Delayed diagnosis and management of injuries involving the distal radioulnar joint and distal ulna in the pediatric population: recognition and conduct

Bibiana Dello Russo · Horacio F. Miscione

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Abstract

Introduction Distal radius fractures associated with ligament or distal epiphyseal injuries of the ulna occur less frequently in skeletally immature patients. The underestimation of the mechanisms of injury leads to conservative management of this type of fracture, resulting in unsatisfactory reductions and loss of range of motion.

Materials and methods Between January 2000 and March 2008, ten cases that were referred to our institution from other centers were studied. Treatment was joint reconstruction. The mean age was 11.9 years. Mechanisms of the fracture, as well as the delay of diagnosis, definitive reduction, and the number of surgeries previously performed, were analyzed.

Results The mean follow-up until the skeletal maturity of the patients was 3.4 years. The mean number of surgeries before the definitive treatment was given was 2.1, varying from attempts of closed reductions under anesthesia to percutaneous pinning in most of the cases. Eighty-seven percent of the patients improved their range of motion after the definitive surgery in the last follow-up, and there has been no evidence of growth disorders.

Conclusions The presented fracture pattern is generally undervalued when evaluating management in children; the reduction of this type of injury should be surgical in order to achieve an adequate alignment. Parents should be informed about the treatment, its evolution, and possible subsequent surgeries to reestablish the joint axes and the adequate length of the wrist bones.

Keywords Fractures · Radius · Children · Galeazzi-equivalent injuries · Open reduction · Ligament injuries · Distal ulnar epiphysis

Introduction

Fractures of the distal end of the forearm are common in children. Their management differs considerably from that of adults, even when they present with the same fracture pattern [1]. Conservative treatment in adults is often not optimum and can result in non-unions, lack of adequate reduction, or the presence of reflex sympathetic syndrome due to prolonged immobilizations. In contrast, the treatment of choice in children is closed reduction and immobilization because of the rapid consolidation and remodeling capacity of residual deformities [2]. It is important to differentiate among the types of fractures that can occur in the pediatric population in order to select the treatment and reduction technique which is the most suitable for a given fracture [3] (Fig. 1).

This review describes the variety of therapeutic decisions taken in cases of less frequently appearing patterns of fractures of the distal end of the forearm and demonstrates the currently available reconstruction techniques around the wrist after initial misdiagnosis and inappropriate treatment.

Materials and methods

In this retrospective, descriptive, and observational study, we evaluated all of the pediatric patients who presented with fractures or epiphysiolysis of the distal radius, as well as fractures, epiphysiolysis, or dislocations of the distal ulna

B. Dello Russo (✉) · H. F. Miscione
J.P. Garrahan Hospital Nacional de Pediatría,
Buenos Aires, Argentina
e-mail: bibianadellorusso@yahoo.com.ar

Fig. 1 Galeazzi-type fracture C II (a, b)

Table 1 Letts and Rowhani classification of Galeazzi-equivalent injuries of the wrist in children

Type A: Fracture of the radius at the junction of the middle third with the distal third	I: Dorsal dislocation of the distal ulnar end
	II: Distal epiphysiolsis of the ulna with dorsal displacement of the metaphysis	
Type B: Fracture of the radius at the distal third level	I: Dorsal dislocation of the distal ulnar end
	II: Distal epiphysiolsis of the ulna with dorsal displacement of the metaphysis	
Type C: Greenstick fractures of the radius with dorsal angulation	I: Dorsal dislocation of the distal ulnar end
	II: Distal epiphysiolsis of the ulna with dorsal displacement of the metaphysis	
Type D: Fracture of the distal radius with palmar angulation	I: Palmar dislocation of the distal end of the ulna.
	II: Epiphysiolsis of the distal end of the ulna with volar displacement of the metaphysis	

Taken from Letts and Rowhani [5]

(Fig. 1) with or without associated carpal pathology between 2000 and 2008. The required preoperative studies were anteroposterior and lateral X-rays, and magnetic resonance imaging (MRI) or computed tomography (CT) scans in order to demonstrate the presence of ligament injuries or joint incongruities of the hand or arm (Fig. 2). The patients whose medical records and imaging studies were incomplete were excluded from this series. All of the patients had been referred to the National Pediatric Hospital of Buenos Aires, Argentina, after having been treated at other institutions where closed fracture reduction was attempted and failed.

