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ORIGINAL ARTICLE

Extraphyseal distal radius fracture in children: is the cast always needed? A retrospective analysis comparing Epibloc system and *K*-wire pinning

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Abstract

Introduction Closed reduction and internal fixation are a widespread surgical treatment for pediatrics displaced extraphyseal distal radius fractures. Post-surgical cast immobilization is usually needed. Epibloc system (ES) is a device used to fix Colles fractures in adults, not requiring post-surgical immobilization. The aim of the study is to investigate the effectiveness of ES in a pediatric population suffering from displaced extraphyseal distal radius fractures.

Methods We retrospectively analyzed 52 patients (age 8–12 years) who underwent CRIF. Patients were divided into two groups. Group A (25 patients): ES osteosynthesis. Group B (27 patients): *K*-wires and short arm cast osteosynthesis. The primary outcome is the maintenance of reduction in radiographs (displacement on frontal and lateral view). The secondary outcome is the reaching of the complete active range of motion recovery (compared with the contralateral side) and the time needed to obtain it. The need of further additional treatment (physiotherapy) and the presence of complication were also assessed.

Results Reduction was equally maintained in both groups ($p > 0.05$). Physiotherapy was mandatory for 11 patients in group B; only for 3 patients in group A, the difference was statistically significant ($p = 0.03$) according to Fisher test. Otherwise, the difference was not statistically significant regarding complications. ($p > 0.05$). At the last follow-up, complete functional recovery was reached in all patients.

Conclusions Functional recovery is faster, and postoperative physiotherapy is rarely required with ES. This device allows us to go beyond the traditional concept of mandatory postoperative immobilization after pediatric wrist fractures surgery.

Keywords Wrist fracture · Pediatric · CRIF · Forearm · Cast immobilization

Introduction

The distal radius represents one of the most common sites of pediatric fracture, amounting about the 25% of all fractures [1]. Stable and extra-articular distal radius fractures could be treated successfully in a conservative way with close reduction and cast immobilization [2]; however, surgery plays an important role in the unstable and displaced fractures [3, 4]. The aims of surgery are to restore the correct length of the bone, to fix the fracture and to avoid a further displacement [5]. Closed reduction and internal fixation (CRIF) is a widespread surgical treatment for pediatrics forearm fractures. Various types of internal fixation can be used as elastic stable intramedullary nailing (ESIN) [6] or crossed K-wire pinning [7]. Further cast immobilization is recommended [5, 8]. In our institution, we have a significant experience in CRIF using Epibloc system (ES), a kind of simple, stable and mini-invasive kind of fixation system [9–12]. The wires are properly bended out of the skin and fixed using an external radiolucent plate. (Fig. 1).

This technique allows a rapid functional recovery without the use of further cast immobilization [9, 10, 12–14]; furthermore, in children, the wires could be inserted without

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Fig. 1 Male, 11 years old. 23r-M/3.1 fracture before and after CRIF using ES. A dorsal displacement of distal fragment frequently occurs

passing through the growth plates. The aim of the present retrospective analysis was to investigate the effectiveness in of ES for displaced distal radius fracture in children (without the use of further immobilization) and compare clinical and radiologic results obtained with *K*-wire fixation (with a further short arm cast immobilization), according to many techniques suggested in the literature [5–8, 15].

Materials and methods

Study design and aim

The present investigation consists in a retrospective analysis on our institutional database of pediatric patients affected by meta-epiphyseal fractures of the distal radius evaluated at our Emergency Department (Fondazione Policlinico Universitario A. Gemelli IRCCS, Rome) and treated with CRIF from January 2015 to April 2019.

The study respects national ethical standards and the Helsinki Convention. An ethical approval was not requested for this retrospective analysis. In our institution, percutaneous fixation is the gold standard for the surgical treatment of pediatric wrist fractures, and CRIF using ES for distal radius fracture is a conventional treatment. All parents of patients expressed a write consent before the surgery. Benefits, risks and possible complications of the surgical treatment compared with conservative treatment (immobilization in a long-arm cast and radiographic assessments) were explained to the parents of all patients.

