

# Pediatric Forearm Fractures

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*Illustrations by Alicia Asturias, B.A.*

# Disclaimer

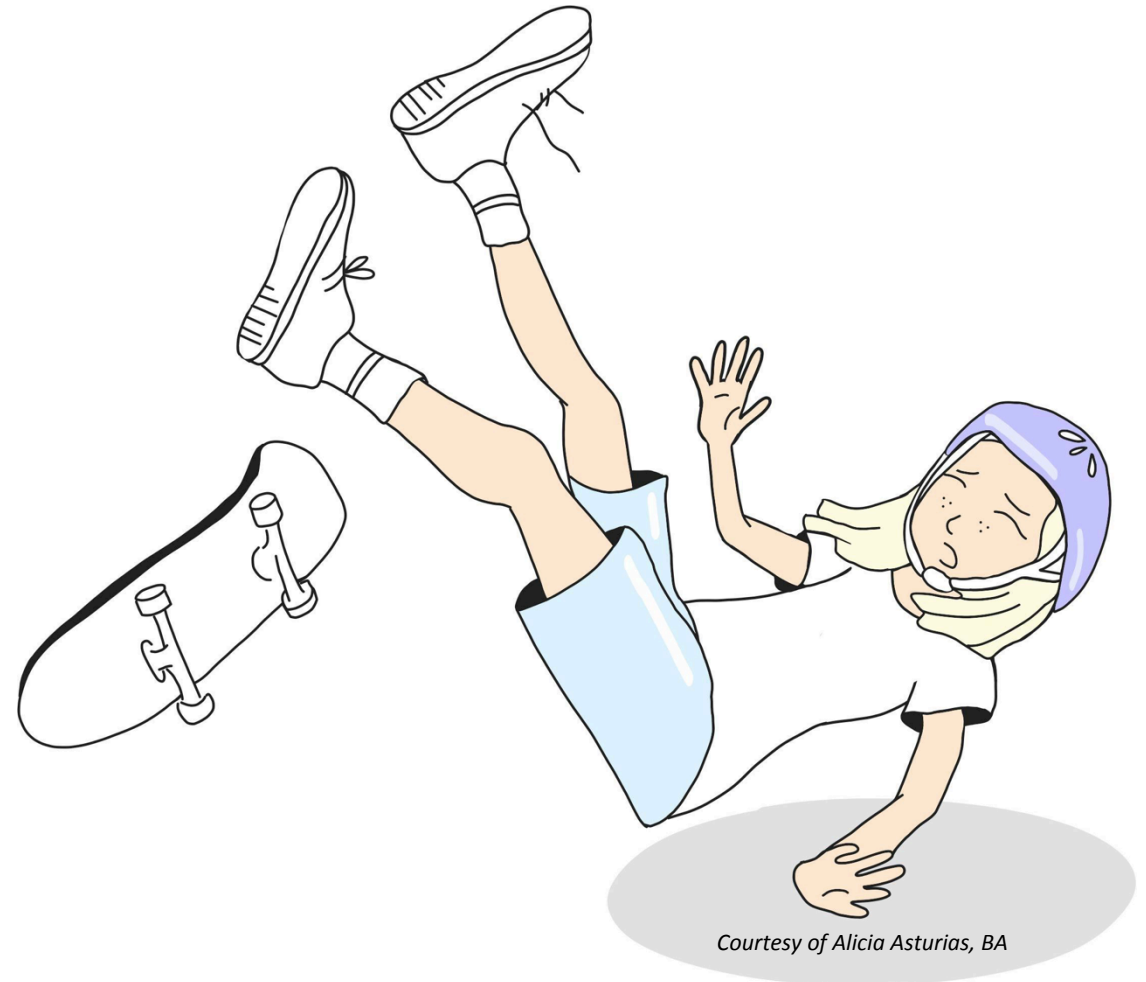
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# OBJECTIVES

- **Physical exam for forearm injuries**
- **Know the anatomy**
- **Evaluate simple and complex forearm fractures**
- **Know primary and alternate treatment methods**
- **Anticipate complications**
- **Return to normal function and activity**

# 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





# Physical Exam

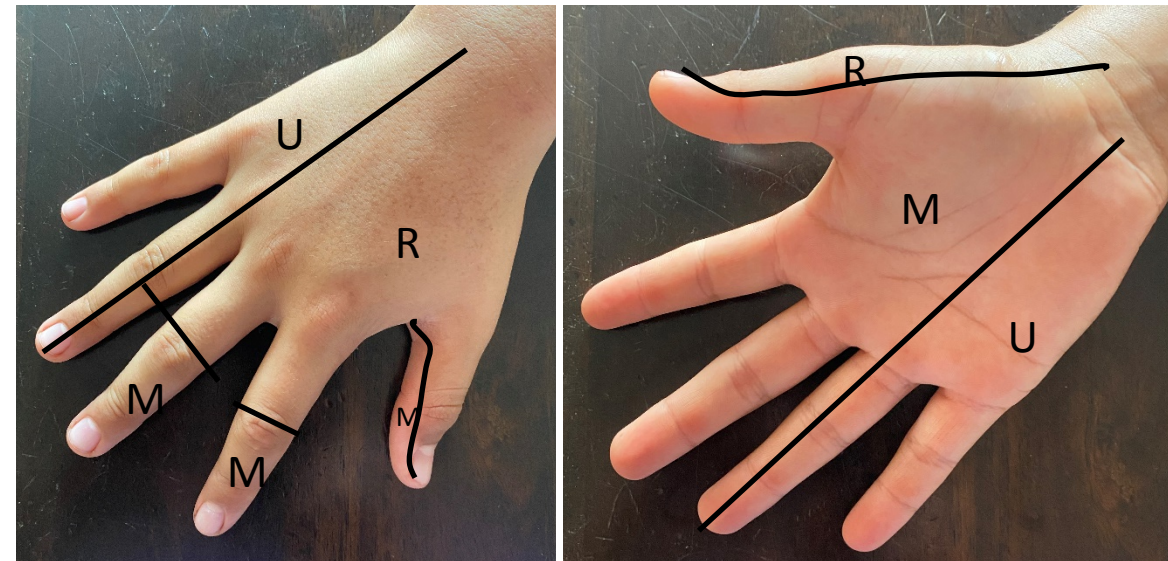
- Head to toe exam – don't miss another injury
- Check the joint above and below the injury
- Check the skin – is the fracture open or closed?
- Is there vascular compromise?
  - Are the radial pulses symmetric
  - Is capillary refill <2seconds
- Is there nerve compromise?

# 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

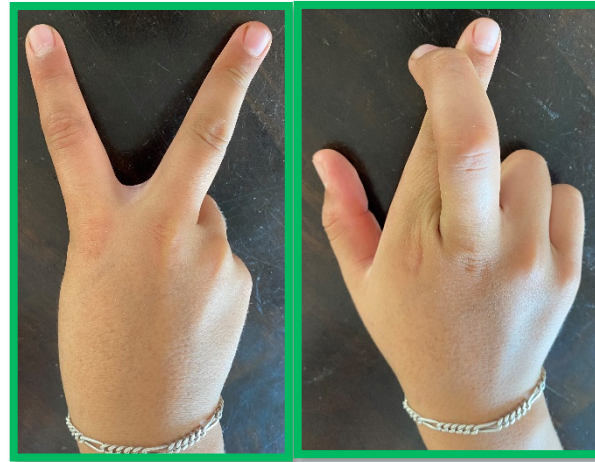


2-point Discrimination  
Test each of the Sensory Dermatomes  
U=Ulnar, R=Radial, M=Median



# 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)



# 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
- Bayonet apposition will remodel



Injury



6 months later

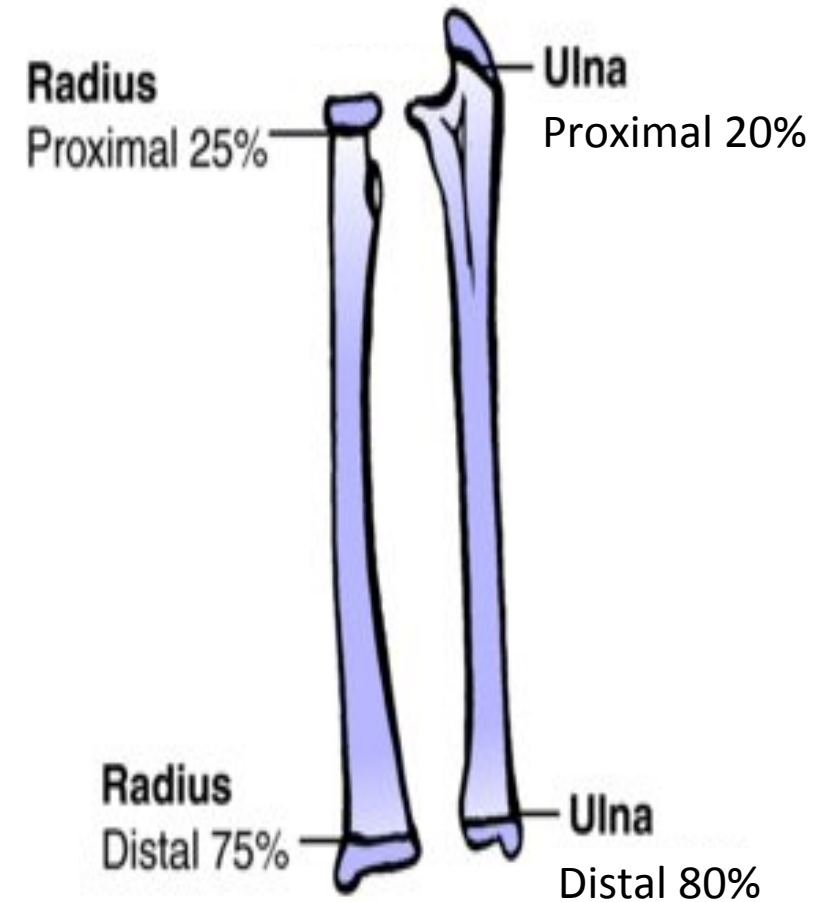


# Recommendations in the literature regarding Acceptable Alignment of Pediatric Forearm Fractures

Source	Age	Angulation (degrees)	malrotation	Bayonette apposition
Price (JPO 2010) Distal and midshaft	<8	<15	<30	100%
	>8	<10	<30	100%
Proximal shaft	<8	<10	<30	100
	>8	anatomic	anatomic	anatomic
Noonan (JAAOS 1998) Distal and midshaft	<9	<15	<45	100%
	>9	<15	<30	If 2 yrs growth left 100%
Proximal shaft	<9	<15	<45	100%
	>9	<10	<30	If 2 yrs growth left 100%

