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Antegrade elastic stable intramedullary nail fixation for paediatric distal radius diaphyseal metaphyseal junction fractures: A new operative approach

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ABSTRACT

Background and purpose: The treatment of paediatric distal radius diaphyseal metaphyseal junction (DRDMJ) fractures is a challenge. The purpose of this study was to introduce a new operative approach at the proximal "safe zone" of the posterior interosseous nerve (PIN) to treat paediatric DRDMJ fractures and analyse the safety and efficacy of antegrade elastic stable intramedullary nail (ESIN) fixation.

Methods: Thirty paediatric patients with unstable and displaced DRDMJ fractures were treated by antegrade ESIN fixation from November 2015 to September 2017. We created the entrance site at the posterolateral side of the proximal radius and 2·4 cm distal to the articular surface of the radius, using the ESIN to immobilise the fractures. In the study, we reviewed patient demographics, complications, time until removal, and intraoperative time for hardware removal.

Results: Complete fracture healing was achieved between 6 and 12 weeks after surgery. Except for 3 patients presenting with irritation of the skin, we did not observe any complications. Radiologically, no secondary displacement, nail migration, loss of fixation, consolidation delay, non-union, or refracture was noted.

Conclusions: The antegrade ESIN fixation is a minimally invasive, easy-to-learn, alternative operative method to treat paediatric DRDMJ fractures.

Level of evidence: Therapeutic Level IV.

Introduction

The surgical treatment of choice for unstable paediatric metaphyseal and diaphyseal forearm fractures is usually percutaneous Kirschner wire (K-wire) fixation and elastic stable intramedullary nail (ESIN) fixation, respectively [1,2]. However, paediatric fractures in the area of the distal radius diaphyseal metaphyseal junction (DRDMJ) represent a unique problem, namely, they are usually located too distally to be treated by classic ESIN fixation and too proximal for conventional K-wires fixation [3,4]. The treatment of paediatric DRDMJ fractures is a challenge, as evidenced by the numerous surgical techniques described, including conventional methods (crossed K-wires, open reduction and plate fixation and conventional ESIN fixation) and modified techniques (transepiphyseal intramedullary Kirschner wire fixation, pre-bending intramedullary nailing fixation, and short, double elastic nailing fixation) [4–7].

To solve this problem, we created the entrance site at the posterolateral side of the proximal radius and 2·4 cm distal to the articular surface of the radius, using the ESIN to immobilise the fractures. No reports have described this new operative approach, mainly due to concerns about radial nerve proximity. The purpose of this study was to introduced a new operative approach at the proximal "safe zone" of the posterior interosseous nerve (PIN) to treat paediatric DRDMJ fractures and analyse the safety and efficacy of antegrade ESIN fixation.

Patients and methods

The study received prior approval from our Institutional Review Board. Informed consent was obtained from the parents of each child. Thirty paediatric patients with unstable and displaced DRDMJ fractures were treated by antegrade ESIN fixation from November 2015 to September 2017. All patients were treated by 2 experienced surgeons. The criteria for inclusion in this study were (1) patients with remaining growth potential ≥ 2 years; and

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(2) ≥ 10° of residual angulation or ≥ 30° of malrotation of the forearm after failed trials of nonsurgical treatments or casting or (3) completely displaced fractures of the distal radius; and (4) ≥ 8 years of age. The exclusion criteria were (1) open fractures; (2) history of previous forearm trauma; (3) underlying bone pathology; and (4) less than 12 months of follow-up.

In our series, we reviewed patient demographics, complications, time until removal, and intraoperative time for performing hardware removal. Patient demographics including sex, age, fracture side, absence/presence of combined ulnar fracture, location of fracture (length of the distal fragment/total radial length), duration of surgery and number of intraoperative X-ray images were extracted from patients' medical records (Table 1). Preoperative and postoperative evaluations were conducted on anteroposterior and lateral radiographs of the forearm. In this study, we did not provide an accurate preoperative displacement of the fractures because the displacement was unstable and most likely changed with the position of the forearm. At the final follow-up, the range of motion of the wrist and rotation of the forearm were assessed.

Operative technique

Under general anaesthesia or brachial plexus block, the patient was placed in the supine position with the upper limb on a radiolucent side table. An ESIN 2.0 or 2.5 mm in diameter was employed based on two-thirds the diameter of the least-narrow part of the radial marrow cavity.

