Elbow Fractures in Children – Initial Management, Treatment, and Prevention Tips

PRESENTED BY: Scott Yang MD,
Assistant Professor, Pediatric Orthopaedic Surgery
Doernbecher Children’s Hospital, OHSU
No disclosures for this presentation
Agenda

Two most common pediatric elbow injuries
1) Supracondylar humerus Fractures &
2) Lateral humeral condyle fractures

Image credits:
1) AO Surgery Reference
Supracondylar Humerus Fractures
Background

- **Supracondylar humerus fractures** are one of the most common types of fractures in children
  - 60% of all elbow trauma in children

- **Extension type** most common (95%)

- **Risk of neurovascular injury, compartment syndrome**
Supracondylar Humerus Fractures Classification

• Type 1
  – Non-displaced

• Type 2
  – Angulated/displaced fracture with intact posterior cortex

• Type 3
  – Complete displacement, with no contact between fragments
Elbow Fractures
Radiograph Anatomy/Landmarks

• Anterior Humeral Line
  – Drawn along the anterior humeral cortex
  – Should pass through the middle of the capitellum
    • >5 y/o, 100% falls on middle 1/3
  – Variable in very young children
    • < 2 y/o, 30% fall on anterior 1/3

Credit:
- Rogers et al, Radiology 1998
- Herman, et al JBJS 2009
- Ryan et al, JPO 2016
Type 1
Non-displaced

- Look for fat pad
  - Posterior fat pad elevation, 76% have occult fracture

- Treat with cast immobilization for 3 weeks

Credit
-Skaggs DL et al, JBJS 1999
Type 2
Angulated/displaced fracture with intact posterior cortex
Caution - Type 2 – Coronal plane is important too

Type II fracture with medial impaction – not recognized and varus / extension not reduced
Type 2 - Treatment

- Closed reduction & casting

- vs

- Closed reduction & percutaneous pinning
Casting can work in select patients...

Spencer et al, JPO 2012

- 189 type II fractures treated with closed reduction & casting
  - 21% lost reduction
  - Associated with:
    - Rotation
    - Persistent extension post-reduction

Rotational Malalignment

<table>
<thead>
<tr>
<th>TABLE 8. Multivariate Logistic Regression Analysis for Subsequent Conversion to Surgical Treatment Among the 189 Patients Who Did Not Receive Initial Surgical Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiographic Features</td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td>Initial rotational deformity</td>
</tr>
<tr>
<td>Postreduction anterior humeral line remaining anterior to the middle third of the capitellum</td>
</tr>
</tbody>
</table>

Area under the receiver-operating characteristic curve using these 2 variables alone was 0.6985 (lower discrimination).
Proponents of Operative Treatment

- Skaggs et al, JBJS 2004, JPO 2008
  - 189 type II supracondylar fractures treated with CRPP (lateral only pins)
    - No loss of reduction, cubitus varus or valgus
    - No nerve injury
    - 2.1% pin site infection rate (4/189)
    - 6% with < 10 degree ROM difference at 8.7 weeks postop
Conclusion

• Personal preference –
  – Pin all type 2 supracondylar humerus fractures
    • Prevents need for repeated radiographic follow ups
  • Minimizes loss of reduction and extension/varus deformity
  • Pin complication rate acceptable
Type 3
Complete displacement, with no contact between fragments

• Higher risk of neurologic and/or vascular compromise
  • 10-20% (Omid et al, JBJS 2008)

• Risk of compartment syndrome

• Treat with closed reduction & percutaneous pinning
  • Rarely, open reduction
Type 3 - Neurovascular Anatomy

• Median / AIN injury most common

• Artery close proximity to median nerve

• Brachial artery draped across proximal fragment
  – Tethered by supratrochlear artery

• Urgency of CRPP depends on vascular status

Image Credits:
1) Rowell PJ, Injry 1975
Nerve Injury Prognosis?

- Shore et al; JPO 2017
  - 244 patients with SCH fracture + nerve injury
  - Avg recovery by 2.3 months
    - 93% full recovery by 6 months
  - 20% open reduction rate
  - 29% have vascular changes
Type 3, Caution

- Important to assess and document preoperative status on nerve function & vascular status!!

  - Cases of median nerve and brachial artery entrapment at fracture site s/p reduction
Type 3 Initial Presentation

- Pulse absent, poorly perfused hand
  - **EMERGENT** reduction / pinning

- Pulse absent, well perfused hand
  - **URGENT** reduction / pinning

- Pulse present, well perfused hand
  - How long can these wait for reduction/pinning
What would you do?