# 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, Kenneth 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

# 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

# Remodeling

- Fractures remodel best in the plane of motion
- Bayonet apposition will remodel
- Angulation (A) and translation(B) remodel better than rotation

A



B



At time of casting

6 months later



# Frequency of Injury

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



# 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



# Fracture Patterns

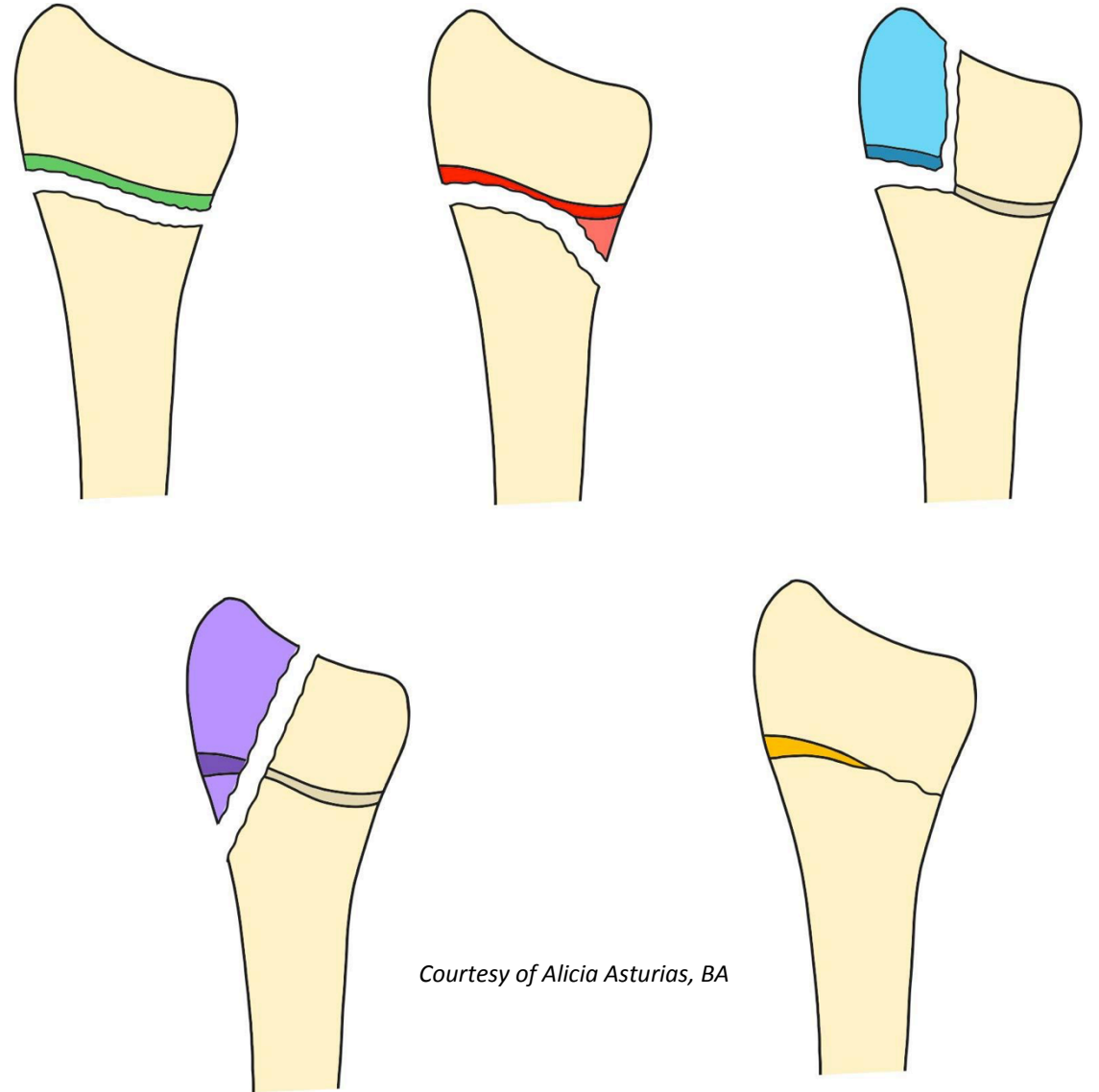
## Complete fractures

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



# Fracture Patterns

- Salter-Harris (SH) fractures are common – the physis is a weak point in the bone
  - SH I through the physis
  - SH II – physeal/metaphyseal
  - SH III- physeal/epiphyseal
  - SH IV – epiphyseal and metaphyseal (across the physis)
  - SH V – crush injury to the physis



*Courtesy of Alicia Asturias, BA*

# 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

# Premature Physeal Arrest

- Monitor all SH fractures 6-12 months
- **4.4% risk of growth arrest following a distal radius physeal fracture**
  - Risk of ulna physeal arrest is much higher
    - ~50%
- Remember 75-80% of growth comes from the distal physes (proximal arrest causes less deformity and length difference)





# Premature Physeal Arrest

- Treatment
  - Complete the distal epiphysiodesis of both bones – accept one short arm –
    - Minimal effect on function, but if young may cause cosmetic problems
  - Physeal bar resection to try and maintain growth potential
    - Technically difficult and results +/-
  - Correction with lengthening at a later date
    - May still need both bone epiphysiodesis)

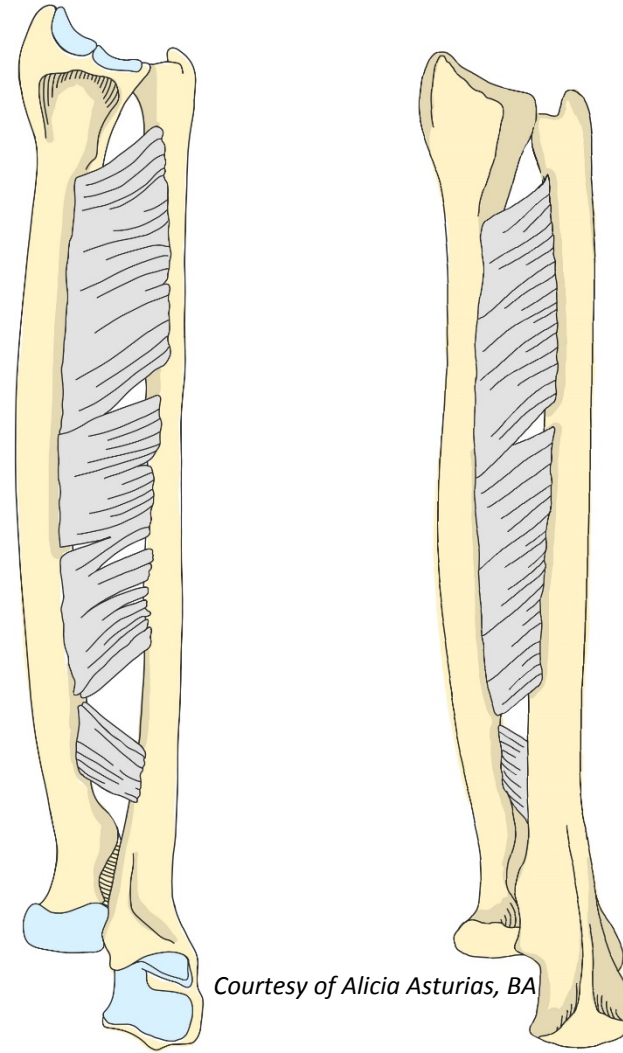
Epiphysiodesis



*Image courtesy of Chris Souder, MD*

# Recreate the Anatomy

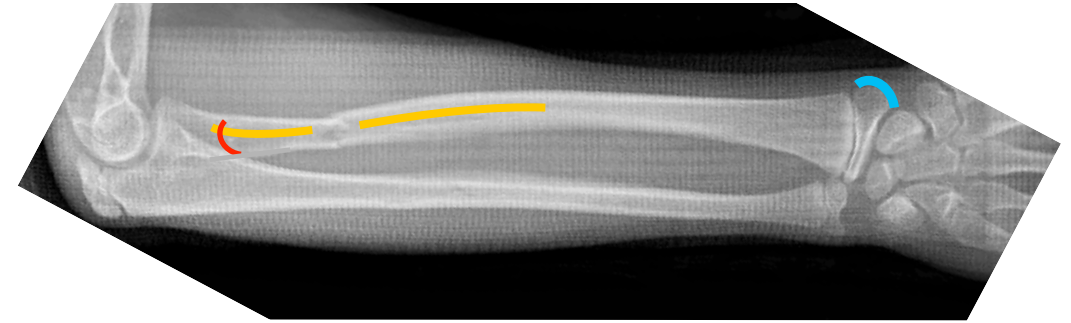
- Ulna must be straight (bow or angulation can cause joint dislocation)
- Radius has dorsal and radial bow to allow pronation and supination around the ulna
- Interosseous Membrane needs to be taut – if the ulna and radius encroach on the interosseus space, forearm will not rotate properly