X-ray images of the lateral position and anterior-posterior position before operation are shown in Fig. 1a and b. First, the fracture was partially reduced by manipulation; then, a K-wire was used to locate the proximal articular surface of the radius under fluoroscopy. With the elbow in flexion 60°-90° and forearm in a pronated position during the operation, the entrance site was at dorsolateral of the proximal radius (Thompson approach) and 2-4 cm distal to the proximal articular surface of the radius (Fig. 1c and d). After creating a 1-cm skin and fascial incision and separating the muscle fibres, dissection was continued down to the bone, and the entry hole was made with an awl. The tip of the ESIN was slightly pre-bent and was introduced into the hole with gentle pushing and rotational movement towards the fracture (Fig. 1e). When the tip was close to the fracture site, closed reduction of the fracture was performed again under C-arm fluoroscopy, and distal traction was continued until the length was re-established; after that procedure, the distal fragment was manipulated to contact the proximal fragment. If the reduction was difficult, a 2- to 2.5-mm-diameter K-wire was used as a reduction pin (Fig. 1f). The skin insertion points were selected on the dorsal and radial aspects of the distal forearm. The pin was manually inserted into the fracture site gently. The pin served as a lever applied to the fragments to reduce the fracture. An assistant adjusted the position of the wrist to correct the misalignment and rotational deformity. Once a satisfactory reduction had been achieved, the nail was advanced distally into the radial metaphysis (distal fragment) without penetrating the epiphysis. The nail position was adjusted with the tip towards the ulnar side. The radius was checked under X-ray imaging in both anteroposterior and lateral directions (Fig. 1g, h) to ensure satisfactory alignment and complete correction of distal angulations. The proximal end of the pin was bent slightly and cut 1 cm from the bone (i.e., sufficiently long to facilitate removal and sufficiently short to avoid irritation of the skin), and the protruding end was left under the soft tissues.

If there was an associated ulnar fracture that required internal fixation, a lateral and dorsal entry point on the ulna was used, approximately 1 to 2 cm from the tip of the olecranon. After fixation, all patients were immobilised in a short-arm cast for 4 postoperative weeks. Free and full arm motion was allowed thereafter. When good fracture healing and remodelling were observed (Fig. 1i, j), hardware removal was performed.

Table 1
Patient demographics.

Patient demographics (n = 30)	
Age at injury (years.months; mean, range)	10.8 (8-16)
Side(left/right)	14/16
Gender (female/male)	11/19
combined ulnar fracture	24
Interval from injury to surgery (days; mean, range)	3(0-7)
Location of fracture* %	16(7-26)
Duration of operative time(min; mean, range)	23 ± 6(10-50)
Number of intraoperative x-ray images	23 (10–50)

Location of fracture* : length of the distal fragment/total radial length.

Results

All thirty patients underwent closed reduction. Basic preoperation and postoperation fracture displacement and translation data are summarised in Table 2.

At the follow-up, 3 patients presented with irritation of the skin, which resolved after the relatively early removal of the radial nail. We did not observe any infection or tendon, nerve, or growth plate injuries during the follow-up period. Before removal of the nail, 3 patients with > 30-degree loss of rotational motion regained full range of motion after the nails were removed (Table 3). Complete fracture healing was achieved between 6 and 12 weeks after surgery. Radiologically, no secondary displacement, nail migration, loss of fixation, consolidation delay, non-union, or refracture was noted. None of the patients showed signs of growth arrest on either the radiological or clinical assessment. All patients had bilateral full flexion-extension of the wrist and unrestricted pronosupination of the forearm at the last follow-up visit. Hardware removal was performed under local anaesthesia or brachial plexus block an average of 5 months (range, 3–9 months) after the index surgery. The mean follow-up was 12.8 months, and the maximum follow-up period was 28 months.

Discussion

Paediatric DRDMJ fractures are uncommon distal radial fractures. There are only a few reports on these fractures [4–7]. Reduction and surgical immobilisation for paediatric DRDMJ fractures remain a challenge [6,7]. Many surgical immobilisation techniques have been reported, but each type of fixation has limitations. First, crossed K-wires are routinely used for the fixation of more distal forearm fractures in children, in which the increased diameter of the bone (especially the radius) allows for easy pin placement [8]. When the fractures are at the DRDMJ, crossed Kirschner wire fixation is difficult in terms of both performance and stability [9,10]. Plate fixation offers excellent and stable reduction but results in large incisions, slower healing and a high rate of refractures [11,12]. With the widespread use of minimally invasive technologies, patients and their families are often unwilling to accept plate fixation. ESIN fixation is a well-established procedure for forearm fractures in children and is mainly applied for unstable diaphyseal and radial head or neck fractures due to its advantages of minimal invasion, greater stability, and fewer complications [2,13]. However, for the treatment of DRDMJ fractures, because of the short distal fragment, the proximal end of the fracture is prone to be pushed to the opposite side by the nail when using retrograde conventional entry and to result in misalignment and unstable fixation of the fracture

