Complications of Pediatric Distal Radius and Forearm Fractures

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Abstract

Distal radius and forearm fractures represent a large percentage of pediatric fractures. The most common mechanism of injury is a fall onto an outstretched arm, which can lead to substantial rotational displacement. If this rotational displacement is not adequately addressed, there will be resultant loss of forearm motion and subsequent limitations in performing the activities of daily living. Good initial reductions and proper casting techniques are necessary when treating distal radius and forearm fractures nonsurgically; however, maintaining an acceptable reduction is not always possible. Atraumatic reduction of a displaced physeal fracture should occur within 7 days of the injury. If an impending malunion presents at 2 weeks or later after injury, observation is warranted because of concerns about physeal arrest with repeated attempts at manipulation, and it should be followed by a later assessment of functional limitations. Pediatric patients and their parents have higher expectations for recovery, which has contributed to an increase in the surgical management of pediatric distal radius and forearm fractures. In addition, surgical interventions, such as intramedullary nailing, have their own associated complications.

Fractures of the distal radius and forearm are some of the most common fractures seen in pediatric patients.1,2 Historically, surgical stabilization has been recommended for unstable fractures, complex fractures, polytrauma patients, and when a loss of reduction has occurred.3 With the evolving patient profile, including increased expectations for faster return to activity and normal motion, innovative surgical techniques, instruments, implants, and treatment options have been developed.4 This increase in surgical intervention has led to the need to recognize and treat complications surrounding these procedures.5,6

Surgical intervention is normally reserved for distal radius and forearm fractures when satisfactory alignment cannot be maintained with nonsurgical management. Although there is an increasing trend toward surgical fixation, closed reduction and casting is still the gold standard for treating distal radius
Distal Radius Fractures

Distal radius fractures occur most frequently in the nondominant limb of children aged 4 to 16 years, with boys having a higher incidence compared with girls. The incidence increases as age increases from birth to 16 years. This increasing incidence is likely related to increasing activity and sports participation. The mechanism of injury is usually a fall onto an outstretched hand.\(^\text{11,17}\) Fractures of the distal radius in skeletally immature patients have excellent healing and remodeling capacity.\(^\text{15}\) Therefore, displaced fractures are often initially treated with closed reduction and cast immobilization.

Acceptable alignment for children younger than 8 years is 25° of dorsal tilt and 15° of radial tilt. Complete displacement (bayonet apposition) within these parameters is still acceptable for this young population. Fractures in patients older than 8 years should be reduced to less than 50% displacement, less than 20° of dorsal tilt, and 15° of radial tilt. Deformities within these parameters will remodel if the patient has at least 2 years of growth remaining; however, any malrotation will not remodel.\(^\text{1,4}\)

Fractures with the following parameters are indicated for surgical management with percutaneous pin fixation or open reduction and internal fixation: severe soft-tissue injuries, additional ipsilateral fractures, failure of closed reduction, open fractures, comminuted intraepiphysial fractures, carpal tunnel compression, or compartment syndrome.\(^\text{8}\)

Loss of Reduction

Loss of reduction occurs in 10% to 90% of fractures, with late presentation of displacement in approximately one-third of all reduced distal radius fractures.\(^\text{14,15}\) The predictors of displacement after closed reduction and cast or splint immobilization include an isolated, severely displaced fracture; bayonet apposition; greater than 50% displacement; and greater than 30° of angulation. Studies have demonstrated that in addition to the degree of initial displacement and the quality of reduction, fractures with greater than 50% displacement have an increased risk of redisplacement.\(^\text{15-19}\) A combination of a distal radius fracture and an associated ipsilateral ulnar fracture at the same level in which adequate reduction was not obtained has the highest radiographic predictor for redisplacement.\(^\text{20}\)

