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ORIGINAL PAPER

Risk factors for refracture of the forearm in children treated with elastic stable intramedullary nailing

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Abstract

Purpose This study aims to investigate risk factors for refracture of the forearm in children treated with elastic stable intramedullary nailing (ESIN).

Methods Clinical data of 267 patients who had been treated for forearm fractures by ESIN in our hospital from January 2010 to December 2014 were retrospectively reviewed. Risk factors for forearm refractures were determined using logistic regression analysis.

Results Forearm refractures occurred in 11 children. Univariate analysis revealed that age, body weight, number of fractures, open fracture, nail diameter, and immobilization time were not associated with refractures. However, gender (male, $P = 0.042$) and fracture location (lower third, $P = 0.007$) were significantly associated with refractures. Multivariate analysis revealed that fracture location was an independent risk factor for forearm refractures ($P = 0.031$).

Conclusion Forearm refracture is uncommon in children treated with ESIN. Fracture location is an independent risk factor for forearm refractures in these patients.

Keywords Forearm · Refracture · Elastic stable intramedullary nailing · Children

Introduction

Forearm fracture is a common injury seen in children [1–3]. Most children with forearm fractures are well managed using closed manual reduction and cast immobilization. Surgical treatment is reserved for difficult reductions and unstable fractures in older children [4, 5]. Elastic stable intramedullary nailing (ESIN) is suitable for the treatment of long-bone shaft fractures in children [6, 7]. Although ESIN is widely used in pediatric forearm fractures, occasional refractures continue to occur with a reported incidence of approximately 5% [8–11].

Some studies have investigated the contributing factors of forearm refractures, including early cast removal and incomplete bony union [9]. Locations of the initial fracture, greenstick fractures, and residual angulations have been investigated in some studies, but its significant relationship remains unclear [8]. Although 18% of initial fractures are located in the middle third of the forearm, the majority of forearm refractures occur in the middle third. Midshaft fractures are over eight times more likely to refracture than distal forearm fractures [8]. Features inherent to patients themselves such as gender, age, and level of activity have also been associated with refracture risk [8, 9]. Understanding modifiable risk factors can aid in adjusting treatment guidelines, in order to decrease the incidence of refractures in children.

In this retrospectively study, we analyzed risk factors for forearm refractures in children treated with ESIN in our hospital.

Materials and methods

Clinical data of 267 children with forearm fractures treated in our hospital from January 2010 to December 2014 were retrospectively reviewed. Inclusion criteria were forearm shaft fractures and/or metaphyseal fractures treated with ESIN. Patients with the following conditions were excluded: (1) pathological fracture; (2) follow-up time of less than six months; (3) fractures of the radial neck and/or the olecranon; (4) fractures fixed using plates, screws, or K-wires; (5) multiple fractures of the

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upper limb, floating elbow; and (6) Monteggia fractures or Galeazzi fractures. Refracture was defined as the fracture of the original fracture location within one year.

Various parameters were evaluated to identify potential risk factors associated with refracture. Age, body weight, gender, fracture bones (radius, ulna, and radius and ulna), open/close fracture, fracture location (upper third, middle third, and lower third), diameter of nails, immobilization time, and angulation of refracture were recorded.

Patients with a nail angulation of < 20° were treated with manual reduction and cast immobilization for four weeks. For patients with a nail angulation of > 20°, the angulated nails were removed and new nails were inserted after reduction.

Statistical analysis

Continuous data were presented as mean ± standard deviation, and categorical data were presented as frequencies. Comparison was performed using Student's *t* test or Pearson/Fisher's exact test when appropriate. Multivariate analysis was performed using logistic regression analysis. Variables with a *P* value < 0.2 in the univariate analysis were entered into the regression analysis. $P < 0.05$ was considered statistically significant.

Results

This study included 165 male and 102 female patients with a mean age of 6.8 ± 2.1 years. Basic information of patients are listed in Table 1. There were 88 cases of pure radial fractures, 47 cases of pure ulnar fractures, and 132 cases of fractures of both the radius and ulna. Thirty-five children had open fractures, which were all Gustilo-Anderson type I. Fracture location was at the upper third in 45 cases, middle third in 122 cases, and lower third in 100 cases. Three hundred twelve nails with a diameter of 2.0 mm and 60 nails with a diameter of 2.5 mm were used. All patients received emergent reduction and ESIN after admission. Cast immobilization was used for four to six weeks, and internal fixation was removed at post-operative four to six months. Patients were followed up for a mean of 12 months (range, 8–18 months).

