
بسم الله الرحمن الرحيم

دانشگاه علوم پزشکی
و خدمات بهداشتی درمانی بابل

Supracondylar Fractures of the Distal Humerus

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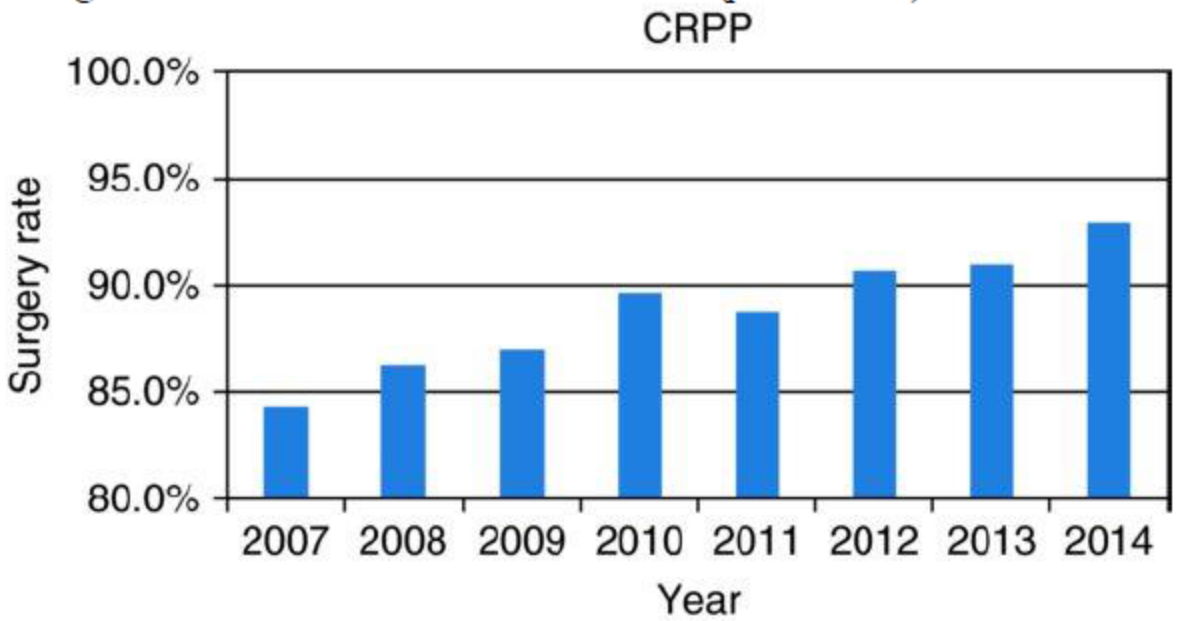
- over 10,000 pediatric supracondylar fractures are seen in emergency rooms each year in the United States.
- Of the 24% of these treated surgically, 87% are closed reduced, and this proportion is growing over time (Fig. 13-1).

Figure 13-1 The percentage of patients who underwent CRPP for the treatment of a supracondylar humeral fracture.
A significant increase in the rate of CRPP ($p < 0.0001$) was demonstrated.



SCH fractures are the most common elbow fractures seen in children,[42] and the most common fracture requiring surgery in children. The peak age range at which most supracondylar fractures occur is 5 to 6 years.[28]

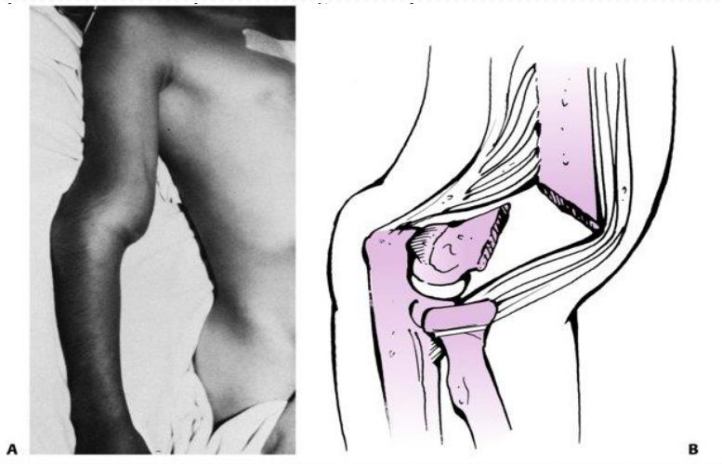
sensory examinations

- sensory areas of the radial nerve (dorsal first web space), median nerve (palmar index fingertip), and ulnar nerve (ulnar side little fingertip).
- If a child is not cooperative or has altered mental status, a wet cloth may be wrapped around the hand and checked for wrinkling of the skin, though in practice this is rarely done.
- In this test, a lack of sensation is demonstrated in areas where the skin does not wrinkle.

- type I supracondylar fracture, there is tenderness about the distal humerus and restriction of motion, particularly lack of full elbow extension.

