The University of Pennsylvania Orthopaedic Journal
15: 43–51, 2002

Pediatric Elbow Fractures: Pearls and Pitfalls

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Abstract: Pediatric elbow fractures can be challenging to manage. Compression of the medial column in Gartland Type I and Type II supracondylar fractures must be reduced to prevent varus deformity. Gartland Type III fractures may be stabilized with two lateral pins or a medial lateral cross-pin technique. Non-displaced lateral condyle fractures require vigilant follow-up. Open reduction of displaced lateral condyle fractures should avoid posterior dissection. T-condylar fractures in children rarely have the articular comminution found in adults. Monteggia fractures in children can be managed well if recognized and treated promptly. Restoration of the ulnar length often reduces the radial head. Angulated proximal radius fractures need to be reduced in order to restore the ability to supinate and pronate. It is important to recognize and understand the diagnostic features of each type of fracture in order to determine the best course of treatment.

Introduction

Pediatric elbow fractures are different from many other pediatric injuries. They are associated with a relatively high rate of complications, and the results of nonoperative management are not always good. The child's elbow is well vascularized, and therefore fracture healing takes place very quickly. Such a narrow window of opportunity makes it imperative that the fracture be properly managed very quickly.

This paper reviews some elbow fractures that are particularly challenging to manage. For each fracture type, we will discuss the indications for closed management versus operative management. In addition, we will describe the technical pearls that have been very helpful during the operation. Finally, we will detail the potential pitfalls in management and ways to avoid them.

Supracondylar Humerus Fracture

Supracondylar humerus fractures are the most common elbow fractures in children, accounting for 60–80% of pediatric elbow fractures [1]. These injuries are associated with a high rate of complications and can be challenging to manage. These fractures have been classified according to both the direction and the degree of displacement. Extension-type supracondylar humerus fractures are overwhelmingly more common than flexion-type fractures (98% vs. 2%) [2], while posteromedial fractures are more frequently encountered than posterolateral fractures (75% vs. 25%) [1]. However, posterolateral fractures are more often associated with neurovascular injury.

Gartland Type I fractures (minimally displaced) are treated with closed reduction and casting. Avoid immobilization with elbow flexion past 100° as this may decrease blood flow to the forearm, possibly increasing the risk of compartment syndrome.

Gartland Type II fractures (displaced with intact posterior cortex) require closed reduction and percutaneous fixation if a long-arm cast does not adequately hold the reduction. Immobilization in a long-arm cast can be discontinued after 3 weeks. Beware of compression of the medial column in Type I and Type II fractures (Fig. 1). Failure to reduce this deformity and maintain the reduction with percutaneous pins can lead to cubitus varus.

Gartland Type III fractures (displaced with no cortical contact) are managed by closed reduction with percutaneous fixation followed by 3 weeks of immobilization in a long-arm cast. The exact method of maintaining the reduction has evolved. Medial and lateral cross-pin technique was the gold standard, but it places the ulnar nerve at risk. Thus, some surgeons advocate a mini-open pin placement technique to avoid nerve injury. A direct injury to the ulnar nerve usually results in only neurapraxia, and children ultimately experience full recovery of ulnar nerve function. Recent studies have confirmed that two well-placed lateral pins provide sufficient fixation in the vast majority of cases [3,4]. Should a third pin be necessary to achieve adequate stability, a medial pin can be placed through a mini-open approach. The key to maintaining adequate stability with two lateral pins is to assure that both pins have good fixation of the distal fragment and engage the medial cortex.

An open reduction of a displaced supracondylar humerus fracture may be necessary on rare occasions. An anteromedial "hockey stick" incision provides a nice exposure to allow freeing of the fracture fragment from the brachialis muscle. Fixation is done percutaneously in the usual fashion. It is important to inform the patient and the family that an open reduction may be necessary for any supracondylar humerus fracture, and, should it be performed, it may lead to some residual elbow stiffness not found in children treated by closed reduction.

Supracondylar humerus fractures can be associated with a vascular injury (5–12%) [2], particularly with posterolateral

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displacement of the distal fragment, which would displace the neurovascular bundle over the medial metaphyseal spike. Management of a suspected vascular injury can be challenging. A pulseless but pink hand can be observed. Patients in this group who underwent vascular intervention developed re-occlusion of the brachial artery without any sequelae, suggesting that careful observation and vascular intervention had equivalent outcomes [5]. The presence of a pulseless and white hand after reduction and pinning is a clear indication for open exploration with a vascular surgeon. The anteromedial approach provides good exposure for the vascular repair and an open reduction.