Refracture occurred in 11 patients (4.1%) within one year after the original fracture, including ten male patients and one female patient. All 11 patients had a history of falling and injury. Mean time from cast removal was 2.3 ± 1.1 months (range, 1–8 months). Refracture incidence was 4.6% in patients immobilized for < six weeks and 3.2% in patients immobilized for ≥ six weeks. In one patient, refracture occurred within one month after removal of the internal fixation (Fig. 1). In ten patients with refractures, mean nail angulation was 25.8° (range, 10–40°). There was no significant difference in refracture incidence between patients with open fractures (2/35) and patients with closed fractures (9/232) ($P > 0.05$). Patients with a nail angulation of < 20° were treated with manual reduction and cast immobilization for four weeks. For patients with a nail angulation of > 20°, the angulated nails were removed and new nails were inserted after reduction (Fig. 2).

Table 1 Basic information of patients

Characteristics	Value
Age (years)	6.8 ± 2.1
Body weight (kg)	27.8 ± 7.1
Gender (male/female)	165/102
Fractured bone	
Radius	88
Ulna	47
Radius and ulna	132
Open fracture	35
Fracture location	
Upper third	45
Middle third	122
Lower third	100
Diameter of nails (mm)	
2.0	312
2.5	60
Immobilization time	
< 6 weeks	203
≥ 6 weeks	64
Follow-up time (months)	12 ± 2.7

Univariate analysis revealed that age, body weight, number of fractures (single and both bones), open fracture, nail diameter, and immobilization time were not associated with refractures. However, gender (male, $P = 0.042$) and fracture location (lower third, $P = 0.007$) were significantly associated with refractures (Table 2). Multivariate analysis revealed that fracture location was an independent risk factor for forearm refractures ($P = 0.031$, Table 3). There was no significant difference in forearm rotation between children with refractures and without refractures (155° vs. 159°, $P > 0.05$).

Discussion

ESIN is widely used in the treatment of paediatric long-bone fractures and has many advantages such as minimal invasiveness, does not require open reduction, and less disruption occurs to the circulation of the fracture site. In addition, most patients treated with ESIN require no cast immobilization, which allows for early exercise and shorter hospitalization. ESIN is associated with few complications such as infection and nonunion. Salem KH and colleagues confirmed the satisfactory results of treating paediatric lower limb fractures using elastic nails [12]. However, torsional differences of greater than 15° were detected by

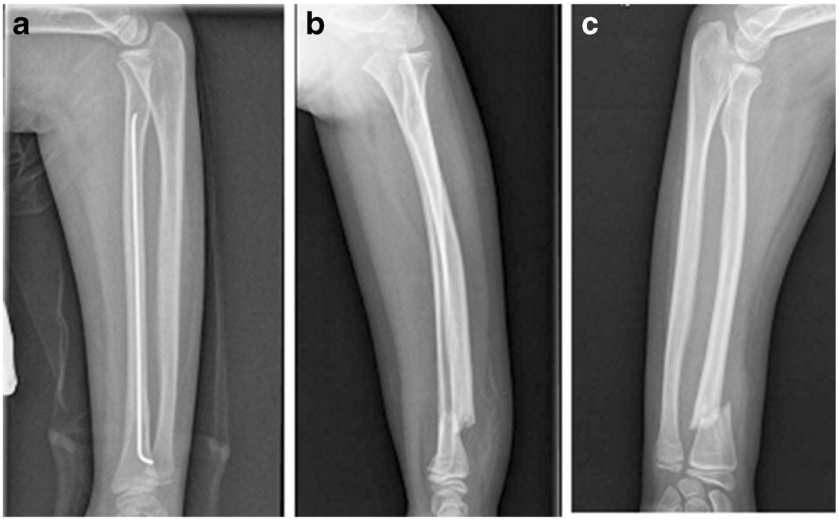

Fig. 1 X-rays of a distal radial fracture of the left forearm in an 11-year-old male patient. **A** Internal fixation using ESIN. **B**, **C** Refracture occurred 1 month after removal of the internal fixation due to falling

computed tomography or navigated ultrasound examination in nearly half of the patients; and four children had clinically apparent gait changes. However, functional impairment after forearm fracture, even refracture was rare [9].

Although this technique is easy to perform, there is a consistent concern of refracture in patients treated with ESIN [8, 13]. In our study, forearm refracture occurred in 11 (4.1%) of 267 children, which is similar to a previously reported incidence of refractures [9].

In our study, univariate analysis revealed that age, body weight, number of fractures, open fracture, nail diameter, and immobilization time were not associated with refractures. Gender (male, $P = 0.042$) and fracture location (lower third, $P = 0.007$) were significantly associated with refractures, although multivariate analysis revealed that the male gender was not an independent risk factor for forearm refractures ($P = 0.16$). Despite these results, we speculate that male children are more active and should wear protective braces for one to two months after cast removal.

