Pediatric Supracondylar Humerus Fractures

 Caroline Tougas, MD
Children's Mercy Hospital, Kansas City
Clinical Assistant Professor - UMKC School of Medicine

OCTOBER 2020
Disclaimer

• All clinical and radiographic images provided are used with permission of Caroline Tougas, MD unless otherwise specified.
OBJECTIVES

By the end of this presentation, learners will be better able to:

• Recognize the signs and symptoms of more severe pediatric supracondylar humerus fractures (SCHF)
• Assess the degree of displacement of pediatric SCHF on radiographs
• Determine the type of fracture according to the modified Gartland classification
• Prescribe appropriate treatment for SCHF based on fracture characteristics
• Describe the technique of closed reduction and percutaneous pinning of pediatric SCHF
• Recognize SCHF that may require more complex care and manage them appropriately
PEDIATRIC SUPRACONDYLAR HUMERUS FRACTURES (SCHF)

- 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)
    - Monkeybars, trampolines, cartwheels, etc
  - Fall on flexed elbow for flexion types (uncommon)
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
PHYSICAL EXAM

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

*Will require milking maneuver (discussed later)

Courtesy of Mark Sinclair, MD
NEUROVASCULAR EXAM

• Relatively high rate of neurovascular injuries due to intimate relationship of nerves and artery to displaced fracture fragments
• Neurologic exam can be challenging 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
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
VASCULAR STATUS

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

Courtesy of Micah Sinclair, MD
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

BEDSIDE TEST (many options):

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

• Occurs almost exclusively in Type 3 or Flexion Types

<table>
<thead>
<tr>
<th>Nerve Injuries</th>
<th>EXTENSION TYPE</th>
<th>FLEXION TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Percentage</td>
<td>12.7%</td>
<td>16.6%</td>
</tr>
<tr>
<td>Median N</td>
<td>3.3% (21.3%)</td>
<td>5.1% (8.7%)</td>
</tr>
<tr>
<td>AIN</td>
<td>5.3% (34.1%)</td>
<td>0%</td>
</tr>
<tr>
<td>Radial N</td>
<td>4.5% (26.6%)</td>
<td>0%</td>
</tr>
<tr>
<td>PIN</td>
<td>1.1% (2.0%)</td>
<td>0%</td>
</tr>
<tr>
<td>Ulnar N</td>
<td>2.3% (15.8%)</td>
<td>16.6% (91.3%)</td>
</tr>
</tbody>
</table>

• RISK FACTOR:
  • Median N/AIN: posterolateral displacement
  • Radial N: posteromedial displacement
  • Ulnar N: flexion types

Babal JC, et al. JPO 2010
OSTEOLOGY

- Distal humerus composed of medial and lateral columns connected by the articular segment
- Displaced fractures inherently unstable
  - Medial/lateral columns displace easily

Tornetta P, Ricci WM, eds. Rockwood and Green's Fractures in Adults, 9e. Philadelphia, PA. Wolters Kluwer Health, Inc; 2019. Figure 33-7
Medial and lateral columns connected by a thin wafer of bone through olecranon fossa

- Point of weakness, prone to fracture
- Muscles lose mechanical advantage when elbow extended past neutral (hyperextension common in children)
- Olecranon acts as a fulcrum
- Capsule transmits an extension force to distal humerus just proximal to the physis
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)
IMAGING

Distal humerus alignment (true lateral):

- **Anterior humeral line (AHL):** should intersect capitellar ossific nucleus

- **Anterior tilt of capitellum (30-40°)**
  - Lateral capitellohumeral angle (LCHA) $\rightarrow < 69^\circ$

- **Posterior fat pad sign** (highly suggestive of fracture whereas anterior fat pad sign can occur without fracture)
Distal humerus alignment (AP):

- **Baumann's Angle**: formed by a line perpendicular to the axis of the humerus, and a line that goes through the physis of the capitellum
  - Wide range of normal for this value (9-26 deg)
  - Best judge of normal is to obtain contralateral comparison views
CLASSIFICATION

• Two Major Fracture Types:
  • Extension:
    • Gartland Classification (1959)
    • Wilkins Modification (1991)
  • Flexion: Considered separately

