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:

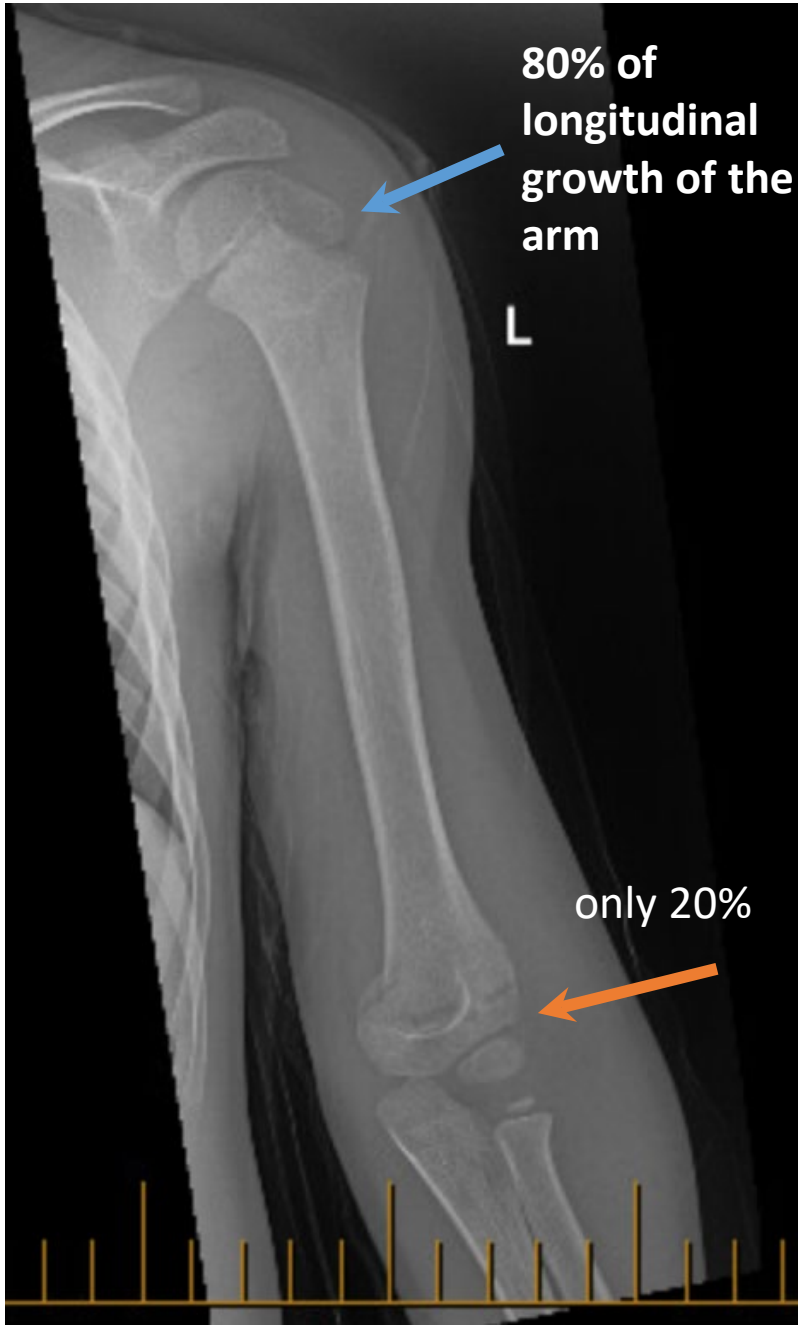
- Recognize the signs and symptoms of more severe pediatric supracondylar humerus fractures (SCHF)
- Assess the degree of displacement of pediatric SCHF on radiographs
- Determine the type of fracture according to the modified Gartland classification
- Prescribe appropriate treatment for SCHF based on 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



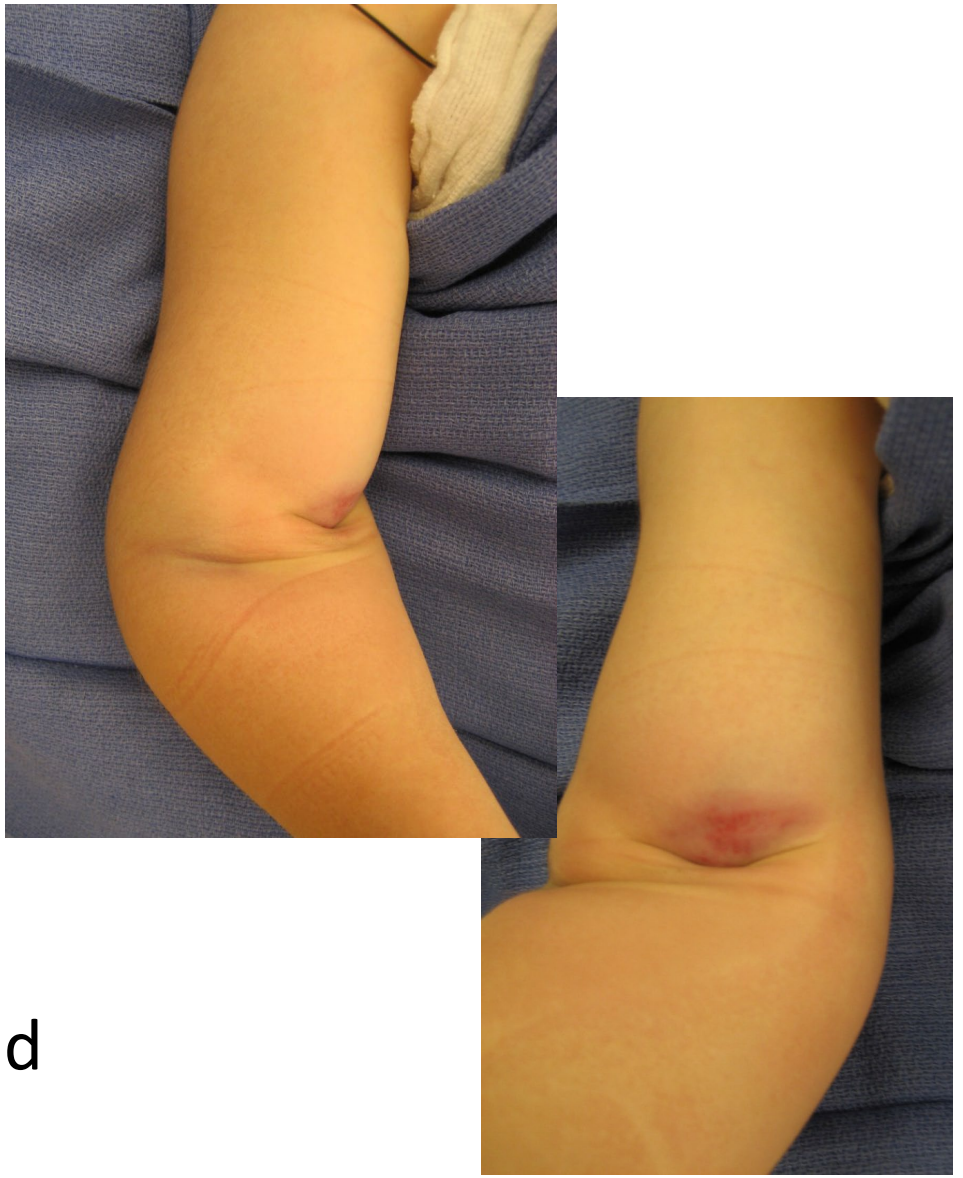
PHYSICAL EXAM

- 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)

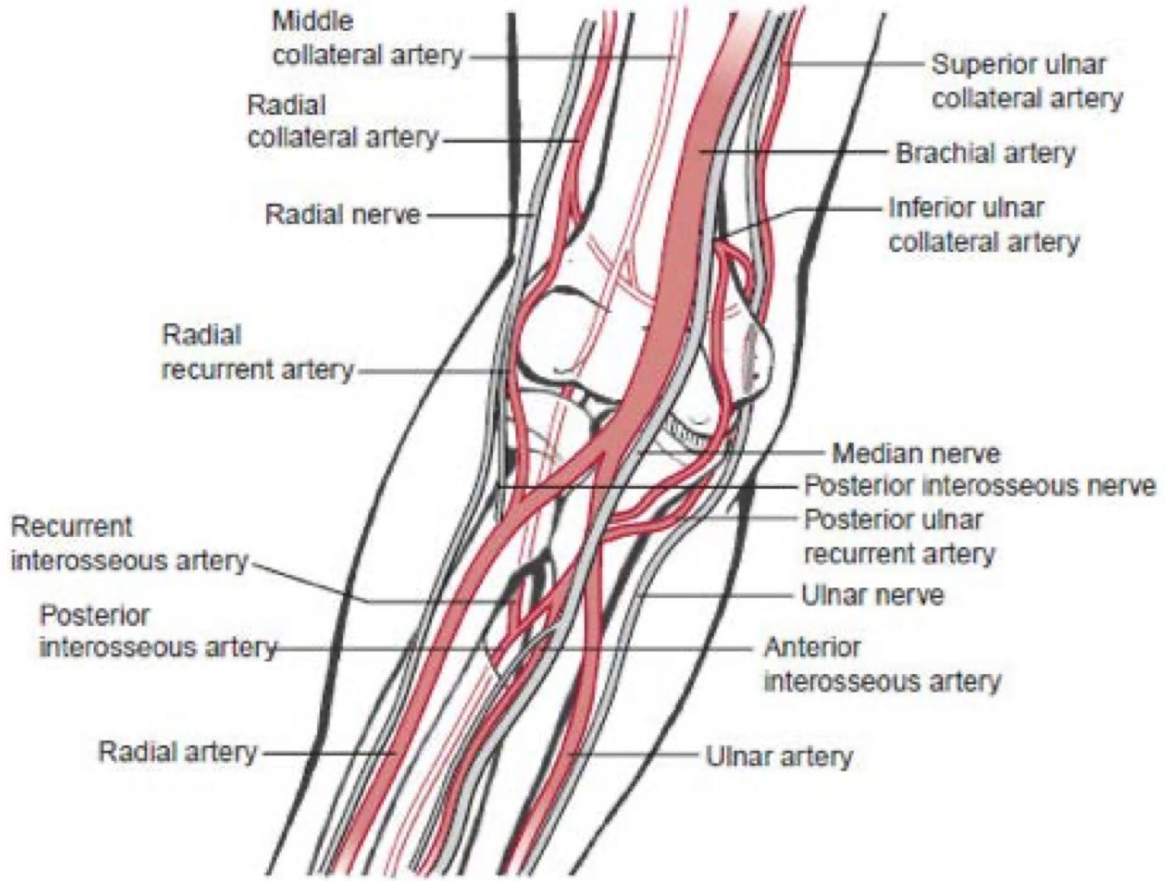


Courtesy of Mark Sinclair, MD

NEUROVASCULAR EXAM

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

Neurovascular structures around the elbow



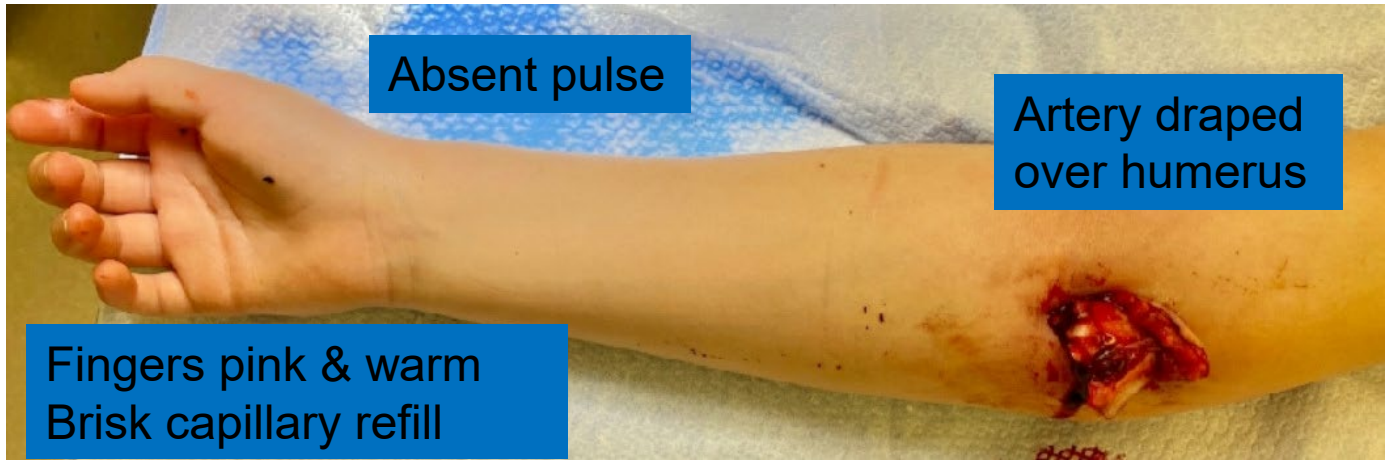
Rockwood and Green, Fig 33-7

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



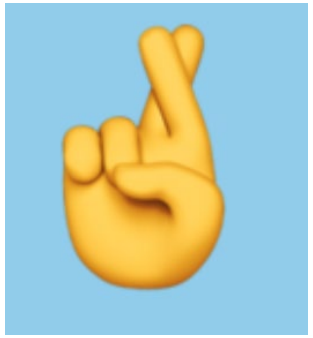
Courtesy of Micah Sinclair, MD

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

Nerve Injuries		
	EXTENSION TYPE	FLEXION TYPE
Total Percentage	12.7%	16.6%
Median N	3.3% (21.3%)	5.1% (8.7%)
AIN	5.3% (34.1%)	0%
Radial N	4.5% (26.6%)	0%
PIN	1.1% (2.0%)	0%
Ulnar N	2.3% (15.8%)	16.6% (91.3%)

