Pearls and Pitfalls of Forearm Nailing

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Abstract: Pediatric forearm fractures are one of the most common injuries that pediatric orthopaedic surgeons manage. Unstable fractures that have failed closed reduction and casting require surgical intervention in order to correct length, alignment, and rotation to optimize forearm range of motion and function. Flexible intramedullary nailing (FIN) is a powerful technique that has garnered widespread popularity and adaptation for this purpose. Surgeons must become familiar with the technical pearls and pitfalls associated with this technique in an effort to prevent complications.

Key Concepts:

- Flexible intramedullary nailing is a useful technique that is widely utilized for most unstable both-bone forearm fractures except in the setting of highly comminuted fracture patterns or in refractures with abundant intramedullary callus formation.
- Proper contouring of the rod prior to insertion and bending of the tip will help decrease the risk of malunion and facilitate rod passage across the fracture site.
- The surgeon must be aware of the numerous pitfalls that are associated with flexible intramedullary nailing and the methods to mitigate each complication.

Introduction

Flexible intramedullary nailing (FIN) offers several key advantages for the management of those pediatric forearm fractures that are not amenable to closed treatment. These advantages include cosmetic incisions for nail insertion, minimal or no disruption of the periosteum, potentially smaller incisions for open reduction when needed, and affordable implant costs compared to traditional plate-and-screw constructs. These advantages resulted in widespread popularity and adaptation in this technique. Flynn et al. demonstrated that surgical management of diaphyseal pediatric forearm fractures significantly increased from 1997 to 2008 from 1.4% to 10.4%, respectively, with FIN as the most popular surgical construct.[1]

As enthusiasm grows for FIN as a treatment for pediatric forearm fractures, surgeons must also clearly understand the technical nuances, controversies, and strategies to mitigate complications associated with this technique. The purpose of this review is to elucidate some pearls and pitfalls of pediatric forearm fractures.

Surgical Indications

Surgery is indicated principally for forearm fractures with unacceptable length, alignment, or rotation, and for fractures that have failed initial closed reduction and cast immobilization. Failure of closed treatment may be due to the inherent instability of the fracture after an initial attempt at closed reduction or loss of reduction in a cast at subsequent follow up that has failed further manipulation such as wedging. Other surgical indications for pediatric forearm fractures include open fractures, associated neurovascular injury, fractures refractory to closed reduction and casting, and concomitant ipsilateral humerus fractures (floating elbow), which often indicates a high energy injury and instability.

Acceptable alignment parameters for pediatric forearm fractures have been extensively reviewed.[2, 3] Fracture malalignment beyond these parameters can lead to functional deficits, particularly with forearm pronation and supination.[4] Price et al. demonstrated that pronation and supination deficits of >30 degrees can lead to functional limitations with daily activities.[4] Children older than 10 years of age are suggested to have less tolerance for fracture malalignment[3] and are associated with nearly 2.8 times increased odds of nonoperative treatment failure.[5]

Radiographic assessment of fracture rotation can be challenging both in the emergency department and in the operating room. As such, some pearls to assess fracture rotation are important to review.

1. It is essential to assess the cortical width of the proximal and distal fragments close to the fracture site. In the setting of rotational malalignment, the cortical widths will be dissimilar.

2. **Pearl: One should consider full arm radiographs (Evan's Views) to ensure appropriate rotation.** In the lateral radiograph, the coronoid process should point anteriorly while the ulnar styloid should point posteriorly. In the anteroposterior view, the radial styloid (pointed radially) should be 180 degrees from the bicipital tuberosity (pointed ulnarly).[6]

Implant Choices

Two main fixation constructs are commonly utilized for the management of displaced forearm fractures that have failed nonoperative treatment: Open compression plating and FIN.

Plating options are most commonly applied with highly comminuted fracture patterns or in the setting of late loss of reduction or refracture. With a loss of reduction, after a period of nonoperative treatment, large amounts of robust fracture callous can prevent reduction and in the cases of refracture the medullary canal may be filled with bone and prevent intramedullary nail passage.[7] **Pitfall: Delayed intramedullary fixation is very challenging, and open approach may be needed.**

Open reduction and plating techniques require larger skin incisions and some limited periosteal elevation. Holmes et al. explained that compression plating optimizes the surgeon's ability to restore the radial bow and create an anatomic reduction of the fractures.[7] Fracture rotation can be better assessed with direct visualization of reduction of the fracture spikes. Separate incisions are suggested for both-bone fractures; a single incision technique is associated with higher incidence of synostosis and decreased forearm pronation-supination.[7]

For most pediatric forearm fractures that have failed nonoperative treatment, FIN techniques have been widely utilized unless there is a compelling reason for open reduction and plating, as detailed above.[1] Elastic intramedullary nailing originated from Nancy, France, in the 1980s and has gained widespread popularity and application for many pediatric long bone fractures.[8] **Pearl: It's important to realize that open fracture reduction does not demand plate fixation. A smaller incision than one required for plate fixation can be used to facilitate reduction and nail passage**. The benefit of this method becomes apparent if the implant requires removal. Plate removal requires a large incision and a period of protection against refracture through screw holes; nail removal is a smaller incision and without the same risks of refracture.