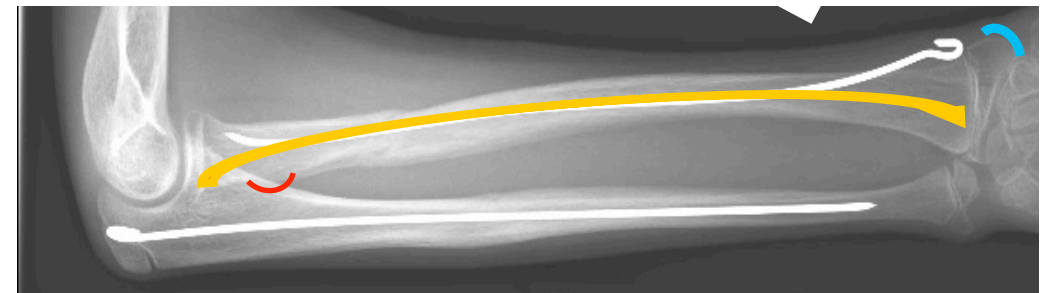


# Recreate the Anatomy

- Check the rotation of each bone
  - Radial styloid and bicipital tuberosity should be opposite each other
  - The diameter and bow of proximal and distal fragments should match at the fracture



Above: **bicipital tuberosity** is not opposite **radial styloid**, Diameter and **bow** at fracture do not match this indicates Rotational Malalignment



Rotational Malalignment corrected

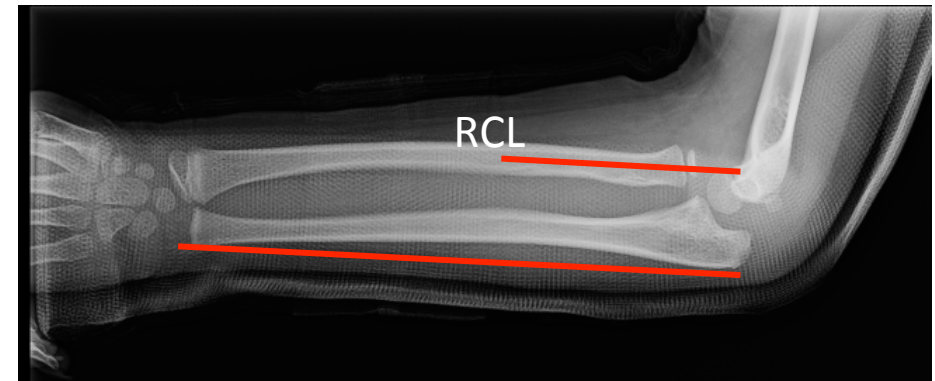
# Recreate the Anatomy

- Always check to ensure reduction of the **Distal Radial Ulnar Joint (DRUJ)** and **Proximal Radial Ulnar Joint (PRUJ)**



# Monteggia fractures

- Dislocation of the PRUJ caused by ulna fracture or bow
  - MUST check radiocapitellar (RC) joint
    - Radiocapitellar line (RCL) must intersect capitellum
- Can occur with ulnar plastic deformation
  - No true ulna fracture

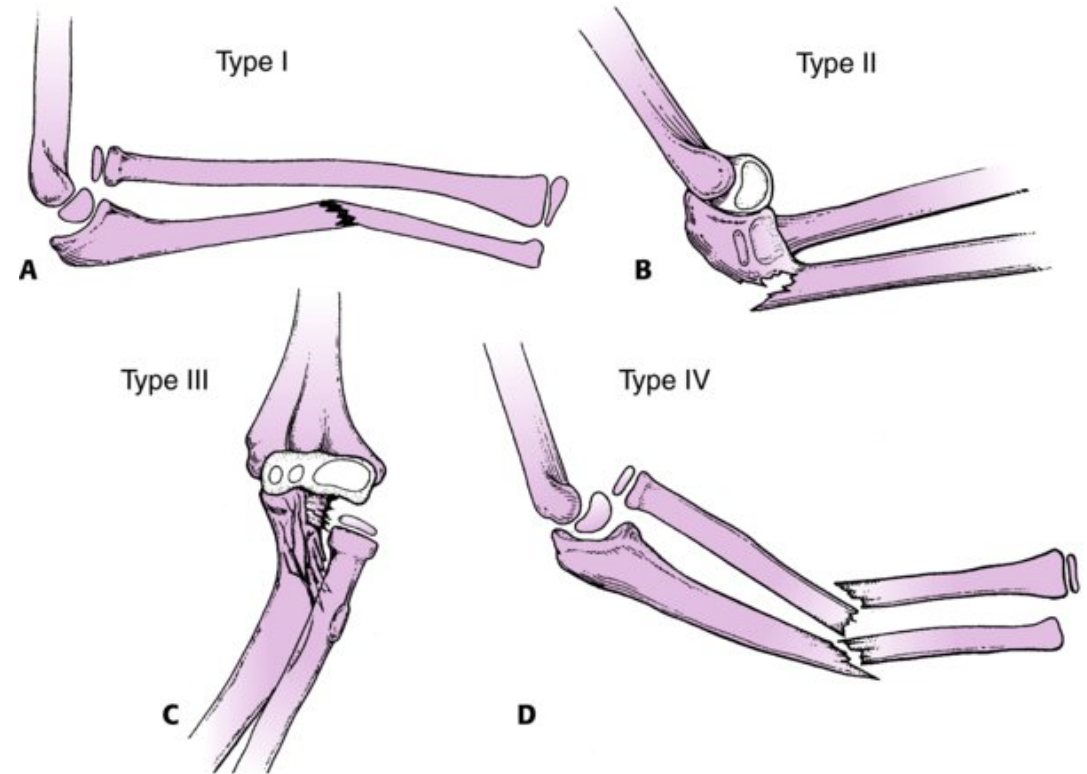


*Images courtesy of Chris Souder, MD*

# Monteggia Fractures

## Bado Classification

- Type I— anterior radio-capitellar (RC) dislocation
  - most common
- Type II— posterior RC dislocation
- Type III— lateral RC dislocation
  - Varus ulnar deformity
- Type IV-- anterior RC dislocation with radial shaft fracture

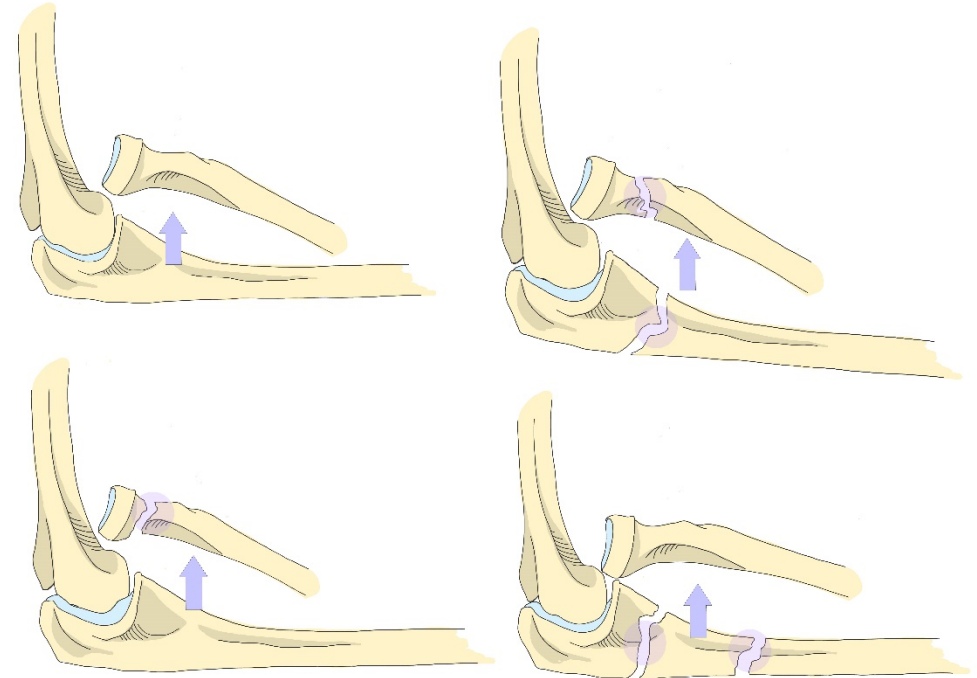


Picture from: Shah AS and Samorah JB. Monteggia Fracture-Dislocation in Children. Waters PM, Skaggs, DL, Flynn JM, eds Rockwood and Wilkins' Fractures in Children 9e. Philadelphia, PA. Wolters Kluwer Health, Inc, 2019, fig 11-1

# Monteggia Fractures

## Type 1 (anterior dislocation) Equivalent Lesions

- Plastic deformation or Bowing of the ulna causes dislocation of the radial head
- Fracture of the ulnar shaft and head or neck of the radius
- Radial neck fracture
- Fracture of the ulnar shaft and fracture of the olecranon



*Courtesy of Alicia Asturias, BA*

# Monteggia fractures

- Treatment: straighten the ulna
  - Greenstick fractures are typically stable with closed reduction
  - Increased need for IM fixation with complete fractures
  - Plate used if length unstable (comminuted or long oblique)
  - MUST monitor carefully until patient regains full motion to assess for late radiocapitellar redislocation



*Images courtesy of Chris Souder, MD*





# Galeazzi Fractures

- Distal radius fracture with dislocation of the DRUJ
- Pediatric equivalent Galeazzi fracture with SH-1 fracture of the distal ulna



Image from: Hennrikus WL, Bae DS. Fractures of the Distal Radius and Ulna. In: Waters PM, Skaggs, DL, Flynn JM, eds Rockwood and Wilkins' Fractures in Children 9e. Philadelphia, PA. Wolters Kluwer Health, Inc, 2019, fig 8-13.