95-98% FOOSH

2-5%
Direct blow to flexed elbow
GARTLAND CLASSIFICATION

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

• Type 1: Nondisplaced
  • Fat pad sign +
  • No angulation
  • +/- Impaction

• Treat with immobilization
• Long-arm cast (LAC)
• 3-4 weeks
GARTLAND CLASSIFICATION

• Type 2:
  • Sagittal angulation
  • Posterior hinge intact
  • If anterior humeral line (AHL) does not intersect at least anterior 1/3rd of capitellum can require CR +/- PP
MODIFIED GARTLAND CLASSIFICATION

- Type 2A: Sagittal angulation only
  - Amenable to CR + LAC
  - Requires close follow-up

- Type 2B: + rotation, coronal angulation (varus, valgus), translation +/- comminution or impaction present
  - Higher rate of failure with CR without percutaneous pinning
  - Recommend CRPP
MODIFIED GARTLAND CLASSIFICATION

• Type 3:
  • Complete posterior displacement
  • Loss of posterior hinge
  • Maintains periosteal sleeve

• Type 4:
  • Instability in extension and flexion
  • Disruption of periosteal sleeve

• Type 3 vs. 4 based on fluoroscopic examination with patient under anesthesia
  --> intraoperative distinction
FLEXION TYPES

• Generally more unstable
• Higher complication rates
• Association with ulnar nerve palsy

• TREATMENT:
  • Any displacement --> CRPP
  • Higher rate of ORPP than extension types
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
MANAGEMENT

• AAOS adopted appropriate use criteria (AUC) for the management of:
  • Pediatric supracondylar humerus fractures (2014)
  • Pediatric supracondylar humerus fractures with vascular injury (2015)
• Can be referenced in the treatment of a pediatric supracondylar humerus fracture.

MANAGEMENT

SUPRACONDYLAR HUMERUS FRACTURE

TYPE 1

LAC x 3-4 WEEKS

CORONAL OR ROTATION ANGULATION?

CRPP +/- ORPP

TYPE 2

TYPE 2A: ANTERIOR HUMERAL LINE INTERSECTS CAPITELLUM?

LAC x 3-4 WEEKS CLOSE FOLLOW UP

Yes

CLOSE FOLLOW-UP FEASIBLE?

Yes

CR + LAC x 3-4 WEEKS WEEKLY FOLLOW UP

No

CRPP

TYPE 2B: CRPP

TYPE 3

FLEXION

CRPP +/- ORPP

swelling
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
      • Type 2B
      • Large arm (circumference)

Lucas DE, et al. JOT 2013  
Fitzgibbons, et al. JPO 2011  
Camus T, et al. JPO 2011
TIMING OF OPERATIVE TREATMENT

• Dependent on:
  • Fracture pattern and displacement
  • Distal vascular status and limb perfusion
  • Neurologic function distal to the fracture
  • Soft tissue swelling
  • Associated fractures
  • Access to OR

• Type 2s can safely be treated as outpatients in delayed manner
• Type 3s should be admitted for monitoring if surgery is delayed
TIMING OF OPERATIVE TREATMENT

• Closed Type 3 SCHF with normal neurovascular exam can be treated safely in a delayed fashion
  • No difference in rates of:
    • Conversion to open reduction
    • Compartment syndrome
    • Iatrogenic nerve injury
    • Vascular complications
  
• Fractures with distal neurologic deficits are more controversial
  • May indicate more significant injury with increased risk of complications with delayed surgery

*over 21 hours in some studies

Ramachandran, et al. JBJS Br 2008
Bales et al. JPO 2010
TIMING OF OPERATIVE TREATMENT

• Emergent (immediately limb- or life- threatening)
  • NONPERFUSED limb
• Urgent
  • Open fractures
  • Skin puckering/compromise
  • Ipsilateral forearm/wrist fractures
  • Significant displacement and/or swelling
  • Neurologic injury?
  • Pulseless but perfused hand?
CLOSED REDUCTION AND PERCUTANEOUS PINNING SCHF


• TECHNIQUE VIDEO with case example
OR SETUP

• Armboard vs C-arm as table
  • Ability to swing through for lateral in very unstable reductions