Nerve injuries occur in 5–19% of elbow fractures and are almost always neurapraxias. These may take 3–4 months to

Fig. 1. A 5-year-old girl fell onto her outstretched hand and sustained a Gartland Type II supracondylar humerus fracture with medial impaction. (**A**) Lateral preoperative radiograph. (**B**) Anterior/posterior (A/P) preoperative radiograph. (**C**) Lateral radiograph after closed reduction and percutaneous pin fixation (cross-wire technique). (**D**) A/P postoperative radiograph. (**E**) Lateral radiograph taken four weeks postoperatively. (**F**) A/P follow-up (4 wks) radiograph. There is good evidence of healing. Note restoration of the medial column.

resolve [2]. The anterior interosseous branch of the median nerve is the most commonly involved nerve. Always perform and document a thorough neurological examination.

Malunion is largely due to rotation and will result in the classic "gunstock" deformity (cubitus varus). Inadequate correction of medial collapse, as mentioned above, can also lead to this deformity.

Lateral Condyle Fractures

Fractures of the lateral condyle represent 15–17% of pediatric elbow fractures [6]. The orthopaedist must be aware of the fracture patterns, relevant anatomy including blood supply, risk of nonunion, and the importance of postoperative follow-up in order to assess potential deformity and neurologic sequelae. The lateral condyle functions as the origin of the extensor muscle mass as well as the lateral collateral ligamentous complex. Most fractures occur in patients with a peak age 5–7 years. The most common mechanism of injury occurs when a varus force is applied to the elbow, causing the extensor muscles and lateral collateral ligaments to avulse the lateral condyle. Appropriate management requires an understanding of the mechanism of injury, as well as an awareness of operative indications and treatment methods to avoid complications.

The diagnosis of a lateral condyle fracture can be challenging because the fracture fragment is often rotated. Therefore, obtaining an oblique view of the elbow, in addition to the standard AP and lateral, can be very helpful. The most classic description of the fracture type has been described by Milch [1]. The Milch Type I fracture travels from the metaphysis of the distal humerus through the distal lateral epiphysis and through the trochleocapitellar groove. The Milch Type II fracture travels from the distal lateral humeral metaphysis above the epiphysis and exits through the trochlea. Because the Milch Type II traverses through the lateral aspect of the trochlea, instability may ensue with posterolateral radius and ulna subluxation. This lateral translocation of the radius and ulna is a concept, which applies to acute operative fixation and late reconstruction in inadequately treated and incompletely reduced fractures.

Nondisplaced fractures (30%) and minimally displaced fractures (10%) of less than 2 mm may be immobilized in a long-arm cast (Fig. 2). Good-quality plain radiographs of the elbow (best taken with the cast off) are obtained 2–3 times in the first 3 weeks to assure that reduction has been maintained. Techniques have also been described for minimally displaced fractures with closed reduction and percutaneous pin fixation with two divergent pins placed percutaneously after a closed reduction in order to maintain the alignment [7]. Fractures displaced more than 2 mm and with evidence of rotation are treated at the authors' institution with open reduction and internal fixation (Fig. 3) followed by 6 weeks of immobilization. The exposure interval is between the brachioradialis and triceps. It is important to avoid posterior dissection of the fragment to preserve the vascular supply. Careful elevation of the anterior capsule and dissection to the medial extent of the fracture fragment can enhance visualization and ensure appropriate reduction. The fracture fragment is frequently much larger than it appears on plain radiographs because it has a large cartilaginous portion.

A fully reduced fracture significantly diminishes risks of nonunion by preventing the fracture surfaces from becoming bathed in synovial fluid. Nonunion is more frequent in unstable fractures with significant displacement. Proximal migration of the fracture fragment may lead to valgus deformity with potential ensuing tardy ulnar nerve palsy. Nonunion with displacement most commonly leads to progressive cubitus valgus deformity, which may be addressed with an osteotomy and correction of any translation of the radius and ulna.

Medial Epicondyle Fractures

Fractures of the medial epicondylar apophysis in children are, fortunately, one of the more benign pediatric elbow injuries. However, the surgeon must consider several important issues in order to formulate a sound management plan and avoid complications. Unlike many fractures of the elbow, fractures of the medial epicondylar apophysis do not involve the joint surface or growth cartilage. The medial epicondyle is a posteromedial structure that serves as the origin of the flexor–pronator muscle mass as well as the medial collateral ligamentous complex. About 80% of medial epicondyle fractures occur in boys with a peak age in early adolescence. The mechanism of injury is typically an acute valgus stress to the elbow, although chronic injuries can occur in growing athletes. Successful management of these injuries requires a heightened awareness of the commonly associated injuries: elbow dislocation and ulnar neurapraxia, an understanding of the operative indications, risks and benefits as supported in the literature, and the avoidance of complications such as both stiffness or persistent instability.

