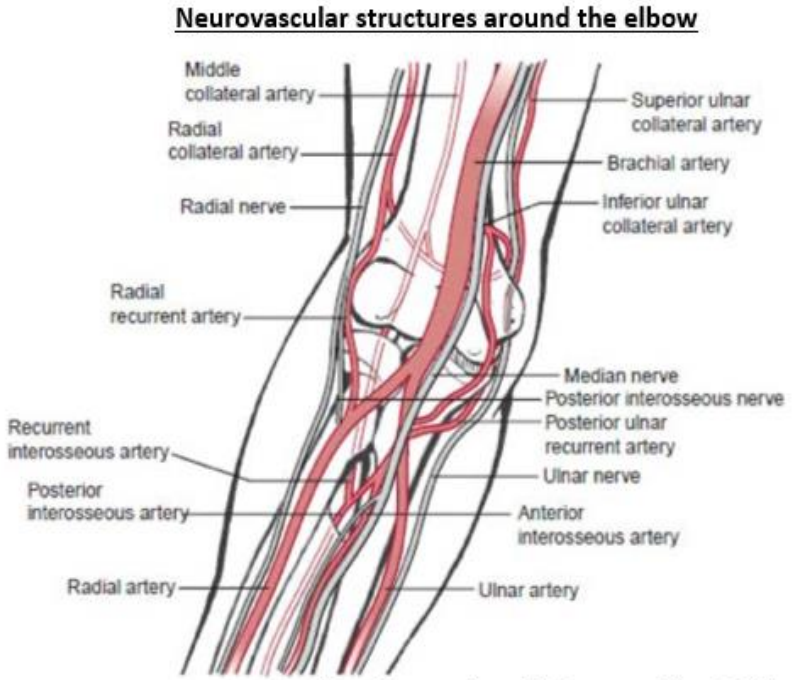
- Brachialis sign:
  - Antecubital ecchymosis
  - Skin puckering
  - Subcutaneous bone fragment (soft-tissue interposition)
  - Indicator of:
    - Significant injury and swelling
    - Potential failure of closed reduction

Courtesy of Mark Sinclair, MD

Supracondylar Fractures

NEUROVASCULAR EXAM

- Relatively high rate of neurovascular injuries due to intimate relationship of nerves and artery to displaced fracture fragments
- Neurologic exam can be challening in injured child but important to document pre-manipulation exam
- Pulseless hand may still be perfused because of excellent collateral circulation in pediatric elbow



Rockwood and Green, Fig 33-7

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Supracondylar Fractures

NEUROLOGIC EXAM

- What to assess:
  - Median nerve: sensation pulp of index finger
  - Anterior interosseus nerve: flexion IP thumb and DIP index
  - Radial nerve: sensation dorsum of thumb
  - Posterior interosseus nerve: extension IP thumb
    - Don't be fooled by intrinsics (extension finger IPs)
  - Ulnar nerves: finger abduction/adduction

Thumbs up (PIN) - Cross Fingers (Ulnar N) - AOK (AIN)

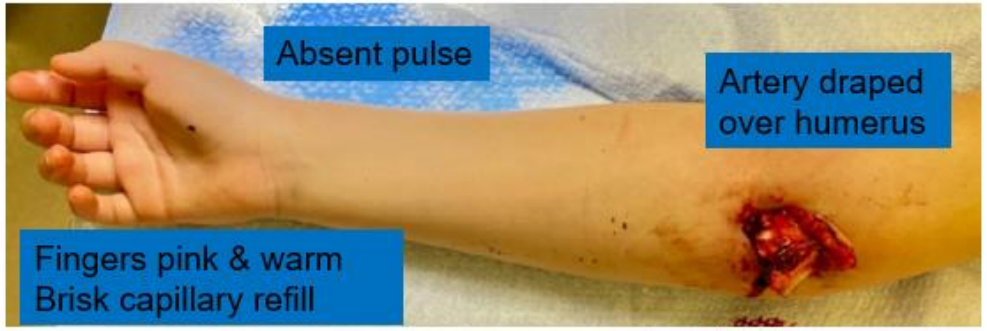
VASCULAR INJURY

- Occurs in 0.5-5%
- Vascular status
  - Assess pulse (palpation or doppler)
  - Assess perfusion
    - Capillary refill (<2s)
    - Warmth of fingers
    - Color of skin

Supracondylar Fractures

VASCULAR STATUS

- **3 categories:**
  Pulse present, perfused hand
  Pulse absent, perfused hand
  Pulse absent, nonperfused hand