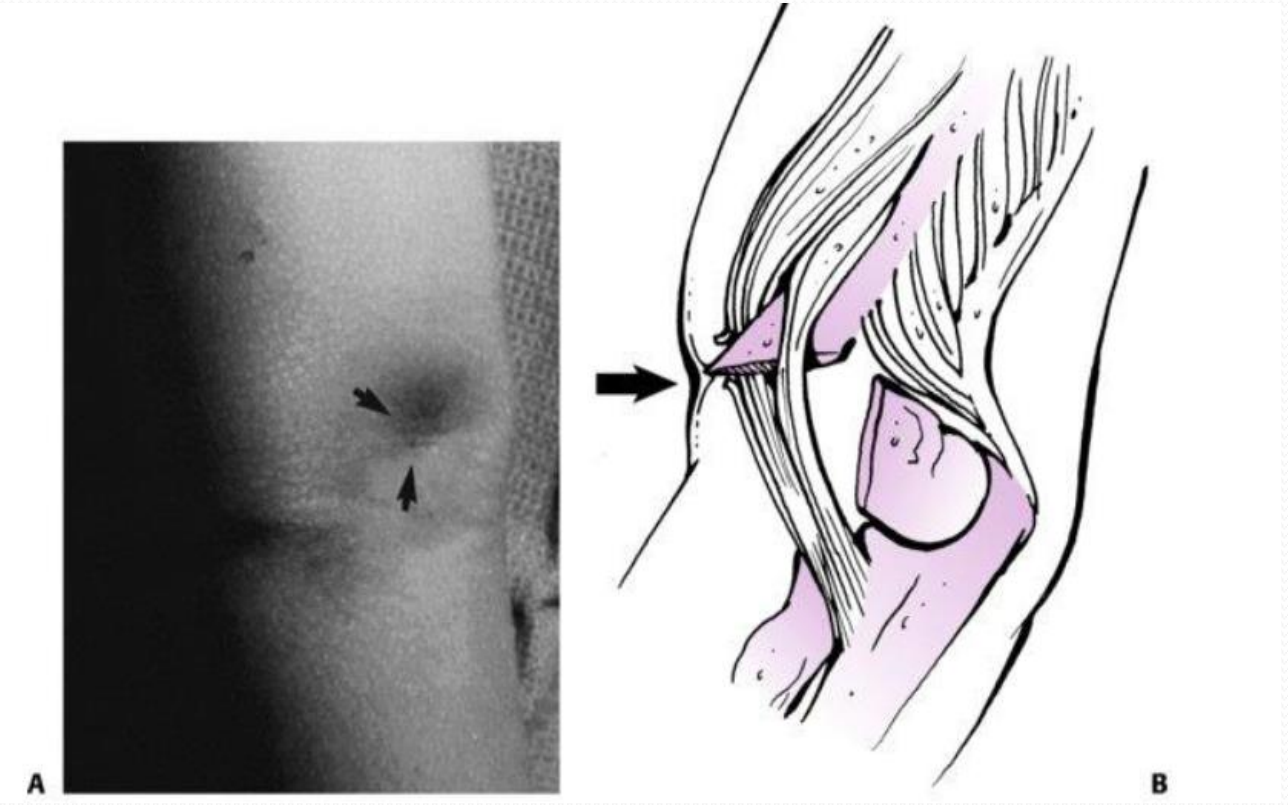
- X-rays may be negative except for a posterior fat pad sign.

- In type III fractures, gross displacement of the elbow is evident



- An anterior pucker sign may be present if the proximal fragment has penetrated the brachialis and the anterior fascia of the elbow Skin

- If any bleeding from a punctate wound is present, this should be considered an open fracture.



- **Motor examination** should include:
- finger, wrist, and thumb extension (radial nerve),
- index finger distal interphalangeal flexion and thumb interphalangeal flexion (anterior interosseous nerve, or AIN),
- finger flexion strength (median),
- and interossei (ulnar nerve) muscle function.

- In young children, the interosseous nerve may be tested by asking the child to pinch something with their thumb and first finger, while palpating the first dorsal interosseous for muscle contracture.

- Pediatric patients with compartment syndromes often present with the **three As**:

- anxiety,
- agitation,
- and increasing analgesic requirement.

Mechanisms of Injury

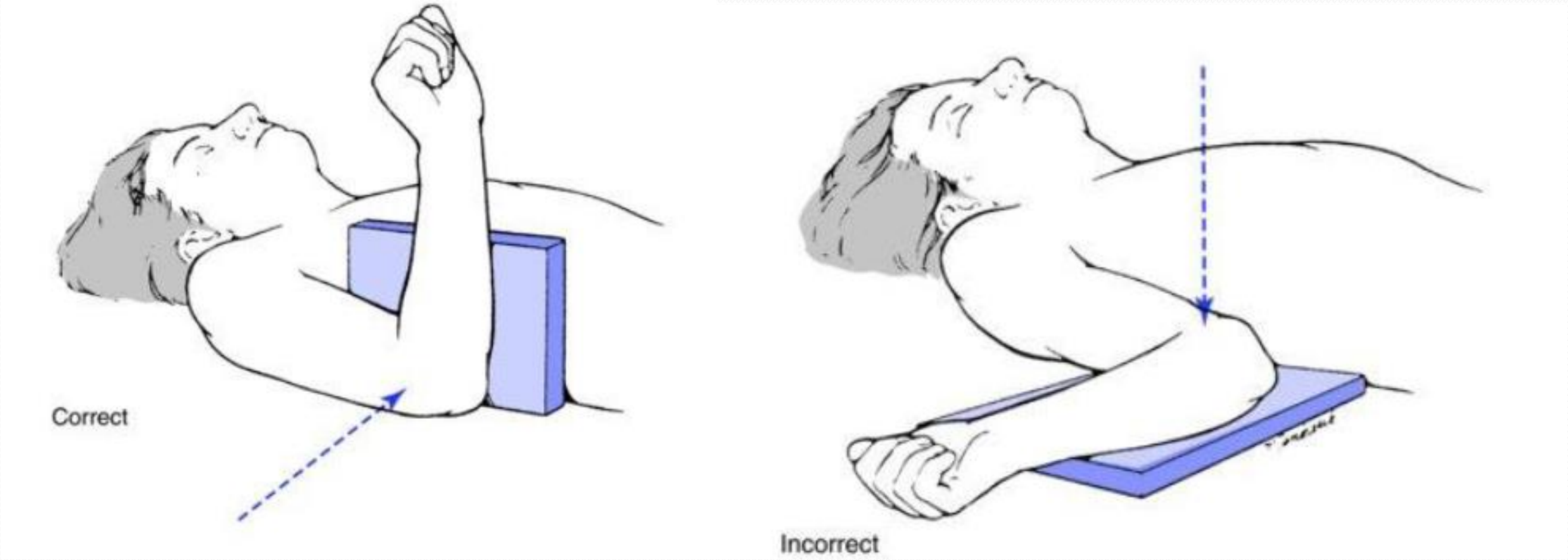
- Supracondylar fractures can be divided into extension and flexion types, depending on the direction of displacement of the distal fragment.

- Extension-type fractures, which account for approximately 97% to 99% of SCH fractures are usually caused by a fall onto the outstretched hand with the elbow in full extension

- ***Imaging***

- Radiographic examination begins with a true AP view of the distal humerus.

- The **lateral** film should be taken as a true lateral with the humerus held in the anatomic position and not externally rotated .