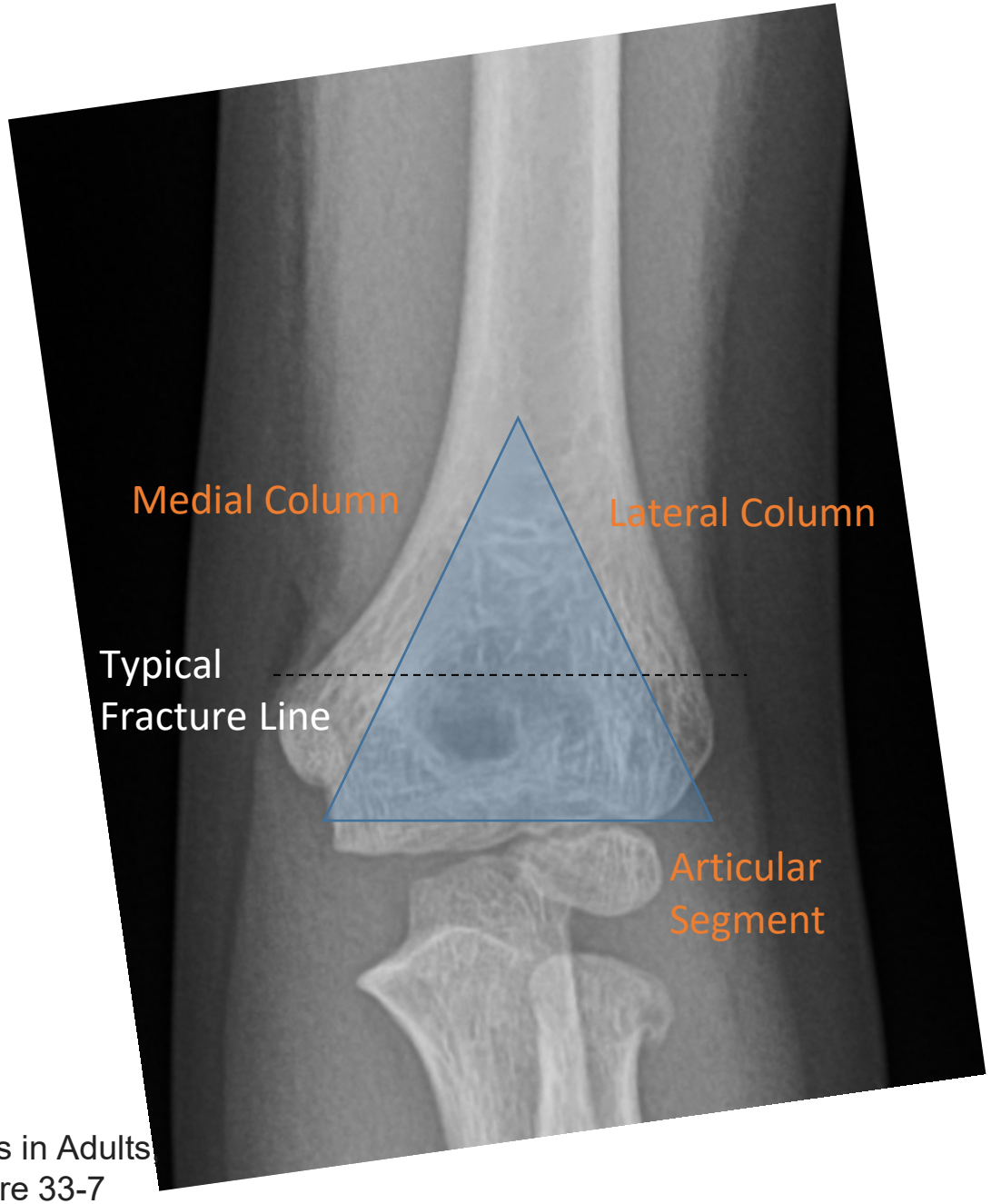
- RISK FACTOR:
  - Median N/AIN: posterolateral displacement
  - Radial N: posteromedial displacement
  - Ulnar N: flexion types

Babal JC, et al. JPO 2010

OSTEOLOGY

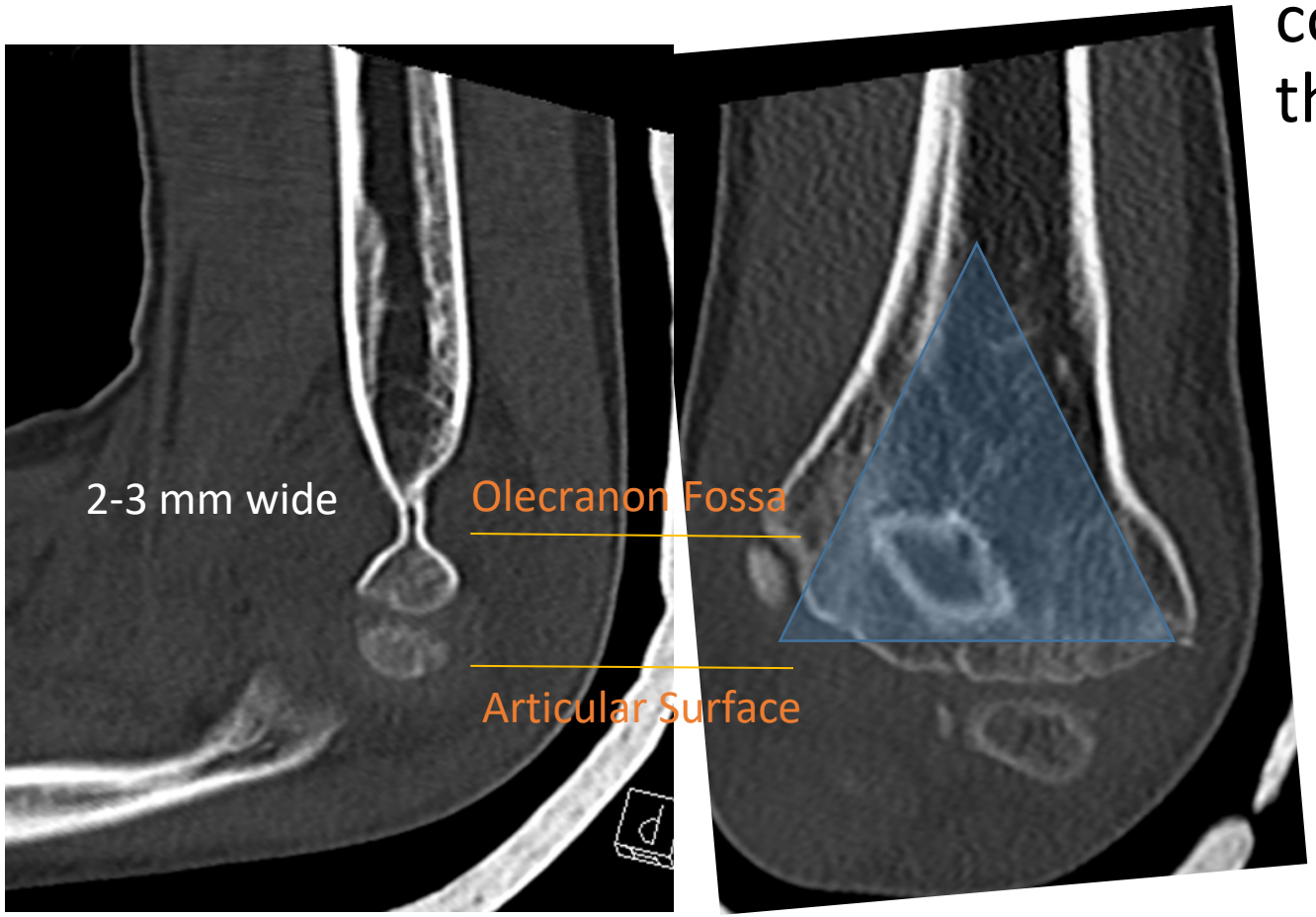
- Distal humerus composed of medial and lateral columns connected by the articular segment

- 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

OSTEOLOGY

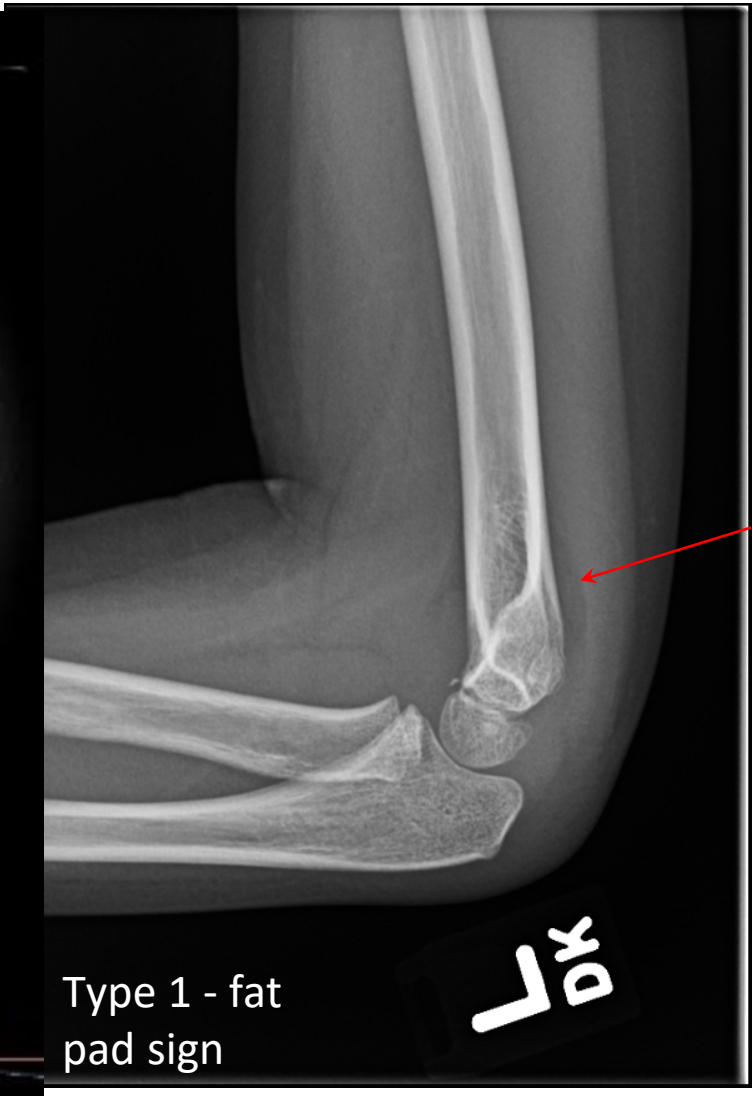


- Medial and lateral columns connected by a thin wafer of bone through olecranon fossa
  - Point of weakness, prone to fracture
  - Muscles lose mechanical advantage when elbow extended past neutral (hyperextension common in children)
  - Olecranon acts as a fulcrum
  - Capsule transmits an extension 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)