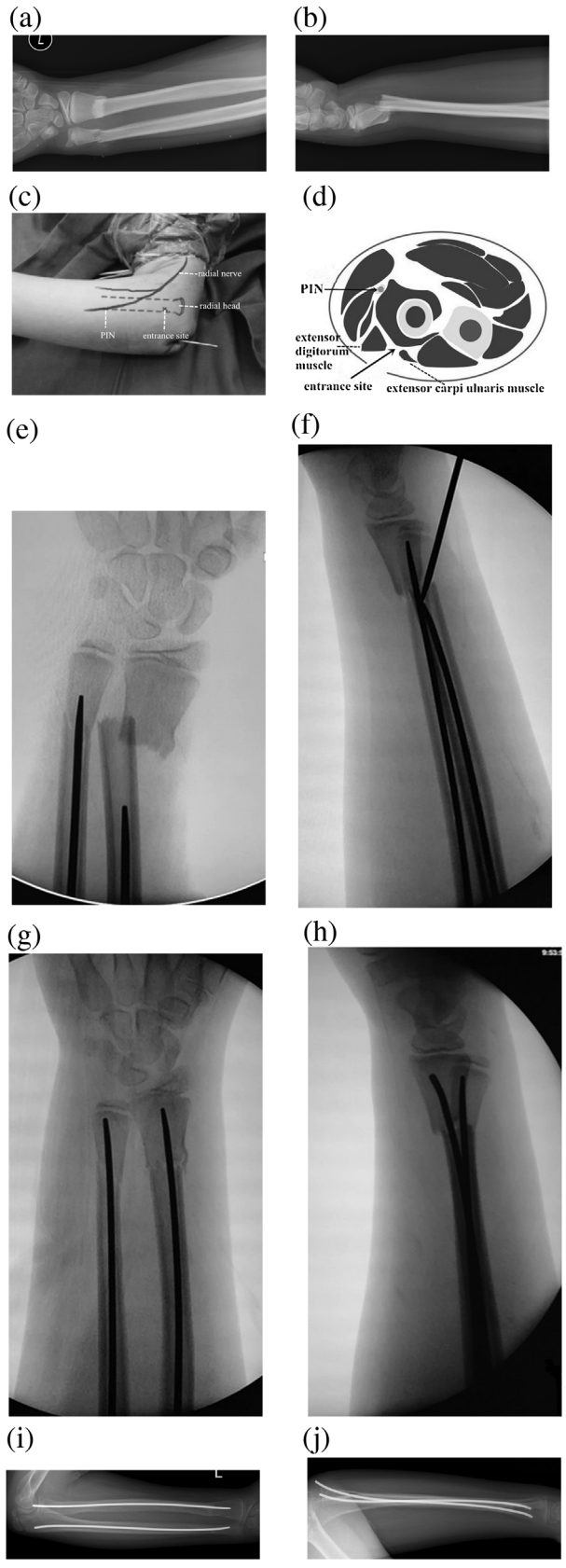

Fig. 1. The surgery procedure and X-ray image of an 11-year-old boy. (a,b) The lateral view and anterior-posterior view before operation. (c) Photograph of the body surface, showing a symbol of the radial head and the entrance site and posterior interosseous nerve (PIN). (d) Anatomical slice of the forearm, 2.4 cm distal to the articular surface of the radius: posterolateral approach. (e) Creation of the entry hole in the proximal radius and introduction of the ESIN into the radial marrow cavity; Then, the ESIN is pushed gently with rotational movement toward the fracture. (f) Use of a 2–2.5 mm diameter K-wire as reduction pin. (g,h) The lateral view and anterior-posterior view after operation. (i,j) At 5 months after operation, the X-ray images were obtained at the lateral and anterior-posterior positions showing good fracture healing and remodelling.

