Common elbow injuries in children: evaluation, treatment, and clinical outcomes

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Purpose of review
Elbow injuries are common in children who fall on an outstretched upper extremity during play. The treatment techniques for many injuries have evolved to the point where excellent or good outcomes can be expected in most children treated in a timely fashion. However, some injuries are prone to late sequelae, which may necessitate reconstructive treatment.
Recent findings
This article reviews recent developments in the evaluation, management, complications, and outcomes of common pediatric elbow injuries. Fixation techniques of fractures are reviewed and compared.
Summary
The information in this review may help orthopedic surgeons who encounter these injuries to further improve their treatment methods. Further research is needed to continue to refine these methods and reduce the incidence of adverse sequelae.

Keywords
pediatric, elbow, trauma

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Introduction

Acute trauma to the pediatric elbow creates injuries that are among the most concerning for orthopedic surgeons to encounter. The unique anatomy and the intimate location of neurovascular structures often result in a spectrum of injury with associated complications and potential long-term disability.

Most elbow injuries in children are obvious in their presentation. Swelling, tenderness, limited range of motion, or gross deformity after a traumatic event will often lead the family to seek medical attention. High-quality radiographs are diagnostic in most cases. Yet the presentation of nondisplaced, or occult, elbow fractures can be subtle. The posterior fat pad sign on a radiograph has recently been shown to be 76% effective in picking up an occult fracture about the elbow [1]. This finding should therefore prompt the treating physician to immobilize the elbow as if a fracture were present.

In the presence of a clearly identified fracture, it is imperative to perform a complete neurologic and vascular examination at the time of initial presentation to document the level of function before treatment. This is because of the moderate rate of neurovascular complications in children with elbow injuries related to the injury itself, the treatment provided, or both.

Most children who have sustained elbow trauma can be expected to have a full functional recovery if they are treated promptly with appropriate intervention and currently accepted techniques. This article reviews the classification, treatment, outcomes, and complications of the most common pediatric elbow injuries with attention to recent contributions in the literature.

Supracondylar humerus fractures

Anatomy and classification

The anatomy of the distal humerus is unique with large medial and lateral columns separated by an intervening space that is only 1 to 2 mm in thickness. This central area, corresponding to the olecranon fossa, creates an area of weakness that, when stressed during forceful extension or flexion, may allow fracture in children.

The classification of these fractures is based on the direction and amount of displacement. The extension type is formally classified using the system of Gartland [2], developed in 1959. Type I fractures are nondisplaced. Type II fractures are displaced, but the posterior periosteal hinge remains intact. The differentiation between type I and II fractures is often made by evaluating the position of the capitellum relative to the anterior humeral line. In type II fractures, the capitellum falls posterior to the anterior humeral line. Type III fractures are completely displaced. The coronal plane direction of the displacement is sometimes helpful in further classifying type III fractures. Posteromedial displacement is associated with a higher incidence of radial nerve injuries, whereas posterolateral displacement is associated with a higher incidence of injury of the brachial artery or median nerve and soft-tissue interposition in the fracture site, which may hinder attempts at closed reduction.

Incidence

Supracondylar fractures are the most common elbow fracture in children, accounting for approximately 60% of these injuries. A recent review noted the incidence of supracondylar fractures during a 5-year period to be 308/100,000 per year [3]. In this series, most fractures were type I (65%) followed by type II (20%) and type III (17%) [3].

Treatment

In general, type I fractures are treated with noncircular immobilization until swelling subsides to allow the application of a long-arm cast. The total duration of immobilization is approximately 3 weeks [4]. Ninety degrees of flexion is preferred unless the swelling of the extremity precludes this. An important variation of the type I fracture includes a fracture with subtle medial comminution, which belies the benign appearance of this injury. The failure to recognize this finding may result in the gradual development of cubitus varus as the medial column continues to collapse during the period of immobilization. A recent report recommended early closed reduction and pin stabilization to prevent this potential outcome in children with this variant of the type I fracture [5].

The treatment of type II fractures is more controversial. Some of these fractures may, by definition, be displaced posteriorly enough to be called type II but with a slight amount of manipulation and casting may be treated closed. The main criteria in deciding to treat this fracture closed are the absence of rotational deformity or medial comminution and the ability to hold the reduction with 90 degrees of flexion.

If the fracture does not meet these criteria or is completely displaced (type III), reduction and stabilization are performed. The recent reports on this subject focus on pinning technique and stability. The major controversy is whether to use two lateral pins (Fig. 1) or a

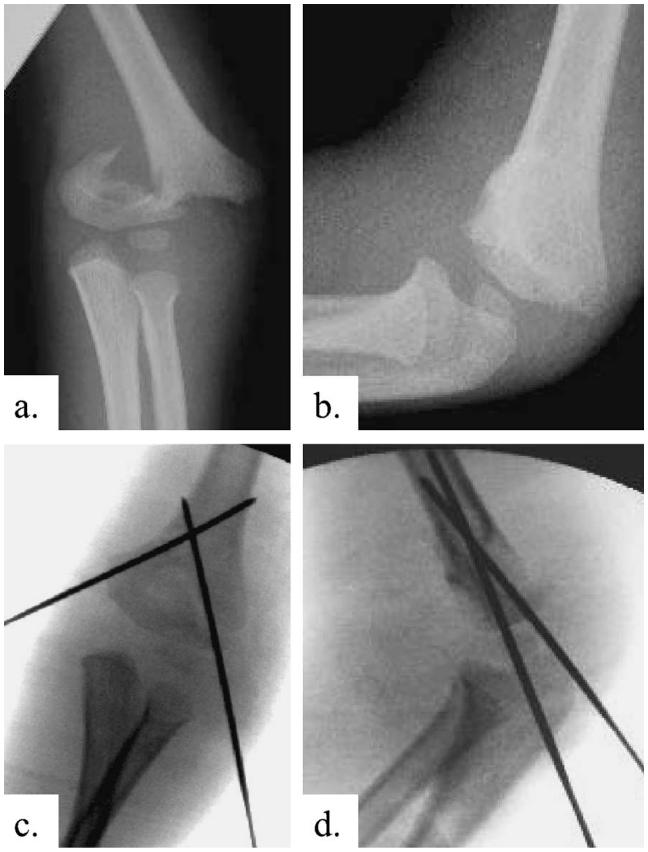
Figure 1. A 6-year-old boy fell on his outstretched arm and sustained a supracondylar humerus fracture of his right arm