Results

Twelve patients had been treated for the selected pathologies, but the medical records and imaging studies of two of them were incomplete and they were excluded from further analysis. The mean age of the remaining ten children was 11.9 years, and they included eight males and three females. Metaphyseal fractures of the radius and distal ulna epiphysiolsis (Galeazzi-type) (Table 1) were detected on admission in eight patients [4], whose injuries were defined according to the Letts and Rowhani [5]

Fig. 2 **a** Computerized tomogram showing exostosis, which is a product of the exaggerated growth of the periosteum. **b** Anteroposterior radiograph showing an injury that can go unnoticed by less trained eyes

classification. Of the remaining two cases, one had a plastic bowing type fracture of the ulna with distal dislocation (Fig. 3), and the other had a triplane fracture of the distal radius [6] plus dislocation of the lunate bone and distal ulna subluxation (Fig. 4).

Seven patients who presented with Galeazzi-equivalent lesions [4] were treated with open reduction for the reduction of the ulnar physis, followed by percutaneous pinning of both fractures. Disruptions of the triangular ligament of the wrist were not observed in any of these cases (Fig. 5). In another patient, a bone protuberance on the volar of the wrist that limited pronosupination was observed on physical examination. The CT scan showed ossification of the periosteum invading the palm that was approached by removing the exostosis and inserting a Gore-Tex mesh into the bloody surface and suturing it to the periosteum in order to prevent synostosis by radioulnar fusion (Fig. 6).

Fig. 3 Radiographic projection showing plastic deformity of the ulna with ulnar distal dislocation (**a**, **b**, **c**)

Fig. 4 Triplane fracture of the radial epiphysis

The patient who presented with a plastic bowing type fracture of the ulna [7–11] with ulnar distal dislocation had a 20-day period without any treatment. Repair of the wrist triangular ligament, removal of the extensor digit minimi tendon from the fracture, posterior anatomical reduction, and percutaneous pinning were performed in open surgery (Fig. 7).

In the remaining patient, a triplane fracture [6] of the distal radius was treated in open surgery with the purpose of removing fibrous tissue in the fracture. Fatty tissue was

placed in the physeal area to remove the physeal arrest, after which the fracture was stabilized with smooth pins. Due to the dislocation, the lunate bone was one-third of the real size

Fig. 5 Treatment of a C II type fracture (a, b)

Fig. 6 Treatment of radial triplane epiphyseolysis plus tenodesis of the carpus (a, b, c, d)

and the remaining bone showed fragmented necrosis. The necrotized tissue was removed and a tenoplasty with the second radial was performed to spread the carpus, thus, preventing collapse or loss of architecture (Fig. 8).

All of the patients were immobilized with brachiopalmar plaster in supination for 6 weeks. Anteroposterior and lateral X-rays were performed every 15 days. The osteosyntheses were removed in the fourth week. The interval between the first unsuccessful treatment and the definitive treatment in our center was between 3 months and 1 year (mean 5 months). Follow-up was continuous until the closure of the physeal plate (Table 2), and it lasted for a mean of 3.4 years for these patients.

Between 1 and 3 surgical procedures (mean 2.1) had been performed before the definitive treatment was given, varying from attempts of closed reductions under anesthesia to percutaneous pinning. After undergoing the definitive treatment, all of the patients achieved fracture consolidation by the sixth postoperative week. They all needed 2 months of physical therapy to improve range of motion, which increased in all planes: the patient with exostosis resection had a 30° decrease of pronosupination caused by inadequate periosteum growth (Fig. 9a–d).

The definitive surgical techniques included surgical realignment of the fracture and reduction with smooth pins. Only two cases required additional ligament repair and plates to correct the radiodistal radius. Superficial infection of the pins was present in one case and it was treated with

Fig. 7 Immediate post-surgical Rxs of the treatment of ulnar distal dislocation with ulnar plastic deformity (a, b)

Fig. 8 Treatment of the bone protuberance (a, b)

local antibiotics. Two other patients had a 1-cm shortening of the ulnar bone at the time of their physeal closures (Fig. 9e, f). There was no case in which the loss of rotation was more than 60°, thus, precluding the need to perform osteotomies for compensation.