Inclusion and exclusion criteria

Patients aged between 8 and 12 years old at the time of trauma, with a wrist fractures type 23r-M/3.1 according to AO classification [16] and surgically treated with CRIF in our institution were eligible for the study.

Were excluded from the study patients with fractures involving the growth plate of the distal radius, the contemporary presence of other upper limb fractures, epilepsy, attention-deficit hyperactivity disorder and/or mental retardation, open fractures, previous upper limb fractures and history of obstetrical traumas, underlying bone pathology, allergy to metals. Patients with incomplete data settings were excluded. In our institution, the complete data setting for pediatric patients suffering from distal forearm and wrist fracture, treated using CRIF, includes:

(1) pre- and immediately postoperative plain radiographs (anterior–posterior view, lateral view).
(2) 7 days postoperative clinical evaluation and plain radiographs (anterior–posterior view, lateral view of forearm), to exclude any further significant displacement.
(3) 30 days postoperative clinical evaluation and plain radiographs (anterior–posterior view, lateral view of forearm), to confirm healing.
(4) 7 days clinical evaluation after the removal of the wires. Active Range of Motion (AROM) of wrist and forearm is recorded, and the need of physiotherapy is assessed. Further radiographs are not considered absolutely necessary after the removal of the wires. From this point on, further X-ray assessment is considered case-by-case.
(5) 30 days clinical evaluation after the removal of the wires. AROM of wrist and forearm is recorded again.
(6) Further assessment is considered case-by-case.

Patients assignment and groups setting

Fifty-two patients were eligible for the study. Patients were divided into two groups considering the treatment they received:

(1) Group A (25 patients): CRIF using ES.

(2) Group B (27 patients): CRIF using *K*-wires and short arm cast.

CRIF is the gold standard for treatment of 23r-M/3.1 fractures [3], and thereby treatment for group A and for group B can be considered as equivalent. The kind of treatment was chosen after an individual consultation between patient's parents and the surgeon.

Surgical techniques

The aim of CRIF is a stable and reliable osteosynthesis [6, 7, 17, 18]. All patients were treated by two experienced hand surgeons (G.T. and R.D.V.). In all cases, a transient ischemia was performed with pneumatic cuff. The patients were divided as follows based on the treatment received.

Epibloc system (ES)

Patients belonging to group A were fixed through ES. Anatomical reduction was obtained under fluoroscopic guidance. The two entry points should be possibly very distal, but always proximal to the growth plate. These entry points should be located as far apart from each other as possible. (Fig. 1).

The wires should be inserted in intramedullary, to find a point of support on the metaphyseal-diaphyseal bone. ES commonly used for wrist fracture in adults is 2 mm caliber. We used 2 mm caliber wires in all cases. The wires should be inserted into the radius without breaking through the opposite cortex. This is possible thanks to the flatten tip of the wire (Fig. 2). According to the original technique [10], the wires should be inserted intramedullary till the radial head. In younger patients, it could be difficult to insert both the whole wire intramedullary along the radius. However, according to our experience, in that case a perfect reduction and a stable and affordable fixation are achieved if a wire leans on the opposite cortex. (Fig. 3).

Conversely, the external locking is of fundamental importance. The wires are externally bended over the skin to avoid the risk of decubitus. Finally, the wires are fixed on the plate away from each other, in order to obtain a "spring back effect" on the fracture site. The stability of the osteosynthesis is verified through a dynamic proof under fluoroscopic guidance. Finally, a soft dressing is made and the entry points are protected with a soft gauze. The ES is completely covered.

