CASE REPORT

Refractures of the paediatric forearm with the intramedullary nail in situ

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SUMMARY

Forearm fractures in children are common. When conservative treatment fails, internal fixation with Elastic Stable Intramedullary Nailing (ESIN) become the first choice in the operative treatment of diaphyseal forearm shaft fractures. Refractures with the intramedullary nail in situ are known to occur but formal guidelines to guide management in such fractures are lacking. We present a well-documented case of a radius midshaft refracture in a 12-year-old boy with the intramedullary nail in situ, managed by closed reduction. Literature is reviewed for this type of complication, the treatment of 30 similar cases is discussed and a treatment strategy is defined.

The refracture of the paediatric forearm fracture with the intramedullary nail in situ is a rare, but probably under recognised complication which is observed in approximately 2.3% of the study population. Closed reduction may be considered in these cases.

BACKGROUND

In the majority of paediatric forearm fractures conservative treatment is the first choice. However, in unstable dislocated diaphyseal fractures operative treatment might be indicated. In these patients intramedullary fixation is the first choice of treatment. Refractures of paediatric forearm fractures with intramedullary nail in situ are known to occur. The incidence of this complication is thought to be low and there are no formal guidelines for management of these fractures. Options for management in these cases include closed reduction, hardware replacement after closed or open reduction and plate osteosynthesis.

Literature is reviewed for this type of complication, the treatment of 30 similar cases is discussed and a treatment strategy is defined.

CASE PRESENTATION

A 12-year-old boy presented to our accident and emergency department with a left forearm fracture after a fall on his outstretched hand. Radiography revealed an isolated complete midshaft radius fracture with less than 10° of dorsal angulation. After closed reduction, he was treated with a wedged above elbow plaster cast immobilisation.

Clinical and radiographical review at 1 week showed progressive deformity and loss of radiographical reduction (figure 1). Closed reduction and internal fixation with elastic intramedullary stable nailing with a 2.5 mm (2/3 of the medullar canal diameter measured at the midshaft) nail (Nancy nail, De Puy, UK) was performed (figure 2). No postoperative cast immobilisation was applied. He

was discharged and advised not to participate in sporting activities until consolidation of the fracture.

At 9 weeks after his initial trauma (8 weeks after operative management) he sustained a new trauma to his left forearm. A refracture of the radius, with the intramedullary nail in situ, angulated 29° in the lateral plane was observed. (figure 3) There was a traumatic S-shape bending of the intramedullary nail.

A closed reduction of the refracture was performed, with correction of the bending of the intramedullary nail until an acceptable reduction was achieved (figure 4). The arm was immobilised in an above elbow plaster cast for 4 weeks. By 6 months clinical and radiological healing of the fracture was demonstrated. The nail was removed at 8 months. At 1-year follow-up the patient had a full range of motion.

DISCUSSION

Forearm fractures account for 40–50% of all fractures in children, of which shaft fractures of the radius are the third most common.^{1 2} In the majority of primary forearm fractures conservative treatment is first choice, but up to 25% of complete forearm fractures displaced during the follow-up

Figure 1 Isolated complete midshaft radius fracture after closed reduction at 1-week follow-up with the loss of reduction.

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Figure 2 The same fracture as in figure 1 after internal fixation with a 2.5 mm elastic intramedullary stable nail.

Figure 3 Refracture, with the intramedullary nail in situ, of an isolated complete midshaft radius fracture after closed reduction and internal fixation with a 2.5 mm elastic intramedullary stable nail. Angulation in the lateral plane of 29°.

and may require a second intervention.^{3 4} In these unstable and displaced fractures operative treatment may be considered. In diaphyseal fractures of the forearm in children, internal fixation with elastic stable intramedullary nails (ESIN) has become the first choice.⁵⁻⁸ Fractures in the transitional area between diaphysis and metaphysis can also be treated with ESIN but in these cases it is recommended to place the entry points at the opposite end of the bone.⁸ It has the advantage of a small surgical wound, minimal risk of neurovascular injury and short hospitalisation. Postoperative mobilisation without plaster cast can begin immediately although in the case of both bone fractures immobilisation of 4 weeks with above elbow casting is common.

