Complications of Pediatric Supracondylar Humeral Fractures

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Abstract
Supracondylar humeral fractures are common in the pediatric population and can result in complications caused by both the injury itself and surgical or nonsurgical treatment. Neurologic complications are frequent, with the anterior interosseous nerve being the most common nerve affected. Vascular injuries, although less common, can result in long-term sequelae and should be recognized and treated promptly. Loss of reduction can occur with both surgical and nonsurgical treatment. Compartment syndrome and infection, although rare, require rapid recognition and treatment. It is important to be familiar with the potential complications surrounding the treatment of pediatric supracondylar humeral fractures to maximize outcomes and know when a referral may be warranted.


Supracondylar humeral fractures are common in the pediatric population and account for 3% of all pediatric fractures.1,2 These fractures occur most commonly in children aged 5 to 7 years but have been reported to occur in children aged 1 to 16 years.3 Fractures most often occur on the nondominant side and occur equally in boys and girls. The usual mechanism of injury is a fall onto an outstretched hand.4,5

The Gartland classification is the most widely used classification system for describing extension-type, supracondylar humeral fractures, which account for 97% to 99% of supracondylar humeral fractures.3 In the original classification scheme, type I fractures were considered nondisplaced, type II fractures had an intact posterior hinge, and type III fractures were completely displaced.6 Wilkins’ modified this classification, subdividing type II fractures into type IIA and type IIB to aid in determining the presence of stability with closed reduction and casting alone versus closed reduction and percutaneous pin fixation (Table 1).

Most supracondylar humeral fractures can be treated with splinting and casting, closed reduction and casting, or closed reduction and percutaneous pin fixation. Open reduction is rarely
necessary, but indications for open reduction include a failure to achieve reduction because of an unstable fracture pattern or soft-tissue interposition, open fractures, or a vascular injury necessitating open repair.

Gartland type I fractures are almost universally treated nonsurgically and have excellent outcomes. Cast immobilization for 3 to 4 weeks in 90° of flexion and neutral forearm rotation is adequate. In contrast, Gartland type III fractures are almost universally treated surgically with closed reduction and percutaneous pinning. The expectant outcomes are excellent, but several complications can occur. Substantial controversy exists regarding the treatment of type II fractures, with some authors recommending surgical treatment of all type II fractures, others recommending nonsurgical treatment, and some determining treatment based on the presence or the absence of rotation, based on the Wilkins subclassification.1,3,7,8 Surgical intervention for all type II fractures limits the potential for loss of reduction and is less intensive regarding the necessary follow-up than exists with nonsurgical care. This chapter’s authors prefer to treat most type II fractures surgically, whereas nonsurgical management is reserved for very young patients and those with minimal extension and no rotational deformity.

The location of pin placement for supracondylar humeral fractures also remains somewhat controversial. Options include placing two or three lateral pins alone or using a cross-pin configuration. Although two crossed pins were initially advocated for more unstable fractures, several studies recently have found no biomechanical advantage for two crossed pins versus two lateral pins,9–11 whereas other authors have found greater rotational stability with two crossed pins compared with lateral pins.12,13

If only two lateral pins are used, the pins should be placed in a bicortical fashion and diverge at the fracture site (Figure 1). The addition of a medial pin is advocated in cases of medial cortex comminution or if the fracture remains unstable, as noted with live fluoroscopy, after the placement of lateral pins.

Bloom et al14 performed biomechanical testing on various pin configurations for both well-reduced and slightly malreduced fracture patterns. Several planes of motion were tested, but there was no difference between crossed pins or the lateral pin configurations. However, adding a third pin in either configuration improved stability. The authors believed that slight internal rotation of the distal fragment is commonly accepted during pinning, which may lead to more internal rotation and varus deformity during healing. Most importantly, Bloom et al14 noted that distal fragment malrotation leads to a less stable fracture after pinning in any configuration. Obtaining anatomic reduction in the axial plane maximized stability in all pin configurations; therefore, the acceptance of any intraoperative malalignment should be avoided.