Crossed K wire pinning

Reduction and osteosynthesis through K-wires pinning [7]. With fluoroscopic guidance, after fracture reduction maneuvers, from a minimum of two to a maximum of three

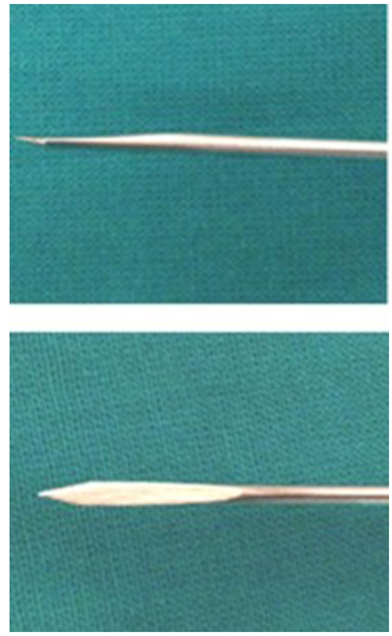

Fig. 2 The wires are made of steel. The tip is properly flattened, to promote bending into the intramedullary canal

Fig. 3 Female, 8 years old. Sometimes the second wire breaks through the opposite cortex. This can occur in youngest patients. Anyway, the fracture site is stable

percutaneous retrograde K-wires were introduced, proximal to the distal radius epiphysis. After surgery an immobilization in a short arm (under the elbow), univalve cast was performed.

After surgery, all patients (group A and B) were instructed to perform active and passive movements of the fingers and wrist allowed by the bandage or cast. In all cases, the implants were removed when the fracture healed. The wires have been removed after 30 days from CRIF.

Variables

Distal radius fragment angle displacement was calculated on preoperative radiographs. CRIF was performed through image intensifier. Anatomical reduction was obtained and an immediate postoperative plain radiographs were performed. Goniometric measurements were performed:

(1) frontal angle of the distal radius (distal fragment inclination compared to the radial axis on anterior–posterior view)
(2) lateral angle (distal fragment inclination compared to the radial axis on lateral view)
(3) sideways displacement on lateral view (percentage of translation on fracture line)
(4) sideways displacement on anterior–posterior view (percentage of translation on fracture line)

Considering children's bone remodeling, angulations of $< 30°$ on lateral plane and angulations of $< 10°$ in coronal plane are considered not significant [5, 19]. Sideways displacement is not considered as clinically significant by itself, even if it can expose any further instability. The same goniometric measures were calculated at any further radiological control. The values were calculated by three different observers (three orthopedic surgeons), and the final value reported was the mean among the three values reported.

The removal of the wires was performed on a sedated patient, as a one-day surgery procedure. The patient and the parents are encouraged to move the wrist and the fingers before the patient's discharge. Seven days after the removal of the wires, a wrist AROM assessment (pronation–supination, flexion and extension) was performed and compared with the contralateral side. AROM assessment was performed at any further visit. AROM lag was calculated in percentage and compared with the contralateral side. In field of pediatrics, according to our experience, we usually recommended physiotherapy if AROM lag was more than 15% compared with the contralateral side in any kind of movement, and parents were recommended to improve child's movement.

Outcomes

The primary outcome is the maintenance of reduction. The secondary outcome is the reaching of the complete AROM recovery (compared with the contralateral side) and the time needed to obtain it. The need of further additional treatment (physiotherapy) and the presence of complication were also assessed. AROM on the affected side was calculated in percentage compared with the contralateral side. A complete AROM recovery was arbitrarily defined as a lag of less than or equal to 5% compared with the contralateral side.

Statistical analysis

Statistical analysis was performed using the Fisher exact test for categorical variables, the Wilcoxon test for two dependent ordinal variables, the Mann–Whitney U-test for two independent ordinal variables. The significance was established for a value of $p < 0.05$. Data were reported as percentage and frequency for categorical variables, and mean ± standard deviation (SD) for continuous variables. Statistical analysis was performed using the SPSS v.19.0 software (SPSS Inc.; Chicago, IL).

Results

Participants

Fifty-eight patients (from 8 to 12 years old at the time of trauma)affected by 23r-M/3.1 fractures and treated with CRIF since January 2015 to April 2019 were considered for the study. All patients were operated within 48 h from the trauma. Two patients were excluded because of incomplete data settings, three further patients were excluded because of the presence of excluding comorbidities (Down syndrome, ADHD, epilepsy), and one was affected by open fracture.