Be objective. **Compare to other side.**
Its either normal, or not normal. Nothing in between
A quick word about Pulseless Poorly Perfused Hand On Presentation

Choi et al, JPO 2010
- Pulseless SCH w/ white hand
- Observe CLOSELY postop for deterioration

Diagram:
- 9 POORLY-PERFUSED HANDS
  - 2 OPEN REDUCTIONS
    - Failed reduction attempt at outside institution
      - Open Reduction, Exploration & Angiogram
        - No vascular injury
          - ORPP Improved Perfusion
        - (+) vascular injury
          - ORPP Improved Perfusion
  - 4 Satisfactory Reduction Improved Perfusion
  - 7 CLOSED REDUCTIONS
    - 3 Initially Improved Perfusion
    - 4 Deterioration in Perfusion
      - Angiogram ORPP Vascular Repair
      - Emergent Fasciotomy ORPP Vascular Repair
    - 2 Delayed Compartment Syndrome
But don’t forget about swelling & compartment syndrome
Compartment Syndrome

Robertson et al; JPO 2018; Harris et al; JPO 2018

- Incidence 0.2% amongst supracondylar humerus fractures
  - Includes type I & II fractures – likely higher in type III
- In patients with nerve injury, 4.5% - 11.4%

**TABLE 4. Multivariate Logistic Regression Analysis of Compartment Syndrome**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Odds Ratio</th>
<th>95% Wald Confidence Limits</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>1.1</td>
<td>1.0</td>
<td>1.2</td>
</tr>
<tr>
<td>Sex (male)</td>
<td>2.7</td>
<td>1.5</td>
<td>4.8</td>
</tr>
<tr>
<td>Race (white)</td>
<td>0.8</td>
<td>0.5</td>
<td>1.4</td>
</tr>
<tr>
<td>Ethnicity (Hispanic)</td>
<td>1.2</td>
<td>0.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Payer type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government</td>
<td>0.6</td>
<td>0.3</td>
<td>1.1</td>
</tr>
<tr>
<td>Other (self-pay)</td>
<td>0.7</td>
<td>0.4</td>
<td>1.4</td>
</tr>
<tr>
<td>Concomitant forearm fracture</td>
<td>3.2</td>
<td>1.7</td>
<td>6.1</td>
</tr>
<tr>
<td>Neurovascular injury</td>
<td>25.0</td>
<td>14.6</td>
<td>42.8</td>
</tr>
</tbody>
</table>
What can we learn from patients who got compartment syndrome?
- 11 patients with type III SCHs w/ intact pulse on presentation who developed compartment syndrome
- Mean time from injury to surgery 22 hours
- On presentation warning signs
  - Severe swelling in 10/11
  - Puckering in 2/11
  - Ecchymosis in 7/11

Use clinical judgment – take warning signs into account
Be on alert if you see this!!
Surgical Treatment of Supracondylar Humerus Fractures

- **Positioning**
  - Radiolucent small hand table
    - OK to use fluoroscopy as table
  - Axilla at the edge of bed

Image credit: Skaggs et al, Masters Techniques in Orthopaedic Surgery, Pediatrics, 2015
Surgical Treatment of Supracondylar Humerus Fractures

- **Step 1:**
  - Milk Brachialis, get tethered soft tissues out of way to reduce risk of neurovascular entrapment

Image credit:
Skaggs et al, Masters Techniques in Orthopaedic Surgery, Pediatrics, 2015
Surgical Treatment of Supracondylar Humerus Fractures

• Step 2:
  – Traction
  – Reduce in coronal plane
  – Check fluoroscopy

Image credit:
Skaggs et al, Masters Techniques in Orthopaedic Surgery, Pediatrics, 2015
Flynn et al, Lovell and Winters Pediatric Orthopaedics, 2014
Surgical Treatment of Supracondylar Humerus Fractures

- Step 3:
  - Correct rotation
  - Flexion maneuver w/ direct thumb pressure on distal fragment
    - Don’t be overly aggressive (iatrogenic type IV)

Image credit:
Skaggs et al, Masters Techniques in Orthopaedic Surgery, Pediatrics, 2015
Surgical Treatment of Supracondylar Humerus Fractures

• Step 4
  – Check transcondylar view
  – Verify reduction on lateral view
    • External rotation @ shoulder
    • Move the humerus!