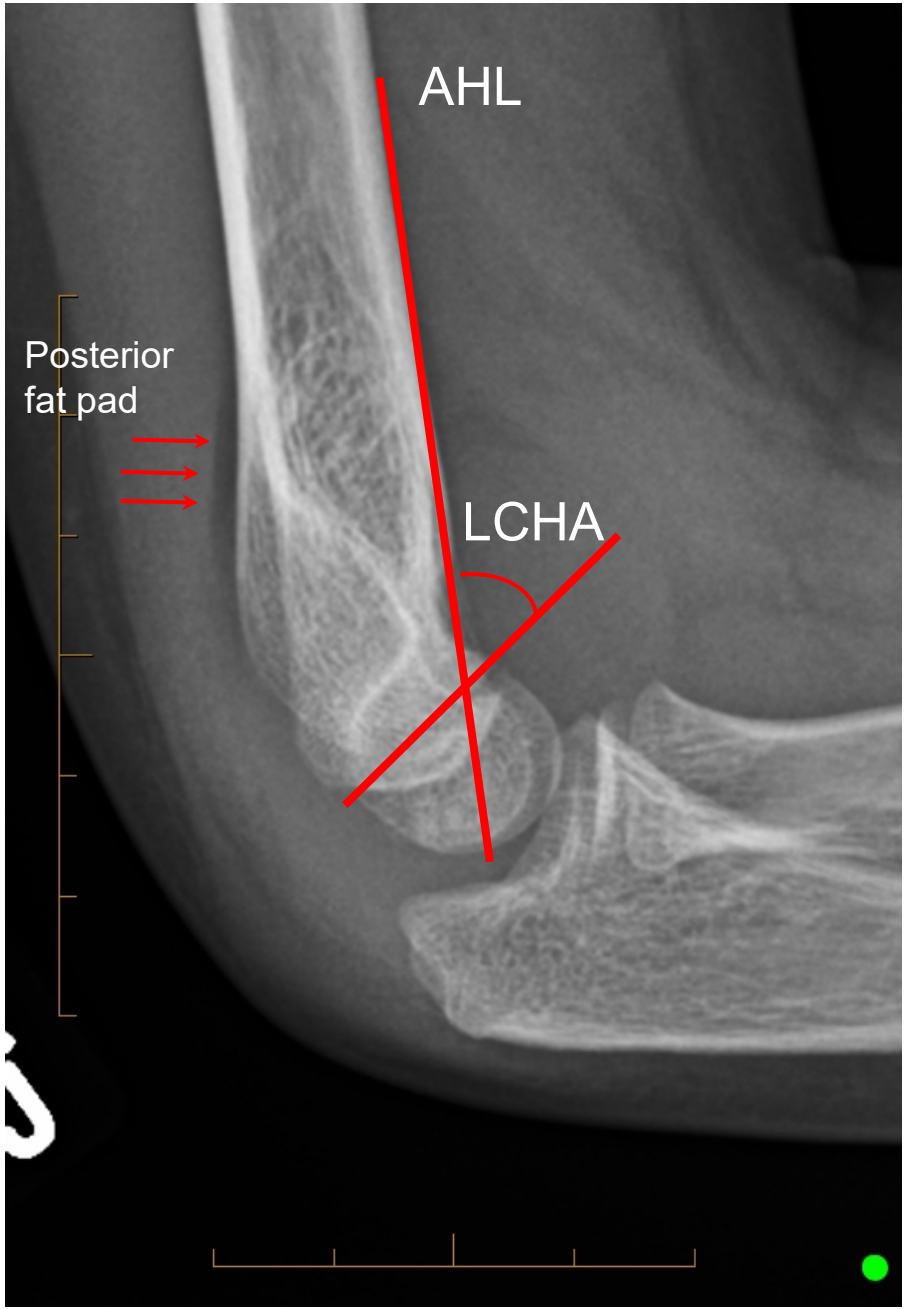
Type 3


Type 1 - fat pad sign

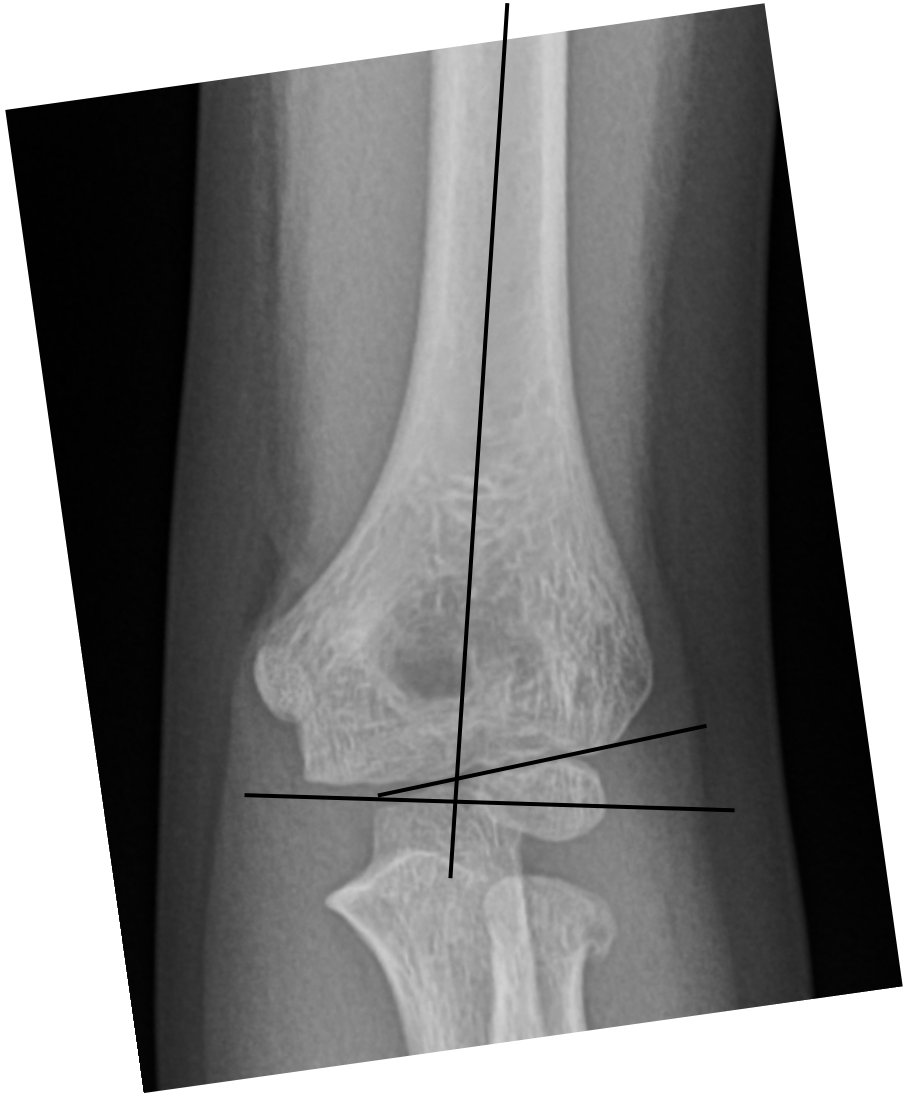
IMAGING

Distal humerus alignment (true lateral):

- Anterior humeral line (AHL): should intersect capitellar ossific nucleus
- Anterior tilt of capitellum (30-40º)
  - Lateral capitellohumeral angle (LCHA)→<69º
- Posterior fat pad sign (highly suggestive of fracture whereas anterior fat pad sign can occur without fracture)



IMAGING



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)