Discussion

The aim of treatment for all fractures that involve the forearm is to facilitate the consolidation with a good range

of motion of the elbow and wrist. In children, fractures of the forearm most frequently involve the distal end [3], and epiphyseal fractures of the distal end mostly occur in preadolescents [12, 13]. Normal supination ranges from neutral to 80°–120°, and normal pronation from neutral to 50°–80° [14]. It is important to emphasize that a normal range of motion is not necessary for normal function [15]. Biomechanical tests have shown that daily activities require 100° of total rotation of the forearm, combining pronation and supination movements. Pronation limitations are easily compensated with shoulder abduction. The cosmetic problems caused by these fractures are a frequent reason for the patients seeking consultation, even in cases of successful reduction. The cause of gross deformities seen in these patients is most often mismanagement of the ulnar reduction [3].

Anatomically, a child's periosteum is thicker than that of an adult, which is why it often does not break when the fracture occurs. Greenstick or torus fractures typically occur in childhood because the long bones have a narrow medullary cavity and extensive spongy bone near the epiphysis [16]. Given these characteristics, the obtaining of anatomical results in the reduction of these fractures is often considered to be of relatively little importance due to the remodeling potential, with the exception of patients who are close to the age of physeal closure. There is a consensus about tolerating angulations from 20° to 25° in the sagittal plane in patients younger than 12 years of age and up to 10° in older patients. Friberg calculated a remodeling percentage in the distal end of the radius as being from 0.9° to 10° per year until 11 years of age [17, 18]. The distal ulnar epiphysis ossifies between 5.6 and 9.6 years in boys and between 4.6 and 7 years in girls, while physeal fusion is complete between 14 and 20 years [19].

The movements of the distal radioulnar articulation are defined as two concentric arches: the smallest is defined by the rotation of the ulnar epiphysis upon itself, and the largest is defined by the external border of the radius. Articulation stabilization is determined mainly by the triangular fibrocartilage complex that is inserted in the styloid process of the ulna and in the distal radial articulation surface, as well as by the pronator quadratus, the ulnar collateral ligaments, and the anterior and posterior radial ligaments. Its purpose is to prevent radial dislocation and to limit the rotating movements [20].

In children, epiphyseal avulsion is more frequent than ligament rupture caused by hyperpronation or hypersupination [21]. Stability and joint mobility are acceptable, however, since the structures of the wrist remain intact. The fracture pattern described by Galeazzi is well-known in adults, but is less common in children. The same applies to these kinds of Galeazzi-type fractures [4, 22], in which

Table 2 Patients' surgical data

Patient no., gender/age/ injury/hand or arm	Fracture pattern	Primary treatment ^a	Interval until definitive treatment	Pre-surgical range of motion
1. F/9 years/ hyperextension/left	Galeazzi-type TCII	Closed reduction + plaster cast	6 months	Radial deviation 30°, Sup 60°
2. M/8 years/ hyperextension/left	Galeazzi-type TDII	Closed reduction + plaster cast	1 year	Radial deviation 40°, Sup 55°
3. F/11 years/ hyperextension/right	Galeazzi-type TBII	Closed reduction + plaster cast	8 months	Radial deviation 50°, Sup 40°
4. M/12 years/ dorsiflexion/right	Galeazzi-type TDII	Closed reduction + plaster cast	2 months	Wrist extension 30°, Sup 40°
5. M/11 years/ dorsiflexion/right	Galeazzi-type TCII	Closed reduction + plaster cast + percutaneous osteodesis	3 months	Sup 30°
6. M/12 years/ dorsiflexion/right	Galeazzi-type TDII	Closed reduction + plaster cast + percutaneous osteodesis	2 months	Radial deviation 30°, Sup 60°, Dorsal deviation 25°
7. M/11 years/ dorsiflexion/right	Galeazzi-type TDII	Closed reduction + plaster cast	1 month	Radial deviation 20°, Sup 55°, Dorsal deviation 30°
8. F/11 years/ dorsiflexion/right	Galeazzi-type TDII	Closed reduction + plaster cast + percutaneous osteodesis	4 months	Radial deviation 20°, Sup 40°, Dorsal deviation 10°
9. M/10 years/ hyperextension/left	Triplane fracture of the radius + semilunar subluxation	Closed reduction + plaster cast + percutaneous osteodesis	3 months	Radial deviation 45°, Sup 20°, volar deviation 40°
10. M/11 years/direct trauma/right	Plastic deformity of the radius	Closed reduction + plaster cast	21 days	Radial deviation 30°, Sup 40°

F female; M male; Sup supination

^a All unsuccessful

the distal ulnar articulation is not interrupted and does not cause injuries as a consequence of the triangular ligament [23, 24]. The distal ulnar epiphysiolysis in the pediatric population occurs instead of the dislocation that occurs in the adult, and there is agreement in the literature that the prognosis in children is better than it is in adult patients with the same initial fracture pattern [4, 25–27].