Evaluation of a patient with a fracture of the medial epicondylar apophysis requires a careful history and physical examination and review of the radiographs to determine the full extent of the injury. In particular, X rays should be studied for evidence of an incarcerated medial epicondyle fragment within the joint (Fig. 4a–c). Although incarcerated fragments can occasionally be removed with manipulation, surgical treatment is often necessary. There is approximately 50% incidence of associated elbow dislocations with medial epicondyle fractures [8]. If the history or radiographs suggest that the elbow was or is dislocated, greater soft-tissue injury is likely present, requiring increased need for early motion. The physical exam should also include a careful neurologic examination, particularly of the ulnar nerve and median nerve. Any change in the sensory or motor exam of the ulna nerve should be noted in the initial evaluation. With reports of increased ulnar nerve symptoms after surgical treatment, it is critical that the surgeon document ulnar nerve function at presentation. If ulnar nerve function is completely disrupted, operative exploration is indicated. Although in the past some authors have expressed concern

Fig. 2. A 6-year-old boy injured his elbow after a fall. (**A**) A/P view of nondisplaced lateral condyle fracture. (**B**) Lateral preoperative view. (**C**) Lateral view. The patient was immobilized in a long-arm cast and was followed weekly to assess displacement. (**D**) A/P view.

that non-operative treatment of displaced medial epicondyle fractures may lead to tardy nerve dysfunction [9], such concerns have not been supported in the literature.

Non-displaced fractures should be treated with 1–2 weeks of cast or splint protection, followed by patient-directed active range of motion program. Results are usually excellent with this treatment program. If the minimally displaced fracture was associated with an elbow dislocation, earlier motion may be warranted. In general, re-dislocation is less of a risk than elbow stiffness.

There is an ongoing debate regarding the operative management of displaced medial epicondyle fractures. There is strong support in the orthopaedic literature for both operative and non-operative management of displaced medial epicondyle fractures [8,10,13]. A recent article by Farsetti et al. [14] confirmed that non-surgical treatment of isolated medial epicondyle fractures with 5–15 mm of displacement yielded results similar to those obtained with open reduction and internal fixation. Like many previous studies, this paper showed that non-operative management of displaced fractures led to an asymptomatic fibrous non-union. However, in many practice environments (including ours), families

Fig. 3. (**A**) A/P injury film of a 4-year-old boy who sustained a displaced lateral condyle fracture after falling down the stairs. (**B**) Lateral injury film. (**C**) Intraoperative lateral view. The patient underwent open reduction and K-wire fixation. (**D**) Intraoperative A/P view.

Fig. 4. A 15-year-old boy sustained a fracture-dislocation of his elbow. (**A**) Lateral radiograph. Note the medial epicondylar fragment (arrow). (**B**) A/P view. Note the medial epicondylar fragment (arrow). (**C**) A/P view after closed reduction. (**D**) A/P view. Open reduction and internal fixation was performed. (**E**) Postoperative lateral view.

and surgeons are often unsatisfied with a non-union, even if it is predicted to be asymptomatic. There is widespread agreement that operative management is best for the dominant arm of throwing athletes and either arm of gymnasts and wrestlers. Although literature support for non-operative management continues to exist, it is generally the practice at Children's Hospital of Philadelphia (CHOP) to treat most medial epicondyle fractures displaced more than 5 mm with internal fixation and an early motion protocol.

Operative management of medial epicondyle fractures includes two fixation and two positioning strategies. As a general rule, children younger than 10 years old with small medial epicondylar fragments can be satisfactorily treated with open anatomic reduction and Kirschner wire (K-wire) fixation. The pins can be bent and left out of the skin and removed at about 3 weeks. Early motion can be allowed even before the pins are pulled. In older children with larger fracture fragments, fixation with a single partially threaded cannulated screw allows optimal stability and motion within the first week (Fig. 4d,e). Again, because stiffness with loss of terminal extension is a major problem, early motion is strongly suggested. At CHOP, most surgeons prefer to operate with the injured arm on a radiolucent table with the patient in a supine position. An incision is made just anterior to the medial epicondyle, the position of the ulnar nerve is verified visually, the fracture is reduced with elbow flexion and pronation to relax the tension on the fragment, and then the fracture is fixed with a wire or screw. As an alternative, some prefer to operate with the patient prone and the injured arm extended behind the patient's back. This allows direct visualization and less tension on the fragment, but imaging is difficult and some patients may experience temporary shoulder pain after surgery.