The cast index, the padding index, the gap index, the three-point index, and the second metacarpal-radius angle have all been used to measure the quality of plaster molding and position after closed reduction.\(^\text{16}\) Several studies have shown that a loss of acceptable alignment after a closed reduction is associated with fracture quality, a poor initial reduction, and a poorly molded cast\(^\text{21,22}\) (Figure 1). The cast index is defined as the sagittal width of the cast divided by its coronal width. The average cast index of patients who lost reduction was 0.79; in patients who did not lose reduction, the average cast index was 0.7.\(^\text{21}\) The three-point index is another valuable measurement for predicting redisplacement, especially in a distal radius fracture, but this measurement should not be used as an independent factor.\(^\text{16,23,24}\) Proper technique ensures that the cast padding is applied evenly, with two to three layers. It is important to avoid overpadding to optimize the cast index.

Muscle atrophy and cast loosening that occur as a result of the subsidence of swelling also can contribute to a loss of reduction seen with cast immobilization. To prevent complications from a loss of reduction, the patient should be followed closely with weekly radiographs for at least 3 weeks. If a loss of reduction occurs, surgical intervention should be considered. McLauchlan et al\(^\text{17}\) compared pin fixation to cast immobilization in completely displaced fractures and found that no repeat manipulations were needed in the pin fixation group, but 21% of patients in the immobilization group required re-manipulation. Miller et al\(^\text{14}\) also evaluated pin fixation versus closed reduction and reported that 39% of casted patients had a loss of reduction requiring repeat manipulation.

Preventing loss of reduction is the best initial treatment. This goal can be
obtained with good initial reduction and proper casting technique. If a loss of reduction is recognized early, prompt treatment can prevent future complications such as malunions.

**Malunion**

Malunions can occur after insufficient initial reduction, following loss of reduction after acceptable reduction, and when unacceptable criteria are accepted in older children (Figure 2). Early recognition of an impending malunion permits intervention with either repeat manipulation or fracture pinning. However, if the impending malunion presents at 2 weeks or later after injury, observation is recommended because union is nearly established. The fracture should be allowed to heal and the remodeling capacity assessed before any surgical intervention. Late repeat manipulation increases the rate of physeal arrest.

Malunion also can lead to a loss of motion, typically wrist flexion, because the distal fragment is often extended. Another concern is that proximal migration of the malunion can alter distal radioulnar joint mechanics. This has led to a condition called supination dissociation, where patients lose supination secondary to the altered mechanics. A radial osteotomy may be necessary to correct dorsal tilt, thus restoring distal radioulnar joint alignment (Figure 3).

**Nonunion**

Nonunion is an exceedingly rare complication after a distal radius fracture. Nonunion has occurred in patients with neurofibromatosis, with congenital pseudarthrosis of the radius, and after open fractures. Treatment should consist of bone grafting and repair of the nonunion, typically with plate fixation.

**Synostosis**

The incidence of synostosis after a distal radius fracture is low. Most incidences occur after a high-energy traumatic injury treated with open reduction and plate fixation. Takedown of the synostosis remains controversial, with the results being worse for children than for adults.

**Physeal Arrest**

Physeal arrest has a reported incidence of 4% after distal radius fractures. The etiology is believed to be from a direct injury to the physis at the time of the trauma or trauma to the physis that occurred from repeated attempts at reduction. Therefore, late reduction attempts and multiple repeated attempts at closed reduction are not recommended. It is important to recognize unacceptable alignment early and understand the remodeling potential given a child’s age and sex.
This chapter’s authors recommend that atraumatic reductions of a displaced physeal fracture should occur within 7 days of the injury.