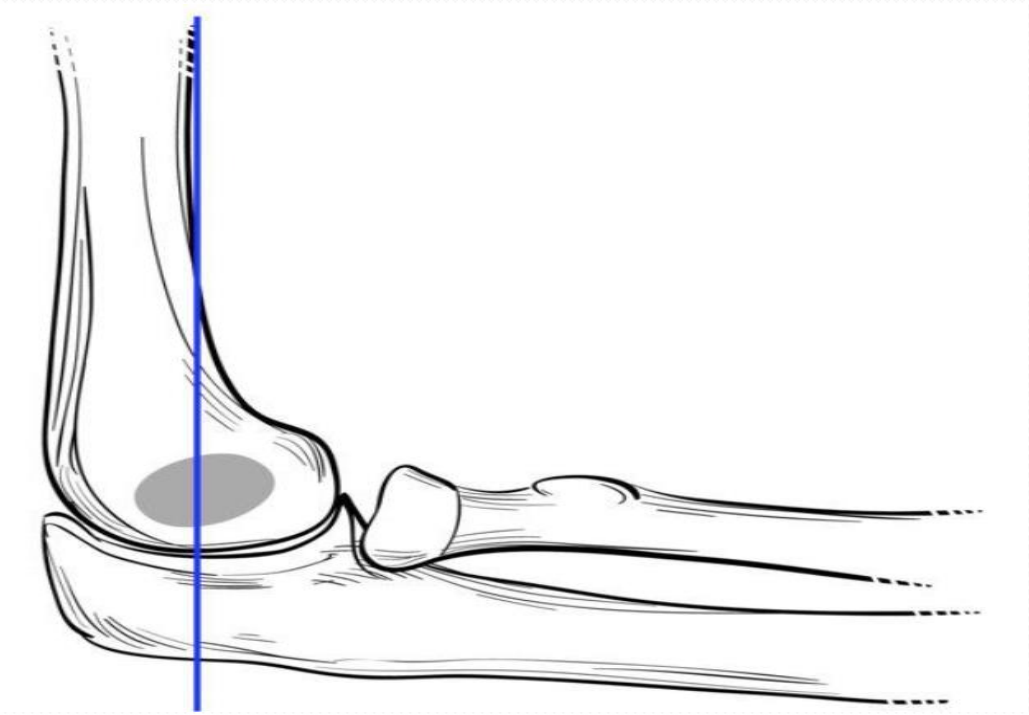
- A: Lateral radiograph demonstrating an elevated posterior fat pad (*white open arrow*) and a normal hourglass which is anteriorly tilted if there is **not** a displaced fracture.
- B: Another example of an elevated fat pad (*solid white arrows*).

- Oblique views of the distal humerus occasionally may be helpful when a supracondylar fracture or occult condylar fracture is suspected but not seen on standard AP and lateral views, but should not be routinely ordered to evaluate for a supracondylar fracture.

- Two main radiographic parameters:
- The anterior humeral line (AHL) should cross the capitellum on a true lateral of the elbow.

- Previous editions of this text and others have stated that in a normal elbow, the AHL should pass through the middle third of the capitellum.

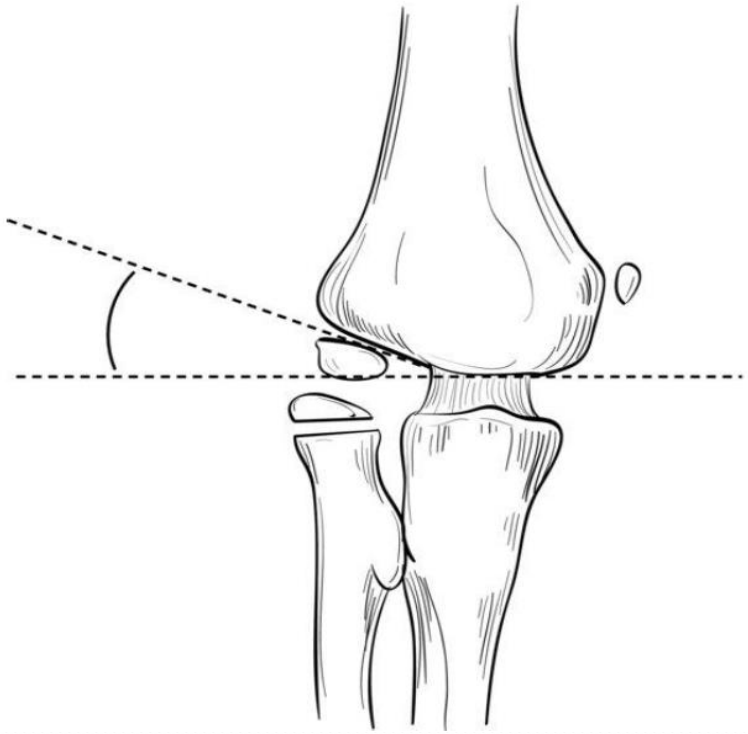
- Anterior humeral line **should cross** the capitellum on a true lateral of the elbow, though not necessarily through the middle third of the capitellum as was previously believed.



- In an extension-type supracondylar fracture, the capitellum is posterior to this line.

- Baumann's angle is between the line perpendicular to the long axis of the humeral shaft and the physeal line of the lateral condyle.
- A rule of thumb is that a Baumann's angle of at least 10 degrees is okay. (normal range, about 9 to 26 degrees)

- A **decrease** in Baumann's angle :
  - is a sign that a fracture is in varus angulation.
  - may indicate medial comminution.



- ***Gartland Classification***

Type I	<2-mm displacement	Fat pad present acutely
Type II	Hinged posteriorly	Only sagittal plane displacement, AHL anterior to capitellum with greater displacement
Type III	Displaced	Sagittal and coronal plane displacement, variable amount of cortical continuity
Type IV	Displaces into extension and flexion	Usually diagnosed with manipulation under fluoroscopic imaging
Medial comminution (not truly a separate type)	Collapse of medial column	Loss of Baumann's angle, requires reduction

- A: Type II SCH fracture

Type III

- As the elbow is flexed, the distal fragment falls into flexion, thus defining a Gartland type IV fracture.

Treatment Options

Treatment	*I*	*II*	*III*	*IV*
Casting without reduction	Almost always			
Closed reduction and casting		Rarely indicated, do *not* flex elbow >90 degrees		
Closed reduction and pinning		Great majority of cases	Great majority of cases	Most cases
Open reduction and fixation		Uncommonly necessary	If closed reduction inadequate	If closed reduction inadequate

Initial Management

- Initially splinted with the elbow in a comfortable position of approximately 20 to 40 degrees of flexion, while avoiding tight bandaging.
- If the arm is pulseless, gentle traction and elbow flexion alone frequently restore a pulse.
- The elbow and hand should then be gently elevated above the heart.

Urgency of Treatment

- Several studies have concluded that delay of surgery of even over 24 hours did not have any deleterious effects on the outcomes of children with supracondylar fractures

- Although there is little published data to support our opinion, we and others believe that if conditions such as :

- poor perfusion,
- pulselessness,
- an associated displaced forearm fracture,
- firm compartments,
- skin puckering,
- antecubital ecchymosis,
- or very considerable swelling are present, operative treatment should not be unduly delayed.