Treatment of a fracture with ESIN allows for micromotion at the fracture site, which are thought to be beneficial for rapid fracture healing.⁹ This micromotion is caused by the elasticity of the nail. The biomechanical principle of treatment with ESIN relies on a three-point fixation of the nail: first at their entry point; second at the opposite side of the intramedullary canal preferably at the site of the fracture; and third in the metaphysis of the other end of the bone. The curvature of the nail is achieved by prebending them beyond their elastic limit. In comparison with titanium alloy nails, stainless steel nails have a

Figure 4 Closed reduction, with reversed bending of the intramedullary nail, of the refracture shown in figure 1. A detail picture of the nail after removal, 8 months after treatment, is provided.

higher tensile strength and a higher elastic limit and have the strength of a titanium alloy nail one size larger.⁸ The curvature is achieved by bending the nail until three times the diameter of the long bone at its isthmus.⁸ When they are in curved position (in the intramedullary canal) they resist the tendency to be straightened or to be further bent. The three-point fixation and the elastic qualities of the nails resist angular, compressive and rotational forces.¹⁰ This biomechanical principle is disturbed when a second trauma with a force beyond the stability of the healed fracture and the elasticity of the nail occurs with a refracture and deformation as a result.

The incidence of refractures of the forearm with an intramedullary nail in situ is thought to be low and there are no formal guidelines available for the management of this situation. A comprehensive literature search was performed using the MEDLINE/PubMed database. Search terms included: forearm fractures AND refracture OR refracture OR complication OR failure AND minimal invasive OR elastic stable intramedullary nailing OR flexible intramedullary nailing OR titanium elastic nailing OR TEN OR ESIN AND children OR paediatric OR paediatric (see online supplement 1). Only publications in English and with links to full-text were retrieved. In addition, citation lists from identified articles were subsequently reviewed to identify relevant articles. Overall 125 different references were screened by title and abstract of which 34 candidates were read in full. Of these, nine were useful to determine incidence or treatment of the paediatric forearm refracture with intramedullary nail in situ. In 17 studies this complication was not mentioned, in five this was the case but without data or advised treatment strategy. In one study refractures with or without intramedullary nails were not seen. In addition, two articles were identified from citation list of selected articles. In total we could find 11 studies or case reports referring to refractures of the forearm with ESIN in situ, accounting for 0.8–8.6% (average 2.3%) of study population^{5 6 11–19} (table 1). This complication typically occurs after a second trauma more than a month after the initial fracture. Before this period a loss of reduction of the fracture due to inadequate technique or indication is seen.^{6 20 21} The intramedullary nails are usually removed 4–9 months postoperatively. Refractures after hardware removal may occur in up to 10% if removed earlier and are most commonly located in the midshaft.^{3 6 11 17} Also, non-union after early hardware removal is reported.^{12 22 23} There are no formal

recommendations regarding the routine removal of metallic intramedullary nails in children; however, the approach of elective removal of nails in children is widely accepted.²⁴

Focusing on forearm fractures after ESIN treatment, as in our patient, 30 cases could be extracted. Treatment is (partially) clear in 14 cases and differs substantially, even within studies (table 1). In these studies it remains unclear whether forearm fractures were antebrachii fractures or, as in our case, an isolated fracture. One study discussed the stability of the intramedullary nail after closed reduction of the forearm with ESIN in situ.¹⁶

Fernandez *et al*⁶ reported 14 refractures in 553 forearm fractures (2.5%) with the nail in situ. Treatment of these refractures was not clearly discussed. Lascombes *et al*¹¹ reported his experience with ESIN in femoral and forearm fractures. The two refractures in the forearm group (0.8%), were treated with closed reduction followed by sling immobilisation for 2–3 weeks. Schmittenbecher,⁵ who describes the same population as Lieber *et al*,¹² found a refracture rate of 2.8%, and treated these with closed reduction, whether cast or a splint was applied remains unclear. Griffet *et al*¹³ treated two forearm refractures (2.5%) differently: a teenager, after a second fall on his already injured arm, was treated with closed reduction and later developed a pseudo arthrosis which had to be treated by decortication and plate osteosynthesis. The second patient was treated successfully with closed reduction and nail replacement. According to their protocol a sling was applied for 8–10 days in both patients. Weinberg *et al*¹⁴ reported one refracture (2.5%) without mentioning the treatment method. Salonen *et al*¹⁸ describes three refractures of which one was treated with replacement of the nails and above elbow cast, one was treated conservatively but it remains unclear in which manner and the last was a patient with a bone fracture of which the plate osteosynthesis of the ulna had to be revised after a refracture as well as the intramedullary nail in the radius was replaced by plate osteosynthesis. Garg *et al*¹⁵ treated their refracture, one of 21 (4.8%), with replacement of the intramedullary nail and above elbow plaster cast for 2–4 weeks. Shahid *et al*¹⁹ reported a novel technique in their refracture after both bone fracture with intramedullary nails in both ulna and radius. With a refracture of the radius only they opened the distal site of radial nail insertion and withdrew the intramedullary nail until the ‘kinked’ part of the intramedullary nail was moved distal of the refracture. Alignment was supported with the remainder of the nail in