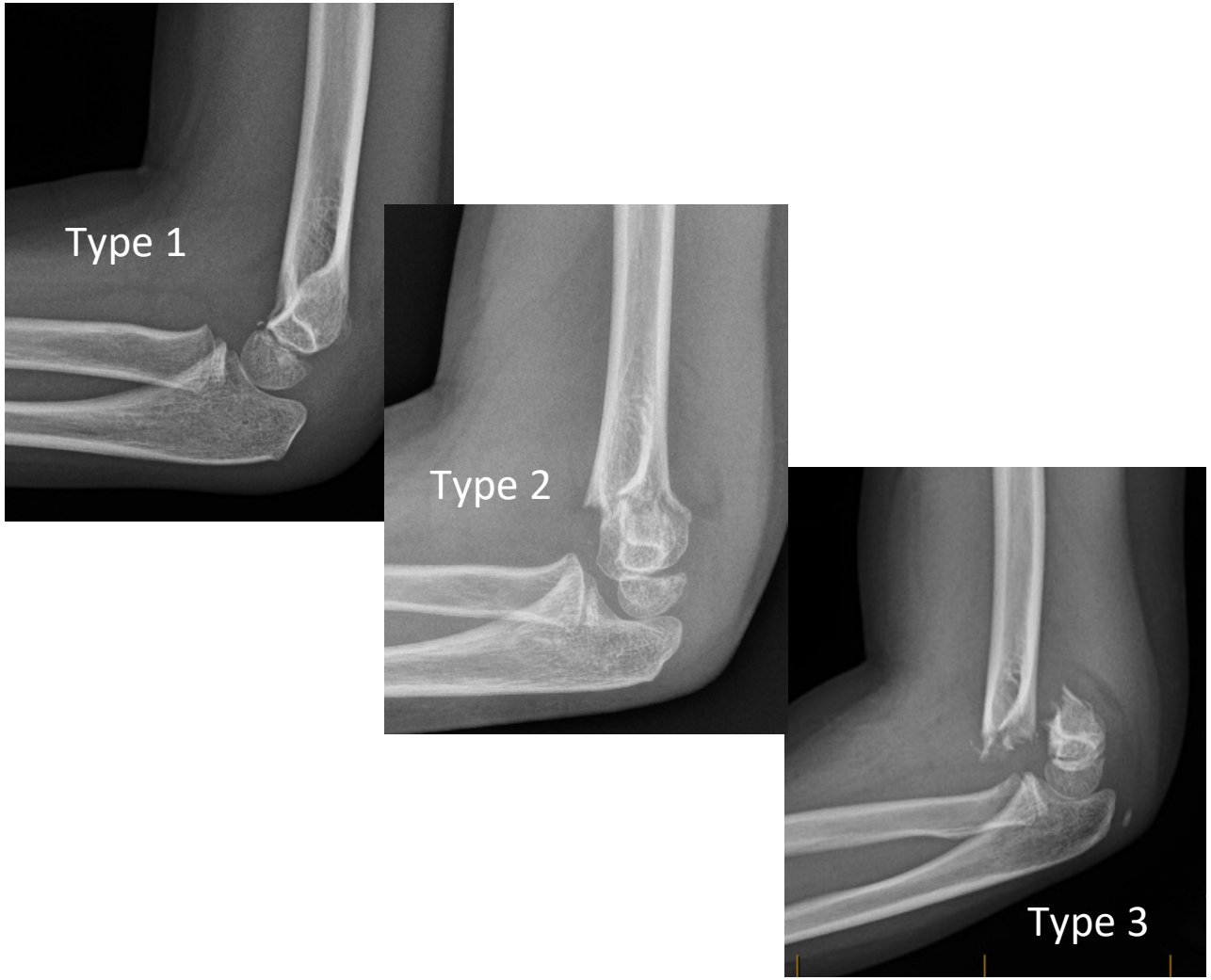
95-98%
FOOSH

  - Flexion: Considered seperately

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



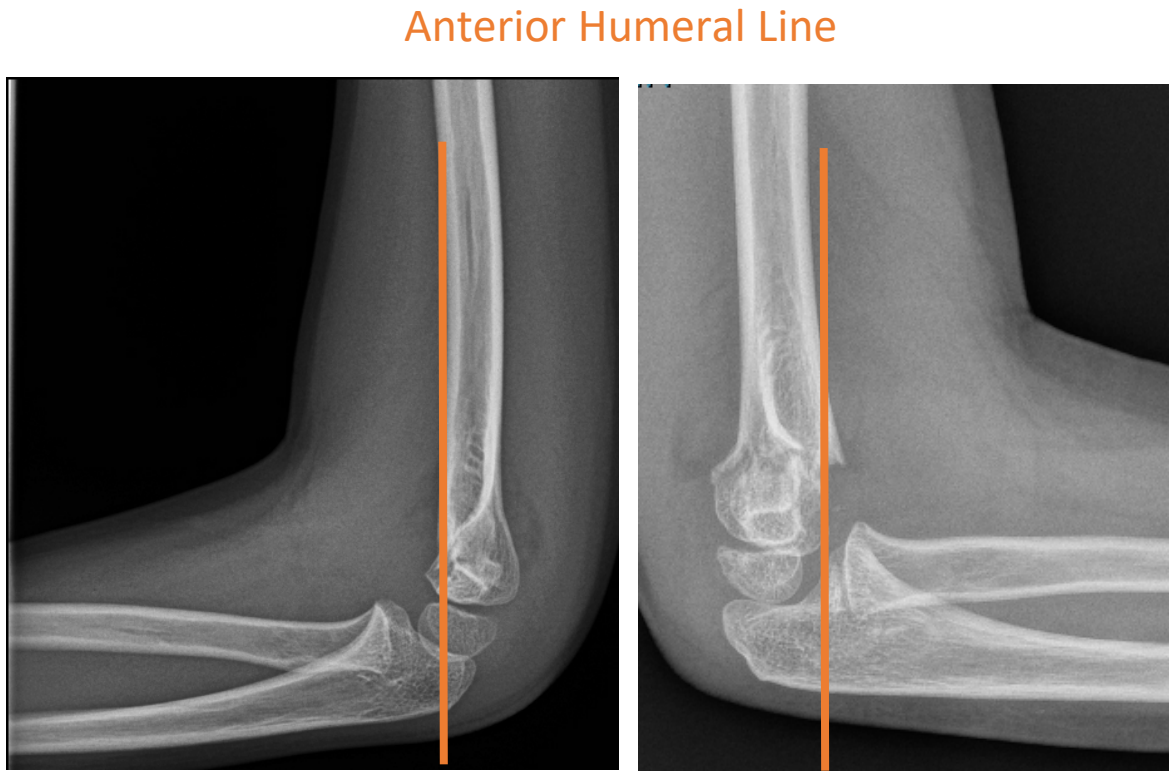
GARTLAND CLASSIFICATION

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

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

GARTLAND CLASSIFICATION

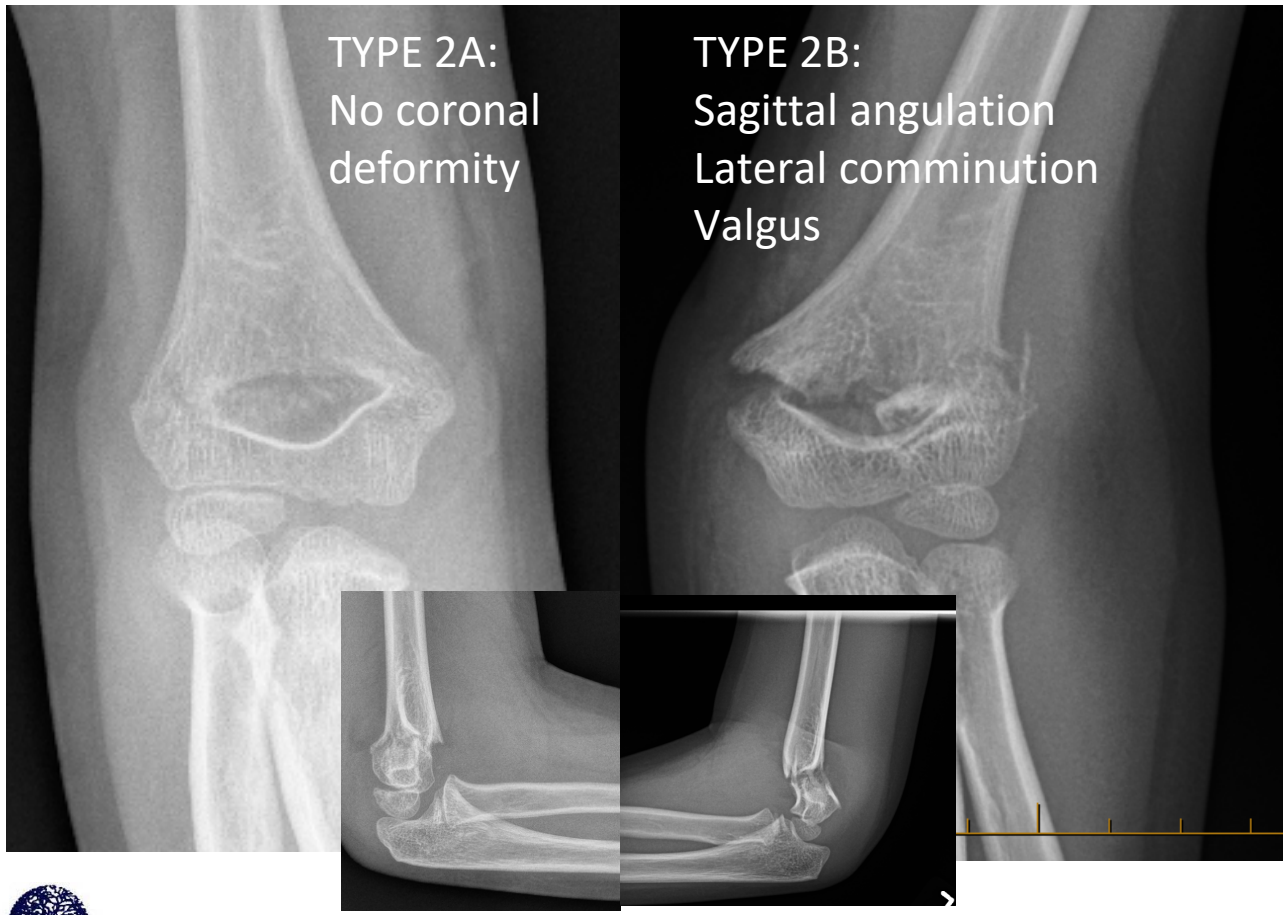
- Type 2:
  - Sagittal angulation
  - Posterior hinge intact
  - If anterior humeral line (AHL) does not intersect at least anterior 1/3rd of capitellum can require CR +/- PP



LAC ok

Needs CR

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
  - Recomend CRPP

MODIFIED GARTLAND CLASSIFICATION

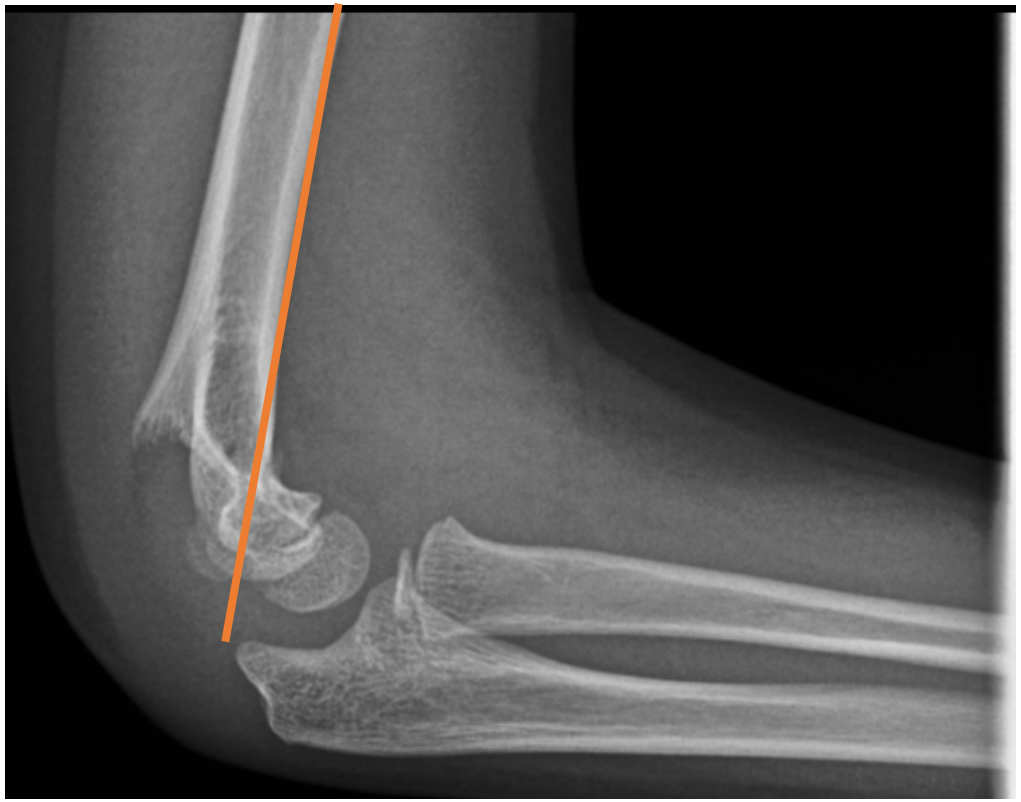
- Type 3:
  - Complete posterior displacement
  - Loss of posterior hinge
  - Maintains periosteal sleeve
- Type 4:
  - Instability in extension and flexion
  - Disruption of periosteal sleeve
- Type 3 vs. 4 based on fluoroscopic examination with patient under anesthesia

  --> intraoperative distinction

FLEXION TYPES

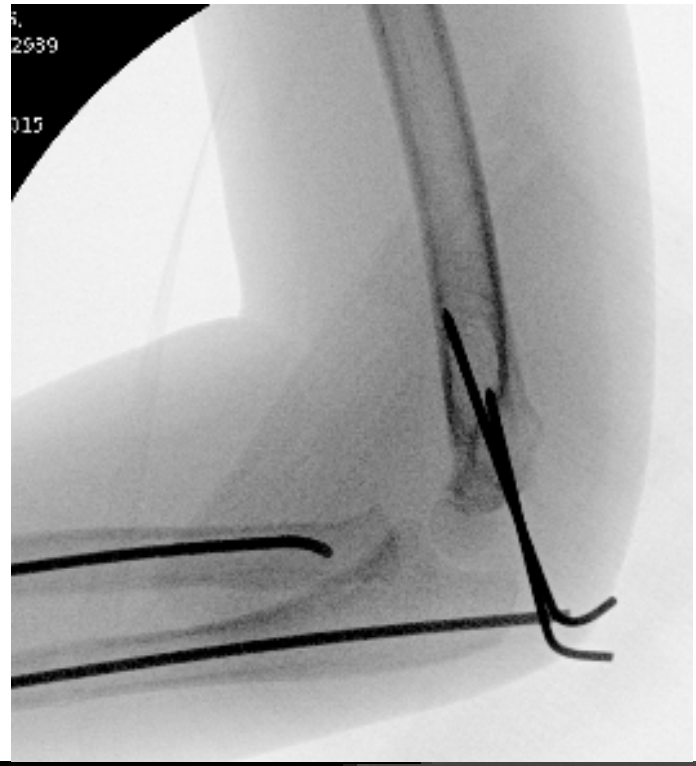
- Generally more unstable
- Higher complication rates
- Association with ulnar nerve palsy