• +/- Invert C-Arm
  • Increases radiation doses
  • Place lead over patient

• Secure head
  • Tape forehead
  • Tube tree
CLOSED REDUCTION

- Longitudinal traction to reestablish length +/- milking maneuver
- Rotation correction
- Coronal plane correction
  - Translation
  - Varus/valgus
- Sagittal plane correction
  - Anterior translation and hyperflexion of distal segment with pressure on olecranon
- Forearm position
  - Hyperpronation vs Supination
CLOSED REDUCTION

• Brachialis sign --> Milking maneuver

pre post

Courtesy of Mark Sinclair, MD

CLOSED REDUCTION

• Rule of Thumb:
  • Thumb points in direction of initial displacement of distal segment
  • Posteromedial
    • Pronation tightens medial soft-tissue sleeve
  • Posterolateral
    • Supination tightens lateral soft-tissue sleeve
DIFFICULT CLOSED REDUCTION

ex: Type 4 and Flexion Types

• Swing through laterals to avoid rotating through elbow
  * advantage of using arm board
• Bump underneath the proximal fragment
• Lessen elbow flexion and/or apply posteriorly directed force to distal segment through forearm

• May use joystick pins in the distal fragment to help control and manipulate it
ACCEPTABLE ALIGNMENT

- Anterior humeral line intersects capitellum
- No significant gapping (suggestive of soft-tissue interposition)
- No clear parameters otherwise:
  - Avoid varus (increased Baumann's angle)
  - Mild rotational deformity acceptable
  - Slight valgus or translation better tolerated
  - Upper limit of acceptable undefined
OPEN REDUCTION

• Variable rates in literature: 1-10%

• Indications:
  • Unable to achieve acceptable alignment
    • Association with posterolateral displacement
    • Flexion types
  • Open fracture
  • Vascular exploration required
OPEN REDUCTION

• Choice of approach: follow metaphyseal spike
  • Anterior: posterior displacement or vascular injury and/or median nerve injury
  • Medial: Posterolateral displacement or flexion type injuries
  • Lateral: Posteromedial displacement
  • Posterior: Generally avoided; poorer outcomes (stiffness, AVN, cosmesis)

• Avoid compromised tissues
• Avoid further disruption of soft-tissues
VASCULAR INJURY

- 1266 consecutive operatively treated supracondylar humerus fractures over 5 years (Texas Scottish Rite)
- 54 (4%) lacked a palpable radial pulse on admission
  - All Type 3s
- 5 (0.4%) were ischemic and underwent direct vascular repair
- 29/54 regained their radial pulse after CRPP of the fracture
- 20 were still pulseless after CRPP, but had perfused hands
  - 1/20 became ischemic and required vascular repair

VASCULAR EXPLORATION

• Indications:
  • Persistent nonperfused hand after adequate CRPP
  • Loss of pulse after fracture reduction
  • Perfused pulseless associated with median nerve injury management controversial
    • To explore or not to explore?
• Anterior approach preferred
• Consider UE vascular surgeon consultation early
NEUROVASCULAR REPAIR

Median Nerve Laceration

Brachial Artery Repair

Median Nerve Laceration

Courtesy of Micah Sinclair, MD
PIN CONFIGURATION OPTIONS

• Laterally based
  • **MOST COMMON technique
  • 2 vs 3 are lateral pins
• Cross-pinning
  • Medial and Lateral
    • Ulnar nerve at risk
  • All-Lateral
    • Radial nerve at risk
    • Less commonly used

• Antegrade ESIN technique also described
  • High SCH fx

Shenoy et al. Cureus 2020
PIN CONFIGURATION OPTIONS

- Laterally based
  - **MOST COMMON** technique
  - 2 vs 3 laterally-based pins

NB: Antegrade ESIN technique also described but less common
  - High SCH fx
PIN CONFIGURATION OPTIONS...