Anteroposterior (**A**) and lateral (**B**) radiographs of the injury reveal a type III fracture. Parallel lateral pins were placed **(C, D)** using a percutaneous reduction technique.

combination of lateral pins supplemented with medial pinning. In a recent retrospective review of 59 type III fractures, there was no difference in the long-term reoperation rate or functional outcome of children treated with either lateral pinning or cross-pinning [6•]. However, there was one iatrogenic nerve injury in the cross-pinning group (Fig. 2) versus none in the lateral pinning group [6•]. In another series of 345 extension type fractures, there was a 7% incidence of iatrogenic ulnar nerve injury when crossed K wires were used and there was no difference in the stability of the fracture when compared with lateral pins [7]. A recent biomechanical study showed no difference in extension, varus, or valgus stress between lateral pins and crossed pins [8]. However, in axial rotation, the crossed pins were more stable [8]. This study also advocated a divergent lateral pinning technique as one resulting in greater stability than the parallel pinning method (Fig. 3) [8].

In our experience, the technique of two lateral pins supplemented with a posterior splint ensures adequate fracture stability during early fracture healing, yet eliminates the possibility of iatrogenic ulnar nerve injury. However, there are some clinical situations in which a

Figure 2. A 4-year-old boy fell on his outstretched arm and sustained a supracondylar humerus fracture of his left arm



Anteroposterior (**A**) and lateral (**B**) radiographs of the injury reveal a type III fracture. Medial and lateral pins were placed (**C, D**) using a percutaneous reduction technique without neurologic compromise.

medial pin is necessary, particularly in the treatment of unstable fractures or those with medial comminution. It has been shown that extending the elbow while placing the medial pin is helpful in decreasing the incidence of iatrogenic ulnar nerve injury [7]. There has recently been described a simple method using anatomic landmarks to help predict the ulnar nerve location during pinning [9].

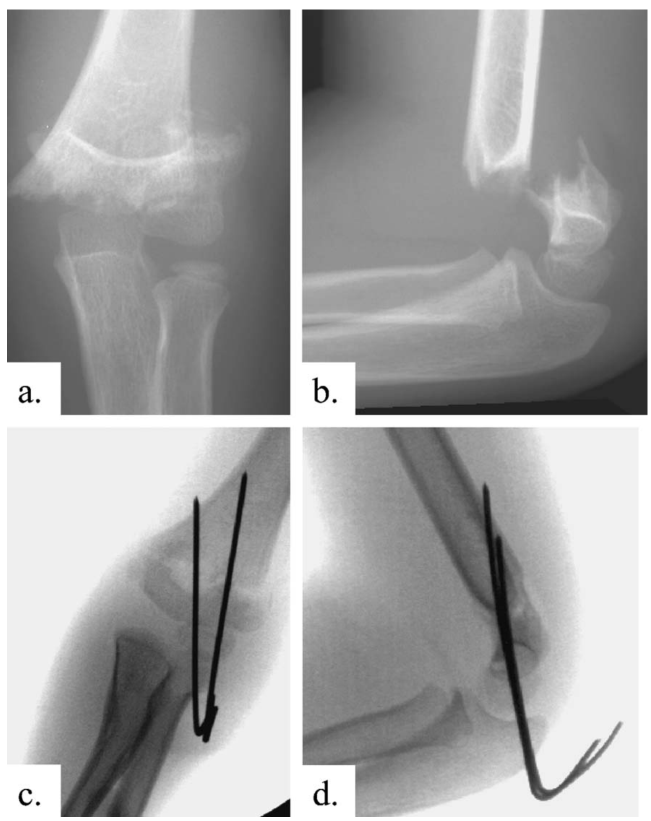
Open reduction and pinning is also an option for treating supracondylar fractures. If a reasonable effort has been made to achieve a fracture reduction by closed manipulation and is unsuccessful, then open reduction is necessary to ensure an anatomic reduction before attempting pin fixation. Kumar *et al.* [10] showed good results in 42 of 44 children treated with primary open reduction for type III fractures. However, decreased range of motion was reported in eight and nerve palsy was identified in five children [10]. Recently, an alternative method for open reduction was described as using an anterior approach, incising only skin and subcutaneous tissue with the thumb and index finger serving as reduction tools [11]. The authors compared this with a historical group that was reduced using a lateral or a medial and lateral approach and found that the anterior open group had less functional loss and less rotational deformity [11].

Skeletal traction remains an option for treating children with severe swelling, soft-tissue loss, or excessive delay in presentation. Favorable outcomes have been recently reported in children treated using traction because of excessive swelling or failed reduction attempts with 11 excellent and two fair results obtained in 13 children with these more complex injuries [12].