Image courtesy of Chris Souder, MD

# Galeazzi Fractures

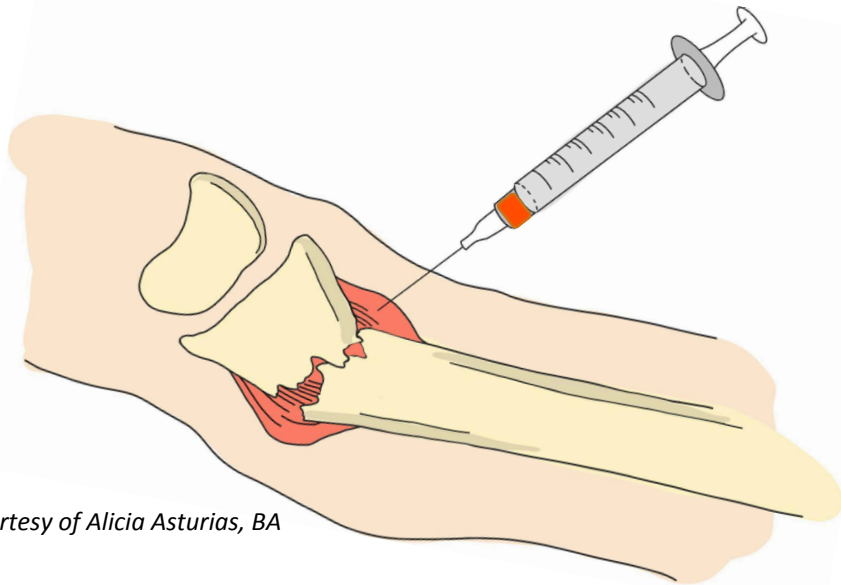
- Treatment: closed reduction of the radius fracture then cast appropriately:
- If the ulna is dislocated dorsally, supinate the forearm (long arm cast) and mold the cast over the dorsal distal ulna/volar distal radius to help to stabilize the joint while it heals
- If the ulna is dislocated palmarly, pronate the forearm (long arm cast) and mold over the dorsal distal radius/volar distal ulna
- If the DRUJ does not reduce completely, or is unstable after 6 weeks of casting, consider open reduction and temporary pin fixation





# Closed Reduction – Pain Management

- Hematoma block
- Aspirate fracture hematoma
- Inject 5-10cc of 1% Lidocaine or Marcaine into the hematoma

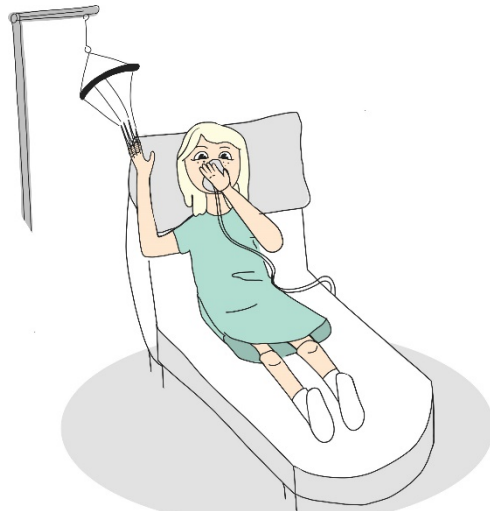


Courtesy of Alicia Asturias, BA

- Regional (Bier Block)
- Juliano reported safe, successful pain relief with the use of a 0.125% solution of lidocaine administered to a total dose of 1 mg/kg
- Double tourniquet – inflate proximal cuff, inject IV lidocaine thru PIV, inflate distal cuff, deflate proximal cuff to minimize discomfort from tourniquet

# Closed Reduction – Pain Management

- Inhaled Nitrous oxide
- N<sub>2</sub>O:O<sub>2</sub> in a 50:50 mixture provides very effective, safe analgesia for fracture reduction in the emergency room setting.



Courtesy of Alicia Asturias, BA

- Conscious Sedation and
  - General Anesthesia
- are also options but will require additional staff (ED or Anesthesia), you need to wait until NPO is adequate, prolonged nurse monitoring is necessary after reduction; these factors may significantly increase ED/hospital stay. So if the ED is busy, it is good to know techniques you can use to get patients treated efficiently and safely.

# Tricks for closed reduction

1. Recreate the deformity
2. Traction to walk the distal fragment up the proximal fragment
3. Then realign the bones



# Tricks for closed reduction

- Gentle Traction – manually or with finger traps
- Allow the muscles to fatigue so they are not fighting against you
- If you want your cast ulnarly deviated, put the finger trap on the thumb

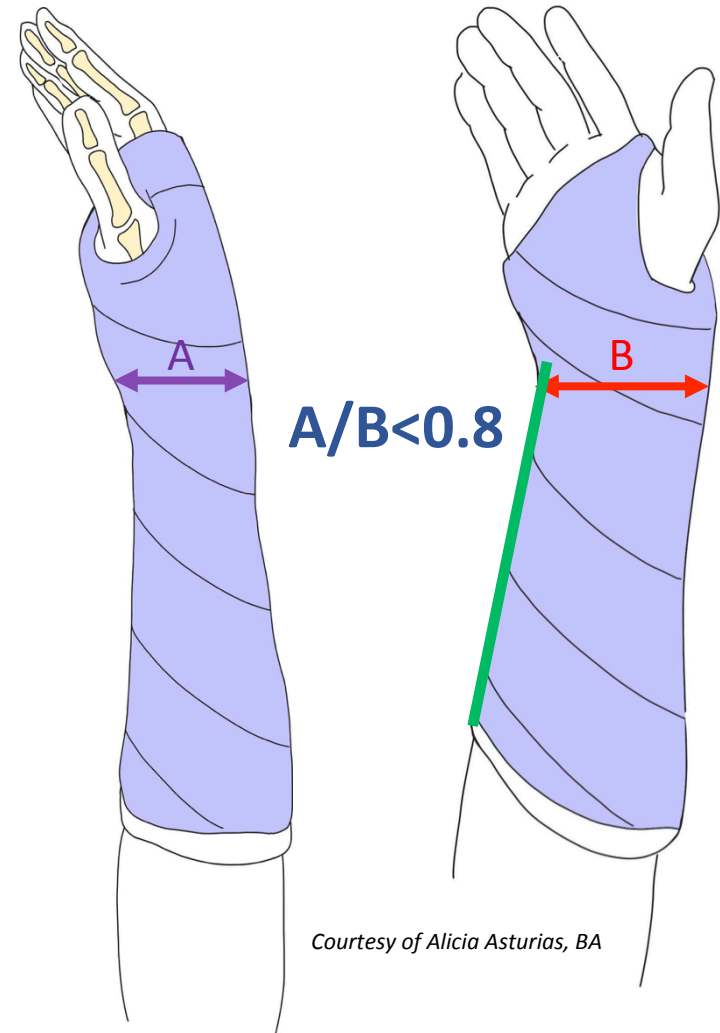


# Maintain the reduction – a good cast is critical

- Distal 1/3 fractures with stable DRUJ do well in a short arm cast, more proximal fractures may need a long arm cast
- Pay careful attention to your Interosseous mold.

**CAST INDEX:** the ratio of  
Lateral cast diameter (A) to  
AP cast diameter (B)  
at the fracture should be  $<0.8$

- **Ulnar border** should be perfectly straight

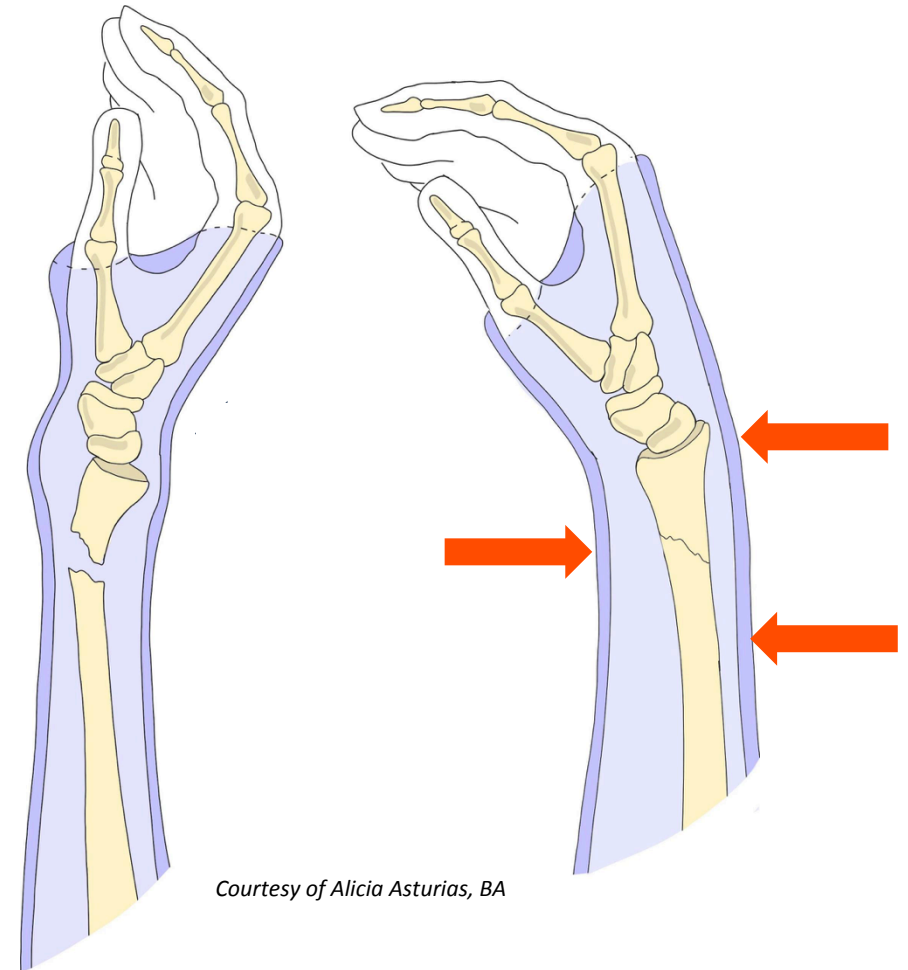


*Courtesy of Alicia Asturias, BA*

# Maintain the reduction – a good cast is critical

- Don't use too much padding – 2 or 3 layers of webroll only
- 3 point mold is necessary to keep the fracture aligned
- Mold at the apex and above and below the fracture