How Late Can Fractures Be Reduced?

- Silva et al. reported on type II SCH fractures treated 7 to 15 days after injury.
- They found that closed **anatomic reduction** was achieved in all fractures, with **equal** outcomes to fractures treated within 7 days of injury.

- We would caution that in very young children, reliable fracture reduction 2 weeks after injury with early callus formation is less likely.
- Two children closed reduced 8 days after injury developed avascular necrosis of the trochlea.

- Lal and Bhan reported that **delayed open reduction** (11 to 17 days after injury) did **not** increase the frequency of myositis ossificans.

- If a supracondylar fracture is unreduced or poorly reduced, delayed **open** reduction and pin fixation appear to be justified.

Traction

- Indications for traction may include:

- lack of anesthesia,
- medical conditions prohibiting anesthesia,
- lack of an experienced surgeon,
- severe open wounds.

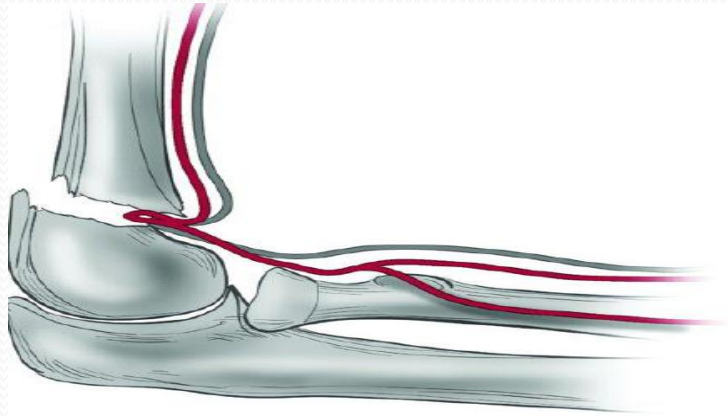
- ***Closed Reduction and Pinning***
- An initial attempt at closed reduction is indicated in almost all displaced supracondylar fractures that **are not open** fractures.

- Criteria for an acceptable reduction include:

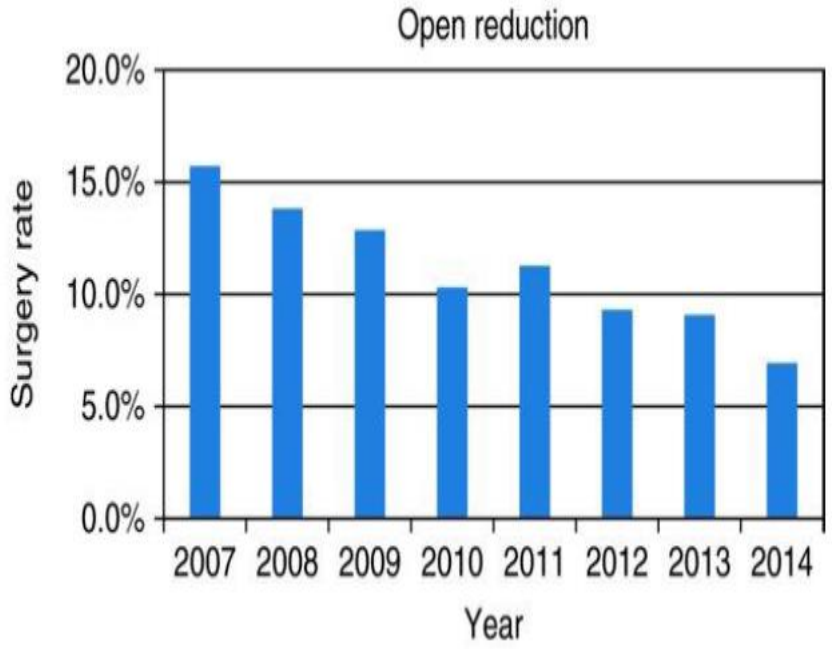
- restoration of Baumann's angle (generally >10 degrees) on the AP view,
- intact medial and lateral columns on oblique views,
- and the AHL passing through the middle third of the capitellum on the lateral view.
- As there is considerable rotation present at the shoulder, minor rotational malalignment in the axial plane can be tolerated at the fracture site.

- The fracture reduction is generally held with two to three Kirschner wires (K-wires) by lateral entry with divergence of pins.
- The elbow is immobilized in 40 to 60 degrees of flexion.

- If there is a considerable gap in the fracture site or the fracture is irreducible with a “rubbery” feeling on attempted reduction, the median nerve and/or brachial artery may be trapped in the fracture site and an open reduction should be performed.



Open Reduction



- Open reduction is indicated in cases of
  - failed closed reduction,
  - a loss of pulse, poor perfusion,
  - or nerve injury following reduction,
  - and open fractures.
- Over time, the rate of open reductions in the United States has been steadily **decreasing** over time, with about 6% in the most recent year reported (Fig. 13-27)

Surgical Approach

- The direct anterior approach.

- The posterior approach for an extended supracondylar fracture risks

❑a higher rate of loss of motion,

❑ further fracture instability with exposure through intact periosteum, and,

❑most importantly, the risk of avascular necrosis secondary to disruption of the posterior end arterial supply to the trochlea of the humerus .

❑This approach is not recommended.

Posteromedial Versus Posterolateral Displacement of Extension type

- With a posteromedially displaced fracture, the medial periosteum is usually intact.

Displacement	*Periosteum Is Torn*	*Forearm Rotation to Aid in Reduction*
Posterior medial	Lateral	Pronation
Posterior lateral	Medial	Supination

- If the posterior periosteal hinge is also disrupted, the fracture becomes unstable in both flexion and extension and this has been described as a multidirectionally unstable, modified Gartland type IV fracture.

The Special Case of Medial Column Comminution

- Fractures with medial comminution must be treated with operative reduction because collapse of the medial column will lead to varus deformity in an otherwise minimally displaced supracondylar fracture.

- The technique for reduction of a medial comminuted fracture is significant valgus force applied across a straight elbow.
- Often, so much force is required that one is fearful of creating a new fracture.

- Well-placed lateral entry pins are sufficient to hold the reduction.

Open Fractures

- Open supracondylar fractures generally have an anterior puncture wound where the metaphyseal spike penetrates the skin .

- Even if the open wound is only a small puncture in the center of an anterior pucker, open irrigation and debridement are indicated.
- The anterior approach, using a transverse incision based on the open wound with medial or lateral extension as needed, is recommended.

- Stabilization is with K-wires.