Courtesy of Micah Sinclair, MD

Supracondylar Fractures

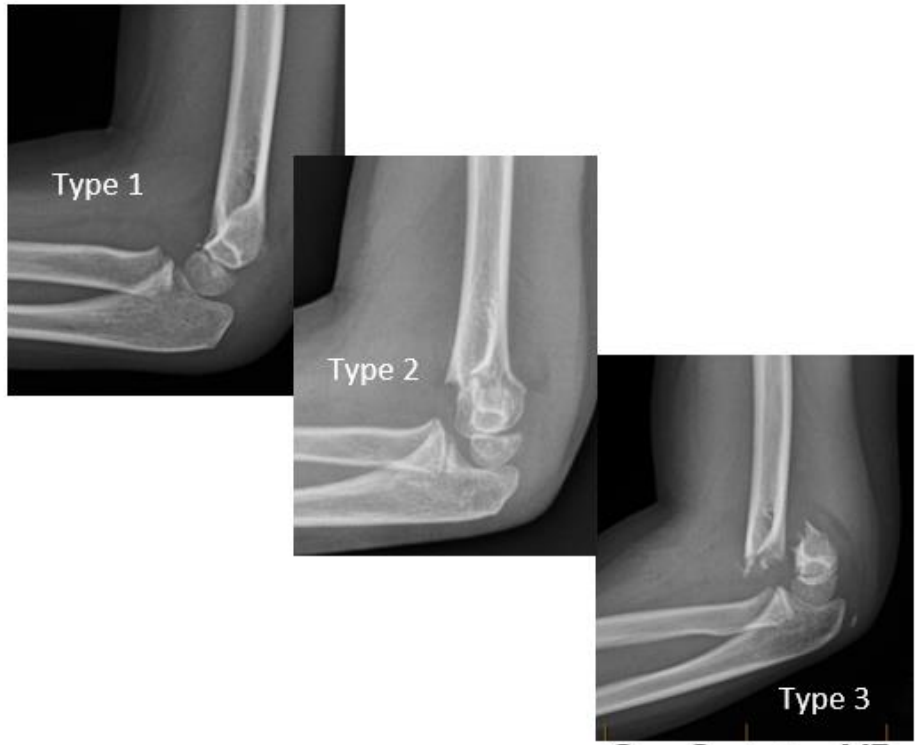
IMAGING

- XR usually sufficient
  - AP + LAT of elbow
  - Ipsilateral forearm/wrist
- Look for posterior fat pad sign in non displaced fractures (arrow)
- Advanced imaging rarely indicated (intra-articular variant)

Supracondylar Fractures

GARTLAND CLASSIFICATION

- Fracture Type: Characteristic
  - Type 1: Nondisplaced
  - Type 2:
    - Angulation
    - Posterior hinge intact
  - Type 3:
    - Complete displacement
    - Loss of posterior hinge



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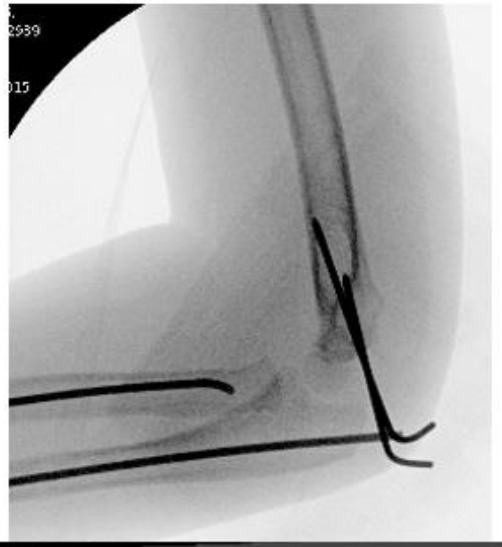
Supracondylar Fractures

IPSILATERAL FRACTURES

- Radius and/or Ulna (shaft or distal)
  - "Floating Elbow"
  - Occurs in 5% of Type 3s
  - Can be missed by distracting SCHF
  - Rate of complications proportional to severity of injury
    - Compartment syndrome rate 2%
  - Consider urgent fixation for higher energy injuries
  - Consider distal fixation if closed reduction required
    - Difficult to hold reduction in LAC with swelling



Baghdadi et al. JPO 2020

Lucas DE, et al. JOT 2013

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Supracondylar Fractures

NON OPERATIVE CONSIDERATIONS

- Avoid casting > 90 deg in swollen elbows
- Consider splitting cast
- Close follow-up
  - Especially for Type 2s
  - ***Especially*** if CR performed
    - Up to 48% rate of loss of reduction
    - Risk factors for displacement:
      - Greater initial displacement
      - Large arm (circumference)