[Application of Reverse Sugar Tong Splint | Procedures & Techniques | OTA Online Trauma Access](#)





# Maintain the reduction – Long arm casts

- If you wrap webril or fiberglass around and around a joint you will end up with:
  - Too much material on the concavity of a joint
  - Not enough on the convex side
- Solution: fan fold on the convex side to give good padding over bony prominences and prevent bunching over the neurovascular bundles
- Elbow must be at 90° while you cast – you cannot change the angle without wrinkling the cast and risking an ulcer



[Application of Long Arm Cast | Procedures & Techniques | OTA Online Trauma Access](#)

# Maintain the reduction – Long arm casts

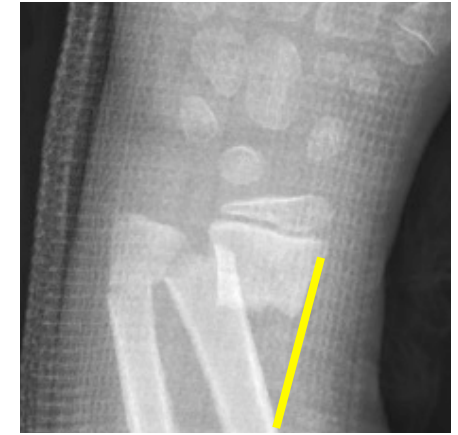
- trying to manage reduction, 3-point mold, ulnar border, appropriate flexion/deviation, interosseus mold, pronation or supination and keeping the elbow at 90° is difficult,
- **consider starting with a short cast, getting your molds then extend to a long arm cast**
- Example is a supinated cast to maintain reduction of the PRUJ following reduction of a Monteggia fracture/dislocation



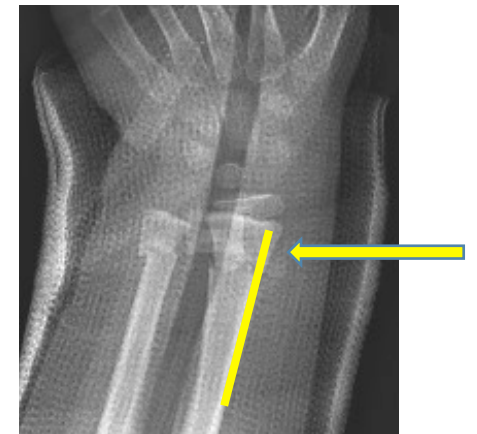


# Maintain the reduction – a good cast is critical

- The most common distal radius fracture is displaced dorsally and radially
- For this fracture pattern, the periosteum is usually torn on the volar/ulnar sides and remains intact on the radial/dorsal sides of the fracture
  - Placing intact periosteum will help maintain the reduction.
- *Flex and ulnarly deviate the cast to tension the intact periosteum*
  - Adequate ulnar deviation when thumb metacarpal is in line with the radius on AP x-ray



Periosteum is intact dorsal and radial  
Cast should put the periosteum on tension to maintain reduction.

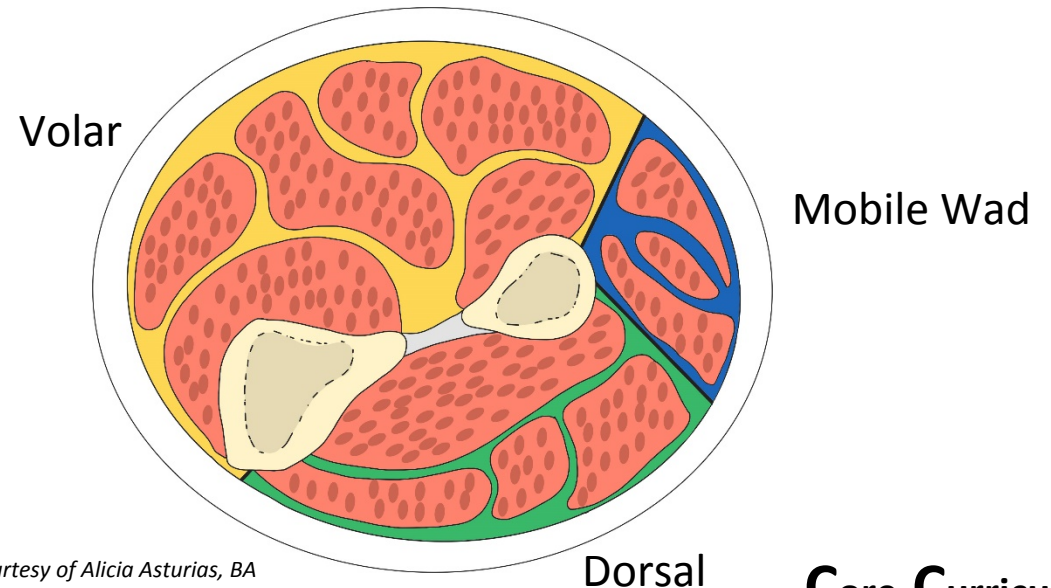


# When to Consider Surgery

- 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

# Compartment Syndrome

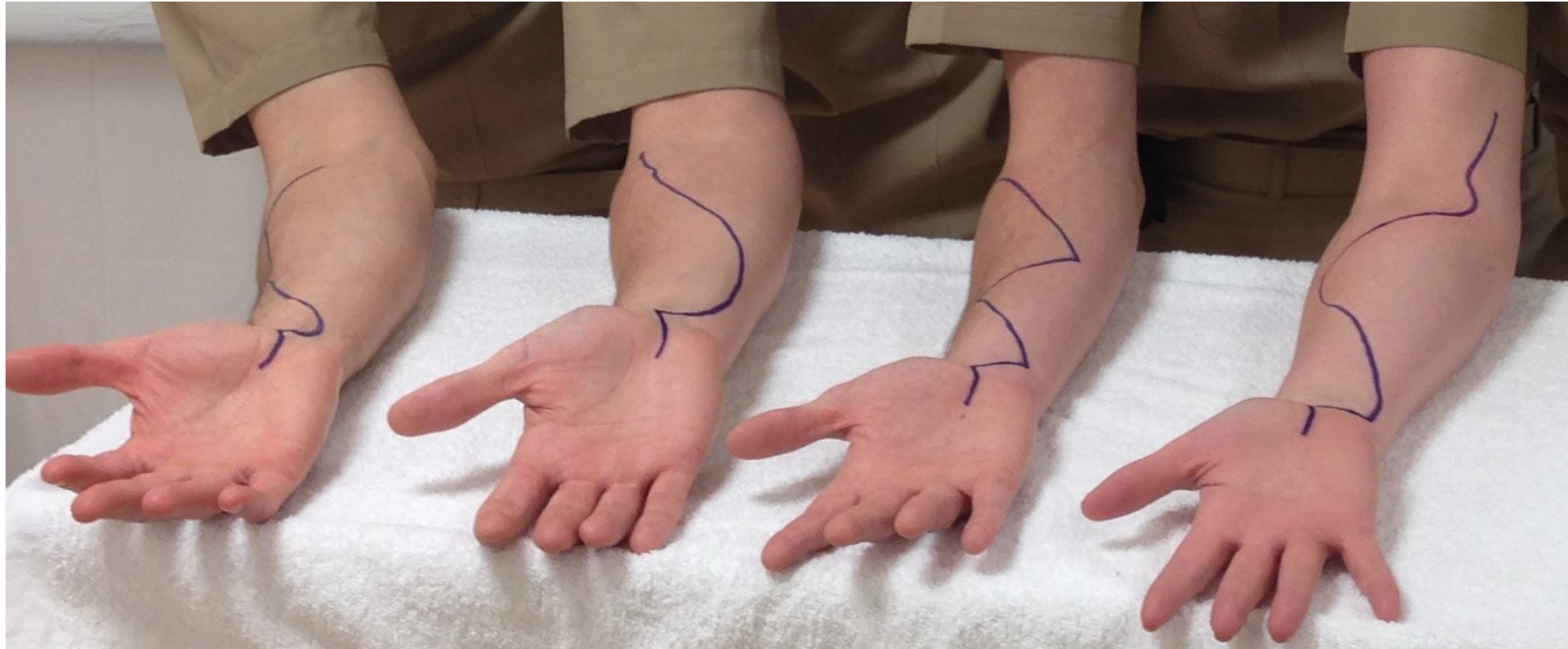
- Can be caused by
  - Injury
  - Multiple attempts at reduction
  - Tight cast
  - Surgery (multiple passes to get flexible nails across the fracture will increase soft tissue bleeding and swelling).
- There are 3 forearm compartments - each may need to be released
  - Dorsal (superficial and deep)
  - Volar (superficial and deep flexors)
  - Mobile Wad (Brachioradialis, ECRL, ECRB)