Timing

A major concern in the management of supracondylar humerus fractures involves the timing of treatment. Historically, it was believed that a delay in fracture reduction might lead to the loss of anatomy landmarks and an increase in the difficulty obtaining a satisfactory closed reduction. Recent reports have disputed this notion. In a review of 146 children, there was no statistical difference with respect to infection, iatrogenic nerve injury, compartment syndrome, or need for open reduction noted between those treated within 8 hours of injury and those treated an average of 23 hours after injury [13]. In this

Figure 3. A 6-year-old girl fell on her outstretched arm and sustained a supracondylar humerus fracture of her left arm



Anteroposterior (**A**) and lateral (**B**) radiographs of the injury reveal a type III fracture. Two lateral pins were placed in a divergent pattern (**C, D**) using a percutaneous reduction technique.

study, a "preliminary" reduction was performed in the emergency department if the skin was threatened and all patients with neurologic or vascular compromise received immediate treatment [13]. Similar results were reported in another study in which reduction was performed an average of 21.3 hours after injury with no provisional reduction attempted before the formal operative treatment [14]. Our experience has also shown that type III fractures may be safely treated on the following day provided that no neurovascular or skin compromise exists at the time of initial presentation.

Complications

Vascular injury occurs in approximately 2.5% of type III fractures and neural impairment can occur in approximately 17% [15••]. Rarely, compartment syndrome may also threaten the limb [16]. Most nerve deficits represent transient neurapraxia, which may be expected to spontaneously resolve with observation. Vascular impairment, however, may require early intervention. We recommend urgent reduction and pinning of supracondylar fractures in children who present with an absent or diminished (Doppler-able but not palpable) radial pulse. Reassessment of the vascular status is performed again after fracture stabilization. If the limb remains pulseless and poorly perfused, then we advocate exploration of the brachial artery under the same anesthetic. However, if the hand is pulseless yet remains well perfused (pink), then a recent report has suggested that observation alone is acceptable in this circumstance [17].

Lateral condyle fractures

Incidence and mechanism of injury

Fractures involving the lateral humeral condyle constitute 12% to 20% of elbow fractures in children. Most commonly caused by a fall on the outstretched upper extremity, these injuries are thought to occur in response to either compression generated across the radiocapitellar joint during valgus load or from tension created by the lateral joint ligaments and capsule during varus load.

Classification

Lateral condyle fractures are classified by the location of the fracture line with respect to the lateral condyle and the amount of displacement of the fracture fragment. The most commonly used anatomic classification is that of Milch [18], which differentiates between type 1, in which the fracture line traverses the secondary ossification center of the capitellum and falls lateral to the lateral crista of the trochlea, and type 2, in which the fracture line extends further medially and potentially enters the joint medial to the lateral crista of the trochlea and essentially destabilizes the elbow joint. In our practice, Milch 2 fractures are far more common than Milch 1 fractures (approximately 15:1). The classification used to describe the displacement of lateral condyle fractures was developed by Rutherford [19] in an effort to help guide treatment of these injuries. Type 1 fractures are nondisplaced, type 2 fractures are displaced less than 2 mm, and type 3 fractures are displaced and malrotated [19].

Treatment

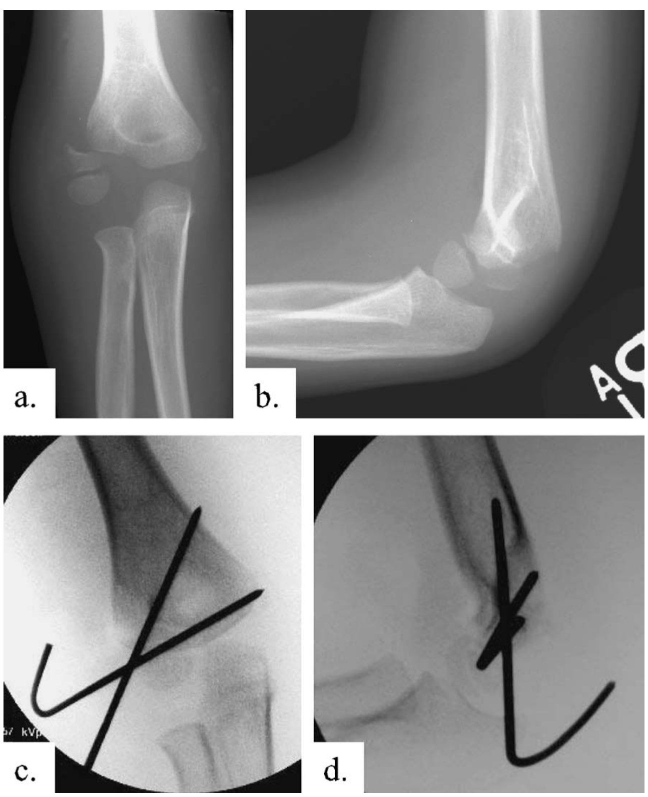
Treatment decisions regarding lateral condyle fractures are influenced by the displacement and stability of the fracture. Displaced and rotated fractures require open reduction and pinning [20••]. Nondisplaced fractures may be treated without surgery using long-arm cast immobilization and frequent radiographic observation to ensure that they remain stable during the period of healing [21]. It is possible for minimally displaced (<2 mm) fractures, which initially appear stable, to subsequently displace and fail to heal [22]. With this concern, there have been efforts made to further study these injuries so as to subcategorize these fractures into those that will or will not have the potential for late displacement [23–25]. In doing so, it may be possible to prevent unnecessary surgery in children with minimally displaced fractures [23]. Many believe that the presence of an intact articular cartilage hinge is the key to stability in these fractures [21,23–25]. Ultrasound, MRI, and contrast arthrography have been used to demonstrate whether the cartilage hinge has been disrupted [23–25]. Unfortunately, the drawbacks with each of these techniques, including expense, requirement for sedation, and technical experience performing and interpreting the results, limits their usefulness in most clinical practice settings.