Lucas DE, et al. JOT 2013

Fitzgibbons, et al. JPO 2011

Camus T, et al. JPO 2011

Supracondylar Fractures

POSTOPERATIVE CARE

- Type 2: Outpatient
- Type 3: Monitoring for 12-24h
  - NV exams
  - Compartment checks
- Split cast or splint
  - Especially if acute or early discharge
- Pain control:
  - Ibuprofen + Acetaminophen often sufficient
  - Narcotics may not be necessary

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Nelson SE, et al. JBJS 2019

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Supracondylar Fractures

FOLLOW UP

- Pin removal generally at 3-4 weeks
- Frequency of follow-up variable per surgeon and/or fracture type

- PT/ROM exercises generally not required

- Post-pin removal radiographs may not provide clinical utility in the absence of other clinical findings.

Supracondylar Fractures

COMPLICATIONS

- Nerve injury
  - Traumatic
    - Mostly neuropraxias with full recovery
    - Nerve transection is rare
    - Prolonged deficit (>6 months) may be due to perineural fibrosis (neurolysis helpful)
  - Iatrogenic from pin placement or entrapment in fracture during reduction
- Vascular injury
- Compartment syndrome (rare)
  - Increased risk with "floating elbow"
  - Can lead to Volkmann ischemic contracture

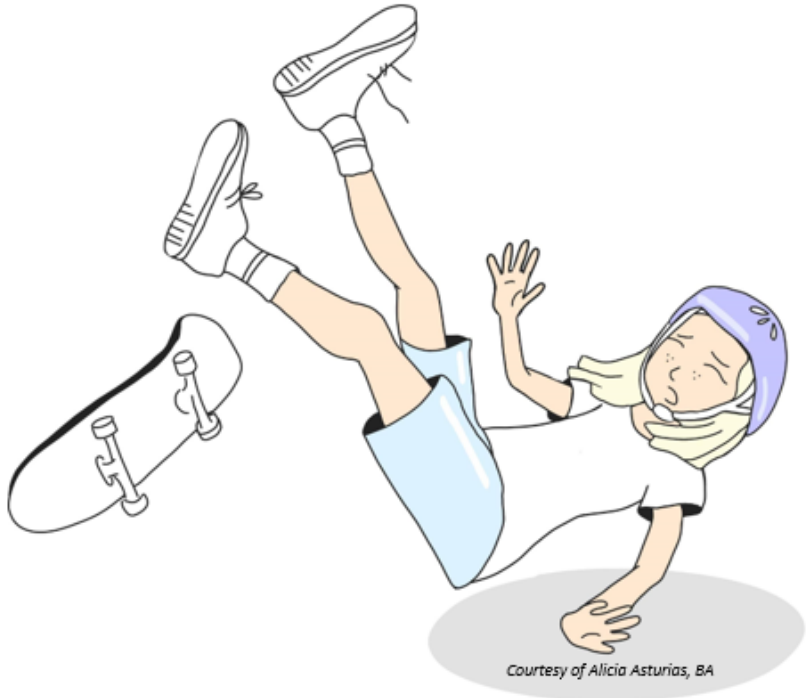
Perineural fibrosis

Courtesy of Micah Sinclair, MD

Forearm Fractures

Pediatric Radius and Ulna Fractures

- Most common fractures seen in pediatric patients; accounts for 17.8% of fractures (age 0-19 yrs) in the National Electronic Injury Surveillance System Database
  (Naranje , JPO 2016)
- Common mechanisms of injury:
  - Fall onto outstretched hand
  - Direct blow
  - Wheeled activities