*Courtesy of Alicia Asturias, BA*

# Compartment Syndrome

- Options for incisions that allow release of all forearm compartments



# Carpal Tunnel Syndrome

- With a dorsally displaced fracture, the median nerve may get tented over the proximal radius fragment
- There is risk to the nerve with delayed reduction and during the reduction
- Significant swelling may also compress the median nerve
- Consider open carpal tunnel release if there are signs of median nerve compromise after reduction



Median nerve likely tented over the metaphyseal spike of bone putting the nerve at risk



# Distal Radius – Minimally Invasive

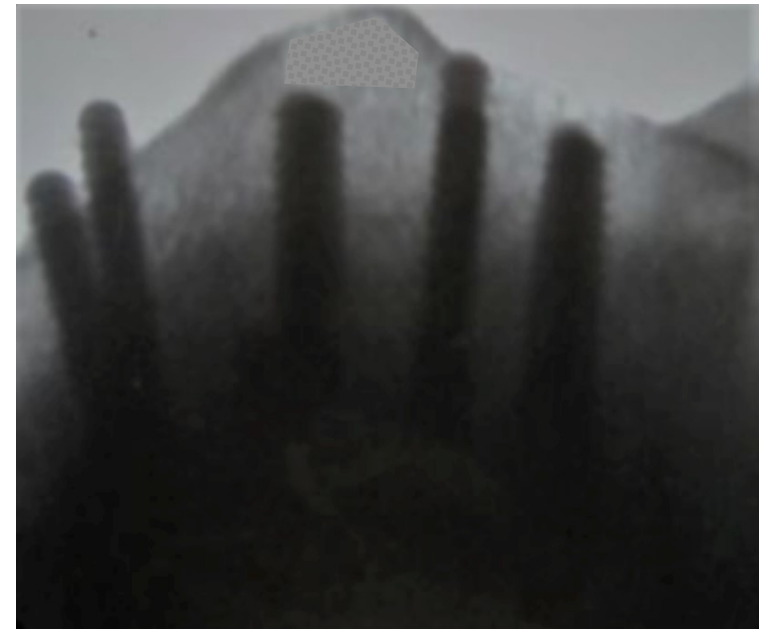
- Soft tissue may block an adequate reduction
- A small incision can be made at the fracture to sweep the soft tissue out of the fracture,
- Then a joker can be used to lever the distal fragment onto the proximal fragment
- The fracture can then be pinned with temporary k-wires
  - K-wires placed radially put SBRN at risk
- Plan to treat in cast with pin removal at 3-4 weeks





# Distal Radius - ORIF

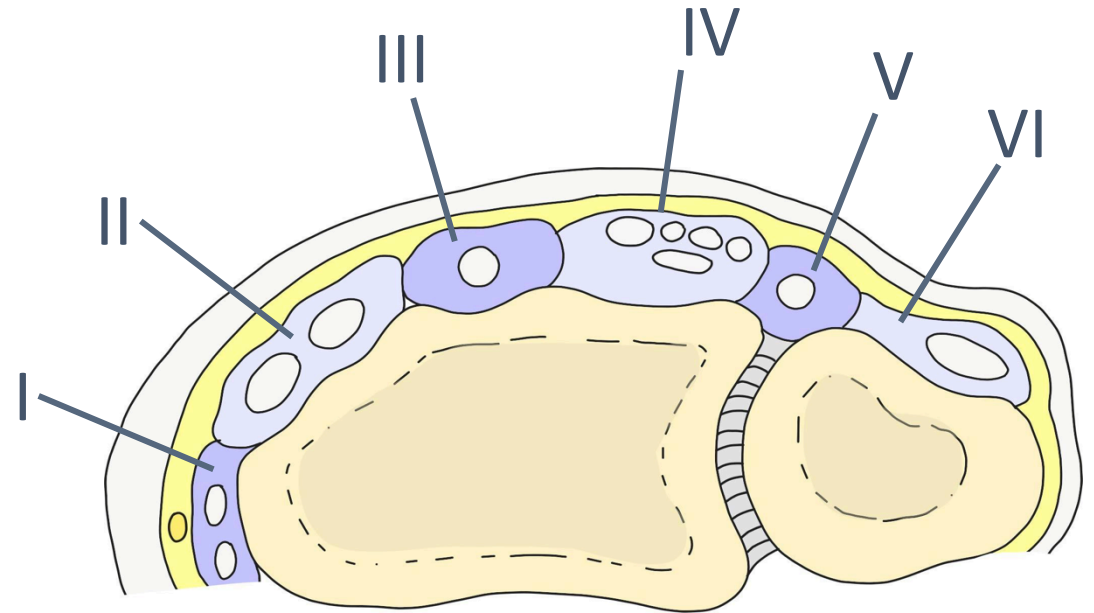
- If there is intra-articular disruption, it is important to get anatomic alignment to protect the joint
  - Consider ORIF to visualize the joint and fix with plate and screws or well placed k-wires
  - Dorsal approach:
    - In the event of impaction or “die punch” lesion that requires direct visualization with arthrotomy
    - Dry arthroscopy can be helpful as well
  - Volar approach:
    - Simple intra-articular fractures that require indirect reduction.
- Caution – do not leave screws long on the dorsal side as there is risk of tendon rupture.



Intra-op Hoya view with fluoroscopy showing cortex perforation with screw tips

# Distal Radius- ORIF

- Dorsal approach can be between the different extensor compartments depending on the specific fracture pattern.
- Radial Column/radial styloid- between compartments I-II or thru the second compartment
- EPL can be retracted either way to facilitate visualization of the scaphoid facet
- Allows for arthrotomy to directly visualize the joint



*Courtesy of Alicia Asturias, BA*

# Midshaft Radius and/or Ulna - IM nails

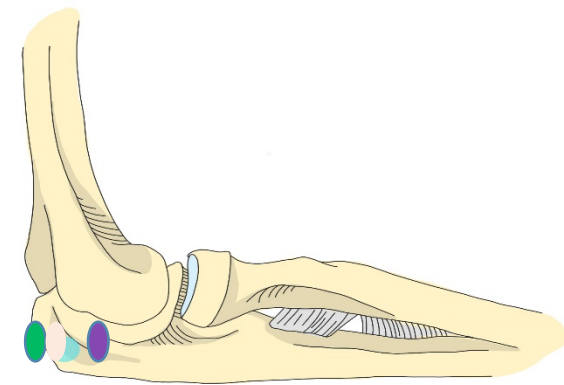
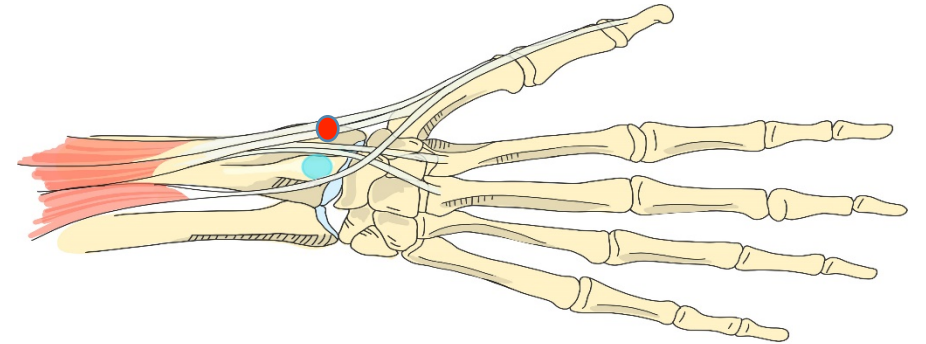
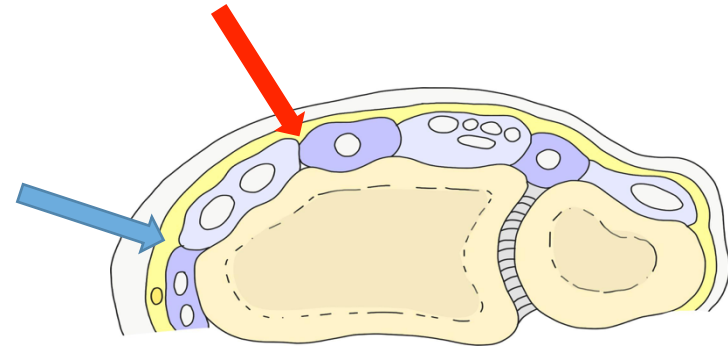
- Flexible IM nails are the most common fixation method for pediatric forearm fractures
- These are easily removed in 6-12 months with little downtime or risk of re-fracture

[IM Nail Forearm | Procedures & Techniques | OTA Online Trauma Access](#)



# Midshaft Radius and/ or Ulna - IM nails

- Radius entry point
  - Proximal to the distal physis
  - Radial and dorsal
    - Between compartments 1/2 or 2/3 (risk of tendon rupture if left too long)
- Ulna entry point
  - Tip of olecranon
    - may be prominent
  - Lateral side of olecranon
    - Midway between the joint and the posterior border of the bone