Neurologic Complications

The incidence of nerve injury after a supracondylar humeral fracture is reported to range from 6% to 16%, including nerve injuries caused by the fracture itself and iatrogenic injuries that primarily result from pin placement.15–17 Typically, injuries that occur as a result of the fracture itself are caused by traction. Patients usually recover between 2 and 2.5 months after the fracture; however, recovery can take up to 6 months.15,16,18,19

Although all nerves around the elbow have been documented to sustain an injury, the anterior interosseous nerve (AIN) is most commonly involved in extension-type fractures10 (Figure 2). In flexion-type fractures, the ulnar nerve is most commonly injured. In a review of 622 fractures, Bashyal et al21 reported neurologic deficits in 11.9% of cases, with the AIN most commonly affected, followed by

### Table 1

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>I</td>
<td>Nondisplaced</td>
</tr>
<tr>
<td>II A</td>
<td>Intact posterior hinge, no rotational deformity</td>
</tr>
<tr>
<td>II B</td>
<td>Intact posterior hinge, with rotational deformity or translation</td>
</tr>
<tr>
<td>III</td>
<td>Complete displacement, no posterior hinge</td>
</tr>
<tr>
<td>IV</td>
<td>Unstable in both flexion and extension</td>
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Bennett et al10 determined Gartland classification to include Gartland type IV fractures, which are “Unstable in both flexion and extension.” The location of pin placement for supracondylar humeral fractures also remains somewhat controversial. Options include placing two or three lateral pins alone or using a cross-pin configuration. Although two crossed pins were initially advocated for more unstable fractures, several studies recently have found no biomechanical advantage for two crossed pins versus two lateral pins,9–11 whereas other authors have found greater rotational stability with two crossed pins compared with lateral pins.12,13

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the radial, median, and ulnar nerves. Only the ulnar nerve was affected in their series of flexion-type injuries.

Dormans et al\textsuperscript{22} studied acute type III extension injuries and found a neurologic injury rate of 9.5%, including seven AIN injuries, four median nerve injuries, five radial nerve injuries, and three ulnar nerve injuries. Each injury was treated expectantly, except for one median nerve injury that accompanied a brachial artery injury. Patients with AIN palsies, which were most common, recovered fully, on average, 12.5 weeks after injury (range, 6 weeks to 4 months). Of note, AIN palsies were more common in fractures with posterolateral displacement.

Garg et al\textsuperscript{23} reported a 12% nerve palsy rate in type II and III fractures, with 75 being identified preoperatively and 30 postoperatively. Most palsies involved the AIN or the median nerve (94 total patients, 24 identified postoperatively). Of the 16 ulnar nerve palsies, 9 were identified postoperatively. Contrary to previous studies, Garg et al\textsuperscript{23} did not find an increased rate of ulnar nerve palsy with medial pin placement. It is unclear from their evaluations how many postoperative palsies were caused by iatrogenic nerve injury versus secondary differences in documentation among providers.

Rasool\textsuperscript{24} reported on six cases of ulnar nerve injury from medial pin placement, which represented 5% of all the supracondylar humeral fractures pinned. In five cases, the pin was found in the cubital tunnel, and two cases resulted in penetrating injuries to the nerve. In one case, a hypermobile nerve was fixed anteriorly secondary to pin placement. At the study end point of 48 months, three patients had full neurologic recovery, two experienced partial recovery, and one showed no recovery after a penetrating injury.

Children can have generalized ligamentous laxity, which may predispose them to ulnar nerve subluxation and place the nerve in jeopardy during medial pin placement. Zaltz et al\textsuperscript{25} found that 71.9% of children with ligamentous laxity exhibited ultrasound evidence of ulnar nerve subluxation. This appears to be more common in children younger than 5 years, and the incidence decreases as children age.

Skaggs et al\textsuperscript{26} reported that medial pinning at 90° or less led to a 4% risk of ulnar nerve injury, whereas hyperflexion during medial pinning increased that risk to 15%, which was caused by the nerve becoming more anterior with elbow flexion. The authors recommended lateral pin placement first to allow for more elbow extension during medial pinning.

When it becomes necessary to place a medial pin, multiple authors have advocated making a small incision before pin placement.\textsuperscript{27,28} This incision permits placement of the pin directly on the bone, thus ensuring that the pin does not go through the bone. Alternatively, recent research has shown that the preoperative use of electrical stimulation twitch monitoring can help map the path of the ulnar nerve and avoid entry into the cubital tunnel during pinning.\textsuperscript{29}

\textbf{Vascular Injuries}

Vascular injury requiring intervention is uncommon in pediatric supracondylar humeral fractures. Approximately 10% to 20% of patients with type III fractures will present with pulseless extremities,\textsuperscript{30-32} which may be further subdivided into perfused (pink) or not perfused (white). In the case of the white, pulseless extremity, emergent intervention is warranted, including reduction of the fracture followed by observation to see if the pulse returns or the hand becomes perfused (pink). If the hand remains white after reduction and pinning, vascular exploration with decompression and/or repair is warranted.
Shaw et al\textsuperscript{31} examined 143 type III injuries in children, 17 of which presented with vascular compromise. Most patients with vascular compromise have a pink, pulseless extremity. In such cases, emergent intervention still should be undertaken in an attempt to restore normal vascular flow.\textsuperscript{28} Reduction of the fracture usually restores the pulse, which is believed to be absent secondary to kinking of the vessel. After the fracture is reduced, the vessel is no longer kinked. However, hospital admission and close observation of the limb is needed to identify any changes that may occur in the vascular examination.