Finally, 52 patients (39 M, 13 F) were included in the study, 25 patients belonged to Group A (19 M, 6 F) and 27 belonged to Group B (20 M, 7 F). The mean age in group A was 9.5 ± 1.4 years. The mean age in group B was 9.3 ± 1.5 years.

The mean follow-up in group A was 37.4 ± 2.3 days, and the mean follow-up in group B was 38.2 ± 3.0 days. Anesthesia was performed with the consent of the child and parents. Regional anesthesia was performed in 15 patients, 7 belonging to group A and 8 to group B. General anesthesia was performed in the remaining. Demographic and clinical features are resumed in Table 1.

Table 1 Demographic and clinical features of studied patient

Demographics	Group A	Group B
Number of patient	25 (48.1%)	27 (51.9%)
Age (years) (mean ± SD)	9.5 ± 1.4	9.3.0 ± 1.5
Gender	6 F, 19 M	7 F, 20 M
Anesthesia		
Regional	7 (28.0%)	8 (29.6%)
General	18 (72.0%)	19 (70.4%)
Follow-up (days post surgery) (mean ± SD)	37.4 ± 2.3	38.2 ± 3.0

SD standard deviation

Radiologic and clinical results

Immediate postoperative reduction was considered satisfactory for all patients. A satisfactory reduction was maintained until the last radiographic assessment in all patients. Union was reported in all patients within 30 days from surgery. The average time passed from surgery to removal was 32.1 ± 2.3 days in group A and 31.5 ± 3.0 in group B.

Maintenance of reduction

A satisfactory reduction was maintained in all patients in both groups at the following assessments. None of the patients had a significant further displacement.

In Group A, at the *X*-ray performed immediately after CRIF, the mean displacement was 2.9 ± 2.5° on frontal view, 3.3 ± 2.9° on lateral view. The mean sideways displacement on lateral view was 4.0 ± 3.7% and 4.5 ± 4.2% on anterior–posterior view. After 7 days, the mean displacement was 3.3 ± 2.4°on frontal view, 3.8 ± 2.5°on lateral view. The mean sideways displacement on lateral view was 4.3 ± 4.0% and 4.3 ± 4.3%on anterior–posterior view.

In Group B, at the *X*-ray performed immediately after CRIF, the mean displacement was on 3.7 ± 3.4° frontal view, 2.0 ± 2.5° on lateral view. The mean sideways displacement on lateral view was 2.6 ± 2.6% and 3.3 ± 2.9% on anterior–posterior view. After 7 days, the mean displacement was 4.1 ± 3.6° on frontal view, 2.2 ± 2.5° on lateral view. The mean sideways displacement on lateral view was 2.8 ± 2.5% and 3.7 ± 2.7% on anterior–posterior view. Reduction obtained with CRIF did not change significantly after 7 days in both groups. Results about maintenance of reduction are resumed in Table 2.

AROM and physiotherapy

After 7 days from implants removal, AROM difference was statistically significant for each movement. The mean flexion in group A was 92.1 ± 4.6% versus 84.8 ± 6.1% in group B ($p = 0.007$). The mean extension in group A was 91.9 ± 8.6% versus 85.0 ± 5.1% in group B ($p = 0.022$). The mean pronation in group A was 93.3 ± 5.3% versus 83.9 ± 6.6% in group B ($p = 0.009$). The mean supination in group A was 92.3 ± 5.0% versus 85.9 ± 5.4% in group B ($p = 0.010$). (Fig. 4).

Physiotherapy was recommended for 11 patients in group B, only for 3 patients in group A, the difference was statistically significant ($p = 0.03$) according to Fisher test. Otherwise, the difference was not statistically significant regarding complications ($p > 0.05$): no infection was observed, and ulcers were revealed on 2 patients in group A and 3 patients in group B at the entry point of the wires. None decubitus ulcer was observed. No cases of loss of wire's tension were observed. After 30 days from wires removal, no significant AROM differences were revealed between group A and B ($p > 0.05$). Results about maintenance of reduction are resumed in Table 3.