Courtesy of Alicia Asturias, BA

Forearm Fractures

Physical Exam

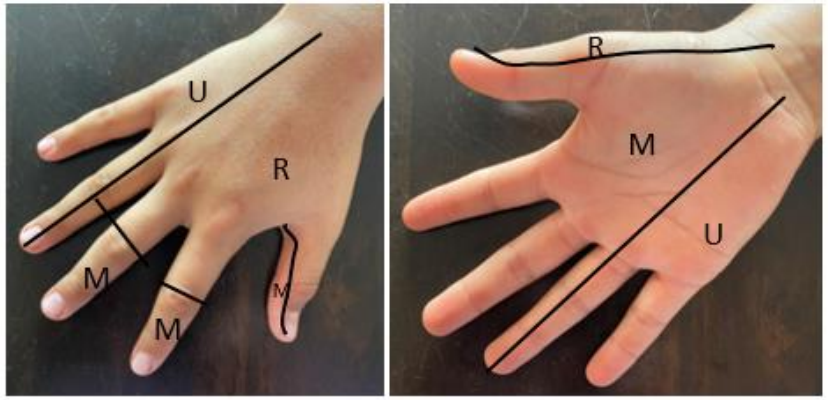
- Head to toe exam – don't miss another injury
- Check the joint above and below the injury
- Check the skin – is the fracture open or closed?
- Is there vascular compromise?
  - Are the radial pulses symmetric
  - Is capillary refill <2seconds
- Is there nerve compromise?

Forearm Fractures

Neurologic Exam - Sensory

- 2 Point Discrimination should be checked in the radial, median, and ulnar nerve distributions
- There should not be severe pain with passive stretch of the digits
- Remember, if a nerve is injured, the patient may not feel any pain even with compartment syndrome or carpal tunnel syndrome

2-point Discrimination
Test each of the Sensory Dermatomes
U=Ulnar, R=Radial, M=Median



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Forearm Fractures

Neurologic Exam - Motor

- Ulnar nerve
  - spread and cross fingers
- Radial nerve (PIN)
  - Extend thumb
- Median nerve
  - flex IPJ thumb, DIPJ index (AIN)
  - opposition of thumb (median)

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Forearm Fractures

Pediatric Radius and Ulna Fractures

- **The vast majority of pediatric forearm fractures can be treated closed**
- **Children heal faster than adults**
- **Remodeling potential is high when <8 years old and decreases as skeletal maturity is reached**

Injury

6 months later

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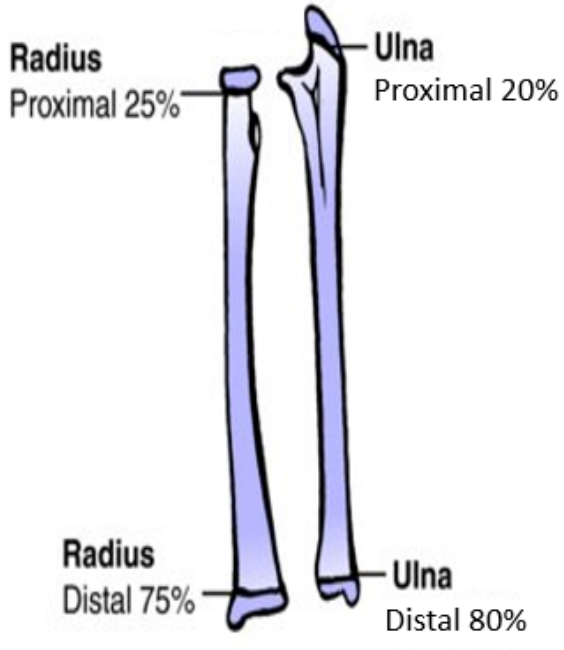
Forearm Fractures

Remodeling

- The distal radial physis is responsible for 75% of the longitudinal growth of the bone
- Distal ulnar physis is responsible for 80%
- Fractures close to these physes have significant remodeling potential due to the rapid growth
- The proximal physes of the radius and ulna have much less growth potential (20-25%)
- Proximal fractures do not remodel as efficiently as distal fractures



(From: Noonan, Keneth J. MD; Price, Charles T. MD, Forearm and Distal Radius Fractures in Children, Journal of the American Academy of Orthopaedic Surgeons: May 1998 - Volume 6 - Issue 3 - p 146-156)

Karl E. Rathjen, Harry K. W. Kim, Benjamin A. Alman. The Injured Immature Skeleton. In Waters PM, Skaggs, DL, Flynn JM, eds Rockwood and Wilkins' Fractures in Children 9e. Philadelphia, PA. Wolters Kluwer Health, Inc, 2019, fig 2-2

Forearm Fractures

Remodeling

- The closer a fracture is to the physis, the better the remodeling potential
- There may be loss of motion during the remodeling process

Radial neck fracture treated with casting, no reduction

Excellent remodeling 6 months post injury

Forearm Fractures

Remodeling

- Fractures remodel best in the plane of motion

- Angulation (A) and translation(B) remodel better than rotation

Forearm Fractures

Frequency of Injury

- Distal Physeal: 14%
- Distal Metaphyseal: 66%
- Shaft: 20%
- Proximal 1%

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Forearm Fractures

Fracture Patterns

Incomplete

- Buckle/Torus – compression of only one cortex – very stable – treated with removable splint x 3-4 weeks
- Greenstick – only one cortex disrupted – reduction if necessary and cast – these heal very quickly
- Plastic deformation-bone does not break but deforms – can be very difficult to reduce
  - Strong gentle pressure to correct the deformity- bone may break as you bend it back
  - Residual bow can cause problems with rotation and PRUJ/DRUJ