Our preferred method for managing lateral condyle fractures in children begins with obtaining high-quality anteroposterior, lateral and internal oblique radiographs out of splint or cast immobilization in all children with suspected lateral condyle injuries. Clinical signs include local tenderness, soft-tissue swelling, and ecchymosis over the lateral epicondyle region of the elbow [26•]. Radiographs are generally easy to interpret for displaced fractures. Radiographic signs in minimally or nondisplaced fractures include the presence of a posterior fat pad on the lateral view and a linear lucency in the posterolateral condyle region on the internal oblique and lateral radiographs.

We recommend open reduction and pinning of all fractures displaced >2 mm. In our experience, attempting closed reduction for displaced fractures does not ensure accurate, anatomic reduction of the joint surface. Provided that care is taken to avoid excessive dissection of the muscular attachments associated with the lateral and posterior aspects of the lateral fracture fragment, there is little added morbidity with the open surgical procedure. The surgical approach is generally facilitated by the extravasation of fracture hematoma into the lateral soft tissues, which often establishes a guide to the correct surgical plane. Two 0.0625-in. K wires are placed in a diverging fashion with care to ensure that the pins cross at the lateral bone margin rather than near the fracture site (Fig. 4). The most distal pin is directed toward the medial epicondyle and should engage bone rather than the trochlear cartilage.

Fractures that are nondisplaced (<1 mm) are treated by close observation with weekly radiographs taken out of the cast to ensure that the fracture is stable. After 3 weeks, the likelihood of displacement is substantially reduced, and there should be signs of periosteal healing to confirm that closed treatment will be successful. An additional 1 to 2 weeks of casting is completed before beginning range of motion exercise in a controlled setting. Final radiographs are taken at approximately 6 to 8 weeks after the injury when the range of motion is assessed. Most children will have recovered acceptable range of motion by that time, and the radiographs should confirm complete healing. If there is a question of complete healing at 6 to 8 weeks, then the child should be followed monthly with repeat radiographs to ensure that nonunion does not develop. Activity restriction should be enforced for a total of 10 to 12 weeks before return to contact sports or aggressive play.

Figure 4. A 4-year-old boy fell on his outstretched arm and sustained a lateral condyle fracture of his right arm



Anteroposterior (**A**) and lateral (**B**) radiographs of the injury reveal a displaced Milch 2 fracture. After open reduction, two lateral pins were placed (**C, D**). Note that the pins are divergent and cross at the lateral bone margin.

Minimally displaced fractures (1–2 mm) create a treatment dilemma in our practice because of our experience of late displacement in some of these fractures. Informed discussion with the family about the risks and benefits of each treatment usually helps to make the decision. Some of these injuries are treated with closed reduction and percutaneous pinning. Alternatively, some children are followed with serial radiographs. Surgical intervention is then performed at the earliest sign of further displacement, if necessary. Because of the low surgical complication rate and high union rate with early treatment and to avoid complications associated with late treatment of displaced fractures, we tend to err on the side of surgery. Percutaneous pinning is possible in many minimally displaced fractures. In these instances, an arthrogram is obtained intraoperatively to ensure that the joint surface is anatomically intact and congruent after the pinning. Any concerns about the adequacy of a closed reduction lead us to abandon this approach and perform open reduction and pinning.

Controversy exists as to the recommended duration for leaving pins in place for the treatment of lateral condyle fractures [22,27]. Late displacement after reduction and pinning has led to recommendations for leaving pins in place for as long as 6 six weeks, if necessary [22]. Serial radiographic evaluation using anteroposterior, lateral, and internal oblique radiographs may be obtained 3 to 6 weeks postoperatively to determine the appropriate time for pin removal. Our experience has suggested that removing the pins at 4 weeks allows adequate time for healing and is often necessary to avoid pin site infections and prevent joint stiffness.

Complications

Lateral condyle fractures are associated with a concerning number of complications and consequences of improper treatment. Delayed union, nonunion, elbow deformity with progressive cubitus valgus, tardy ulnar nerve palsy, and loss of motion are among the problems seen with these injuries [28–30]. Vigilance and meticulous attention to detail are essential in managing these injuries to ensure a positive outcome.

Nonunion, when it occurs, creates the risk of gradual progressive valgus deformity of the elbow and the occurrence of tardy ulnar nerve palsy. When identified, nonunion should be treated with open debridement of the nonunion fibrous tissue and *in situ* fixation with bone graft to achieve union and prevent further deformity [28,30]. It is often not possible to restore normal anatomy and not worth the risk of avascular necrosis to perform an overly aggressive debridement of the fracture site in an effort to improve the appearance of the reduction in fractures treated more than 3 weeks after injury with more than 1 cm of fracture displacement [30].