In a previous retrospective study of 768 children with forearm fractures, refracture occurred in 39 children (4.9%) [8]. All children were treated with closed or open reduction. This study revealed that refracture is closely associated with the location of the original fracture. The incidence of refracture was 14.7% in shaft fractures, 2.7% in radial metaphyseal fractures, 1.5% in fractures of both the radius and ulna, and 0% in epiphyseal fractures. Bold M indicated that the midshaft fracture is at the highest risk of refracture [8]. The current study also indicates that the original fracture location is closely associated with refracture. Further, univariate analysis revealed that the incidence of refracture was significantly higher in the forearm shaft (middle and lower thirds; upper:middle:lower thirds = 1:1:9; $P < 0.05$). Similarly, multivariate analysis revealed that forearm shaft location (middle and lower thirds)

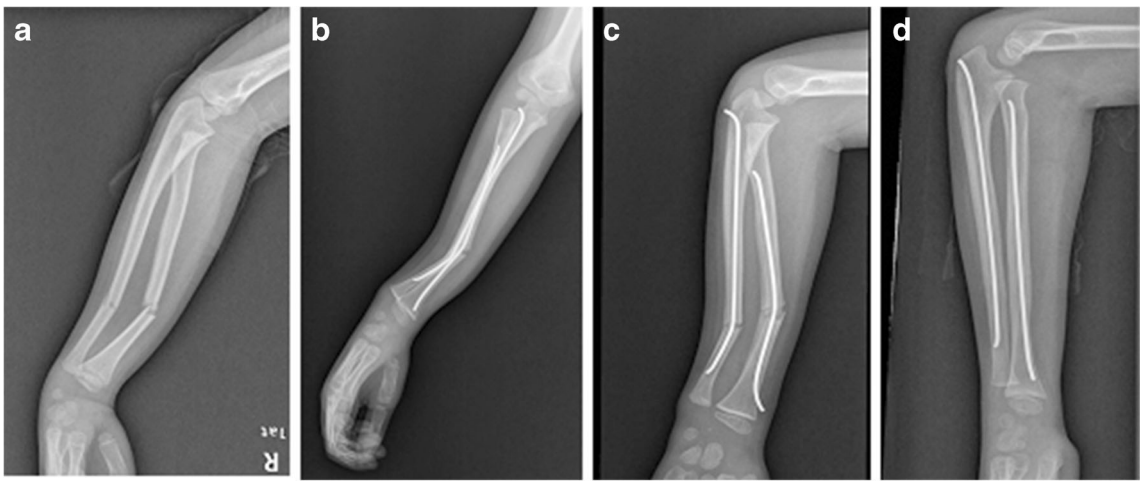

Fig. 2 X-rays of radial and ulnar fractures in an 8-year-old male patient. **A** The original fractures. **B**, **C**) Refracture occurred at postoperative 2 months due to falling. **D** The angulated nails were removed and new nails were inserted

Table 2 Comparison between patients with and without refractures

Characteristics	Refractured ($n = 11$)	Non-refractured ($n = 256$)	P value
Age (year)	8.1 ± 1.6	6.3 ± 1.4	0.361
Body weight (kg)	29.2 ± 5.6	26.8 ± 6.0	0.553
Gender (male/female)	10/1	155/101	0.042*
Fractured bone			0.185
Radius	1	87	
Ulna	2	45	
Radius and ulna	8	124	
Open fracture	2	33	0.642
Fracture location			0.007*
Upper third	1	44	
Middle third	1	121	
Low third	9	91	
Diameter of nails (mm)			0.525
2.0	15	197	
2.5	4	56	
Immobilization time			0.741
< 6 weeks	9	194	
≥ 6 weeks	2	62	

* $P < 0.05$

was an independent risk factor for refracture ($P = 0.031$). Though diaphysis, compared with the metaphysic, had a slow rate of healing relatively, mean time of refracture from cast removal was 2.3 months in our study. It may bear no relation to delayed union even in diaphysis or metaphysic.

Delayed healing or nonunion may occur in 0–4% of children with forearm fractures treated with ESIN [14, 15]. These complications are more often seen in fractures of the middle third of the ulna, which might be associated with open fractures or open reduction. Delayed healing has been proposed to be associated with refractures after ESIN [16]. In a previous study of 553 children with forearm fractures treated with ESIN, delayed healing occurred in 14 patients and nonunion of the ulna occurred in seven patients [14]. In the present study, no such complications were observed in the 35 patients with Gustilo-Anderson type I open fractures, which might be attributed to the non-severity of the open fractures. There was no significant difference in refracture incidence between patients with open fractures (2/35) and patients with closed fractures (9/232; $P > 0.05$).