- 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



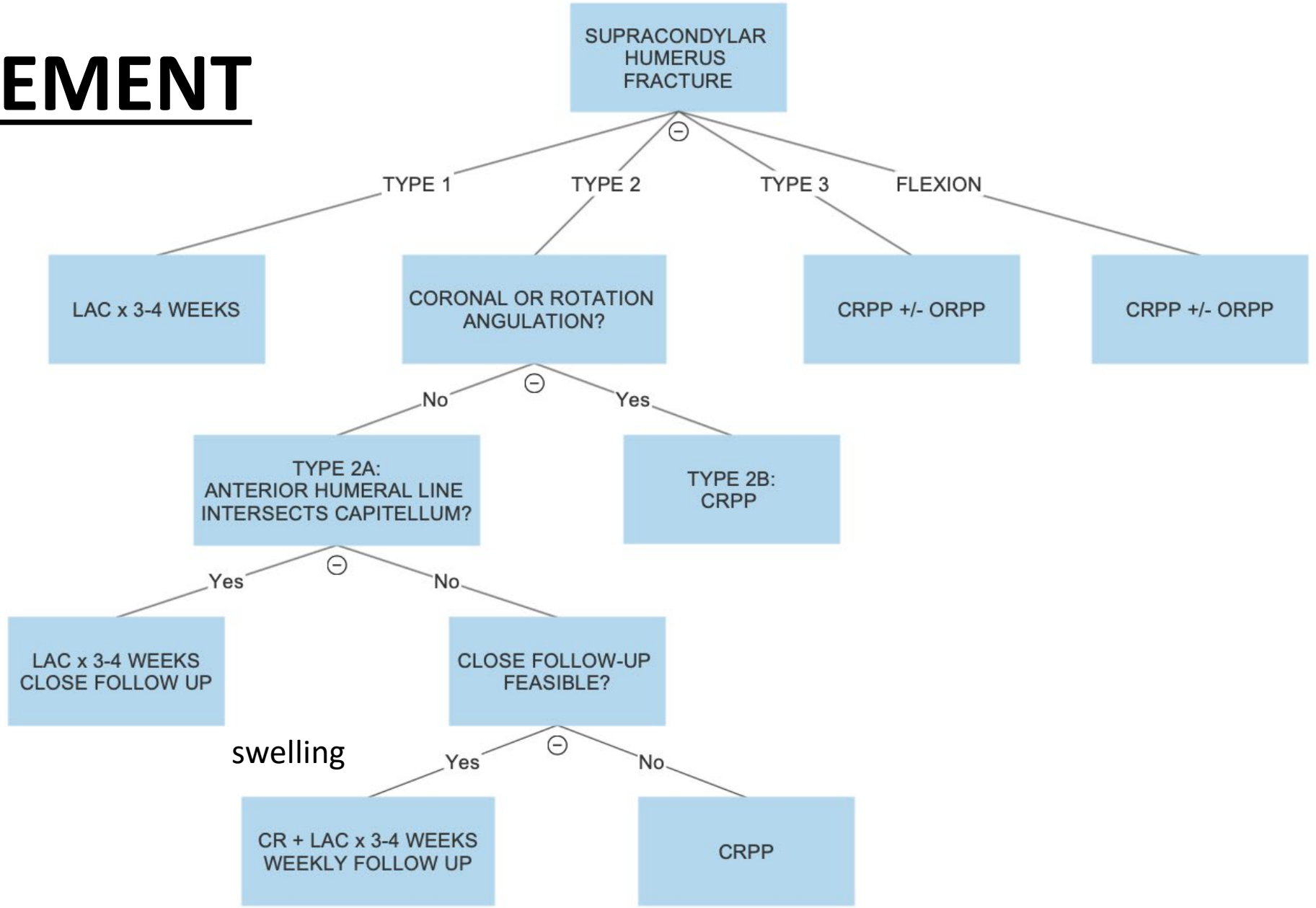
Baghdadi et al. JPO 2020

Lucas DE, et al. JOT 2013

MANAGEMENT

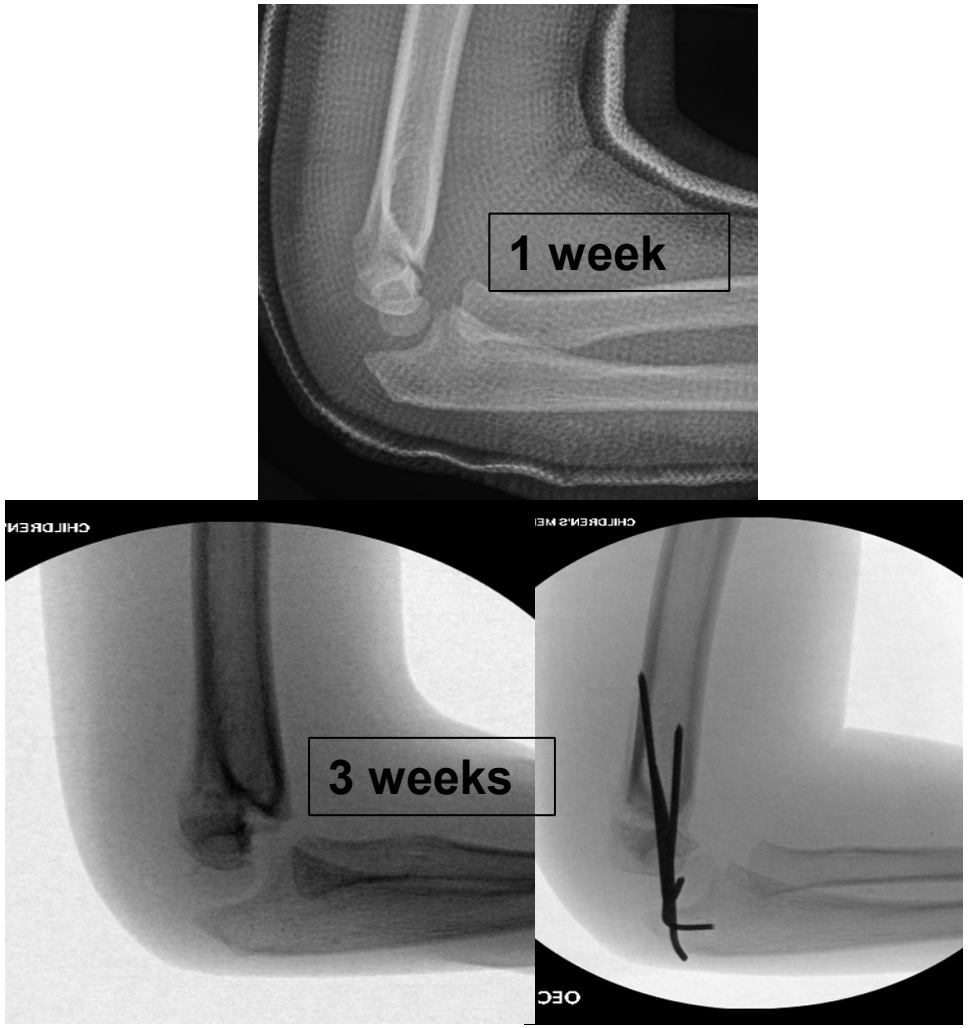
- AAOS adopted appropriate use criteria (AUC) for the management of:
  - Pediatric supracondylar humerus fractures (2014)
  - Pediatric supracondylar humerus fractures with vascular injury (2015)
- Can be referenced in the treatment of a pediatric supracondylar humerus fracture.

MANAGEMENT


SUPRACONDYLAR HUMERUS FRACTURE
TYPE 1
TYPE 2
TYPE 3
FLEXION
LAC x 3-4 WEEKS
CORONAL OR ROTATION ANGULATION?
CRPP +/- ORPP
CRPP +/- ORPP
No
Yes
TYPE 2A: ANTERIOR HUMERAL LINE INTERSECTS CAPITELLUM?
TYPE 2B: CRPP
Yes
No
LAC x 3-4 WEEKS CLOSE FOLLOW UP
CLOSE FOLLOW-UP FEASIBLE?
swelling
Yes
No
CR + LAC x 3-4 WEEKS WEEKLY FOLLOW UP
CRPP

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)



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

over 21 hours in some studies

- Fractures with distal neurologic deficits are more controversial
  - May indicate more significant injury with increased risk of complications with delayed surgery

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?

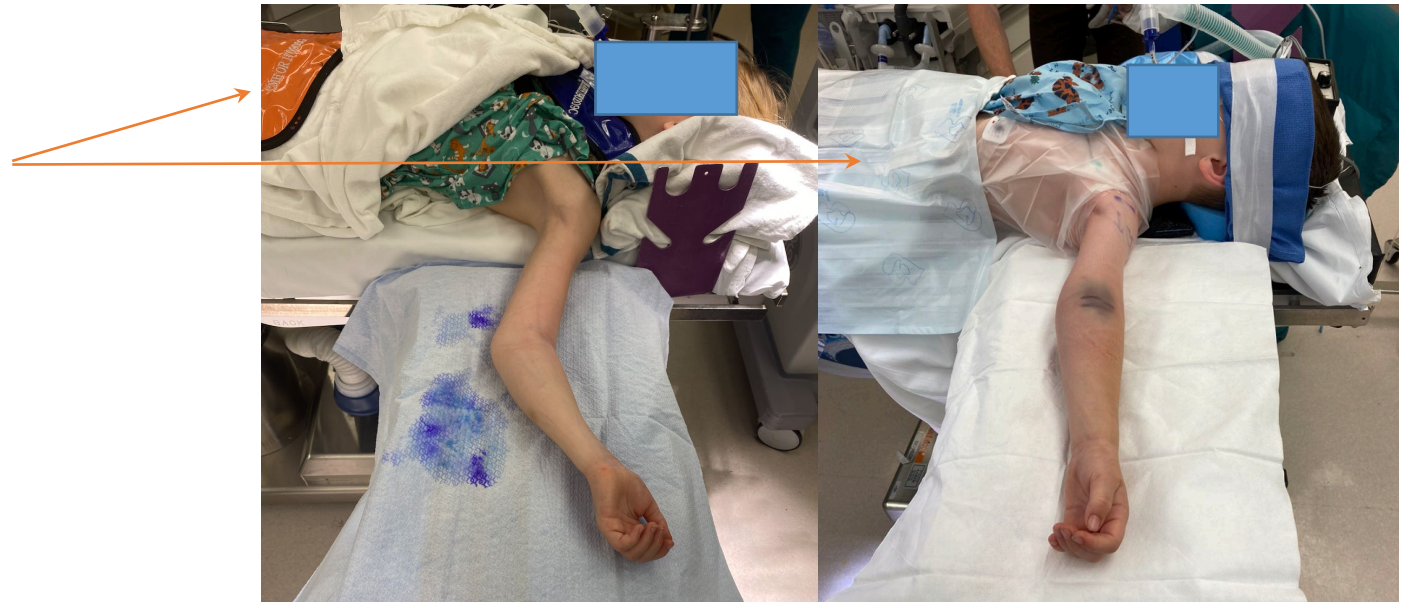
CLOSED REDUCTION AND PERCUTANEOUS PINNING SCHF

- https://otaonline.org/video-library/45036/procedures-and-techniques/multimedia/17165284/closed-reduction-percutaneous-pinning-of-a

- TECHNIQUE VIDEO with case example

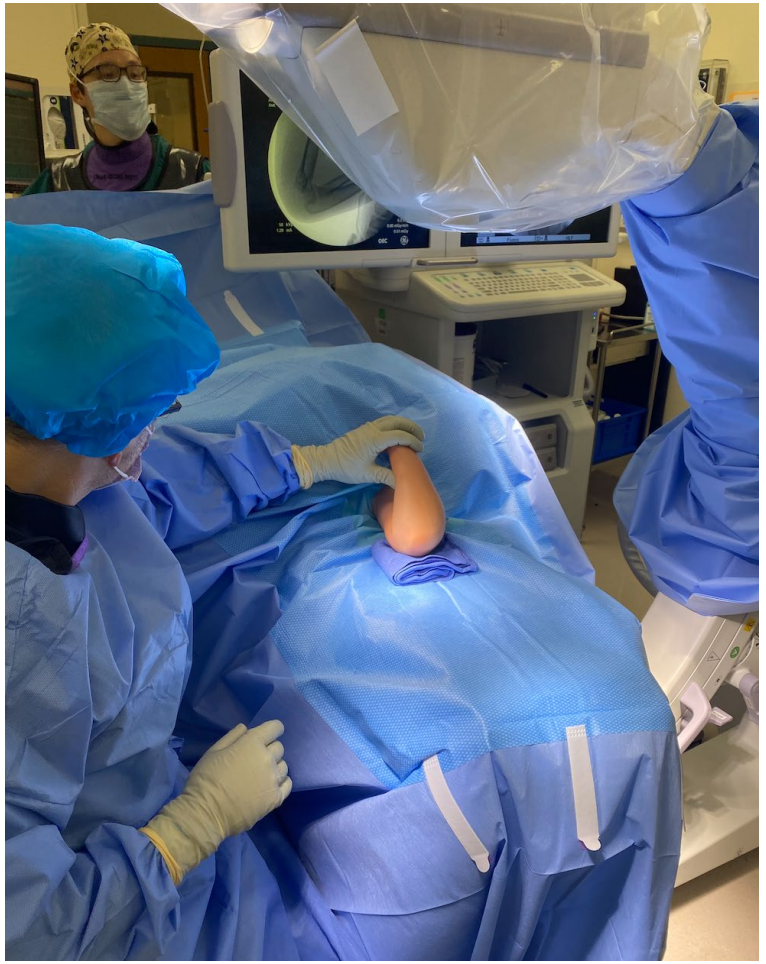
OR SETUP

- 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

Courtesy of Mark Sinclair, MD

Archibeck. J Pediatr Orthop. 1997

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

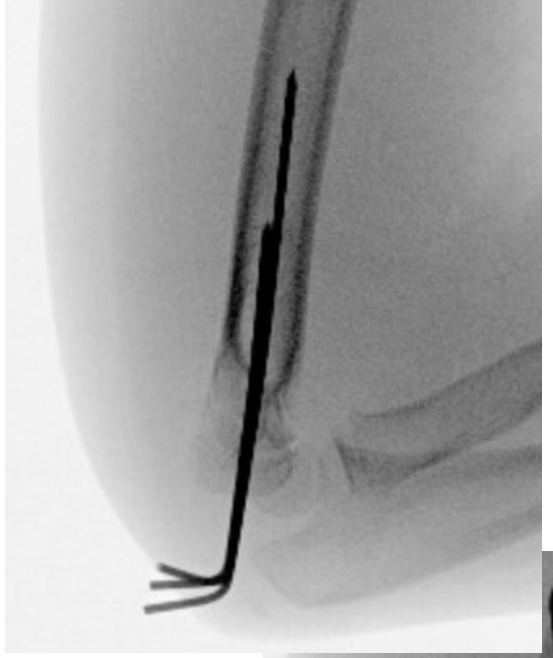
ex: Type 4 and Flexion Types

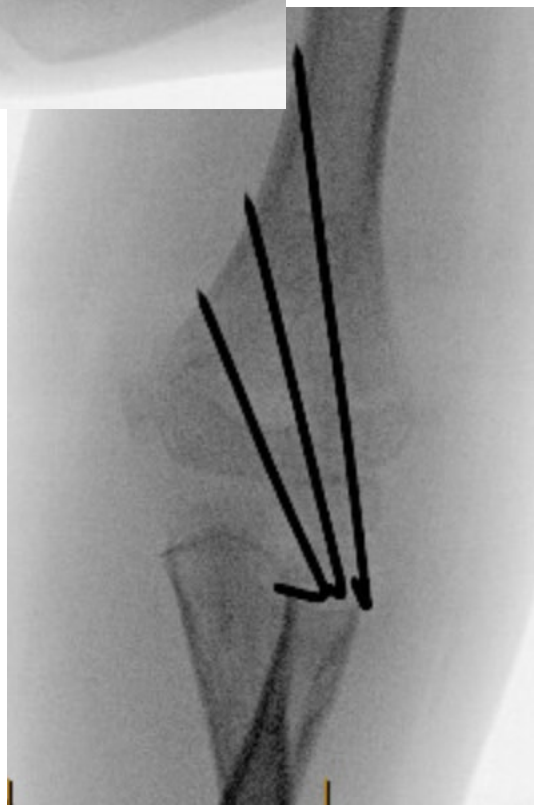
- Swing through laterals to avoid rotating through elbow
  *advantage of using arm board
- Bump underneath the proximal fragment
- Lessen elbow flexion and/or apply posteriorly directed force to distal segment through forearm