- All patients with open fractures are also treated with antibiotics: generally, cefazolin for Gustilo type I, II, and IIIA injuries, with the addition of appropriate antibiotics to cover gram-negative organisms for type IIIB and C fractures.

Medial Pin

- After placing lateral entry pins, the elbow is fully extended to relax tension on the ulnar nerve and surrounding tissue, and the surgeon can palpate the medial epicondyle.

- The entry site for medial pin placement is anterior on the medial epicondyle.
- A small incision is made to expose and protect the ulnar nerve.
- A drill guide is used to prevent binding of the perineural soft tissues that could kink the nerve.

- Type I fractures are managed in a long-arm cast with approximately 60 to 90 degrees of elbow flexion with the forearm in neutral rotation for approximately 3 weeks.
- Follow-up x-rays at 1 week are recommended for assessment of fracture position.

- We prefer closed reduction and pinning of most type II supracondylar fractures.
- Two lateral pins are chosen as the initial postreduction fixation method in nearly all cases .

- If two lateral pins fail to provide acceptable fixation, we do not hesitate to place a third lateral pin.

- For type III fractures, CRPP is attempted first.
- If closed reduction cannot be obtained, open reduction with pinning is performed.

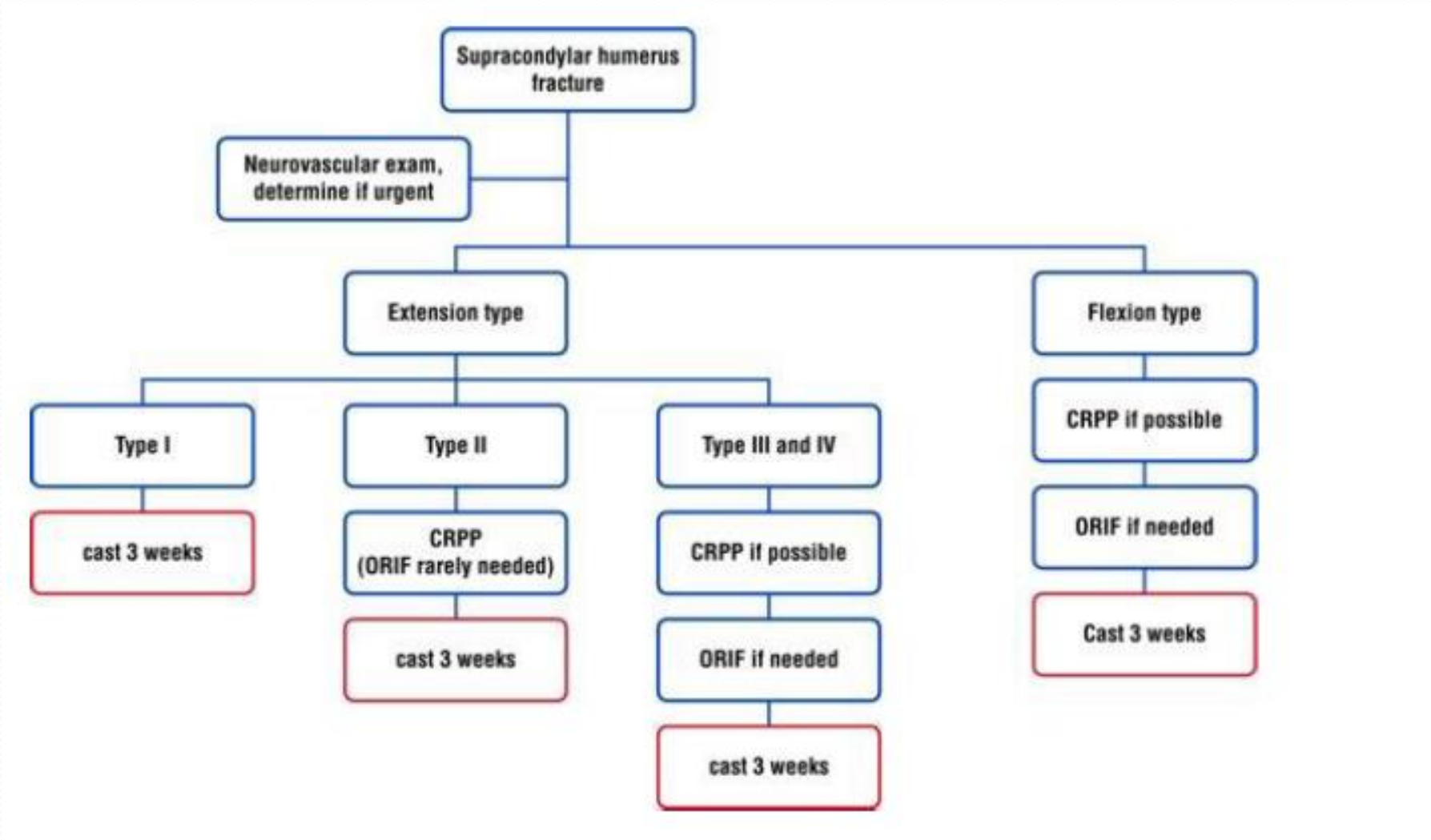
- A well-padded cast with sterile foam is applied, with x-rays at postoperative weeks 1 and 3, and pin removal at week 3

- ***Type IV Fractures*** .Although this extremely unstable fracture could be treated with open reduction, we follow the protocol recommended by Leitch et al:
- First, place two K-wires into the distal fragment.
- Next, the fracture is reduced in the AP plane and verified by imaging.
- At this point, rather than rotating the arm for a lateral image as is commonly done in more stable fracture patterns, the fluoroscopy unit is rotated into the lateral view (see Fig. 13-38B).

- The fracture is then reduced in the sagittal plane and the K-wires are driven across the fracture site.

- The reduction often is in midposition of flexion and extension (~60 degrees) and requires holding the reduction with distraction by the surgeon while the assistant places the first lateral entry stabilizing pin.

- Subsequent studies have also reported that over 80% of type IV fractures can be closed reduced and pin stabilized with good results


Supracondylar humerus fracture
Neurovascular exam, determine if urgent
Extension type
Flexion type
Type I
Type II
Type III and IV
CRPP if possible
cast 3 weeks
CRPP (ORIF rarely needed)
CRPP if possible
ORIF if needed
cast 3 weeks
ORIF if needed
Cast 3 weeks
cast 3 weeks

Postoperative Care

- Swanson et al. reported that acetaminophen is as effective,
  and Kay et al.reported that perioperative ketorolac.
- We use acetaminophen and an NSAID as the first-line drugs for pain relief.