Table 2
Basic preoperation and postoperation data.

	preoperation	postoperation
Angulation on the frontal plane	5 to 60 degrees	< 5 degrees
Angulation on the lateral plane	5 to 50 degrees	< 5 degrees
Translation on the frontal plane	5% to 100%	<25%
Translation on the lateral plane	5% to 100%	<10%

[7,14]. Thus, the optimal treatment of unstable fractures of the DRDMJ is still a matter of debate.

To address the difficult fixation of DRDMJ fractures, we developed a new approach at the proximal radius to avoid the above problems. The application of anterograde ESIN fixation in the treatment of DRDMJ fractures prevented not only internal fixation through the repeated epiphyseal insertion of K-wires but also large incisions required by steel plates; in addition, this approach yielded satisfactory alignment, increased fixation stability, and decreased migration. The average operative time was 23 min in this series, which is comparable to the time required for the conventional elastic nail operation on the radial shaft.

Some doctors are reluctant to choose the proximal entrance site to the radius because of the thick muscles of the proximal radius and the proximity to the posterior interosseous nerve (PIN). However, we found a safe and convenient proximal entry point to the radius for treating DRDMJ fractures. The radial nerve crosses the elbow joint on its anterior aspect, and while the superficial branch runs along and underneath the brachioradial muscle, the PIN passes through the supinator canal and winds around the proximal radius to reach the forearm extensors, where it spreads into its motor branches [15]. In considering a lateral approach to the radial head, Hackl describes a proximal “safe zone” of at minimum 58 mm in pronation. When considering a posterolateral approach to the radial head, the proximal “safe zone” increased [16,17]. Diliberti et al. have also already shown that pronation increases the distance of the PIN to the radiocapitellar joint line [18]. Therefore, with the forearm in maximum pronation during the operation, the entrance site was chosen at dorsolateral to the radius and 2.4 cm distal to the radiocapitellar joint line, which is in the proximal “safe zone” of the PIN. Additionally, this site is the space between the extensor digitorum muscle and extensor carpi ulnaris muscle; the radius is only covered by the thinner supinator muscle, making the entry hole easier to generate. Flexion and extension did not alter the course of the PIN; surgery was facilitated with the elbow in flexion 60°–90° [18].

The fracture was only partially reduced by manipulation before advancing the ESIN. Advancing the ESIN often results in a loss of reduction because this type of fracture is unstable due to traction of the brachioradialis, extensor pollicis longus, and abductor pollicis longus [19]. Therefore, when the tip of the ESIN was close to the fracture site, close reduction of the fracture was necessary. If reduction is difficult, a reduction pin can be used as a lever by applying it to the fragments to reduce the fracture, as introduced by Ann Chir Main [9,20]. After passing through the fracture site, the tip of the nail was advanced as closely as possible to the epiphysis to achieve longer linear support at the fracture site without penetrating the epiphysis. To solve the problem of the transverse diameter of the radial marrow cavity being larger than the anteroposterior diameter and the easy transverse displacement, when the nail was advanced distally into the radial metaphysis

Table 3
Grading System of Price et al.

Outcome	Symptoms	Loss of Forearm Rotation (degrees)	Before removal of the nail	At final follow-up
Excellent	No complaints with strenuous activity	15	20	25
Good	Mild complaints with strenuous activity	15–30	7	5
Fair	Mild complaints with daily activity	31–90	3	0
Poor	All other results	90	0	0

(distal fragment), the nail position was adjusted with the tip towards the ulnar side, and the top of the elastic nail bow was directed to the radial side. The main complication was irritation of the skin in this series; however, the incidence was relatively low, and this irritation can be easily resolved by the relatively early removal of the radial nail. Before removal of the nail, 3 patients suffered more than a 30-degree loss of rotational motion of the forearm without irritation of the skin, and all patients regained full range of motion after removal of the nail. We found that the proximal end of the pin was bent to almost 90° and left too long in these 3 patients; it is possible that the nail end stimulates the surrounding muscles when the forearm rotates. Therefore, we suggest that the nail be left approximately 1–2 cm outside the medullary canal and that the nail end should not be bent [21].

This study was the first to report antegrade ESIN fixation of the radius, which provides a safe operative approach to treat paediatric DRDMJ fractures. However, our study has limitations. First, the study involved a relatively small number of patients and had a retrospective design. Second, we did not compare antegrade ESIN fixation with other techniques such as retrograde ESIN fixation, crossed K-wires fixation or plate fixation.

In conclusion, our technique is an easy, minimally invasive and safe method that yields a good functional outcome in paediatric DRDMJ fractures.

Conflict of interest

There are no conflicts of interest.

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