- 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



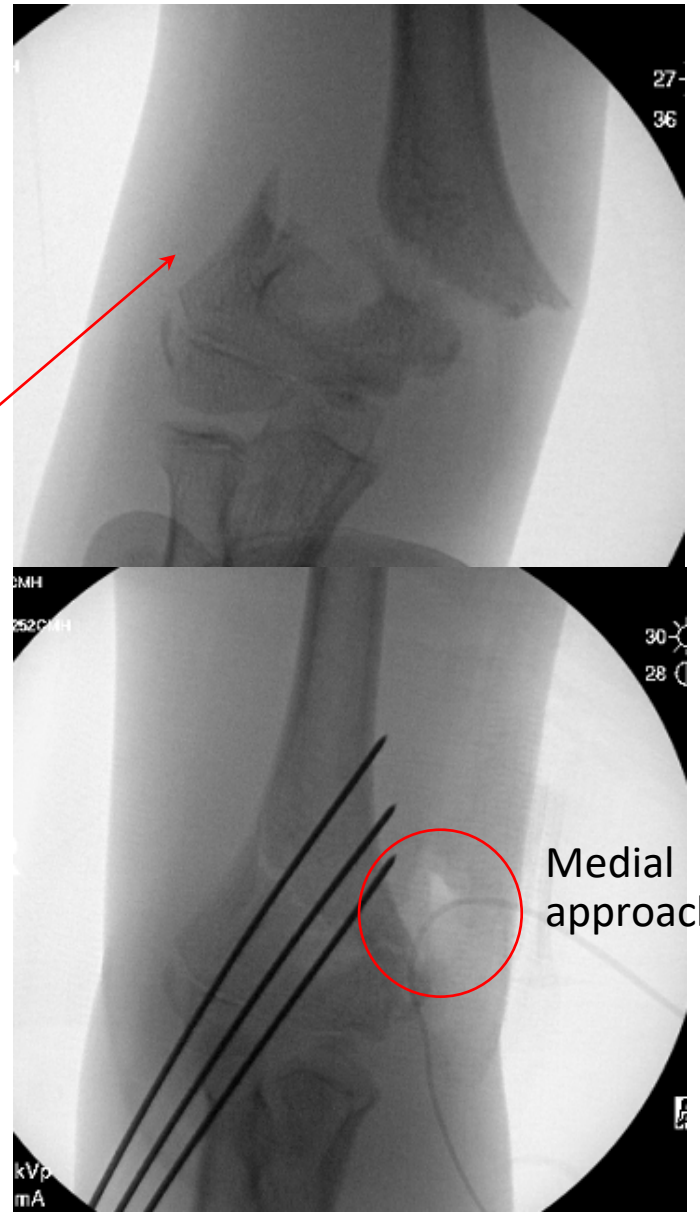


OPEN REDUCTION

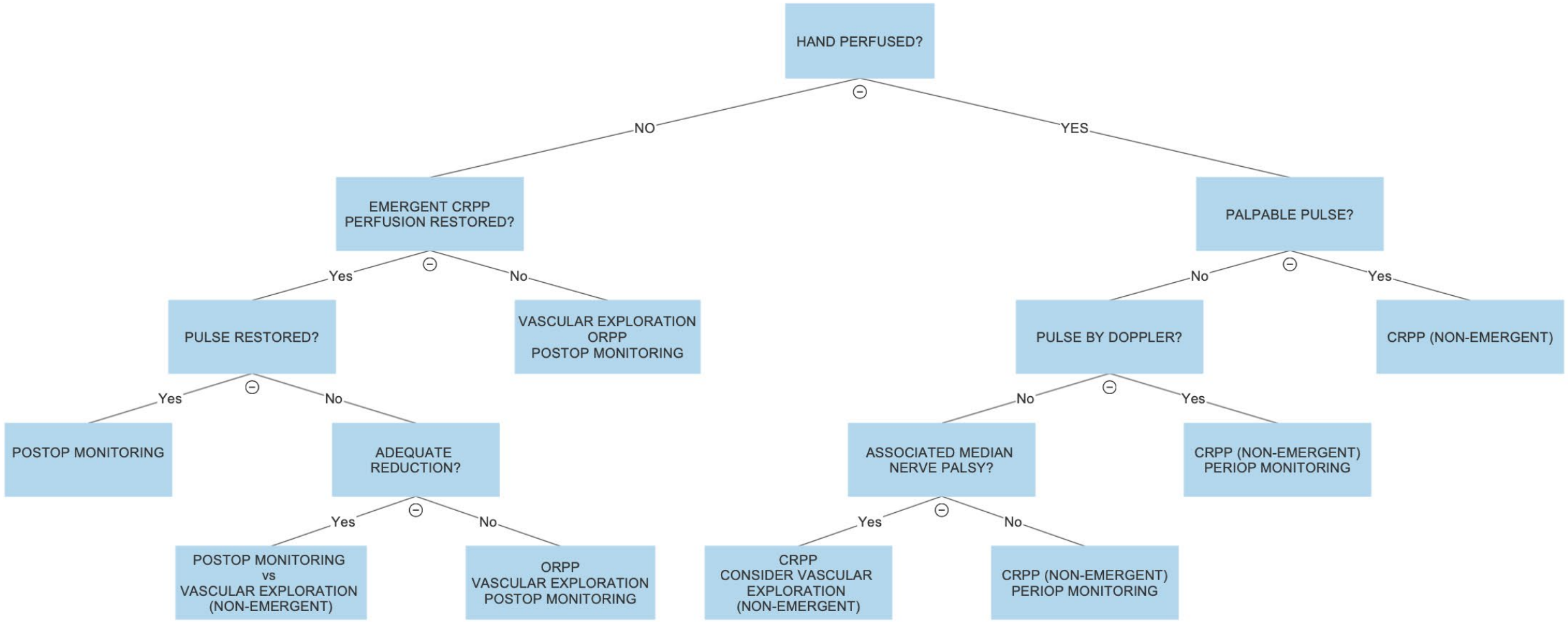
- Variable rates in literature: 1-10%
- Indications:
  - Unable to achieve acceptable alignment
    - Association with posterolateral displacement
    - Flexion types
  - Open fracture
  - Vascular exploration required