- Cross-pinning
  - Medial and Lateral
    - Ulnar nerve at risk
  - All-Lateral
    - Radial nerve at risk
PIN CONFIGURATION

• Cross-pinning most stable biomechanically

• No clear CLINICAL advantage to cross pinning over lateral pinning for most Type 3 fractures with
  • Greater risk of iatrogenic ulnar nerve injury (4.3X)

• Indications for medial pin:
  • Medial comminution
  • Proximal medial to distal lateral oblique fracture pattern (reverse oblique)
  • Intra-articular variants

Woratanarat P, et al. JOT 2012
**PIN CONFIGURATION**

**Medial Pin Technique:**
- Fix with 2 lateral pins
- Extend elbow 45deg to relax ulnar nerve
  - Beware of ulnar nerve subluxation
  - 16% of children (Zaltz 1996)
- Thumb pressure or small incision to protect ulnar nerve as pins inserted

*If iatrogenic nerve palsy postop, controversy re: leave or remove pin*

**Figure 1.** The transverse distance between the medial and lateral epicondyles was divided evenly in 4 different zones, with the most lateral zone labeled as zone 1 and the most medial zone labeled as zone 4. In the absence of medial comminution, 4 possible lateral-only pin configurations were tested. In the presence of medial comminution, 2 possible pin configurations were tested.

PERCUTANEOUS PINNING

• IDEALLY:
  • 1.6-2mm k-wires
  • Engage lateral and medial columns
  • Divergent
    *Greater pin spread = Greater stability

Type 2A: 2 pins
Type 2B: 2-3 pins
Type 3: 3 pins

1.6mm k wires
PIN CONSTRUCT

- Wide spread at fracture site
- Control lateral column with pin along metaphyseal flare
- Control medial column with laterally based pin
  - Engage distal humerus just above fracture site
- A 3rd pin can be added between these two for additional stability
**FLUOROSCOPY**

• After stable reduction and pinning:
  - Review AP alignment with elbow extended
  - Obtain true lateral view to assess alignment
  - Oblique views to assess reduction of medial and lateral columns

• Consider stress views under fluoroscopy to assess stability of construct/reduction
  * Especially if considering limited follow-up
    - On AP: rotational stress, varus/valgus stress
    - On LAT: flexion/extension arc

Bauer JM, et al. JPO 2019
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

Nelson SE, et al. JBJS 2019
POSTOPERATIVE ANALGESIA

- $n = 81$ Type 2 & 3 SCHF $\rightarrow$ CRPP
- Pain levels decreased to clinically unimportant levels by POD 3
- Rx of 7 opioid doses postop should be sufficient
- Pain scores $>6$ after d/c are outliers and should be screened for compartment syndrome or ischemia

Nelson SE, et al. JBJS 2019
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.
COMPLICATIONS

• Pin site infections
• Loss of fixation, pin migration
• Malunion
  • Cubitus varus - thought to be only esthetic, however may contribute to loss of motion and posterolateral rotatory instability
• Nonunion: very rare
• Stiffness: uncommon long term

Courtesy of Mark Sinclair, MD

O’Driscoll SW, et al. JBJS Am 2001

Ho, CA. JPO 2017
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
SUMMARY - SCHF

- Very common pediatric elbow injury
- Careful pre-operative neurovascular exam is essential
- Don't miss ipsilateral fractures (the “floating elbow”)
- Closed reduction and casting possible for Type 2A fractures
- Close follow-up for some nonoperatively treated fractures
- Surgical timing only emergent if vascular compromise
- Surgical treatment generally some variation of CRPP
- Variation in the approach to managing pediatric SCHF
REFERENCES


• Baghdadi S;CORTICES. Pediatric floating elbow injuries are not as problematic as they were once thought to be: A systematic review. J Petri Orthop 2020;40(8):380-389.


• Frick SL, Mehlman CT. The community orthopaedic surgeon taking trauma call: pediatric supracondylar humeral fracture pearls and pitfalls. J Orthop Trauma 2017;31:S11–S15

REFERENCES

• Ho, CA. Cubitus Varus - It's more than just a crooked arm! J Pediatr Orthop 2017;37(Suppl 2):S37-S41


REFERENCES


• Zusman NL, Barney NA, Halsey MF, Yang S. Utility of Follow-up Radiographs After Pin Removal in Supracondylar Humerus Fractures: A Retrospective Cohort Study. JAAOS 2020; 28(2):e71-e76