*Courtesy of Alicia Asturias, BA*

# Midshaft Radius and/or Ulna - ORIF

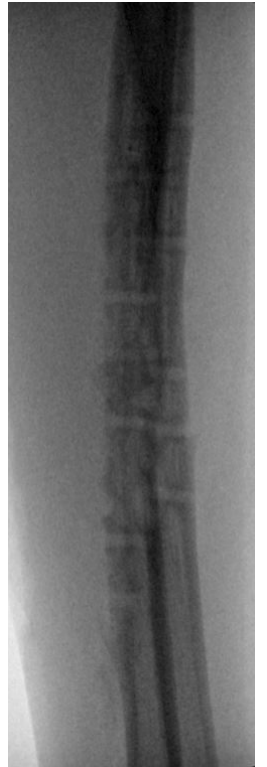
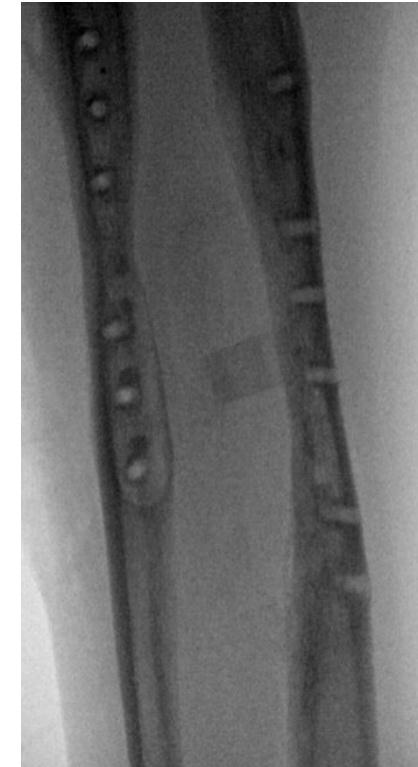
- Consider ORIF with plates and screws
  - Older Children
  - High energy fractures
  - Compartment syndrome
  - Open fractures
  - Comminuted fracture pattern



- Volar Henry approach to the radius
- Posterior Approach to ulna
  - ECU/FCU interval
- Use 3.5 LC-DC plate vs. 2.7 LC-DC plate depending on size of child

# Midshaft Radius and/or Ulna - ORIF

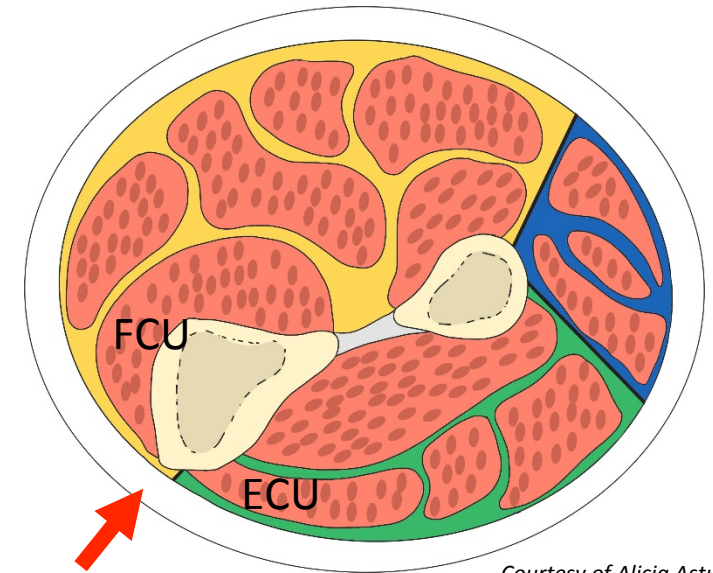
- There is risk of fracture if the plates are removed - prolonged protection (6-12 weeks) after plate removal is necessary





# Midshaft Ulna - ORIF

- The ulnar border of the ulna is subcutaneous so a direct approach to ulna fractures is straightforward
- Incision can be made from the tip of the olecranon process to the ulnar styloid to expose the entire bone
- Interval is between FCU and ECU



*Courtesy of Alicia Asturias, BA*

# Radial Neck Fractures

- Displaced radial neck fractures can be difficult to reduce closed
- Use fluoroscopy to find the plane of maximum angulation and translation
- Tilt (A) is better tolerated than translation (B).

A. Acceptable tilt  $<30^\circ$



Unacceptable tilt  $>30^\circ$



B. Unacceptable translation  $>2\text{mm}$



Treated With CRPP



# Radial Neck – Closed Reduction

1. One person can create a varus force on the elbow with lateral force on the radial shaft while the second person pushes the radial head back into place
2. An Esmarch bandage can be wrapped tightly from distal to proximal to use the soft tissues to push the radial head back into place.



# Radial Neck – Closed Reduction

- Israeli or Pronation Technique
  - Pronate the supinated forearm with the elbow flexed to 90d
  - Apply direct pressure over the radial head
  - Use of an esmarch from the wrist toward the elbow aids in the reduction



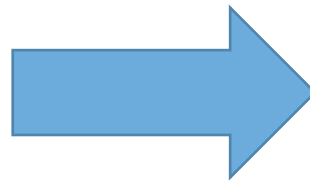
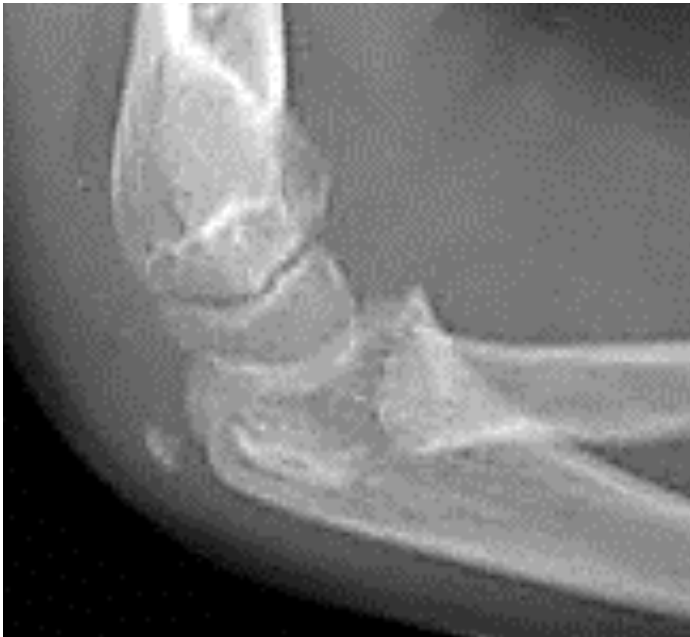
Pronate  
→





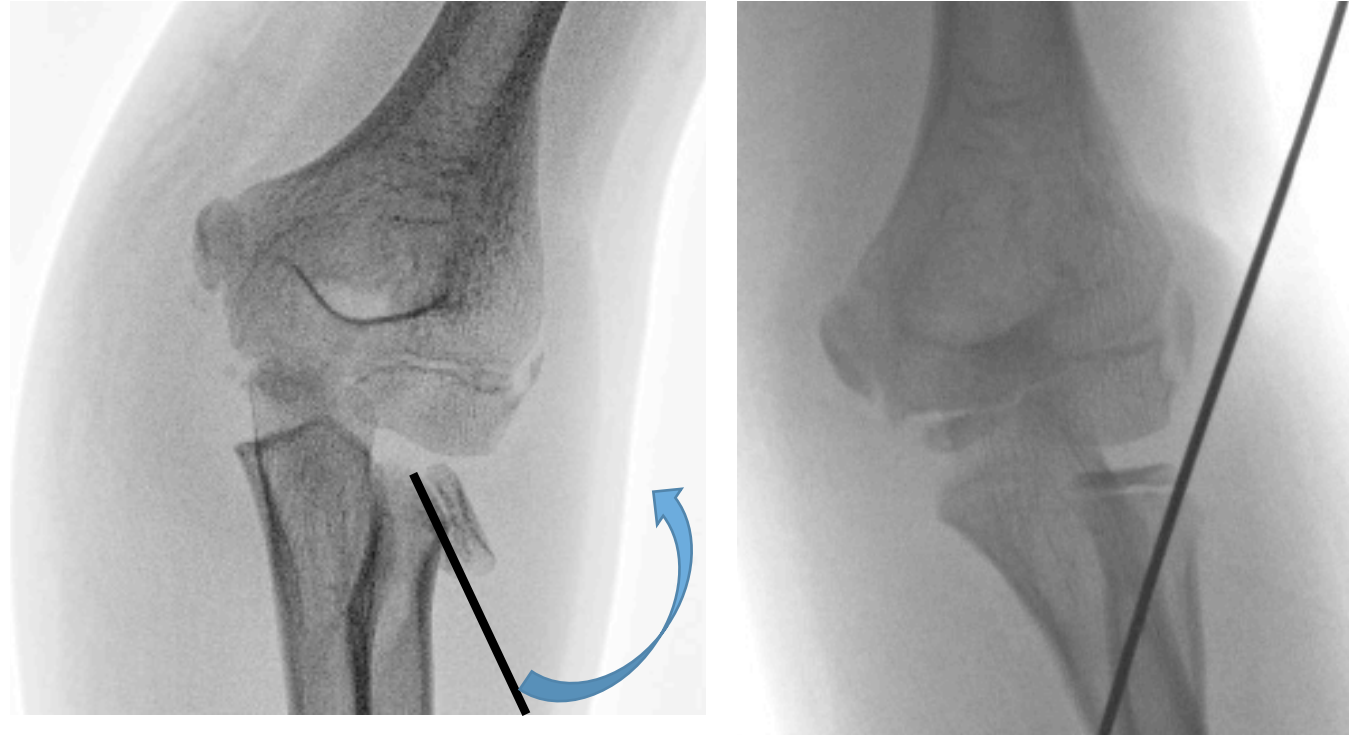
# Radial Neck Fractures

- Check your post reduction x-rays carefully-severely displaced radial head fractures can flip 180° during the reduction so the cancellous fracture surface ends up at the joint