All of the patients in this series were treated with open reduction. Generally, the periosteum or the extensor digitorum communis, the extensor indicis proprius, as well as the extensor digit minimi, can be interposed in the fracture focus of the ulna. The materials used for osteosynthesis were mainly Kirschner pins, and plates with screws for the radius and ulna were used in only two cases, which also had the longest period to post-primary reduction consultation.

As in all fractures that involve the physis, there is a real risk of a shortened limb at maturity, and this happened in two of our patients. Parents should be warned about this possibility [28]. Ulnar lengthening was proposed to the parents of both of these patients, since there was only 1.5 cm of discrepancy to elongate in either of them.

Most of the fracture patterns found in the radius were metaphyseal fractures with none or little dorsal displacement. One of our patients had a triplane epiphyseal fracture, which is a type that occurs in the three planes (coronal, sagittal, and transverse) at the end of all long

bones in a child with open growth cartilage [19]. The transverse fracture occurs at the level of the physal plate, the sagittal fracture at the level of the epiphysis, and the coronal fracture at the level of the metaphysis [29]. In 1957, Johnson and Fahl [30] included them in physal fractures. Most of the cases reported so far are in the distal end of the tibia. In the distal end of the humerus, only one case is reported by Peterson [6], where the fracture was in the distal end of the radius. All of the reduction attempts in these types of fractures were anatomical ones aimed to prevent physal arrest. Thus, open reductions are preferred to achieve adequate articular congruence followed by stabilization. There are, however, reports in the literature of conservative treatment for this fracture type with good results [31]. In our single case, the incongruence of the wrist and the lack of alignment of the physis, together with the time that had elapsed since the injury, led to the decision to perform definitive stabilization in an open operation with removal of the fibrous tissue that composed the physal bar and the interposition of fat, with stabilization of the fracture with plain pins, since the patient had a bone age of 8.7 years (as determined by the maturation assessment method of the carpal bones in the Greulich and Pyle atlas) [20, 32].

Cases of radioulnar synostosis have been described by others, but there were none in our cohort. The exostosis

Fig. 9 **a–d** Pre- and postoperative range of motion after removing the ulnar exostosis. **e, f** Radiograph showing remnant ulnar shortening

that was resected in case 4 (Table 2) was not joined to the radius and the application of a Gore-Tex mesh over the bloody surface prevented the possibility of synostosis of both bones, with satisfactory increase of range of motion and the return of the patient to his daily routine (in this case, to play a wind instrument) [23].

Small series of plastic deformities of the forearm have also been reported in the literature [7, 8, 33]. The mean age at presentation was 7 years and there was always a residual deformity, since it is very difficult to completely reduce the deformity.

The mechanism of injury is frequently trauma in the longitudinal axis and rarely in the transversal axis [34], as happened in our case. All of the reported series concur that

the chronic forms require surgical treatment, especially if there is distal ulnar dislocation as well [19, 24]. In one such case, the interposition of the expanders had to be separated, and the fibers of the triangular ligament inserted in the ulnar styloids were repaired [22]. Immobilization was the same as in the previous cases, but distal radioulnar osteodesis was performed and then removed after 3 weeks. That patient has recovered total mobility without any evidence of synostosis. Andersen and Hvolris reported the first case of this type of fracture in the literature in 1999 and described the difficulty in recognizing the injury on the first consultation [7].

Schemitsch and Richards measured the maximum radial curve radiographically and established that the deformity should not exceed 10% of the length of the bone segment

[16, 35] (Fig. 8a). These parameters need to be taken into account when assessing the sequelae of these fractures, which are difficult to diagnose at first sight [29].

In conclusion, fractures associated with dislocations or epiphysiolysis of the distal end of the forearm are difficult to diagnose initially and, as such, the treatment and final reduction will be equally problematic. We recommend the following guidelines for correct diagnosis and treatment:

1. Carrying out an in-depth and highly detailed clinical and radiological evaluation.
2. Determining the prognosis according to the type of injury and, fundamentally, on the initial treatment of injuries that involve the distal ulnar physis.
3. Performing surgical reduction in order to achieve adequate physeal alignment of the ulna.
4. Informing parents about the nature of the fracture, and the possibility of the need for additional procedures in order to reestablish the articular axes and to achieve adequate length of the bones of the wrist.
5. Periodically evaluating patients with these types of injuries until physeal closure is achieved.

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