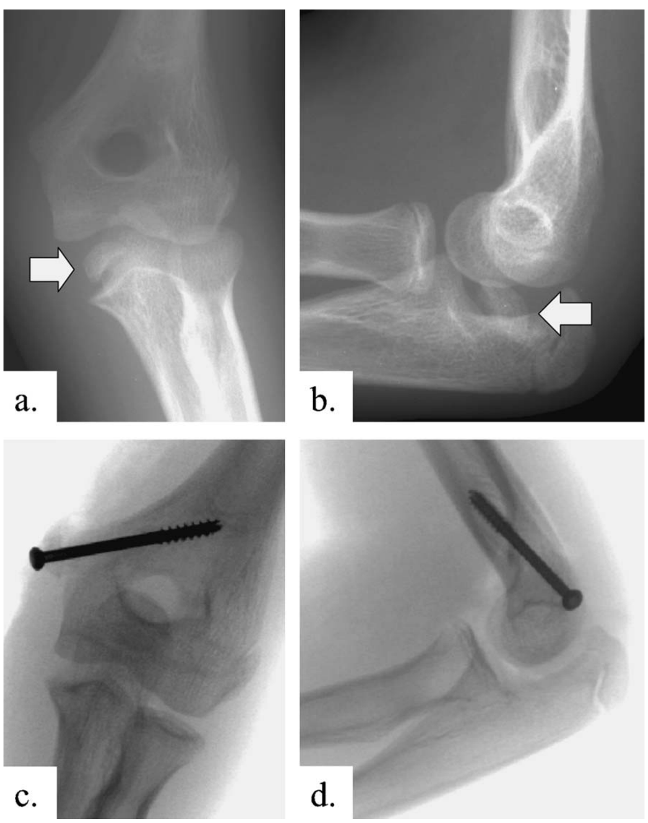
Late effects of lateral condyle fractures that have successfully healed include an increase in trochlear height, often referred to as a "fish-tail deformity," prominence of the lateral margin of the distal humerus, and cubitus varus or valgus [28]. Mostly these irregularities are minor occurrences without functional significance. Occasionally, the fish-tail deformity may lead to a stress-riser, which may predispose to an intercondylar fracture pattern with new injury [28].

Medial epicondyle fractures

Incidence and classification

Medial epicondyle fractures account for approximately 8% to 10% of pediatric elbow fractures. The mechanism of injury often involves a fall on the outstretched hand with forced wrist hyperextension and a valgus stress at the elbow. In approximately 50% of cases, an associated elbow dislocation occurs. Entrapment of the medial epicondyle in the joint during relocation of the elbow may occur as much as 15% of the time (Fig. 5). These fractures are often classified by the amount of displacement of the medial epicondyle fracture fragment.

Figure 5. A 13-year-old girl fell and sustained a medial epicondyle fracture of her left arm that was noted after the reduction of her elbow dislocation



The medial epicondyle (arrow) is entrapped within the joint seen on anteroposterior (**A**) and lateral (**B**) radiographs. After open reduction, one cannulated screw was placed for fixation (**C, D**).

Treatment

Treatment of minimally displaced fractures (<5 mm) involves immobilization for 5 to 7 days in a sling or posterior splint followed by self-guided range of motion exercises. A recent long-term outcome study of moderately displaced fractures (5–15 mm) showed that nonsurgical treatment yielded results that were similar to those obtained with open reduction and fixation [31]. The nonunion of the epicondylar fragment seen with nonoperative treatment did not adversely affect the functional outcome. The average duration of follow-up in this study was 34 years [31]. Greatly displaced fractures (>15 mm) should be treated with open methods to restore the flexor pronator group to its anatomic position. Excision of the medial epicondyle fragment should be avoided because of poor long-term results.

Complications

Medial epicondyle fractures are associated with elbow stiffness, especially if immobilization is prolonged. Early range of motion exercises should help to avoid this concern. The late occurrence of painful nonunion is another potential complication. This also may be associated with an elbow contracture. Conservative treatment with anti-inflammatory medication, range of motion exercises, and modification of activity is preferred over late excision of the fragment.

Radial head and neck fractures

Incidence

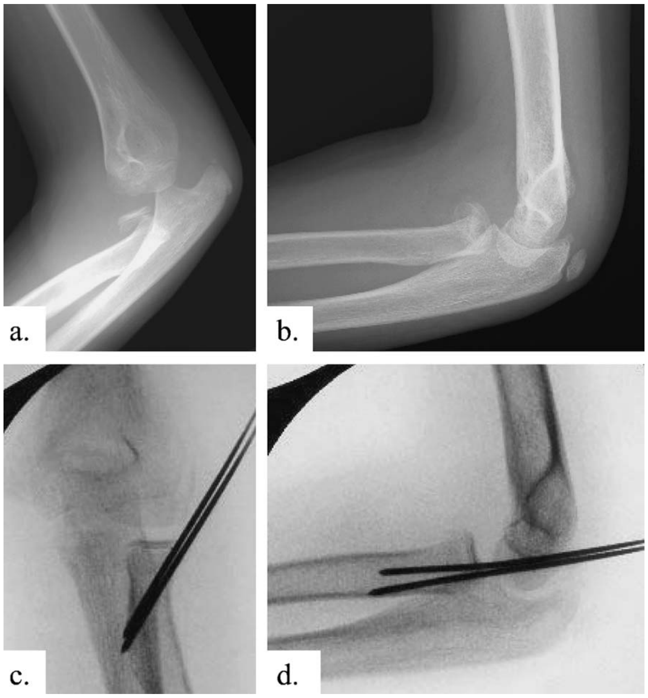
Radial neck fractures comprise approximately 6% of pediatric elbow fractures. The mechanism of injury is a fall on an outstretched hand with a valgus moment. These injuries can be associated with dislocation of the elbow.

Treatment

Treatment of radial head and neck fractures is based on the amount of angulation between the head and shaft. The indication for surgery is generally determined by angulation of greater than 30 degrees. One study suggested that angulation of as much as 50 degrees may be treated without surgery [32]. A recent report showed that 86% of children having radial neck fractures with angulation of no more than 30 degrees had good outcomes at 15-year follow-up [33].