Physeal arrest of the distal radius can lead to ulnar-sided wrist pain because the ulna is impacting the lunate with continued ulnar growth (Figure 5). In addition, secondary incongruity of the distal radioulnar joint and triangular fibrocartilaginous complex tears can result.29 This is more common in younger patients with substantial growth remaining. Pain and limited range of motion will persist until the length discrepancy is addressed.30

If less than approximately 50% of the physis is affected, a bar resection can be attempted.31 If more than 50% of the physis is affected, complete physeal arrest (ulnar epiphysiodesis) is necessary to maintain forearm alignment.30

Neurovascular Compromise
The median nerve lies in close proximity to the volar edge of the proximal metaphyseal fragment of dorsally displaced distal radius fractures. Fortunately, the flexor tendons and the pronator quadratus protect the nerve. Nerve irritation can occur because of swelling or substantial displacement that causes pain and paresthesias. Typically, these symptoms dissipate after fracture reduction.32

Pin Tract Infection
Superficial pin tract infections can occur with percutaneous pinning and should be treated with pin removal and oral antibiotics (Figure 6). Persistent drainage requires pin removal to prevent osteomyelitis. Miller et al14 reported that 38% of distal radius fractures treated with pin fixation had pin-related complications, all of which resolved without long-term sequelae after pin removal.

Forearm Fractures
Forearm fractures account for 10% to 45% of all pediatric upper extremity injuries.33 The mainstay of treatment is cast immobilization with or without reduction. Technologic advances, including the use of flexible nails, have led to an increasing trend toward surgical intervention. Surgical indications include open fractures, factors precluding cast immobilization, floating elbow injuries, and irreducible or unstable fractures that have failed nonsurgical treatment. A more recent relative indication is fractures that occur in the midshaft or the proximal third of the forearm in patients at or near skeletal maturity.

The general rules for acceptable alignment include less than 20° of angulation for children younger than 10 years and less than 10° of angulation for children older than 10 years. Complete bayonet apposition can be accepted if at least 2 years of growth remains and angulation is not greater than 20°. The loss of reduction can be symptomatic.

Loss of Reduction
Weekly radiographs should be obtained for the first 3 weeks for all unstable fractures, including all fractures that have
A 15-year-old boy sustained a distal radius fracture while wrestling. The fracture healed with 20° of dorsal angulation. One year after injury, the patient presented with a report of decreased supination: 30° compared with 80° on the contralateral side. The patient was treated with an osteotomy to correct the dorsal angulation. Postoperatively, the patient had 50° of supination. PA (A) and lateral (B) radiographic views. (Courtesy of Joshua M. Abzug, MD, Baltimore, MD.)

Figure 3

Figure 4  PA (A) and lateral (B) radiographs of a fracture with distal radius physeal arrest in an 11-year-old boy. (Courtesy of Shriners Hospital for Children, Philadelphia, PA.)

Figure 5  Preoperative fluoroscopic image of a distal radius physeal arrest, with the ulna impacting the lunate (ulnar abutment). (Courtesy of Joshua M. Abzug, MD, Baltimore, MD.)

Figure 6  Clinical photograph of a superficial pin tract infection that occurred after closed reduction and percutaneous pinning of a distal radius fracture. Complete resolution without long-term sequelae occurred after pin removal and a 5-day course of oral antibiotics. (Courtesy of Joshua M. Abzug, MD, Baltimore, MD.)
been reduced, because the reported incidence of loss of reduction is as high as 40%\(^\text{14}\) (Figure 7). Although loss of reduction is primarily dependent on fracture type and complexity, technical aspects of the reduction and cast application also play a major role. For example, a higher cast index is associated with a loss of reduction.\(^\text{16,22,23}\) Therefore, it is imperative that the cast padding be evenly applied and only two to three layers thick to optimize the cast index.

Yang et al\(^\text{35}\) showed that poor reduction and complete fractures are more likely to result in a loss of reduction; therefore, surgical management should be considered in these cases. However, Colaris et al\(^\text{16}\) reported that pinning of apparently stable both-bone fractures of the distal forearm in children can reduce fracture redisplacement and improve the results of forearm rotation, but there was a higher rate of overall complications compared with the nonsurgical group.

**Refracture**

A 5% refracture risk up to 1 year later has been reported after forearm fractures, with the highest risk being noted when discontinuation of immobilization occurs when visible fracture lines are still present.\(^\text{37-39}\) Baitner et al\(^\text{39}\) showed that 38% of the initial fractures in the refracture group were of the proximal or the middle third of the forearm; thus, fractures in these areas should be immobilized for longer periods of time.