- A recent series found administration of postoperative antibiotics after closed reduction and percutaneous pinning of pediatric SCH fractures does not decrease the rate of surgical-site infection

- We recommend that the elbow is elevated over the heart for at least 48 hours postoperatively.

- The patient customarily returns 5 to 7 days postoperatively at which time AP and lateral radiographs are obtained.

- The cast is generally removed 3 weeks postoperatively, at which time we have traditionally obtained radiographs out of the cast.

- The pins are removed in the outpatient setting at this time.
- ROM exercises are taught to the family, targeting gentle flexion and extension, to be started a few days after cast removal.
- The child returns 6 weeks postoperatively for a ROM check, with no radiographs at that time.

Operative Treatment : Potential Pitfalls and Preventions

- **Nerve entrapment**

- If during the reduction maneuver the fracture does not stay reduced, and a "rubbery" feeling is encountered instead of the desired "bone-on-bone" feeling, the median nerve and/or brachial artery may be trapped within the fracture site .

- If this occurs, an open reduction is generally necessary to remove the neurovascular structures from the fracture site.

Inability to obtain closed reduction

- In general, plan on a minimum of two pins for type II fractures and three pins for type III fractures.
- Aim to separate the pins as far as possible at the fracture site—at least 13 mm or one-third the width of the humerus at the level of the fracture.

- Pin separation is more important than whether the pins are divergent or parallel.

Loss of reduction

- It is acceptable to cross the olecranon fossa, which adds **two more cortices** to improve fixation.

- A small amount of **translation or axial** rotational malalignment may be accepted rather than doing an open reduction, but accept very little frontal or sagittal plane angular malalignment.

- The child's elbow should sufficiently flex so that the fingers touch the shoulder.
- If not, the fracture is still likely **not reduce**d and is in too much extension .

Figure 13-49 If fingers cannot touch shoulder, flexion deformity may not be reduced.

Management of Complications

Vascular Injuries

- Approximately 1% to 15% of patients with supracondylar fractures present with an absent pulse but only a minority of these patients will require vascular repair.

- If there is no pulse, slight traction and gentle elbow flexion often restore the pulse and improve perfusion.

- If there is not a palpable pulse, a Doppler may be used to assess for a triphasic pulse.

- Generally accepted normal perfusion criteria (viable hand) are :
  - capillary refill equivalent to the opposite side and less than 3 to 5 seconds,
  - normal pulp turgor,
  - and pink color.

- Hand perfusion, not presence or absence of a pulse, appears to be predictive of the need for arterial repair and risk of compartment syndrome.

- Choi et al. reported on 25 pulseless patients whose hands were well perfused at presentation, and none (0%) required vascular repair or developed a compartment syndrome.

- An absent radial pulse is not in itself an emergency.

- In the case of a pulseless, well-perfused hand, urgent, but **nonemergent,** reduction with pinning in the operating room is indicated.

- If the arm is pulseless and also has signs of poor perfusion (white color, decreased turgor, and/or slow capillary refill), this is an emergency.

- Fracture reduction should not be delayed by any waiting time for an angiographic study, as reduction of the fracture usually restores the pulse.

- Several authors state angiography is an unnecessary test that should not delay treatment

Pulseless Hand

- ***Prereduction White, Pulseless Hand***

- Standard treatment for a pulseless hand is closed reduction and percutaneous pinning then the pulse and perfusion of the hand should be evaluated.

- Usually, hand perfusion is restored.

- Following pinning when the arm is extended, the pulse frequently does not return immediately.
- This is presumably secondary to arterial spasm.
- Because of this phenomenon, up to 10 to 15 minutes should be allowed for recovery of perfusion in the operating room
- However, all poorly perfused hands require exploration.
- In cases of poor limb perfusion for over 6 hours, prophylactic forearm compartment release should be considered.

Postreduction White (Poorly Perfused), Pulseless Hand

- If there was a pulse before fracture reduction, but not after reduction, one must assume the artery or surrounding tissue is trapped at the fracture site, and pins should be pulled, and artery explored if the pulse does not return quickly.

- If there was not adequate perfusion before fracture reduction, and the hand remains poorly perfused after reduction, arterial exploration should be performed emergently.

- Exploration through an anterior approach.
- Once the artery is freed from the fracture, associated arterial spasm may be relieved by application of lidocaine, warming, and 10 to 15 minutes of observation.

- Following anatomic fracture reduction and decompression of the NVB of a pulseless limb, if the hand remains poorly perfused, vascular reconstruction is indicated by an appropriate specialist.

Postreduction Pink (Perfused), Pulseless Hand

- If the pulse does not return, but the hand is well perfused following reduction, treatment is controversial.

- Our practice is to admit the child to the hospital with gentle arm elevation and careful observation for at least 48 hours.

Pulseless Arm With Median Nerve Injury

- With injury to both the brachial artery and a nerve, we can assume that **significant soft tissue damage** has occurred, which places the child at higher risk for a compartment syndrome.

- The pain of a compartment syndrome may be masked by the nerve injury, so, very careful assessment and monitoring for a compartment syndrome.

- Mangat et al. recommend **early exploration** of the brachial artery in a Gartland type III supracondylar fracture in patients who present with an absent pulse and a coexisting anterior interosseous or median nerve palsy, as these appear to be strongly predictive of nerve and vessel entrapment.

Compartment Syndrome

- The prevalence of compartment syndrome is estimated to be 0.1% to 0.5%.

- The classic five Ps for the diagnosis of compartment syndrome—pain, pallor, pulselessness, paresthesias, and paralysis—are poor indicators of a compartment syndrome in children.

- Resistance to passive finger movement and dramatically increasing pain after fracture are clinical signs of compartment syndrome of the forearm.

- The authors also noted that even if distal pulse is found by palpation or Doppler examination, an evolving compartment syndrome may be present.

Neurologic Deficit

- A meta-analysis found an overall neurapraxia rate of 13%, with the AIN (5%) being the most common.
- If the distal fragment is displaced posteromedially, the **radial** nerve is more likely to be injured.
- Conversely, if the displacement of the distal fragment is posterolateral, the NVB is stretched over the proximal fragment, injuring the complete **median** nerve or isolated AIN.
- In a **flexion-type** supracondylar fracture, which is rare, the **ulnar** nerve is the most likely nerve to be injured.

- Open reduction and exploration of the injured nerve are not necessarily indicated in cases of nerve injury in a closed fracture.

- Neural recovery, generally occurs with observation, but may take 6 months or more.