After internal fixation, the screw may become symptomatic, necessitating its removal. If full motion is obtained, results are usually excellent. As long as the surgeon understands the anatomy and associated injuries, and chooses a treatment that allows early motion, epicondyle fractures will be one of the least intimidating elbow injuries the surgeon encounters in children.

T-Condylar Fractures

The T-condylar fracture of the distal humerus is a very rare fracture of the elbow region in the pediatric patient, accounting for less than 1% of elbow fractures [1]. As such, there is very little data in the literature on the most reliable way to achieve the best outcome. This injury typically occurs in the adolescent near skeletal maturity, usually from a direct blow to a flexed elbow. The fracture line originates from the apex of the trochlea and extends proximally. Successful management of this fracture requires understanding the intra-articular aspect of the fracture and planning treatment based on the skeletal maturity of the patient. This fracture usually requires surgical management to restore anatomic articular congruence. However, the joint line often does not need to be directly visualized because, unlike adults' fractures, articular comminution is rare. The most stable construct allowing early range of motion (ROM) is achieved with 90/90 reconstruction plates.

The injury mechanism of this fracture is likely from a direct wedge effect of the articular surface of the olecranon on the distal humerus. Biomechanical studies reproducing the T-condylar fracture have done so with a direct blow to the olecranon with the elbow flexed at 90° [15]. The flexion type mechanism can help account for the rarity of presentation in children as most elbow injuries in these patients occur from hyperextension. Occasionally, the fracture pattern can be produced by an extension type mechanism with the elbow only slightly flexed.

The T-condylar fracture can sometimes be confused with other fractures, most commonly extension-type supracondylar fractures. Therefore, good-quality plain films are key to the proper diagnosis and treatment. The key to differentiation from the other fractures is the presence of the vertical fracture line extending down to the apex of the trochlea.

There are no large series of T-condylar fractures available for a thorough analysis of the outcomes. Recent papers support the use of open reduction and internal fixation as the best way to restore anatomic articular congruence and to provide enough fracture stability to start ROM exercises as early as 2–4 weeks after the operation [16].

When confronted with this fracture, the surgeon must consider some key surgical principles. The first goal must be to restore the articular congruence. The stability of the elbow depends on the strength of the medial and lateral supracondylar columns. Most patients are near skeletal maturity and will have little potential for remodeling.

In younger children or when there is minimal displacement of the columns and no articular incongruity, acceptable fixation can sometimes be achieved with closed reduction and percutaneous pin fixation of the supracondylar columns. The pins are usually removed at 3 weeks, and ROM is started.

Fractures with displacement of the condylar fragments and marked disruption of the articular surface are treated with open reduction and internal fixation. We prefer the Morrey utilitarian triceps-sparing approach to the olecranon osteotomy approach. The Morrey approach allows direct visualization of the distal humerus and spares the olecranon. An olecranon osteotomy is only necessary in the rare case of a fracture with articular comminution. The first goal is to achieve anatomic alignment of the articular surface. The reduction is held by a transverse screw through the center of the axis of rotation. This part of the procedure converts the fracture into a supracondylar fracture. The next surgical goal is stabilization of the supracondylar columns. In older patients near skeletal maturity, we prefer the use of reconstruction plates with screw fixation placed at 90° angles to each other. This provides a construct that is stable for early ROM exercises and addresses the fact that this is essentially an adult-type fracture.

We attempt to start ROM as soon as 1–2 weeks postoperatively in the patients stabilized with plate fixation. Before the operation, it is essential to explain the serious nature of the fracture and the associated elbow stiffness to the patient and family members. Avascular necrosis of the trochlea is also a potential complication [17]. Proper diagnosis, careful consideration of the pitfalls, and strong anatomic fixation allowing early ROM are the keys to the management of this rare but serious fracture.

Monteggia Fractures

Monteggia fractures in children are easily manageable if recognized and treated soon after injury. Only about 1% of all forearm fractures in children are classified as Monteggia fractures. Three out of 4 of such cases occur in boys. These fractures are characterized by dislocation of the radial head accompanied by an associated ulnar fracture, most often located in the proximal third of the bone [18,19]. These injuries are typically sustained after a fall onto an outstretched hand resulting in hyperextension or hyperpronation of the elbow [18].