We prefer to treat displaced or angulated fractures with an attempted closed reduction under conscious sedation or general anesthesia [34]. If closed reduction fails, then we proceed first to percutaneous attempts at reduction (Fig. 6) followed by open reduction, if necessary. The radial neck may be manipulated closed by first extending the elbow to engage the olecranon in the olecranon fossa. Then, under fluoroscopic guidance, the radius is rotated to identify the maximal plane of angulation. While holding a varus force across the elbow joint to open up the radiocapitellar space, thumb pressure is applied against

Figure 6. A 4-year-old boy fell and sustained a radial neck fracture



Anteroposterior (**A**) and lateral (**B**) radiographs of the injury reveal a displaced radial neck fracture. Using a percutaneous technique, the radial neck was reduced and fixed with pins (**C, D**).

the radial head, which is typically felt subcutaneously. The radial head is then directed back in position beneath the capitellum, and the varus force is released from the elbow. A recent report described the success of this method of reduction [35•].

Arthrography may be necessary to assist in the reduction when the radial head is unossified [36].

If the radial head is completely displaced or is irreducible by the methods described above, then open reduction must be performed. The caveat to open reduction is that this method leads to worse outcomes because of the increased incidence of elbow stiffness and avascular necrosis of the radial head.

Complications

Complications seen with radial neck fractures include malunion, radial head overgrowth, avascular necrosis, and nonunion. These problems lead to pain, stiffness, and early degeneration of the joint. Factors contributing to a poorer outcome include older age, delayed treatment, associated injury, severe displacement, and the need for open reduction. Waters and Stewart [37] recently reported a series of radial neck nonunions in children that had occurred after treatment of fractures that had been angulated an average of 83 degrees with a high degree of displacement. Unfortunately, achievement of union in these cases did not lead to a significant improvement in the ultimate outcome for these children [37].

Elbow dislocation

Incidence and mechanism of injury

Elbow dislocations are relatively rare in childhood as they account for less than 6% of pediatric elbow injuries. Dislocations mainly occur through a hyperextension mechanism, which explains the predominance of posterior dislocations. Because dislocations may be associated with fractures of the medial epicondyle or radial neck, these injuries must be carefully sought before and after closed reduction of the elbow. Entrapment of the medial epicondyle into the elbow joint or complete displacement of a radial neck fracture may occur during the reduction process. A recent report noted the occurrence of a lateral condyle fracture associated with posteromedial dislocation of the elbow in four boys [38•].

Treatment

Closed treatment is usually successful in restoring a congruent elbow joint. Reduction may be performed under conscious sedation by first correcting any coronal plane displacement, which reduces the risk of neurovascular entrapment, and then by applying longitudinal traction across the extended elbow. Once the coronoid process of the ulna clears the trochlea of the humerus, a palpable clunk is typically felt to signify the reduction has been successfully achieved. Care should be taken to avoid hyperextension, which may cause injury to the brachialis muscle. Immediately after reduction, fluoroscopy is used to assess the radial neck and medial epicondyle positions as well as joint congruity. The elbow is taken through a full range of motion and tested for recurrent instability. The purpose of this testing is to develop a sense for the duration of immobilization, which may be necessary during the early rehabilitation process.

Most elbows may be immobilized for 5 to 7 days in a posterior splint or sling followed by a progressive, self-guided range of motion program. Elbows that demonstrate a high degree of recurrent instability immediately after reduction may require as long as 3 weeks of immobilization with the elbow flexed at 90 degrees to allow the joint capsule to begin healing before beginning a range of motion program. Because stiffness is a concern after elbow dislocation, it is important to avoid unnecessarily prolonging immobilization. As with most pediatric elbow injuries, the best means to restore motion after injury is through active exercises performed by the child. Formal occupational therapy exercise has a very limited role and should be considered after several weeks of observing the child's progress with self-guided exercise and activities. Static progressive splinting with a Dynasplint or Ultraflex splint at night may help to slowly improve some flexion contractures of the elbow. Experience has shown that surgical release of moderate to severe elbow contractures is not as successful in restoring functional joint mobility in children as it is in adults [39]. Therefore, conservative treatment should be given for a substantial period of time before considering more aggressive alternatives. Range of motion may gradually improve spontaneously for as long as 1 year after elbow trauma in children.

Complications

The two most common outcomes after elbow dislocation in children are stiffness and recurrent instability. Stiffness is commonly seen after prolonged immobilization and can be avoided with timely range of motion exercises beginning as early as 5 to 7 days after the injury. Recurrent instability is rare in children. Excessive laxity of the ulnar collateral ligament after healing may be addressed by ligamentous reconstruction.

Olecranon fractures

Incidence

Pediatric olecranon fractures are relatively uncommon, representing an incidence of only 5% of all elbow fractures in children. Most are minimally displaced and very few require operative intervention. These fractures often occur as the result of direct trauma with an average age of occurrence between 7 and 11 years.

Another subset of olecranon fractures occurs in children with osteogenesis imperfecta. In one review of 10 children with OI, there were 17 olecranon fractures, indicating a high rate of bilateral asynchronous injuries (70%) within this population [40]. The authors also reported a high rate of refracture after the hardware was removed [40]. Based on their findings, families with children with osteogenesis imperfecta with an olecranon fracture should be warned of the increased risk of bilateralism and refracture.