- Isolated median nerve injuries recovered faster (70% by 3 months) than median nerve injuries associated with multiple nerve injuries, which took 54% longer to recovery.
- Radial nerve injuries took 30% longer to recover.

- There is no indication for early electromyographic analysis or treatment other than observation for nerve deficit until 3 to 6 months after fracture.

- An irreducible fracture with nerve deficit is an **indication** for open reduction of the fracture to ensure that there is no nerve entrapment.

- **Iatrogenic injury to the ulnar** nerve has been reported to occur in 1% to 15% of patients with supracondylar fractures.

- If an **immediate postoperative neural injury** is documented, we **prefer** to explore the ulnar nerve and to replace the pin in the proper position or convert to a lateral pin construct.

- Because of the frequency of ulnar nerve injury with crossed pinning, most surgeons prefer to use two or three lateral pins if possible and no medial pin.

Elbow Stiffness

- Clinically significant loss of motion after extension-type supracondylar fractures is rare.
- In a study who did not undergo physical therapy, 90% ROM returned at 30 days for extension and 39 days for flexion.

- Although most children do not require formal physical therapy, we generally teach the parents ROM exercises to be performed at home following pin and cast removal at about 3 to 4 weeks.
- A follow-up appointment to assess ROM is scheduled about 4 to 8 weeks later, and if motion is not nearly normal at that time, a physical therapy to improve elbow motion is begun.

Pin-Tract Infections

- The reported prevalence : less than 1% to 2.5% with closed reduction and standard pinning techniques .

- Pin-tract infections generally resolve with pin removal and antibiotics.

Pin Migration

- In one retrospective series of 622 patients, the most common complication was pin migration, necessitating unexpected return to the operating room for pin removal in 11 patients (1.8%).

- This complication can be minimized by both bending at least 1 cm of pin at a 90-degree angle, at least 1 cm from the skin, and protecting the skin with thick felt over the pin or using commercially available pin covers.

Myositis Ossificans

- Myositis ossificans is a remarkably rare complication of supracondylar fractures, but it can occur .
- This complication has been described:

- after closed and open reductions due to disruption of the brachialis with injury,
- but vigorous postoperative manipulation or
- physical therapy is believed to be an associated factor.

- Aitken et al. noted that limitation of motion and calcification disappeared after 2 years.

- Postoperative myositis ossificans can be observed with the expectation of spontaneous resolution of both restricted motion and the myositis ossificans.

- There is no indication for early excision.

Nonunion

- We have not seen nonunion of this fracture.

- With infection,
- devascularization,
- and soft tissue loss, the risk of nonunion would presumably increase.

Avascular Necrosis

- Avascular necrosis of the trochlea after supracondylar fracture has been reported.
- If the fracture line is very distal, this artery can be injured, producing avascular necrosis of the ossification center and resulting in a classic fishtail deformity.

- Cubitus varus deformity developed in all cases.

- Symptoms of avascular necrosis of the trochlea do not occur for months or years.
- Healing is normal, but mild pain and occasional locking develop with characteristic radiologic findings and motion may be limited depending on the extent of avascular necrosis.

- An important risk for AVN of the trochlea is following an open reduction through a posterior approach, which presumably disrupts the blood supply of the trochlea .

*Cubitus Varus (*gunstock deformity)

- The malunion also includes hyperextension, which leads to increased elbow extension and decreased elbow flexion .
- On the AP view, Baumann's angle is more horizontal than normal .
- On the lateral view, hyperextension of the distal fragment posterior to the AHL.

- Five-year-old girl with cubitus varus of right elbow following a malunion of a supracondylar humerus fracture.

- A: Hyperextension of right elbow. B: Decreased flexion of right elbow.

- The most common reason for cubitus varus in patients with supracondylar fractures is likely malunion rather than growth arrest.

- A decrease in frequency of cubitus varus deformity after the use of percutaneous pin fixation less than casting.

- Indications for an operative reconstruction with a supracondylar humeral osteotomy:

- aesthetic reasons
- increased risk of lateral condyle fractures,
- pain,
- and tardy posterolateral rotatory instability.

- Tardy ulnar nerve palsy has also been associated with varus and internal rotational malalignment.

- ***Treatment***
- As for the treatment of any posttraumatic malalignment, options include :

- observation with expected remodeling,
- hemiepiphysiodesis and growth alteration,
- and corrective osteotomy.

- Hemiepiphysiodesis of the distal humerus is rarely of value in restoring anatomic alignment, only to prevent cubitus varus deformity from developing in a patient with clear medial growth arrest or trochlear avascular necrosis.

- Osteotomy is the only way to correct a cubitus varus deformity with a high probability of success.

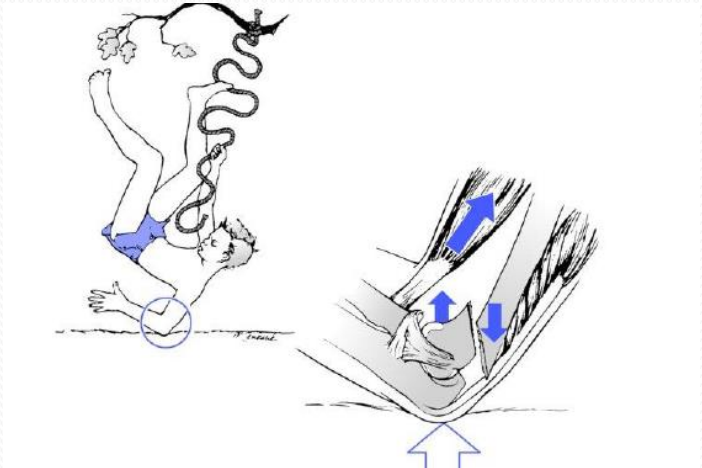
Flexion-Type

- account for about 2% of humeral fractures.

- A flexion-type supracondylar fracture is unstable in flexion, whereas extension-type fractures generally are stable in hyperflexion.

- ***Mechanisms of Injury***

- The mechanism of injury is generally believed to be a fall directly onto the elbow rather than a fall onto the outstretched hand .
- The distal fragment is displaced anteriorly and may migrate proximally in a totally displaced fracture.