The use of ultrasound and/or Doppler has been advocated to assess brachial artery injuries or spasms in the case of a pink, pulseless hand. One study identified 11 children who had vascular impairment after a type III supracondylar humeral fracture, 8 of whom had a pulseless but clinically well-perfused hand.\textsuperscript{33} Four of these patients showed spasms and kinking of the brachial artery but no occlusion or thrombosis, and all had return of pulse after closed reduction maneuvers. The other four patients showed severe spasms and decreased flow in the brachial artery on color-coded Doppler without return of flow after reduction. All four of these children underwent exploration and vascular repair with no sequelae reported.

There has been concern for the long-term effects of vascular injury, including growth disturbance, arm circumference, endurance strength, and cold intolerance. A recent study by Scannell et al\textsuperscript{34} evaluated 29 patients with pink, pulseless extremities at the time of injury. The authors collected follow-up data for an average of 19.5 months after the injury. They reported only one instance of cold intolerance during ice hockey and no differences in average arm circumference, arm length, muscle endurance, or grip strength compared with the contralateral side.

**Compartment Syndrome**

The rate of compartment syndrome after isolated supracondylar humeral fractures has been reported between 0.1% to 0.3%.\textsuperscript{35} This rate increases in combined injuries of the elbow and the forearm or wrist, the so-called floating elbow injuries (Figure 3). Ring et al\textsuperscript{36} reviewed 16 children with floating elbow injuries: compartment syndrome developed in 2 patients, and symptoms of compartment syndrome began in 4 patients but responded to splitting of the cast.

Battaglia et al\textsuperscript{35} found that flexing the elbow past 90° of flexion increases forearm compartment pressures. Therefore, children splinted in the emergency department or postoperatively should be placed in 90° of flexion or less.

The presence of compartment syndrome in children is more likely to be manifested by an increase in analgesia requirement, anxiety, or agitation, known as the three A's, rather than the five P's (pain, pallor, pulse, paresthesia, and paralysis) commonly described for adults.\textsuperscript{37} Special attention should be paid to children with median nerve injuries because they will lack sensation in the volar forearm, thus masking the signs of compartment syndrome.\textsuperscript{38} If compartment syndrome is missed or the diagnosis is delayed by more than 6 hours, this can result in Volkmann ischemic contracture of the forearm, which affects the deep volar compartment most profoundly. The typical posture of the limb is elbow flexion, forearm pronation, wrist flexion, and thumb adduction, with the metacarpophalangeal joints in extension and the proximal interphalangeal joints in flexion. The median nerve is often affected more profoundly than the ulnar nerve because the median nerve lies in the deep flexor compartment.

Blakey et al\textsuperscript{39} examined 26 children at a mean of 3 months after they were referred to the authors’ facility for weak or absent radial pulses after reduction and pinning. With the exception of 3 children who were treated with artery exploration and repair, the remaining 23 children all had some amount of ischemic contracture or fibrosis within their forearm compartments.
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The goal of treatment after Volkmann ischemic contracture is to restore function; however, normal function should not be anticipated. Treatment consists of débriding necrotic tissue and muscle and preserving neurovascular structures. Subsequently, a flexor/pronator slide or a free muscle transfer may be used to improve hand position and function.40,41 Individual flexor tendon tenolysis or lengthening should not be performed because of the high rate of recurrent contracture. However, extensor to flexor tendon transfers may be performed to improve individual functions of the hand and the wrist after release of the volar contracture.

Cubitus Varus

Cubitus varus is a common complication after supracondylar fractures, and it can be the result of either casting or surgical treatment with pinning. Cubitus varus is currently thought to be caused by inadequate fracture reduction, which leads to malunion rather than growth arrest1 (Figure 4).