The Bado classification of Monteggia fractures corresponds with the mechanism of injury and is useful in determining the optimal treatment for such injuries. Type I fractures are characterized by anterior radial head dislocation, whereas Type II fractures, which are rare in children, have posterior dislocations. Type III fractures are characterized by lateral radial head dislocation. Lateral Monteggia injuries are usually associated with a buckle-type or greenstick fracture of the ulna and may fail to be recognized. A Bado Type IV injury is characterized by a radial fracture in conjunction with a radial head dislocation and an ulnar fracture. Previously the direction of radial head dislocation was used to determine treatment. More recently, however, the nature of the ulnar injury has begun to dictate management [19].

Patients with Monteggia fractures present with elbow or forearm pain accompanied by tenderness localized over the radial head [18,19]. The most reliable method to recognize a Monteggia fracture is to determine whether the axis of the radius bisects the capitellum on every view [18–20].

Bado described forearm injuries with similar mechanisms of injury to Monteggia fractures, which he called "Monteggia equivalents." Plastic deformation of the ulna occurs in 17% of these "Monteggia equivalents." Other "Monteggia equivalents" are pulled elbow syndrome (nursemaid's elbow), both–bone forearm fractures, isolated radial neck fractures, and dislocation of the elbow with an ulnar diaphyseal fracture [19].

Approximately 8–17% of pediatric Monteggia fractures have associated neurologic deficits, usually a neurapraxia, involving most commonly the posterior interosseous branch of the radial nerve. Recovery of nerve function takes several days to 2 months after injury [18,19].

The goal of treatment is to correct the ulnar deformity while restoring ulnar length and realigning the radiocapitellar joint [20]. Reduction of the ulnar fracture often reduces the radial head [19].

If initial closed reduction fails, the surgeon should proceed to fluoroscopically aided operative reduction, possibly with internal fixation. It is essential to confirm maintenance of reduction.

Open reduction is often necessary for unstable fractures or when closed treatment fails. Early minimal internal fixation of the ulna with an intramedullary Kirshner wire may allow reduction of the radial head. This method is preferred over plate fixation [19]. The Kocher (posterolateral) approach is often utilized for open reduction of the radial head. Other surgeons prefer the Boyd approach to gain additional exposure.

Complications arise when there is a delay in diagnosis of a Monteggia fracture or with re-fracture. If the time between injury and diagnosis is prolonged, the patient may experi-