Table 2 Table showing the main results about reduction maintenance in each group

Maintenance of reduction	Immediately after CRIF	7 days after reduction	*p* value
Group A			
Frontal angle (degrees ±SD)	2.9 ± 2.5°	3.3 ± 2.4°	$p = 0.96$
Lateral angle (degrees ±SD)	3.3 ± 2.9°	3.8 ± 2.5°	$p = 0.96$
Sideways displacement on lateral view (%±SD)	4.0 ± 3.7	4.3 ± 4.0	$p = 0.98$
Sideways displacement on anterior–posterior view (%±SD)	4.5 ± 4.2	4.3 ± 4.3	$p = 0.98$
Group B			
Frontal angle (degrees ±SD)	3.7 ± 3.4°	4.1 ± 3.6°	$p = 0.95$
Lateral angle (degrees ±SD)	2.0 ± 2.5°	2.2 ± 2.5°	$p = 0.96$
Sideways displacement on lateral view (%±SD)	2.6 ± 2.6	2.8 ± 2.5	$p = 0.99$
Sideways displacement on anterior–posterior view (%±SD)	3.3 ± 2.9	3.7 ± 2.7	$p = 0.98$

SD standard deviation

Fig. 4 Male, 10 years old. Clinical outcome 7 days after the removal of the wires

Table 3 Table showing the main results divider per groups

Variables	Group A	Group B	*p* value
Healed patients	100%	100%	
AROM measured 7 days after wire removal (% compared to the contralateral ±SD)			
Flexion	92.1 ± 4.6	84.8 ± 6.1	$p = 0.007$
Extension	91.9 ± 8.6	85.0 ± 5.1	$p = 0.022$
Pronation	93.3 ± 5.3	83.9 ± 6.6	$p = 0.009$
Supination	92.3 ± 5.0	85.9 ± 5.4	$p = 0.010$
AROM measured 30 days after wire removal (% compared to the contralateral ±SD)			
Flexion	97.9 ± 2.5	97.0 ± 2.5	$p = 0.98$
Extension	98.6 ± 2.3	98.0 ± 2.5	$p = 0.98$
Pronation	98.1 ± 2.5	98.0 ± 2.5	$p = 0.99$
Supination	98.1 ± 2.5	97.6 ± 2.6	$p = 0.97$
Number of patients who need for physiotherapy	3 (12.0%)	11 (40.7%)	$p = 0.03$

SD standard deviation

Discussion

Pediatric distal radius fractures are more common in boys and peak in teenage years [1]. Half of these fractures are angulated, with the two bone segments remaining in contact [1]. Healthy children and teenagers commonly incur fractures during forceful trauma, such as falls from playground equipment or in sports activities.

Surgery plays an important role in restoring the anatomy, as well as possible, with a stable fixation, without iatrogenic physeal injury [6]. Many surgical techniques have been reported, but each type of fixation has limitations. Fixation with plate and screws offers excellent and stable reduction but results in large unaesthetic incisions and slower healing [20, 21], besides the widespread use of minimally invasive technologies, often makes patients and their families reluctant to accept plate fixation [21–23]. Conventional techniques of osteosynthesis with K-wire pinning are widely used for distal radius fractures; however, these techniques present insufficient biomechanical ability to maintain the reduction alone [6, 24]. Hence, in addition to the discomfort to undergo surgery, a cast immobilization is usually needed at least for 4 weeks postoperatively, with possible soft tissue suffering [25].

The need of cast immobilization, even after an osteosynthesis, opened a debate in literature on the real indication for surgery, compared with a conservative treatment [8, 26]. Moreover, a retarded mobilization of the wrist could lead to a slower AROM recovery of affected wrist and a higher pain during the rehabilitation [27].