Cast immobilization time has also been associated to refractures of the forearm [8]. It was reported that refracture incidence of the forearm was 6% in patients immobilized for less than six weeks, 4% in patients immobilized for four to eight weeks, and 1% in patients immobilized for over six weeks, which is similar with our study. We recommend the use a protective short arm brace two to three months after cast removal for children with forearm fractures [17].

Bone plasticity is excellent in children. Functional recovery after forearm fracture is good in most children. Even upon incomplete bone union, forearm dysfunction is rarely observed in children after fractures. In a previous study of 47 children with malunions, 92% of them had good or excellent results [18].

Table 3 Multivariate analysis of risk factors for forearm refractures

Variables	P value
Gender	0.164
Fracture location	0.031*
Number of fractures	0.656

* $P < 0.05$

Conclusions

Refracture is rare in pediatric forearm fractures treated with ESIN and is often caused by a second trauma. The male gender and the lower third location of the original fracture are risk factors for forearm refractures, and the latter is independent risk factor for refracture. We recommend the use of a protective short arm brace 2–3 months after cast removal for children with forearm fractures.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Kosuge D, Barry M (2015) Changing trends in the management of children's fractures. Bone Joint J 97(4):442–448
2. Hussain S, Dar T, Beigh AQ, Dhar S, Ahad H, Hussain I, Ahmad S (2015) Pattern and epidemiology of pediatric musculoskeletal injuries in Kashmir valley, a retrospective single-center study of 1467 patients. J Pediatr Orthop B 24(3):230–237
3. Sinikumpu JJ, Serlo W (2015) The shaft fractures of the radius and ulna in children: current concepts. J Pediatr Orthop B 24(3):200–206
4. Shoemaker SD, Comstock CP, Mubarak SJ, Wenger DR, Chambers HG (1999) Intramedullary Kirschner wire fixation of open or unstable forearm fractures in children. J Pediatr Orthop 19(3):329–337
5. Luhmann SJ, Gordon JE, Schoenecker PL (1998) Schoenecker, Intramedullary fixation of unstable both-bone forearm fractures in children. J Pediatr Orthop 18(4):451–456
6. Kuremsky MA, Frick SL (2007) Advances in the surgical management of pediatric femoral shaft fractures. Curr Opin Pediatr 19(1):51–57
7. Lascombes P, Haumont T, Journeau P (2006) Use and abuse of flexible intramedullary nailing in children and adolescents. J Pediatr Orthop 26(6):827–834
8. Bould M, Bannister GC (1999) Refractures of the radius and ulna in children. Injury 30(9):583–586
9. Schwarz N, Pienaar S, Schwarz AF, Jelen M, Styhler W, Mayr J (1996) Refracture of the forearm in children. J Bone Joint Surg Br 78(5):740–744
10. van Egmond PW, van der Sluijs HA, van Royen BJ, Saouti R (2013) Refractures of the paediatric forearm with the intramedullary nail in situ. BMJ Case Rep. https://doi.org/10.1136/bcr-2013-200840
11. Park HW, Yang IH, Joo SY, Park KB, Kim HW (2007) Refractures of the upper extremity in children. Yonsei Med J 48(2):255–260
12. Salem KH, Lindemann I, Keppler P (2006) Flexible intramedullary nailing in pediatric lower limb fractures. J Pediatr Orthop 26(4):505–509
13. Karaman I, Halici M, Kafadar IH, Guney A, Oner M, Gurbuz K, Karaman ZF (2014) Mid-term results of the elastic intramedullary nailing in paediatric long bone shaft fractures: a prospective study of 102 cases. J Pediatr Orthop B 23(3):212–220
14. Fernandez FF, Eberhardt O, Langendörfer M, Wirth T (2009) Nonunion of forearm shaft fractures in children after intramedullary nailing. J Pediatr Orthop B 18(6):289–295
15. Schmittenbecher PP, Fitze G, Gödeke J, Kraus R, Schneidmüller D (2008) Delayed healing of forearm shaft fractures in children after intramedullary nailing. J Pediatr Orthop 28(3):303–306
16. Baitner AC, Perry A, Lalonde FD, Bastrom TP, Pawelek J, Newton PO (2007) The healing forearm fracture: a matched comparison of forearm refractures. J Pediatr Orthop 27(7):743–747
17. Tisosky AJ, Werger MM, McPartland TG, Bowe JA (2015) The factors influencing the refracture of pediatric forearms. J Pediatr Orthop 35(7):677–681
18. Fuller DJ, McCullough CJ (1990) Malunited forearm fractures in children. J Pediatr Orthop 10(6):705–712