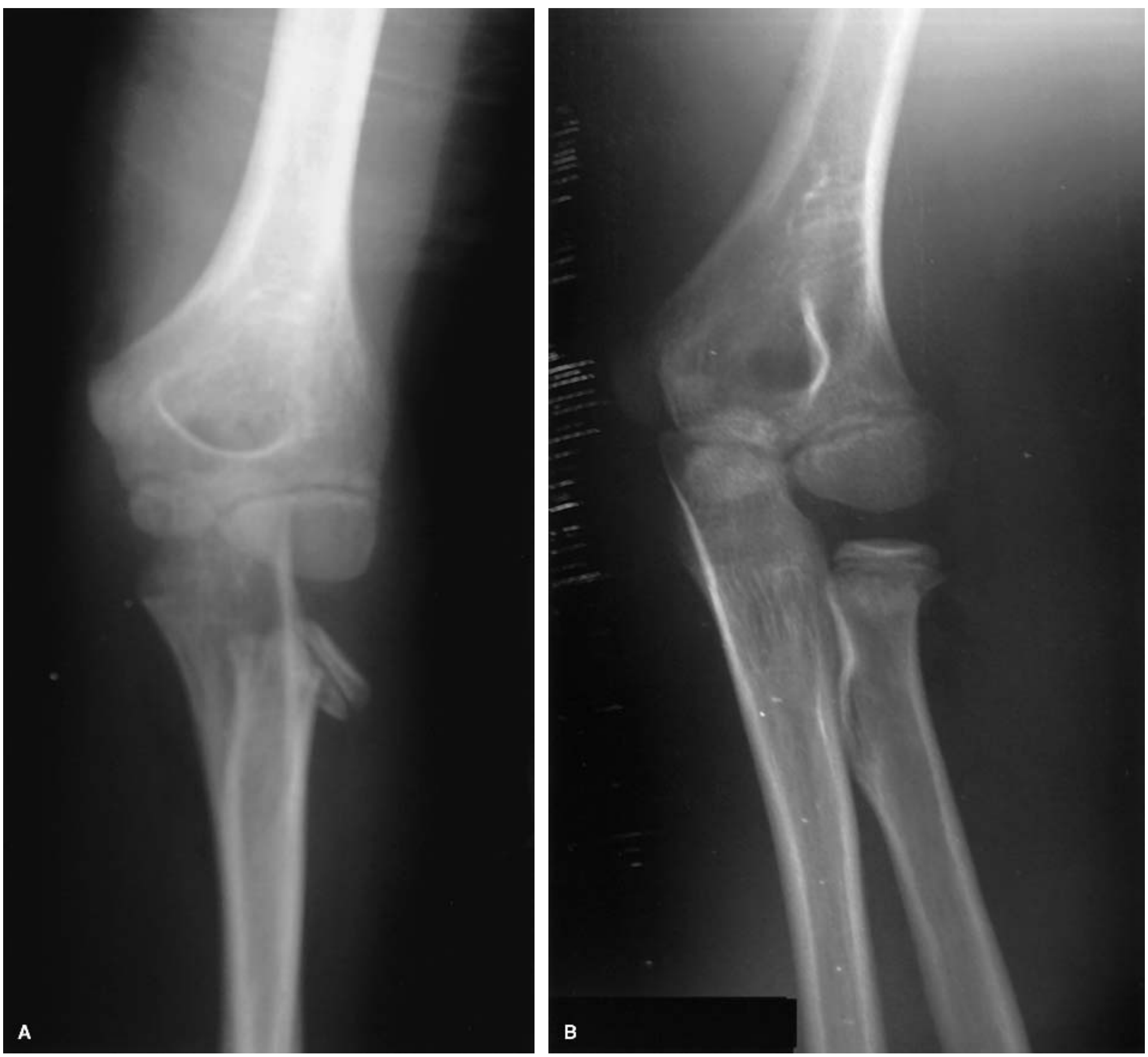

Fig. 5. (**A**) A/P injury film of a 12-year-old boy who sustained a Salter-Harris Type II radial head fracture after a fall. (**B**) A/P follow-up film. The patient underwent closed reduction and was immobilized in a long-arm cast for 2 weeks.

ence limited elbow range of motion, arthrosis, or additional nerve complications [18,19]. These patients may also present with a partially or fully healed ulnar fracture with a radial head dislocation [18]. The goals for the late treatment of a Monteggia fracture are the same. However, achieving proper ulnar length and angulation is difficult, and usually, an ulnar osteotomy followed by open reduction of the radial head and reconstruction of the annular ligament is required. However, ligament reconstruction has received mixed reviews in the literature, as it is often technically challenging and results are unpredictable [19].

Proximal Radius Fracture

Proximal radius fractures in children, unlike those in adults, generally involve the metaphysis or the physis, and not the radial head. These injuries occur most commonly between ages 8 and 12 and result from a fall onto an outstretched hand with a valgus moment directed through the radius [21]. Beware of the possibility of a Monteggia fracture or an "equivalent" when recognizing the proximal radius injury. The length and alignment of the ulna should be compared to the other side, when in doubt.

The goal of treatment is to restore the ability to supinate and pronate, usually about 60° in either direction. Displacement of the fracture fragment results in a cam effect at the proximal radioulnar joint, thereby interfering with normal motion.

Patients with fractures with less than 30° of angulation do not need to undergo reduction and can be treated in a long-arm splint and with ROM exercises 10–14 days after injury. Fractures with angulation from 30° up to 45° should be treated with closed reduction (Fig. 5). The Patterson technique involves direct pressure on the radial head with the surgeon's thumb while an assistant places a varus stress on an extended arm [22]. Another technique is to rotate the forearm from full supination to full pronation, while fully flexing the arm and applying direct pressure on the radial head [1]. If closed manipulation is unsuccessful in restoring 60° of pronation and supination (total arc of 120°), a percutaneous reduction can be performed with a Steinman pin or a K-wire under fluoroscopic control. Be sure to pronate the forearm so as to minimize the chance of injuring the posterior interosseous branch of the radial nerve. In the rare instance when the above methods have all failed to restore proper motion, an open reduction can be performed through the Kocher approach using the interval between the anconeus and the extensor carpi ulnaris. Once reduced, these fractures are usually stable and do not require internal fixation. After any sort of reduction the elbow should be immobilized in a posterior splint for 2–3 weeks and then be started on a range of motion program.

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