Image credit:
Skaggs et al, Masters Techniques in Orthopaedic Surgery, Pediatrics, 2015
Surgical Treatment of Supracondylar Humerus Fractures

- **Step 5** –
  - Place percutaneous pins in the transcondylar view
  - Maximize divergence of the pins

Image credit:
Skaggs et al, Masters Techniques in Orthopaedic Surgery, Pediatrics, 2015
Surgical Treatment of Supracondylar Humerus Fractures

• Personal preferred technique:
  – Lateral only pins
    • Two lateral pins for type II
    • Three lateral pins for type III
Surgical Treatment of Supracondylar Humerus Fractures

- Step 6
  - Check pulse!
  - Do not leave OR until hand is well perfused
Scenarios after successful closed reduction & pinning

Pulse Intact

Pulse Gone, white hand

Pulse Gone, Pink hand?
AVOID THIS!
Pulseless but perfused after reduction: Observe?

Weller et al, JBJS 2013
• 54 pulseless type III supracondylar humerus fractures
• All underwent reduction & pinning

Diagram:
- 54 pulseless
  - Reduction & Pinning
    - 26 restored palpable pulse
    - 20 restored doppler pulse pink hand
    - 4 Unknown postop exam
    - 4 immediate vascular procedure
  - 19 regained palpable pulse
  - *1 deteriorated, required vascular exploration
Pulseless but perfused after reduction: Observe?

**SAFE : Pink, but dopplerable pulse afterwards - observe patients 24-48 hours**

### TABLE I Patients Requiring Vascular Surgery

<table>
<thead>
<tr>
<th>Patient</th>
<th>Postreduction Examination</th>
<th>Surgical Finding and/or Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient 1</td>
<td>Pink hand, no pulse detected with use of Doppler ultrasound</td>
<td>Intimal tear resected with primary repair; angiogram done</td>
</tr>
<tr>
<td>Patient 2</td>
<td>Brisk capillary refill, no pulse detected with use of Doppler ultrasound</td>
<td>Patch angioplasty with saphenous graft</td>
</tr>
<tr>
<td>Patient 3</td>
<td>Sluggish capillary refill; no pulse detected with use of Doppler ultrasound</td>
<td>Thrombose brachial artery; saphenous graft repair (interpositional)</td>
</tr>
<tr>
<td>Patient 4</td>
<td>Open fracture (Gustilo and Anderson grade II*); pink hand, no pulse detected with Doppler ultrasound</td>
<td>Brachial artery laceration with primary repair</td>
</tr>
<tr>
<td>Patient 5</td>
<td>Brisk capillary refill and normal (“triphasic”) Doppler velocity waveform initially; cool, pale hand 9 hrs postoperatively</td>
<td>Thrombose brachial artery; saphenous graft bypass (9 hrs after reduction)</td>
</tr>
</tbody>
</table>
Pulseless but perfused after reduction: How do they do?

Scanell et al, JBJS 2013

- 20 patients s/p CRPP for pulseless perfused SCH fx
  - Mean 20 months f/u

- Outcomes:
  - 7/20 (35%) – Early palpable pulse after reduction
  - 20/20 (100%) – **Palpable pulse at final follow up**
  - Duplex scan of brachial artery:
    - 14 patent
    - 6 occluded/stenotic
  - Clinical exam:
    - No difference in circumference, length, ROM, grip strength, muscle endurance compared to uninjured side
    - **3 osteonecrosis of trochlea, 1 distal humeral chondrolysis**
Pink Pulseless Hand – Other helpful tests?

- Bae et al: “We recommend surgical exploration in patients with pink pulseless hand if there is any evidence of altered perfusion (after CRPP) – ischemic pain, sluggish capillary refill, abnormal doppler signal)

- Adjuncts
  - Doppler for pulse
  - Pulse oximetry waveform?
Conclusion

• Observe pink pulseless hand 24-48 hours, with serial checks for compartment syndrome and vascular compromise
  – Be weary of nerve injury that mask a good examination

• Use best judgment to assess adequacy of perfusion
  – Doppler? Pulse Ox?