All these downsides can be avoided thanks the introduction of elastic percutaneous osteosynthesis systems that exploit their dynamic stabilization with inter-fragmentary compression to produce a stable callus bone, without need of an external orthosis [21, 28]. This type of synthesis matches perfectly with biomechanical characteristics of pediatric bones and their high remodeling capacity [29]. Elastic stable intramedullary nailing (ESIN) of pediatric forearm shaft fractures has been widely described in the literature utilizing various implant designs (TEN, SEN and standard K-wires) as a stable, effective and safety procedure, even if mostly followed by the use of postoperative cast immobilization [30].

Other authors described surgical techniques similar to ES for pediatric distal radius fractures that allowed an early functional recovery, without an immobilization period. One of these is the Delta osteosynthesis, described by Tangari and Minniti De Simeonibus that adds a transversal nail linked to the two intramedullary ones, to achieve a more stable and rigid construct, reducing the translation forces on the frontal plane [13]. Another example is a technique recently described by Varga et al. They described a ESIN technique, obtained using two short, thick (2.5–3.5 mm diameter) and pre-bent titanium nails, inserted using a retrograde approach and without passing through the growth plates. In this way, the fracture site is under spring tension. They found that this technique is very stable and they suggest a short postoperative immobilization period, proposing 1 to 2 weeks splinting time [6]. However, this latter interesting technique should be critically analyzed. Two intramedullary nails from different entry points provide rotational, translational and bending stability, although lying separate, two nails do not provide complete stability for the fracture. Hence, postoperative immobilization should be applied. Furthermore, very thick nails (2.5–3.5 mm diameter) should be applied to obtain a satisfying stability, and the exposure of the entry point is needed [6].

ES leads to the mechanical benefits of two intramedullary elastic wires, and it is possible to achieve a more solid growth plate sparing construct simply linking the two wires together with an external binding system. Furthermore, an effective spring tension is achieved using longer and thinner wires (2 mm).

According to our findings, ES is effective in treating pediatric distal radius fractures, providing, satisfactory alignment of bones, stability and without limiting movement. Moreover, often postoperative physiotherapy is not necessary. ES is stable by itself and further immobilization is not needed. This device allows us to go beyond the traditional concept of mandatory postoperative immobilization after pediatric wrist fractures surgery. Our patients have never shown discomfort towards ES, both because they do not see the external wires, and also because they do not "perceive" them, and they try to move the wrist in a spontaneous and natural way. In the very first days, the biological activity is very high at the site of fracture, pain is severe and exacerbated by motion. During the first week, it could be useful to perform analgesic therapy, NSAIDs are enough. It is very important to explain to patients and their parents how important is to move the wrist and the fingers. It is also important to reassure them about the stability of the ES. In fact, according to our results, the occurrence of further displacement is improbable. A clinical assessment 7 days after surgery is useful both to check if a patient is observing the instructions taught by the surgeon and to encourage movement. Non-dangerous manual activities should be encouraged. Many parents observe that their children spontaneously start to draw, to write and to play videogames before the wires' removal.

In the present study, we compared a widely accepted and used technique with ES in two homogeneous group of patients. This study is the first to report the ES as valid technique for treatment of pediatric distal radius fractures. We found that they lead to similar results in terms of alignment of bones, maintenance of reduction and functional results (in terms of AROM) at the last follow-up (almost 60 days after surgery). Nevertheless, functional recovery is faster when fracture is fixed using ES.

Limitations

The study involved a relatively small number of patients; the age range was very broad, including patients in different stages of evolution, but consonant with the other similar studies and had a retrospective design [3, 6, 24]. A large-scale prospective study will provide rigorous control of potentially confounding factors.

Conclusions

In conclusion, ES is an easy, minimally invasive, easily learnable and safe alternative operative method that yields a better functional outcome when compared to percutaneous pinning in pediatric distal radius fractures.

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Compliance with ethical standards

Conflict of interest The authors report no conflicts of interest.

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