Typically, in childhood, this deformity is painless and does not interfere with elbow range of motion. Less commonly, children may have an increased risk of lateral condyle fractures or snapping medial triceps.42,43 It is important to note that there have been reports of elbow pain and instability in adults in whom cubitus varus developed after a supracondylar humeral fracture was sustained as a child. This is believed to be caused by tardy posterolateral elbow instability as a result of medialization of the elbow mechanical axis and attenuation of the lateral collateral ligaments across time.44 A three-dimensional CT analysis of adult patients with cubitus varus found generally increased sizes of the posterior trochlea, lateral capitellum, and radial head, with medial shift of the ulna, compared with the contralateral, unaffected side.

When considerable cubitus varus occurs after a pediatric supracondylar humeral fracture, the preferred treatment method of Kim et al45 is to use a lateral closing wedge osteotomy with or without ligament reconstruction (Figure 5). If a sagittal plane deformity also is present, a biplanar closing wedge, dome, or step-cut osteotomy is required for correction. These latter procedures are more technically demanding and require accurate preoperative planning.46-48

Stiffness

It is generally anticipated that full return of elbow motion will occur after supracondylar humeral fractures. Spencer et al49 studied the range of motion in children treated both surgically and nonsurgically after supracondylar humeral fractures and found significant differences in range of motion between those treated surgically and nonsurgically until 24 weeks after injury. Although the average flexion contracture at cast removal was 47°, by week 9, children had an average of 2° of hyperextension of the affected arm, with an arc of motion of 132° compared with 150° on the contralateral side. The need

Figure 4  Images from a 7-year-old girl with a left supracondylar humeral fracture. A, Clinical photograph showing cubitus varus. B, AP radiograph showing cubitus varus. C, Lateral radiograph with slight extension at the fracture site. (Courtesy of Martin J. Herman, MD, Philadelphia, PA.)

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for surgery, fracture severity, and age younger than 5 years all contributed to longer times needed to return to full motion. By 48 weeks after injury, 88% of all the children had recovered 90% of motion compared with their contralateral side. Garg et al23 noted that 8% of their types II and III supracondylar humeral fracture patients were sent to physical therapy because of elbow stiffness.

Pin-Related Complications

Loss of Reduction

Loss of reduction after the surgical treatment of pediatric supracondylar humeral fractures is most commonly caused by technical errors in pin placement or malreduction of the fracture. Common errors include a failure to engage both fragments with at least two pins (Figure 6), failure to achieve bicortical fixation with at least two pins (Figure 7), and failure to achieve at least 2 mm of pin separation at the fracture site (Figure 8).

Sankar et al50 reported loss of reduction in 8 of 279 fractures (2.9%) treated surgically. Seven of those eight fractures were treated with two lateral pins, and loss of reduction was attributed to technical errors. On further radiographic review, four cases had only one pin in the distal fragment, and three cases had inadequate pin separation at the fracture site. One fracture did not have bicortical fixation of the pins. Therefore, the surgeon must ensure that pin placement is adequate. After fracture reduction and pinning, live fluoroscopy should be performed to ensure fracture stability. The elbow should be brought through a range of motion in flexion and extension, and varus and valgus stresses should be applied, all while evaluating for fracture motion.28

The experience of the treating surgeon is related to the adequacy of
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fracture reduction and stability. A study of pediatric fellows found that nonideal reductions occurred in the first eight patients treated independently.31 The surgeons’ lack of experience, however, did not lead to any increase in complications in this study because the malreductions were not clinically relevant.

Infection
Pin site infection is common in pediatric fractures, ranging from 1% to 21%; however, the rate for supracondylar humeral fractures tends to be much lower, with reported incidences between less than 1% and 6.6%.32,34 Most series report resolution of the superficial pin tract infection with oral antibiotic use and pin removal.34,35 This chapter’s authors prefer dose-appropriate cephalaxin or clindamycin if the patient has a penicillin allergy.

Deep infections are rare but serious complications that can result from the pin tracking through the elbow joint, thus leading to septic elbow arthritis. The reported incidence is less than 1% of supracondylar humeral fractures treated surgically.31 A deep infection requires surgical débridement, including irrigation and débridement of the elbow joint.

Summary
Pediatric supracondylar humeral fractures represent a wide spectrum of injury severity and have several important nonsurgical and surgical complications. Neurovascular complications are common, and close attention should be paid to the initial presentation and any changes in the child’s physical examination across time. Surgical treatment of this fracture continues to evolve as more work is done on the biomechanical stability of fracture fixation and the long-term sequelae of small changes in fracture alignment. If surgical treatment is required, anatomic reduction and accurate pin placement are critical to optimal outcomes.

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