Treatment

Because most of these fractures are nondisplaced, long-arm cast immobilization is acceptable treatment. After the fracture is healed in 4 to 6 weeks, range of motion exercise is started. In a review of 39 olecranon fractures, favorable outcomes were noted at 24-year follow-up in all nondisplaced fractures (defined as <2 mm of displacement) [41]. Displacement greater than 2 mm, which occurred in 7.6% of the 39 children, resulted in a poor outcome [41].

Displaced fractures are treated with open reduction and internal fixation. We recommend parallel K-wire fixation with figure of eight tension band wiring using 18-gauge wire or no. 2 fiber wire suture. Recent reports have described a new method of fixation using an intramedullary pin with an adjustable locking bead to compress the olecranon tip [42,43•]. This newer technique may have the same biomechanical stability as the more common tension band method [42,43•].

The long-term outcome of these fractures is related to the pattern of fracture, amount of residual displacement, or the presence of associated fractures such as those of the radial neck or lateral condyle [41]. The clinical results are usually good, with satisfaction rates in more than 90% of children [33]. However, displaced fractures that involve the sigmoid notch may result in early posttraumatic elbow arthritis.

Complications

Ulnar or radial nerve palsies have been reported in as many as 7% of children with olecranon fractures but usually resolve with observation [41]. Concomitant fractures of the radial head and posterior dislocation of the radial neck may rarely occur and adversely affects the outcome. Growth disturbance of the olecranon has been reported in 11% of olecranon fractures [44]. This disturbance stops the longitudinal growth of the olecranon and shortens the space available for the trochlea, creating joint incongruity and potentially leading to degenerative joint disease in the future [44].

Conclusion

Pediatric elbow trauma is extremely common owing to the unique anatomic features in a location that is frequently exposed to mechanical force capable of producing injury in children at play. Because of the numerous potential pitfalls in managing these injuries, it is important for orthopedic surgeons who treat these conditions to respond in a timely manner with appropriate vigilance and technical skill. Excellent outcomes can be expected in most children with these injuries. However, some late consequences of injury or treatment may require long-term follow-up and reconstructive options should they occur.

References and recommended reading

Papers of particular interest, published within the annual period of review, have been highlighted as:

- • Of special interest
- •• Of outstanding interest

1 Skaggs DL, Mirzayan R: The posterior fat pad sign in association with occult fracture of the elbow in children. J Bone Joint Surg Am 1999, 81:1429–1433.

2 Gartland JJ: Management of supracondylar humerus fractures of the humerus in children. Surg Gynecol Obstet 1959, 109:145–154.

3 Houshian S, Mehdi B, Larsen MS: The epidemiology of elbow fracture in children: analysis of 355 fractures, with special reference to supracondylar humerus fractures. J Orthop Sci 2001, 6:312–315.

4 Green, N, Swiontowski, M (eds): Skeletal Trauma in Children. Philadelphia: Saunders; 1998:259–317.

5 De Boeck AC, De Smet P, De Rydt D: Supracondylar elbow fractures with impaction of the medial condyle in children. J Pediatr Orthop 1995, 15:444–448.

6 • Solak S, Aydin E: Comparison of two percutaneous pinning methods for the treatment of the pediatric type III supracondylar humerus fractures. J Pediatr Orthop B 2003, 12:346–349.

This is a retrospective comparison of two lateral pinning versus medial and lateral pinning techniques that demonstrates no difference in redisplacement rates and cosmetic deformity.

7 Skaggs DL, Hale JM, Basset J, et al.: Operative treatment of supracondylar fractures of the humerus in children. The consequences of pin placement. J Bone Joint Surg Am 2001, 83:735–740.

8 Lee SS, Mahar AT, Miessen D, et al.: Displaced pediatric supracondylar humerus fractures: biomechanical analysis of percutaneous pinning techniques. J Pediatr Orthop 2002, 22:440–443.

9 Wind WM, Schwend RM, Armstrong DG: Predicting ulnar nerve location in pinning of supracondylar humerus fractures. J Pediatr Orthop 2002, 22:444–447.

10 Kumar R, Kiran EK, Malhotra R, et al.: Surgical management of the severely displaced supracondylar fracture of the humerus in children. Injury 2002, 33:517–522.

11 Koudstaal MJ, De Ridder VA, De Lange S, Ulrich C: Pediatric supracondylar humerus fractures: the anterior approach. J Orthop Trauma 2002, 16:409–412.

12 Agus H, Kalenderer O, Kayali C, et al.: Skeletal traction and delayed percutaneous fixation of complicated supracondylar humerus fractures due to delayed or unsuccessful reductions and extensive swelling in children. J Pediatr Orthop B 2002, 11:150–154.

13 Mehlman CT, Strub WM, Roy DR, et al.: The effect of surgical timing on the perioperative complications of treatment of supracondylar humeral fractures in children. Bone Joint Surg Am 2001, 83:323–327.

14 Leet AI, Frisancho J, Ebramzadeh E: Delayed treatment of type 3 supracondylar humerus fractures in children. J Pediatr Orthop 2002, 22:203–207.

15 Gosens T, Bongers K: Neurovascular complication and functional outcome in
•• displaced supracondylar fractures of the humerus in children. Injury 2003, 34:267–273.

A large study demonstrates the risks of nerve injury with supracondylar humerus fractures.

16 Battaglia TC, Armstrong DG, Schwend RM: Factors affecting forearm compartment pressures in children with supracondylar fractures of the humerus, J Pediatr Orthop 2002, 22:431–439.

17 Sabharwal Stredwell SJ, Beauchamp RD, Mackenzie WG, et al.: Management of pulseless pink hand in pediatric supracondylar fractures of the humerus. J Pediatr Orthop 1997, 17:303–310.