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



MANAGEMENT OF VASCULAR INJURIES



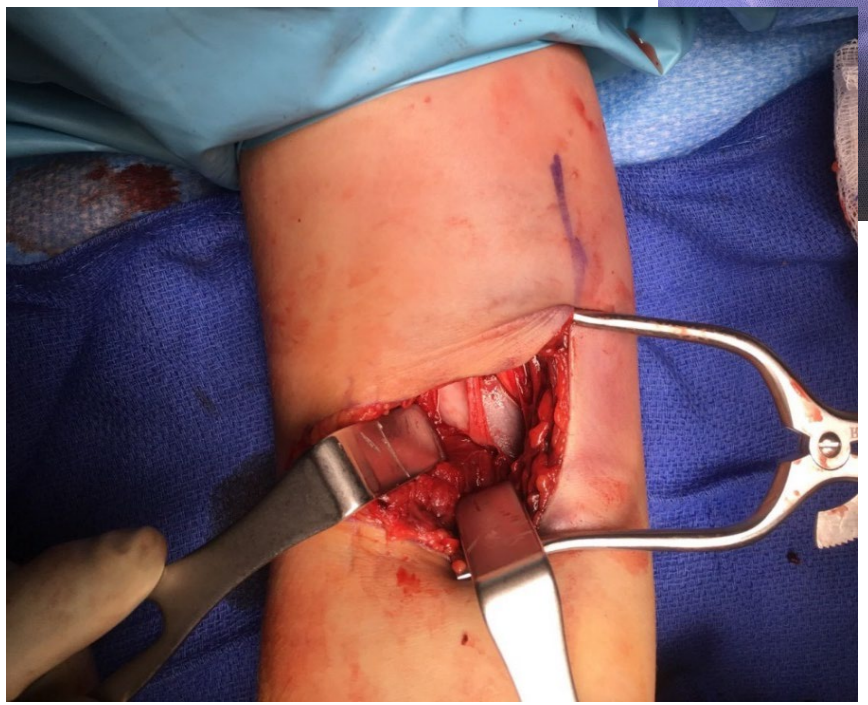
VASCULAR INJURY

- 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

Weller A et al. J Bone Joint Surg Am 2013

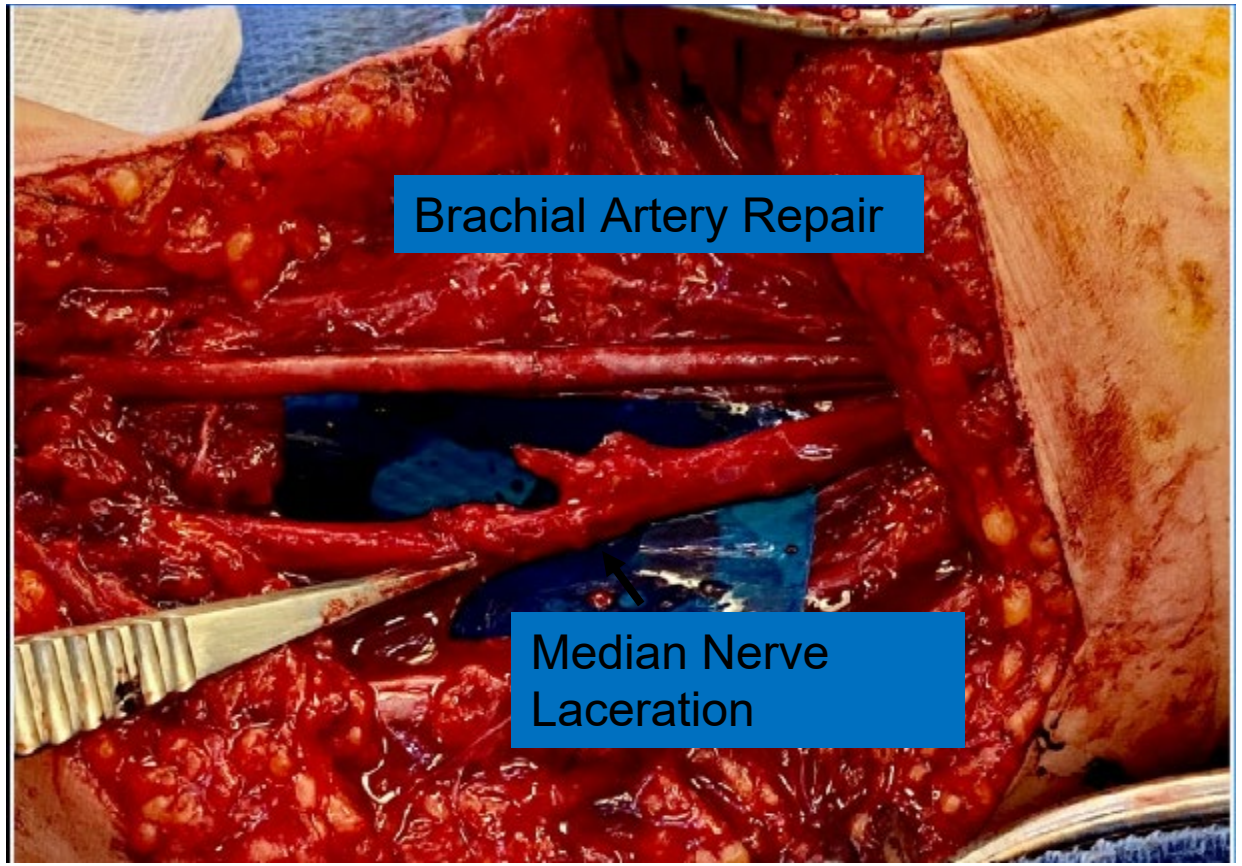
VASCULAR EXPLORATION

- 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



Courtesy of John Anderson, MD

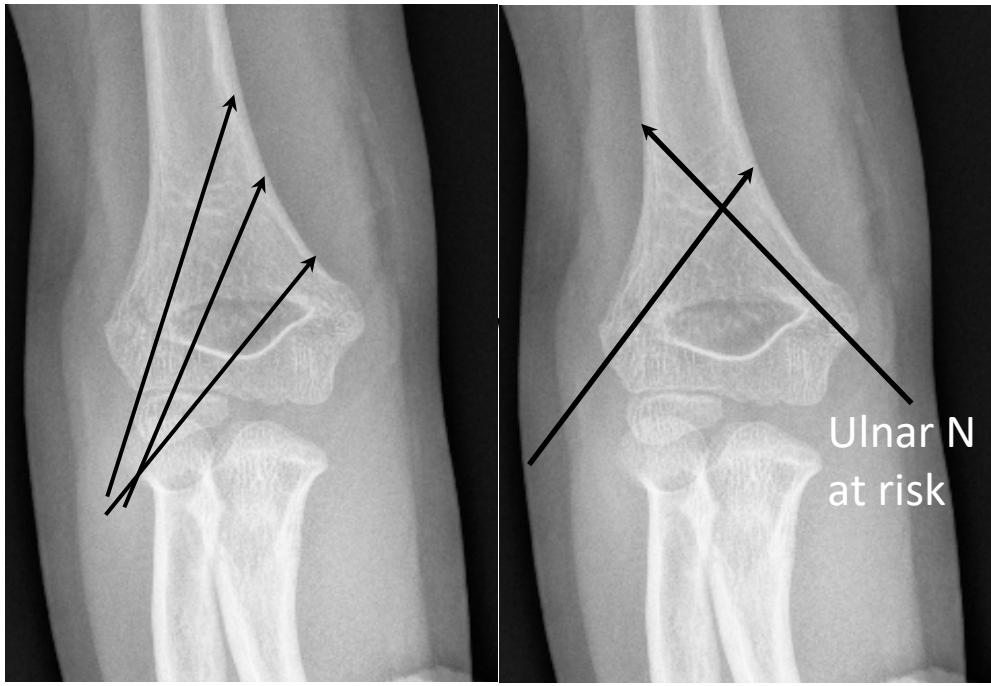
NEUROVASCULAR REPAIR



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



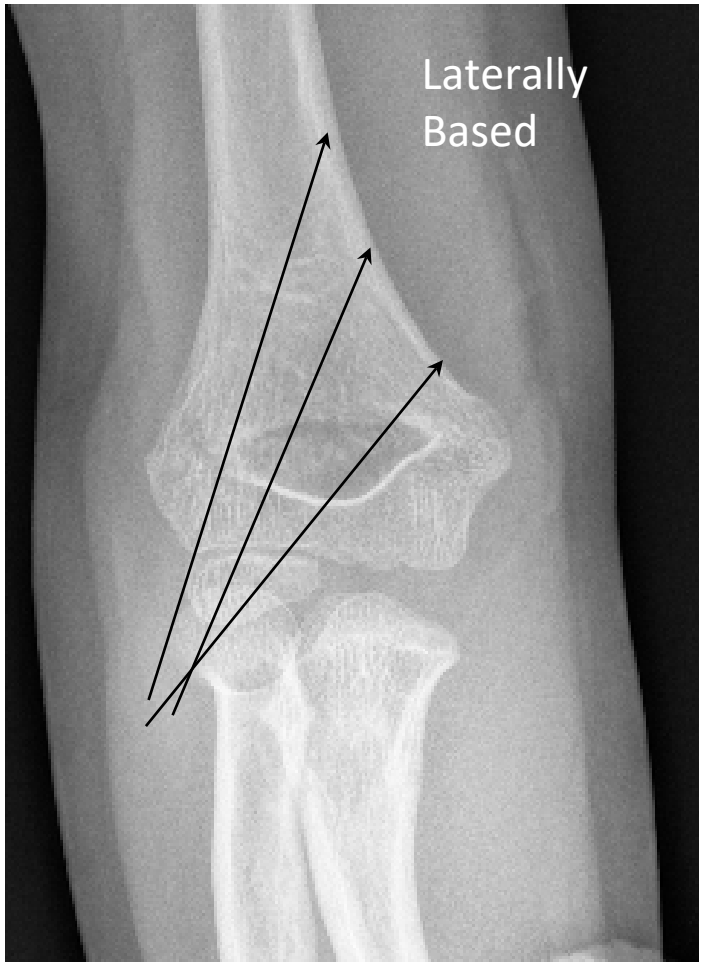
Shenoy et al. Cureus 2020

PIN CONFIGURATION OPTIONS

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

NB: Antegrade ESIN technique also described but less common

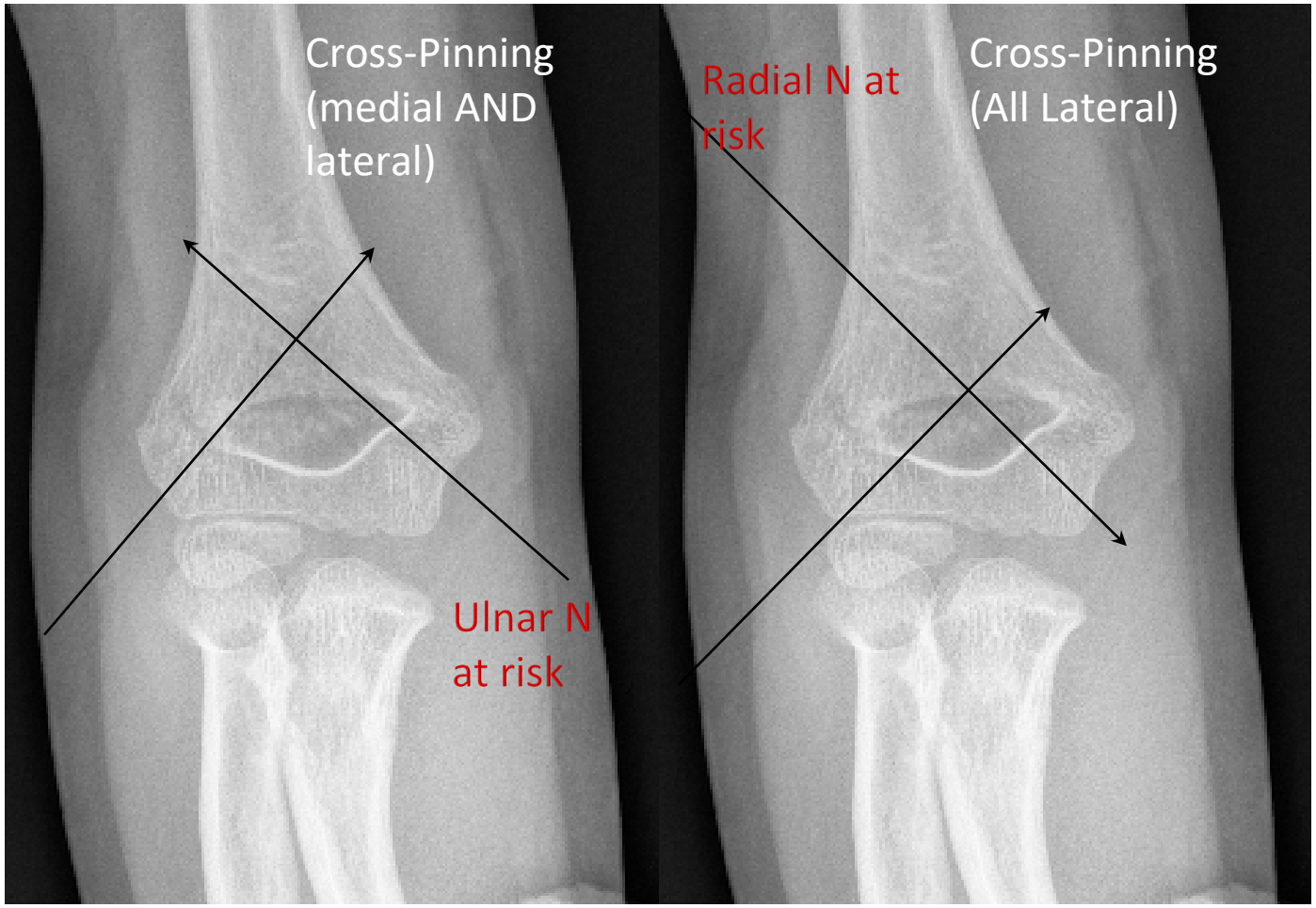
- High SCH fx



Shenoy et al. Cureus 2020

PIN CONFIGURATION OPTIONS…

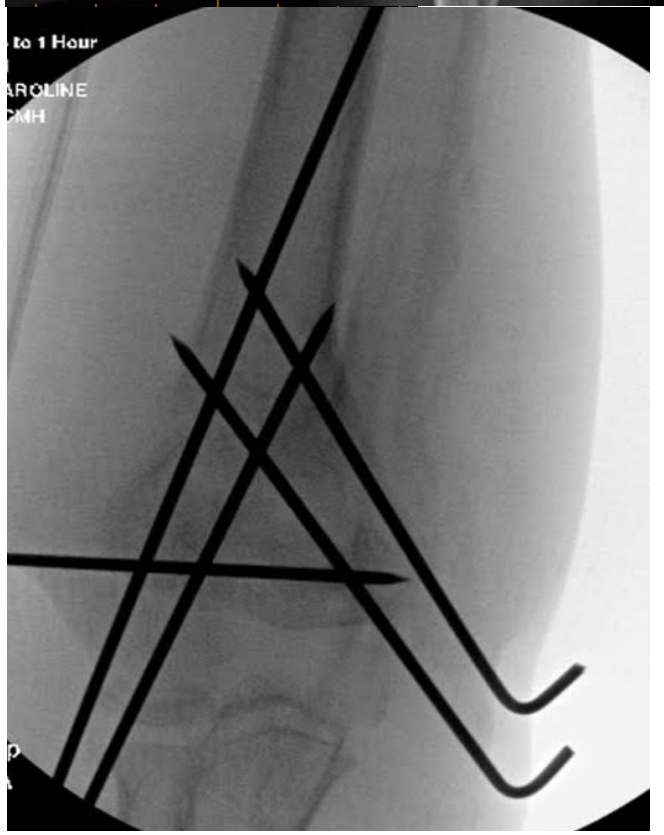
- Cross-pinning
  - Medial and Lateral
    - Ulnar nerve at risk
  - All-Lateral
    - Radial nerve at risk



Shenoy et al. Cureus 2020

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

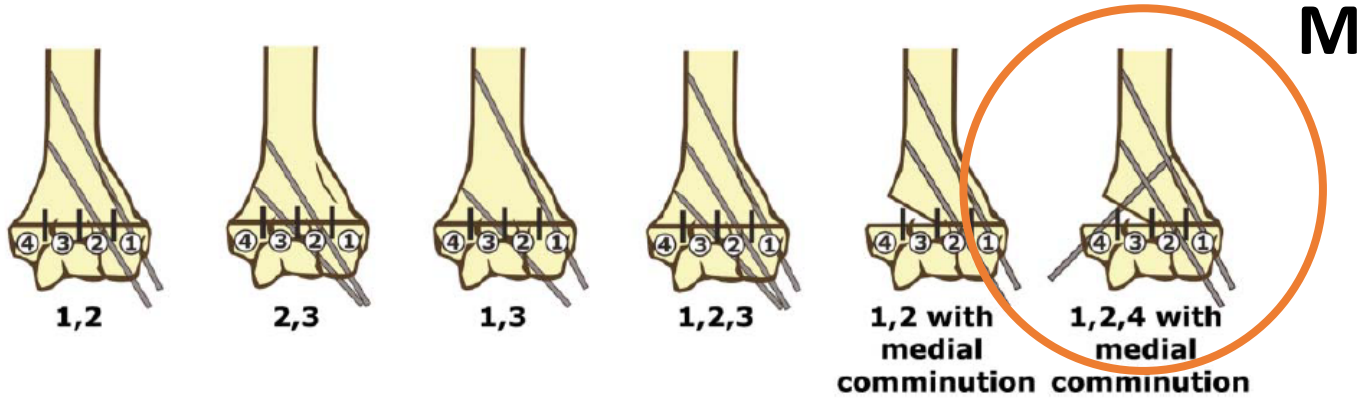


FIGURE 1. The transverse distance between the medial and lateral epicondyles was divided evenly in 4 different zones, with the most lateral zone labeled as zone 1 and the most medial zone labeled as zone 4. In the absence of medial comminution, 4 possible lateral-only pin configurations were tested.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

Silva M, Knutsen AR, Kalma JJ, et al. Biomechanical Testing of Pin Configurations in Supracondylar Humeral Fractures: The Effect of Medial Column Comminution. Journal of Orthopaedic Trauma: May 2013 - Volume 27 - Issue 5 - p 275-280

Medial Pin Technique:

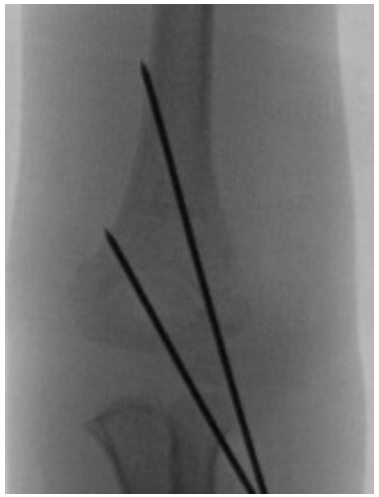
- Fix with 2 lateral pins
- Extend elbow 45deg to relax ulnar nerve
  - Beware of ulnar nerve subluxation
    - 16% of children (Zaltz 1996)
- Thumb pressure or small incision to protect ulnar nerve as pins inserted