- ***Imaging***

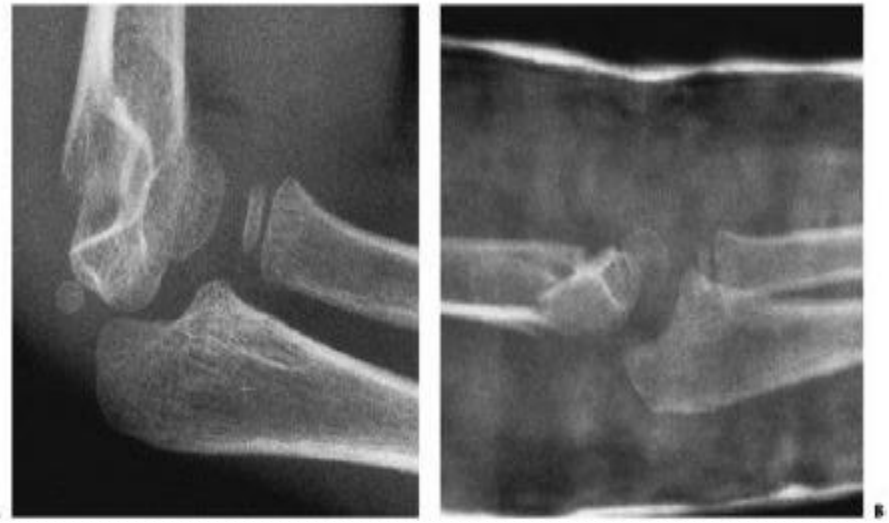
- Fracture classification is similar to extension-type supracondylar fractures:

- type I, nondisplaced fracture;
- type II, flexion angulations only with anterior cortical contact;
- and type III, totally unstable displaced distal fracture fragment.

Treatment Options

- ***Nonoperative Treatment***
- Type I ➡ long-arm cast.

- Type II fracture ➡ reduction in extension, the arm can be immobilized with the elbow fully extended.



- The cast is removed at 3 weeks.

- If closed reduction is performed without skeletal stabilization, follow-up x-rays usually are taken at 1 week and when the cast is removed at 3 weeks.

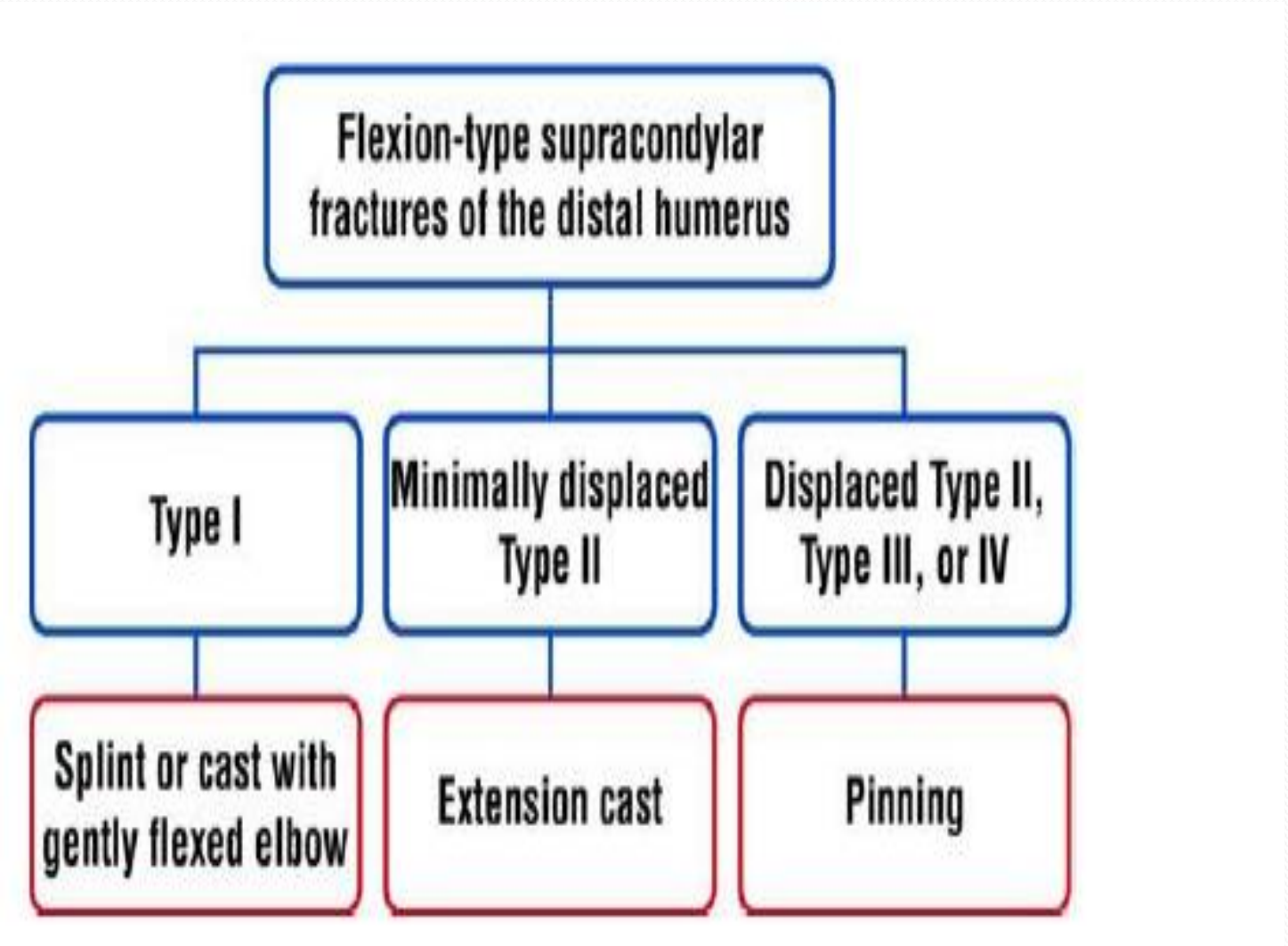
Operative Treatment

- Pinning is generally required for unstable type II and III flexion supracondylar fractures.
- Place a lateral entry pin in the distal fragment, place a second parallel or divergent pin.
- Cut and bend pins, protect skin with sterile felt or other barrier, and cast to allow for swelling, with less than 90 degrees of elbow flexion.

- ***Open Reduction***
- Open reduction is required for flexion-type supracondylar fractures in up to 23% of cases; and if the ulnar nerve is injured, the open reduction rate is 60% in one series.

- Open reduction through a medial or posterior approach is used if an anatomic closed reduction cannot be obtained.

- The ulnar nerve is identified and protected throughout the exposure and fracture stabilization.


Flexion-type supracondylar fractures of the distal humerus
Type I
Minimally displaced Type II
Displaced Type II, Type III, or IV
Splint or cast with gently flexed elbow
Extension cast
Pinning