18 Milch H: Fractures and fracture dislocations of the humeral condyles. J Trauma 1964, 4:592–607.

19 Rutherford A: Fractures of the lateral humeral condyle in children. J Bone Joint Surg 1985, 67:851–856.

20 Bhandari M, Tornetta P, Swiontkowski MF: Displaced lateral condyle frac-
•• tures of the distal humerus. J Orthop Trauma 2003, 17:306–308.

This article critically evaluates the evidence-based treatment of lateral condyle fractures with respect to arthrography and open reduction and internal fixation. To date, only case series and expert opinion are available to provide weak evidence at best for any one treatment to prevail.

21 Bast SC, Hoffer MM, Aval S: Nonoperative treatment for minimally and nondisplaced lateral humeral condyle fractures in children. J Pediatr Orthop 1998, 18:448–450.

22 Cardona JI, Riddle E, Kumar SJ: Displaced fractures of the lateral humeral condyle: criteria for implant removal. J Pediatr Orthop 2002, 22:194–197.

23 Horn BD, Herman MJ, Crisci K, et al.: Fractures of the lateral humeral condyle: role of the cartilage hinge in fracture stability. J Pediatr Orthop 2002, 22:8–11.

24 Kamegaya M, Shinohara Y, Kurokawa M, et al.: Assessment of stability in children's minimally displaced lateral humeral condyle fracture by magnetic resonance imaging. J Pediatr Orthop 1999, 19:570–572.

25 Vocke-Hell AK, Schmid A: Sonographic differentiation of stable and unstable lateral condyle fractures of the humerus in children. J Pediatr Orthop 2001, 10:138–141.

26 Meyer NJ, Lyon RM: Lateral elbow ecchymosis as a clinical sign of lateral
• humeral condylar fractures. Am J Orthop 2003, 32:260–261.

The finding of lateral elbow ecchymosis is useful clinically to direct a more concerted effort to identify minimally displaced lateral condyle fractures.

27 Thomas DP, Howard AW, Cole WG, et al.: Three weeks of Kirschner wire fixation for displaced lateral condylar fractures of the humerus in children. J Pediatr Orthop 2001, 21:565–569.

28 Skak SV, Olsen SD, Smaabrekke A: Deformity after fracture of the lateral humeral condyle in children. J Pediatr Orthop 2001, 10:142–152.

29 Toh S, Tsubo K, Nishikawa S, et al.: Long-standing nonunion of fractures of the lateral humeral condyle. J Bone Joint Surg Am 2002, 84:593–598.

30 Wattenbarger JM, Gerardi J, Johnston CE: Late open reduction internal fixation of lateral condyle fractures. J Pediatr Orthop 2002, 22:394–398.

31 Farsetti P, Potenza V, Caterini R, et al.: Long-term results of treatment of fractures of the medial humeral epicondyle in children. J Bone Joint Surg Am 2001, 83:1299–1305.

32 Vocke AK, Von Laer L: Displaced fractures of the radial neck in children: long-term results and prognosis of conservative treatment. J Pediatr Orthop B 1998, 7:217–222.

33 Karlsson MK, Hasserius R, Karlsson C, et al.: Fractures of the olecranon during growth: a 15–25-year follow-up. J Pediatr Orthop 2002, 1:251–255.

34 Evans MC, Graham HK: Radial neck fractures in children: a management algorithm. J Pediatr Orthop 1999, 8:93–99.

35 Neher CG, Torch MA: New reduction technique for severely displaced pedi-
• atric radial neck fractures. J Pediatr Orthop 2003, 23:626–628.

This interesting article describes a technique of reduction for radial neck fractures. The authors report excellent results when using it.

36 Javed A, Guichet JM: Arthrography for reduction of a fracture of the radial neck in a child with a non-ossified radial epiphysis. J Bone Joint Surg Br 2001, 82:542–543.

37 Waters PM, Stewart SL: Radial neck fracture nonunion in children. J Pediatr Orthop 2001, 21:570–576.

38 Kirkos JM, Beslikas TA, Papavasiliou VA: Posteromedial dislocation of the
• elbow with lateral condyle fracture in children. Clin Orthop 2003, 408:232–236.

Posteromedial elbow dislocations are rare, comprising less than 30% of elbow dislocations. These authors report four cases of lateral condyle fractures associated with posteromedial elbow dislocation treated successfully with closed reduction of the elbow dislocation and open reduction and pinning of the lateral condyle fracture.

39 Stans AA, Maritz NGJ, O'Driscoll SW, et al.: Operative treatment of elbow contracture in patients twenty-one years of age or younger. J Bone Joint Surg Am 2002, 84:382–387.

40 Zionts LE, Moon CN: Olecranon apophysis fractures in children with osteogenesis imperfecta revisited. J Pediatr Orthop 2002, 22:745–750.

41 Caterini R, Fasretti P, D'Arrigo C, et al.: Fractures of the olecranon in children. Long-term follow-up of 39 cases. J Pedatr Orthop B 2002, 11:320–328.

42 Gicquel P, Maximin M-C, Boutemy P, et al.: Biomechanical analysis of olecranon fracture fixation in children. J Pediatr Orthop 2002, 22:17–21.

43 Gicquel P, Giacomelli M-C, Karger C, et al.: Surgical technique and prelimi-
• nary results of a new fixation concept for olecranon fractures in children. J Pediatr Orthop 2003, 23:398–401.

This interesting article describes a new device for pinning olecranon fractures.

44 Gicquel P, De Billy B, Karger CS, et al.: Olecranon fractures in 26 children with mean follow-up of 59 months. J Pediatr Orthop 2001, 21:141–147.