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

PERCUTANEOUS PINNING

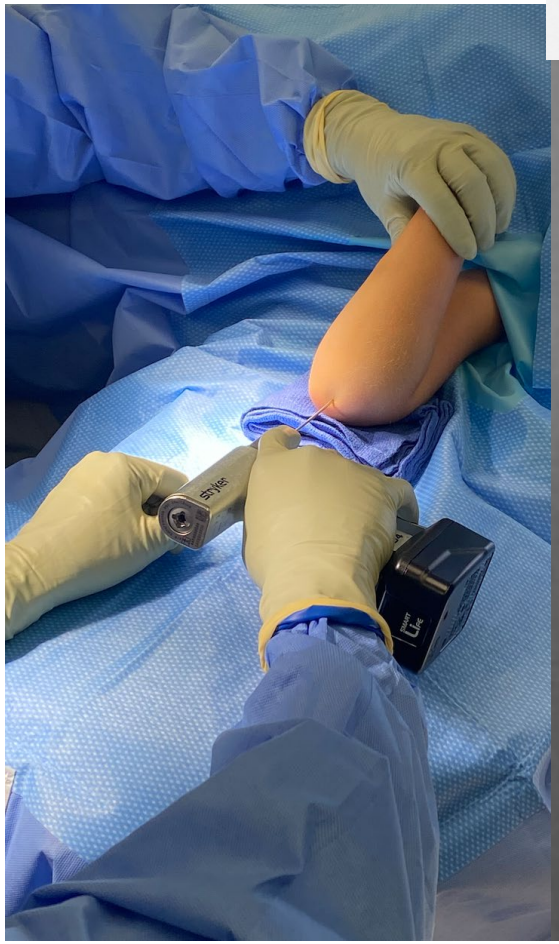
- IDEALLY:
  - 1.6-2mm k-wires
  - Engage lateral and medial columns
  - Divergent

    ***Greater pin spread = Greater stability**

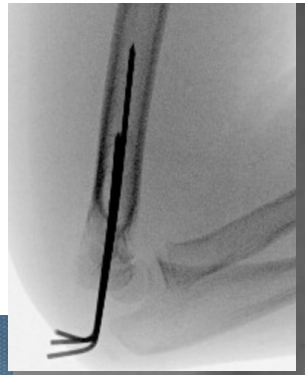


Type 2A:
2 pins

Type 2B: 2-3 pins



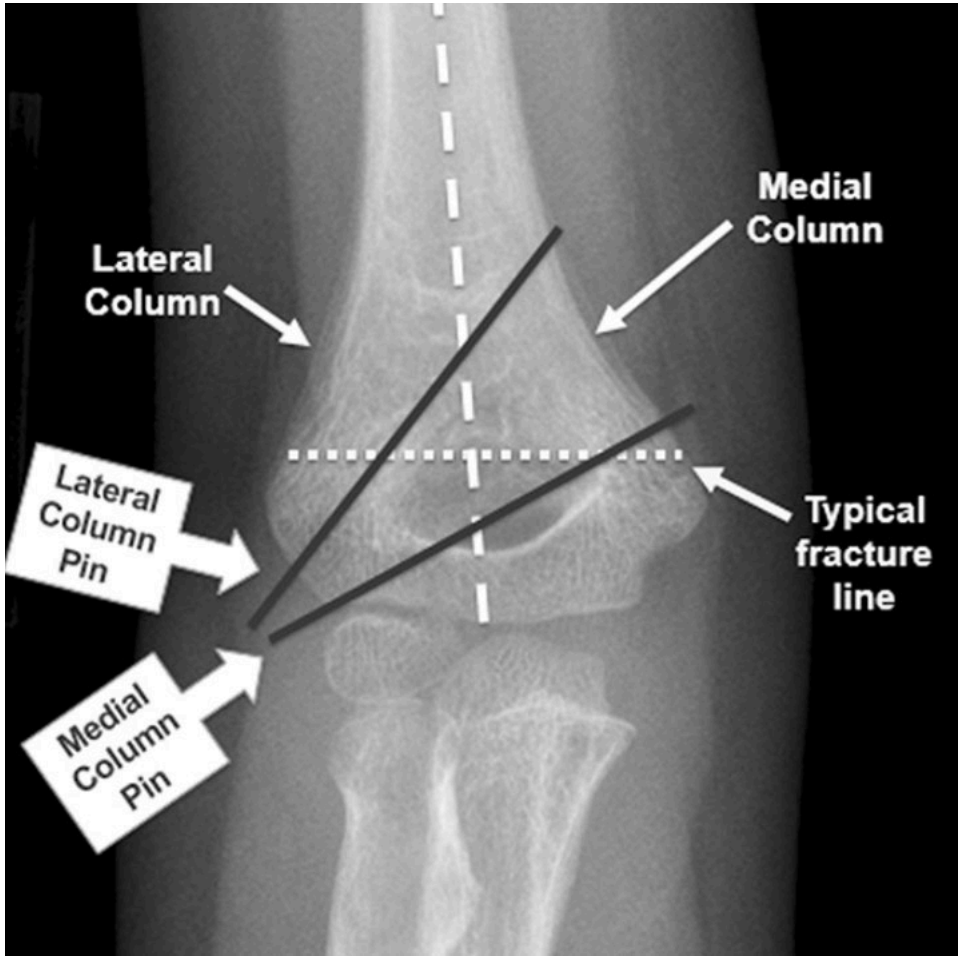
Type 3:
3 pins



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 contruct/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 --> 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

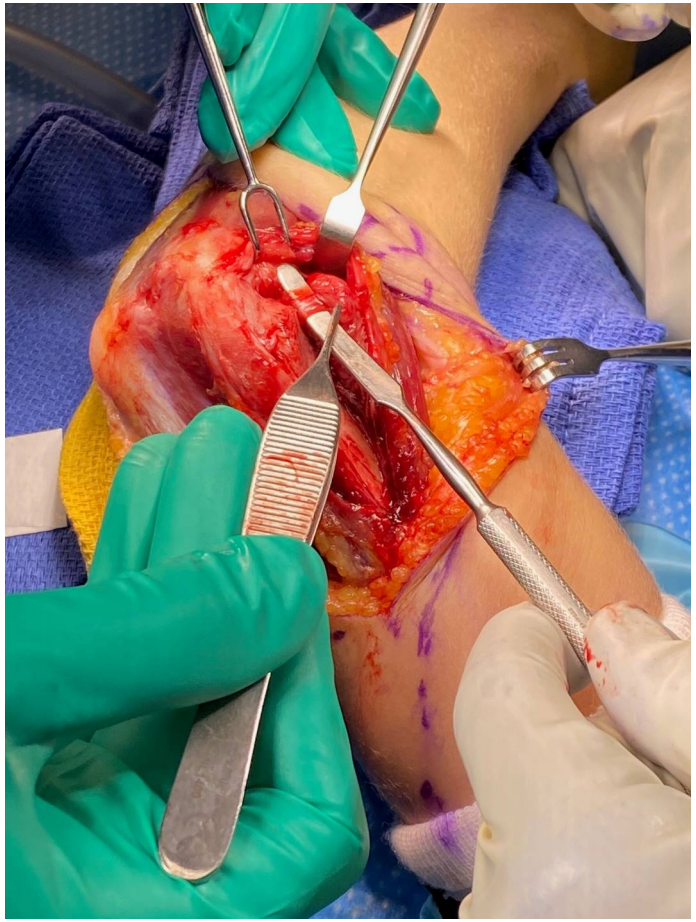
- Pin site infections
- Loss of fixation, pin migration
- Malunion
  - Cubitus varus - thought to be only esthetic, however may contribute to loss of motion and posterolateral rotatory instability
- Nonunion: very rare
- Stiffness: uncommon long term

Courtesy of Mark Sinclair, MD

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

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

- Appropriate Use Criteria: Management of Pediatric Supracondylar Humerus Fractures. Journal of the American Academy of Orthopaedic Surgeons, 2015. 23(10): p. e52-e55
- Alton TB, Werner SE, Gee AO. Classifications in brief : the Gartland classification of supracondylar humerus fractures. Clin Orthop Relat Res. 2015;473:738–741.
- Archibeck MJ, Scott SM, Peters CL. Brachialis muscle entrapment in displaced supracondylar humerus fractures: a technique of closed reduction and report of initial results. J Pediatr Orthop. 1997 Apr.;17(3):298–302.
- 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.
- Bales JG, Spencer HT, Wong MA, et al. The effects of surgical delay on the outcome of pediatric supracondylar humeral fractures. J Pediatr Orthop. 2010;30:785–791)
- Bauer JM, Stutz CM, Schoenecker JG, Lovejoy SA, Mencio GA, Martus JE. Internal rotation stress testing improves radiographic outcomes of Type 3 supracondylar humerus fractures. J Pediatr Orthop 2019;39(1):8-13.
- Camus T, MacLellan B, Cook PC, Leahey JL, Hyndman JC, El-Hawary R. Extension type II pediatric supracondylar humerus fractures: a radiographic outcomes study of closed reduction and cast immobilization. J Pediatr Orthop 2011;31(4):366-371.
- Edmonds EW, Roocroft JH, Mubarak SJ. Treatment of displaced pediatric supracondylar humerus fracture patterns requiring medial fixation: a reliable and safer cross-pinning technique. J Pediatr Orthop. 2012;32: 346–351
- Fitzgibbons PG, Bruce B, Got C, Reinert S, Solga P, Katarincic J, et al. Predictors of failure of nonoperative treatment for type-2 supracondylar humerus fractures. J Pediatr Orthop 2011;31(4):372–376.
- 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
- Gartland. Management of supracondylar fractures of the humerus in children. Surg Gynecol Obstet. 1959;109:145-54.

REFERENCES

- Ho, CA. Cubitus Varus - It's more than just a crooked arm! J Pediatr Orthop 2017;37(Suppl 2):S37-S41
- Karalius VP, Stanfield J, Ashley P, et al: The utility of routine postoperative radiographs after pinning of pediatric supracondylar humerus fractures. J Pediatr Orthop 2017;37:e309-e312
- Lee SS, Mahar AT, Miesen D, Newton PO. Displaced pediatric supracondylar humerus fractures: biomechanical analysis of percutaneous pinning techniques. J Pediatr Orthop. 2002 Jun.;22(4):440–443.
- Lucas DE, Willis LM, Klingele KE. Factors Predictive of Early Radiographic Failure After Closed Reduction of Gartland Type II Supracondylar Humeral Fractures. Journal of Orthopaedic Trauma: August 2013 - Volume 27 - Issue 8 - p 457-461
- Mohammad S, Rymaszewski LA, Runciman J. The Baumann angle in supracondylar fractures of the distal humerus in children. J Pediatr Orthop. 1999;19(1):65–69.
- Muchow RD et al. Neurological and vascular injury associated with supracondylar humerus fractures and ipsilateral forearm fractures in children. J Pediatr Orthop 2015;35:121-125
- O'Driscoll SW, Spinner RJ, McKee MD, et al. Tardy posterolateral rotatory instability of the elbow due to cubitus varus, J Bone Joint Surg Am. 2001;83:1358-1369
- Ramachandran M, Skaggs DL, Crawford HA, et al. Delaying treatment of supracondylar fractures in children: has the pendulum swung too far? J Bone Joint Surg Br. 2008;90:1228–1233
- Shenoy PM, Islam A, Puri R. Current management of paediatric supracondylar fractures of the humerus. Cureus 2020;12(5):e8137

REFERENCES

- Silva M, Knutsen AR, Kalma JJ, et al. Biomechanical Testing of Pin Configurations in Supracondylar Humeral Fractures: The Effect of Medial Column Comminution. Journal of Orthopaedic Trauma: May 2013 - Volume 27 - Issue 5 - p 275-280
- Tremains MR, Georgiadis GM, Dennis MJ. Radiation exposure with use of the inverted-c-arm technique in upper-extremity surgery. J Bone Joint Surg Am. 2001 May;83-A(5):674–678.
- Tuomilehto N, Kivisaari R, Sommarhem A, et al: Outcome after pin fixation of supracondylar humerus fractures in children: Postoperative radiographic examinations are unnecessary. Acta Orthop 2017;88:109-115.
- Weller A et al. Management of the Pediatric Pulseless Supracondylar Humeral Fracture: Is Vascular Exploration Necessary? J Bone Joint Surg Am 2013;95:1906-12.
- Wilkins KE. Changes in the management of monteggia fractures. J Pediatr Orthop. 2002;22(4):548–554.
- Wingfield JJ, Ho CA, Abzug JM, et al. Open reduction techniques for supracondylar humerus fractures in chil dren. Instr Course Lect. 2016;65: 361–370
- Woratanarat P, Angsanuntsukh C, et al. Meta-Analysis of Pinning in Supracondylar Fracture of the Humerus in Children. J Orthop Trauma 2012;26:48–53
- 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