Buckle

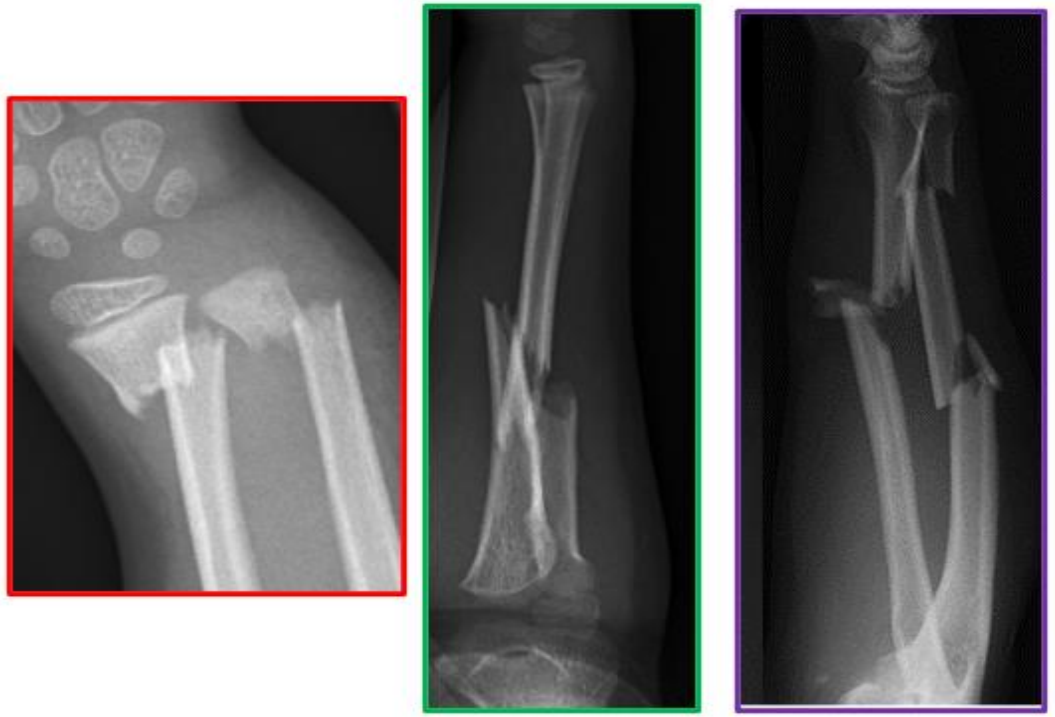
Ulna—Greenstick
Radius—Plastic

Forearm Fractures

Fracture Patterns

Complete fractures

- Transverse
- Oblique
- Comminuted
  - Rare in pediatrics
- Needs acceptable reduction (rarely fixation) and casting



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Forearm Fractures

Salter Harris Fractures

- If patients present late or have loss of reduction of a SH I or SH II fx
  - Do NOT try to reduce if > 7 days post injury
  - Physis is unlikely to recover.
  - Allow healing, most will remodel,
  - If not, an osteotomy can be done away from the physis at a later date
- SH III and SH IV fractures need to have anatomic joint reduction – consider reduction even with late presentation
  - a short arm is better than a disrupted joint surface

Initially seen 3 wks post injury - Casted in situ

8 months after injury Remodeling nicely

Forearm Fractures

Treatment

- Splint
- Brace
- Closed reduction and casting
  - SAC
  - LAC
- Surgical fixation and casting

Forearm Fractures

When to Consider Surgery

Most pediatric forearm fractures can be treated closed, surgery is considered if there is:

- An open fracture
- Neurovascular compromise
- Intra-articular disruption
- Inability to obtain or maintain the reduction within acceptable limits for age with closed treatment

Summary Upper Extremity Fractures

Children and adolescents are treated differently than adults due to growth and remodeling potential. Educate athletes and families on sidelines.

Always do a good neurovascular examination

Immobilize early (above and below the injured region)

Refer to orthopedics early (especially if suspect growth plate injury)

Thank You

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Clavicle Fractures

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Supracondylar Fractures

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Supracondylar Fractures

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