# Radial Neck–Percutaneous Reduction

- If unable to get an adequate closed reduction, a k-wire can be used to percutaneously joystick the radial head back into place
- A joker can be used between the radius and ulna to push the radial shaft laterally back underneath the radial head





# Radial Neck–Percutaneous Reduction

- Metaizeau Technique
- A flexible IM nail can be inserted from the distal radius and the curved tip can be used to engage the radial head
- The rod is then rotated to reduce the fracture and hold the radial head in place

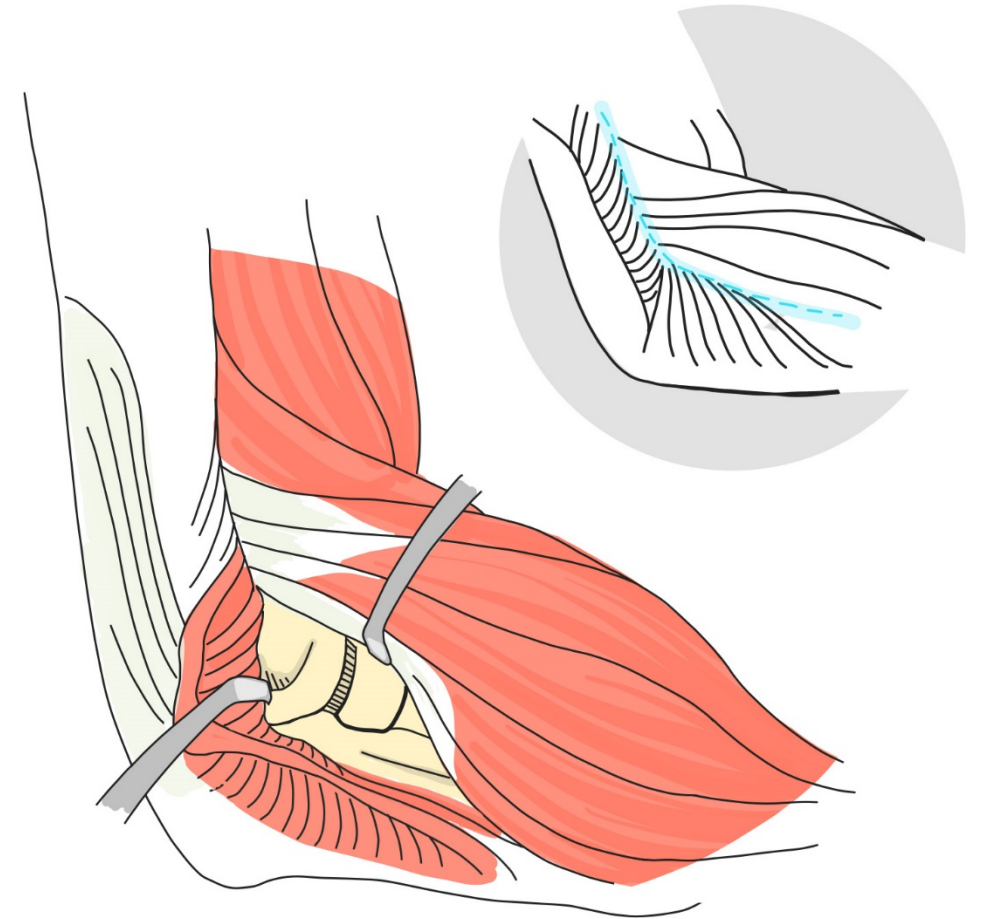


Flexible nail can be used to reduce radial head

*(Images courtesy of Chris Souder, MD)*

# Radial Neck – Open Reduction

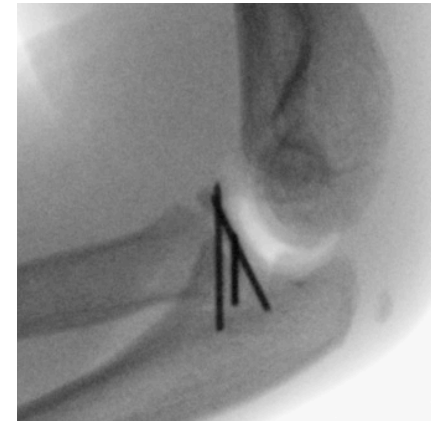
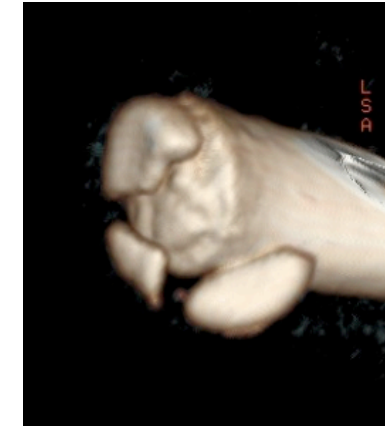
- If closed and percutaneous methods fail, a Kocher approach to the elbow can be used
  - Interval between the anconeus and the extensor carpi ulnaris allows safe access to the lateral elbow joint
- Fracture can be pinned to hold reduction– pins can be removed in clinic in 3-4 weeks
- Start motion early!
- High risk of arthrofibrosis
  - Risk factors
    - Multiple attempts
    - Worse fracture pattern
    - Open surgery



*Courtesy of Alicia Asturias, BA*

# Radial Head Fractures

- CT or MRI may be beneficial to evaluate fragments and displacement
- Often need open reduction to get the joint anatomically aligned- Kocher approach
  - Interval between the anconeus and the extensor carpi ulnaris allows safe access to the lateral elbow joint
- High risk of physeal arrest, AVN and stiffness



# Proximal Ulna

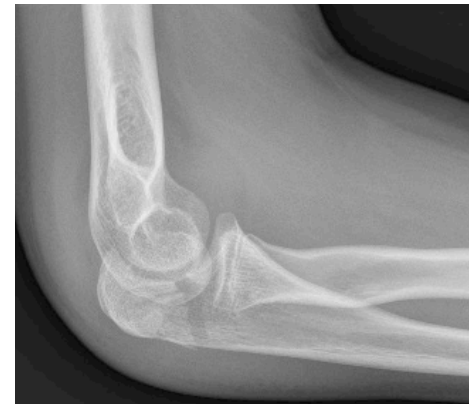
- The ulno-humeral joint needs to be anatomically reduced to decrease the risk of arthritic change, pain and loss of motion
- Step off or gap  $>2\text{mm}$  is not well tolerated
- MRI or arthrogram may be valuable to evaluate the articular surface
- Olecranon fractures may reduce with extension of the elbow (use thumb spica so cast does not fall off)





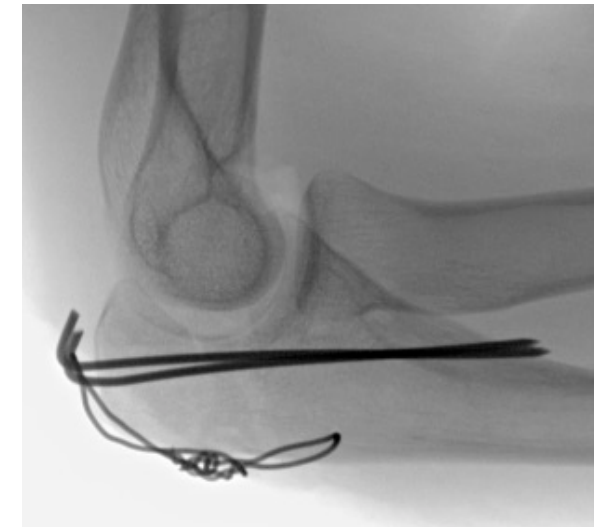
# Proximal Ulna

- Some fractures can be reduced closed but need temporary fixation to prevent loss of reduction.
- A K-wire can be used as a joystick to reduce and maintain alignment in younger children
- A single screw can be used percutaneously for compression



# Proximal Ulna

- Keep your incision lateral to allow joint visualization and avoid the ulnar nerve on the medial side
- A tension band can be created with K-wires and fiber-wire or 18 gauge wire.
- A contoured plate and screws can also be used in adolescents but is usually not necessary for younger children.
- These fractures heal quickly so often don't need rigid fixation





# Proximal Ulna

- Complex fracture dislocations can be seen with higher energy mechanism of injury
  - May require fixation of multiple fractures around the elbow
- CT with 3D reconstructions is often useful to determine extent of injury
- Implants around the olecranon tend to become symptomatic and can be removed 6-12 months after initial surgery



# Implant removal

- Percutaneous Pins:
  - Remove after 3-4 weeks to prevent infection.
  - May need further casting after pin removal.
- Intramedullary implants:
  - Remove 6-12 months postop
  - If left in place for too long bone will grow over the ends of the implants making removal difficult and destructive.
- Plates and screws:
  - Often left in place
    - If left in place there is risk of fracture at the ends of the plate
  - Can be removed if the patient is symptomatic
    - Remove 6-12 months postop
    - After plate removal screw holes are stress risers to cause potential fracture for 6-12 months

# SUMMARY

- Most pediatric forearm fractures can be treated closed.
- Expert reduction and casting skills are necessary for taking care of pediatric fractures
- It is important to know acceptable alignment as immature bone remodels so anatomic reduction is often not necessary or beneficial
- The exception to this is any articular surface which should be as close to anatomic as possible

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