**Malunion**

Care should be taken to ensure that alignment is acceptable when treating pediatric forearm fractures because forearm loss of motion has been shown to be the most common complication. Assessment of the fracture as well as the patient’s characteristics, including age, sex, skeletal maturity, and anticipated compliance, are necessary to prevent malunion from occurring. Matthews et al\(^\text{40}\) showed that residual angulation of 10° in midshaft fractures of the radius, the ulna, or both forearm bones will not limit forearm rotation. However, loss of forearm rotation can be expected with residual angles of 20° or more. For every degree of rotational deformity present, a corresponding 1° to 2° loss of forearm rotation occurs.\(^\text{41}\)

Historically, 50° of pronation and 50° of supination have been accepted as necessary for the activities of daily living.\(^\text{42}\) However, a recent study showed that the functional range of motion necessary for modern activities, including computer and cellphone use, requires up to 65° of pronation and 145° of elbow flexion.\(^\text{43}\)

**Synostosis**

Proximal third fractures of the forearm are at the highest risk for synostosis. Additional risk factors include associated head injuries, high-energy trauma, multiple attempts at reduction, using a single incision for the fixation of both bones, and wire fixation crossing both bones.\(^\text{26}\) Synostosis treatment is unpredictable, with the results of takedown not as successful in children compared with adults.

**Intramedullary Nail Fixation Complications**

Flynn et al\(^\text{5}\) reported an overall complication rate of 14.6% when treating pediatric forearm fractures with intramedullary nail fixation, including a 6.7% rate of compartment syndrome when intramedullary nailing was performed the day of the injury. In addition, overall worse outcomes and
increased rates of delayed union were noted with older children.\(^5\) In older children and adolescents, open reduction with plate-and-screw fixation may be a better choice. This can be performed using a volar or dorsal approach to the radius, depending on the level of the fracture. A direct approach is used for the ulna. However, this technique has its own set of possible complications, including tendon rupture, hardware prominence, stiffness, nonunion, and synostosis.

Rupture of the extensor pollicis longus tendon can occur when a dorsal insertion on the radius is used\(^5\) (Figure 8). Care should be taken to visualize the tendon after insertion of the flexible nail, and the thumb should be moved through a full range of motion to ensure that the tendon is not rubbing on the cut edge of the nail. The nail can be left superficial to the level of the extensor retinaculum to prevent any contact from occurring with the tendons. Alternatively, the tendon can be transposed, changing its line of pull away from the nail.

Using a radial-sided entry for the insertion of a flexible nail avoids the issues with the extensor pollicis longus but can lead to dorsal radial sensory nerve irritation. Therefore, careful dissection and gentle retraction are necessary when using this approach.

Compartment syndrome after intramedullary fixation occurs more commonly with open fractures and longer surgical and fluoroscopic times.\(^4\) Occurrence rates of postoperative compartment syndrome have been reported to range from 3% to 10%.\(^5,45\) Yuan et al\(^45\) recommended a low threshold for converting difficult cases to open reduction to prevent soft-tissue trauma from multiple attempts at reduction and nail passage. Following the surgical procedure, increased anxiety, agitation, and analgesia are the hallmarks of compartment syndrome in pediatric patients.\(^4\)

**Summary**

Pediatric distal radius and forearm fractures are extremely common. Although excellent results are the norm, many complications can occur when treating these fractures. Nonsurgical care can result in a loss of motion from malunions. The increasing trend toward surgical fixation has led to a unique set of complications. Careful evaluation of the fracture characteristics while also considering a patient’s characteristics can aid the surgeon in determining whether surgical intervention is necessary. For nonsurgical treatment, close observation and the use of fundamental casting techniques are imperative to limit potential complications. Precise surgical techniques and knowing when to proceed to formal open reduction are necessary when performing surgical intervention for these fractures.

**References**