Table 1 Overview of studies with reported refracture of the paediatric forearm with intramedullary nail in situ

Article	Level of evidence of study	Number of patients	Refractures, ESIN in situ (%)	Both bone fracture	Treatment of refracture	Cast
Fernandez <i>et al</i> ⁶	IV	553	14 (2.5)	Yes	(CR±HR)?	?
Lascombes <i>et al</i> ¹¹	IV	250	2 (0.8)	?	CR±HR	No
Schmittenebecher ⁵ /Lieber <i>et al</i> ¹³	IV	143	4 (2.8)	Yes	CR	No
Griffet <i>et al</i> ¹⁸	IV	81	2 (2.5)	?	CR±HR	No
Weinberg <i>et al</i> ¹⁴	IV	77	1 (1.3)	Yes	?	?
Garg <i>et al</i> ¹⁵	IV	21	1 (4.8)	?	CR+HR	Yes, AB
Salonen <i>et al</i> ¹⁸	IV	35	3 (8.6)	Yes	1×OR+HR* 2×CR±HR	Yes
Muensterer and Regauer ¹⁶	IV	1	1 (–)	Yes	CR	Yes, AB
Shahid <i>et al</i> ¹⁹	IV	1	1 (–)	Yes	CR±HR	Yes, AB
Mittal <i>et al</i> ¹⁷	IV	1	1 (–)	Yes	CR+HR	Yes, AB
Total		1160†	27 (2.3)†			

†In computing total patients and average prevalence, case reports were not included. When adjusted for population size the prevalence did not change.

CR, closed reduction; HR, hardware replacement; HR*, hardware replacement → plate osteosynthesis; OR, operative reduction; AB, above elbow plaster cast; ?, unknown.

situ and supported postoperative by an above elbow plaster cast. Muensterer and Regauer¹⁶ treated a refracture successfully with closed reduction and an above elbow plaster cast for a week. In the case described by Mittal *et al*¹⁷ the 80° bent nail broke during reversed bending. The nails were replaced and the forearm was protected with an above elbow plaster cast for 6 weeks.

Muensterer and Regauer¹⁶ conducted an in vitro mechanical study and concluded that the mechanical stability of the nails is significantly reduced after one cycle of reversed bending. However, no macroscopic evidence of metal fracture or fatigue was seen, which corresponds with the rarity of reported nail fractures in the literature.

In many of the above mentioned studies refractures with the intramedullary nails in situ were managed by closed reduction of the fracture. Hereby bending the nails in their original position. One study showed a reduced mechanical stability after reversed bending. Another case report described a minimal invasive technique in which the nail was withdrawn from the site of the refracture until the 'kinked' part of the nail was more distally in the intramedullary canal, and then shortened. In this scenario a lateral bending force is not necessary and the properties of the nail will not be compromised. However, the position of the nail is altered and the optimal three-point fixation gone. In both methods we feel the important biomechanical principles of ESIN are reduced and mechanical stability cannot be guaranteed.

In our case we saw a refracture with ESIN in situ after the internal fixation of an isolated fracture of the radius 8 weeks after surgical treatment. The nail was bent in an S-shape and the three-point fixation was probably not optimal after the second intervention (figure 2). In addition, the strength of the nail was reduced by reversed bending. Above elbow plaster cast immobilisation after secondary closed reduction, with some help of the stability of the nail, facilitated a successful treatment.

Learning points

- ▶ Refracture of the paediatric forearm fracture with the intramedullary nail in situ is a rare; but probably under recognised, complication which is seen in approximately 2.3% of study population.
- ▶ Closed reduction may be considered in these cases.
- ▶ The reverse bending of the intramedullary nail is reduced after one cycle of reversed bending and the mechanical stability cannot be guaranteed.
- ▶ Four weeks of above elbow plaster cast immobilisation is advised.
- ▶ If immediate mobilisation is indicated, closed reduction alone is not sufficient and the hardware should be replaced.

Contributors PWvE was involved in the design and drafting of the manuscript, writing and literature review. JAvdS and BJvR were involved in the revision and critical discussion. RS was involved in the critical discussion, literature review and design.

Competing interests None.

Patient consent Obtained.

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