• Still need longer f/u and more objective ways to assess adequacy of perfusion
Lateral Humeral Condyle Fractures
Background

- 10-20% of pediatric elbow fractures
- Age 3-10
- Fall on outstretched hand
  - Push off mechanism
    - Radial neck pushes into it
  - Pull off avulsive mechanism
    - Between BR and ECRL
What’s Special About Lateral Condyle Fractures

• You can’t leave the bones untouched in the same room and expect a good outcome
  – INTRA-ARTICULAR Injuries

• Delayed Union / Nonunion doesn’t happen in kids...
  – Except sometimes in the.... LATERAL HUMERAL CONDYLE

Milch H, J Trauma 1964
Evaluation

• Neurovascular injury rare on initial presentation
  – Different from supracondylar

• Radiographs:
  – Internal oblique is CRITICAL for diagnosis
  • Often shows maximal displacement

AP (left) and Internal oblique (right) radiographs demonstrating maximal displacement on the internal oblique
Know how to interpret PEDIATRIC Xrays
Classification

*Weiss classification* simpler, most prognostic of complications

Type I: < 2 mm displacement

Type II: 2 – 4 mm displacement with intact cartilage

Type III: ≥ 4 mm displacement with articular incongruity.

Image credits
Weiss et al, JPO 2009
Treatment Type I

- Type I (<2 mm maximal displacement)
  - Chance for displacement with immobilization
    - Wide range 0-18% (Knapik et al JPO 2017; Greenhill et al JPO 2019)
    - Check post casting xray in 1-2 weeks!
    - Can take a long time to heal!!!
Treatment Type II

- Type II (2-4 mm maximal displacement)
  - Attempt closed reduction
  - Confirm with arthrogram
  - Place pins or screw
  - Be ready to open
Percutaneous Treatment Type II

5 y/o M
Percutaneous Treatment Type II

How to perform arthrogram: Direct posterior approach
Joint surface OK. Reduce with Valgus force & thumb pressure
Percutaneous Treatment Type II

Place pins
Open Treatment Type II

6 y/o F
Open Treatment Type II
Open Treatment Type II

Periosteum in Fracture Site
Treatment Type III

- Type III (>4 mm maximal displacement)
  - Open reduction
  - Get the joint perfect
Open Reduction - Steps
• Between wrist extensors
• Traumatic dissection already done, open with...
• Dissect anteriorly enough to expose joint surface
• Place hohman or bennett under brachialis
Caution!

- No need to aggressively dissect the fractured fragment
- Just enough to see anterior joint surface
- Preserve posterior blood supply

Adapted from Yamaguchi K, JBJS 1997
Adapted from Jakob et al; JBJS Br 1975
• Don’t worry about mild lateral gap if joint is perfect
• Always some mild deformation laterally
Optimal Fixation for Lateral Condyle Fractures

Two divergent pins @ 60 degrees, or three pins

Prognosis & Complications

• Mean time to union ~6.5 weeks

• 10-16% clinically significant complication rate in lateral condyle fractures

• Stiffness ROM >15 degrees
  – Up to 15.6% (Sinikumpu et al, Int Orthop 2017)
  – Mean 12 yr follow up
    • ALL Mayo elbow functional scores Excellent or Good
Prognosis & Complications

- **Delayed union**
  - 11-16% (Salgueiro et al, JPO 2017)
  - Increased risk if increased intraoperative residual displacement

- **Nonunion**
  - Up to 3% (Pace et al; JPO 2018)

These only happen if you
1) Failed to diagnose initial injury
2) Did not follow fracture to healing
3) Did not act on an impending nonunion
Treatment of Chronic Nonunion

- **Cubitus Valgus / Severe Deformity?**
  - No → In situ bone graft & screw
  - Yes → In situ bone graft & screw + supracondylar osteotomy
Complication? This **Always Happens**

- Lateral spurring
  - Occurs in 73% (Pribaz et al, JPO 2012)
  - Does not cause functional or ROM deficit
Lateral Condyle Fracture Summary

• Avoid missed diagnosis
  – Internal oblique radiograph

• Avoid malreduction
  – Low threshold for open reduction

• Avoid nonunion
  – Follow until clinical union
  – Place a screw if robust healing not occurring by 2 months & still tender

• Avoid AVN
  – Don’t dissect posterior aspect of fracture fragment

• Avoid parental lateral bump concern
  – Explanation preop always looks better than making excuses postop
Prevention of Injury

• ED Visits for Elbow Fracture

• Why summer?
  – Active! Play!

Shah A et al, Understanding the Epidemiology of Pediatric Supracondylar Humeral Fractures in the United States: Identifying Opportunities for Intervention, JPO 2018
Prevention of Injury

• Trampoline Safety
• Bunk Bed Safety
• Monkey bars
Questions?