Both stainless steel and titanium elastic nails are utilized but titanium nails have greater ease of insertion and therefore are more commonly utilized.[9, 10] Some authors recommend the use of titanium over stainless steel due to titanium's comparable elastic modulus to cortical bone and improved biomechanical findings.[11, 12] The time to radiographic union, surgical time, and complication rates are comparable between stainless steel and titanium elastic nails;[13] however, the cost per implant must be considered. Heare et al. demonstrated a significant difference between the two types of implants, with the average cost of a titanium nail as $639 versus $172 for a stainless steel implant.[13] The authors recommend weighing the costs and benefits of each material for surgical decision-making.

Other biomaterials for intramedullary nailing have also been investigated in an effort to prevent implant removal. Korhonen et al. demonstrated the utility of a poly(lactide-co-glycolide) (PLGA) with a tri-calcium-phosphate (β-TCP) marker implant in the shape of a straight intramedullary nail.[14] The material has a hydrolytically activated memory, and the diameter of the implant increases while length decreases after introduction into tissue which is suggested to increase fixation stability. The material is designed to degrade through hydrolysis. The biodegradable implant material is highly elastic and cannot hold a pre-bent curve. As such, the authors recommend external support with casting.[14] In their series, the authors compared this biodegradable implant with standard titanium nails for the surgical management of pediatric both-bone forearm fractures and reported two cases of implant failure with biodegradable implants as demonstrated with refracture. These patients required reoperation with plate fixation. Outside of these two complications, the radiographic and clinical outcomes were comparable between the two biomaterials.[14]

Several studies have assessed the optimal implant construct for the management of forearm fractures.[1,15,16] Shat et al.[16] and Flynn et al.[1] demonstrated lower rates of complications with FIN when compared to conventional plating. In addition, the location of the radial bow was noted to be more distal with FIN, but this did not translate to a difference in forearm range of motion.[16] In contrast, Smith et al. demonstrated a higher complication rate with FIN, most of which resolved after implant removal.[17] In a more comprehensive assessment, Patel et al. performed a systematic review of studies comparing plate fixation with FIN techniques.[15] The authors assessed forearm range of motion as the primary outcome. There was no statistical difference in terms of postoperative range of motion between the surgical constructs. In addition, the authors concluded that the complication rates (refracture, infection, implant failure, nonunion), time to fracture union, and residual radiographic angulation, shortening, and rotation were comparable. As expected, the operative time and hospital length of stay were shorter with FIN.[15]

Figure 1. *Example of hybrid fixation*

Hybrid fixation has garnered some attention and investigation in the literature (Figure 1) Elhalawany et al. reported outcomes for FIN of the radius and conventional plating of the ulna.[18] This study was performed in response to reports of increased ulnar versus radial nonunion rates with FIN.[19-21] The higher ulnar nonunion rate is suggested to result from distraction of the fracture site by the curved nail tip with antegrade ulnar insertion along with higher biomechanical stress forces on the ulna.[18, 21] Older patients (>10 years of age) have been shown to be particularly susceptible to this problem.[19-21] Elhalawany et al. demonstrated union in all cases at 24 months but did have delayed union in four patients (two in the radius and two in the ulna).[18] The authors concluded that hybrid fixation is a viable option to prevent ulnar nonunion in the older patient age group.[18] Similar findings were also reported by Zheng et al.[22]

Plating of the radius and FIN of the ulna has some benefits. **Pearl: The radius can be difficult to reduce, and an open reduction may be frequently required. In such situations, plating of the radius can help restore the radial bow and rotation. For the ulna, the subcutaneous position will enable an easier closed reduction followed by a FIN fixation with a small incision.** In addition, a subcutaneous plate may be more symptomatic than an intramedullary nail which also provides a stress sharing support that may prevent fracture distal to the radial plate.

The decision to remove implants may also play a role in implant choice. Removing nails can be faster and less invasive than removing plates. It should be noted that both constructs have the risk for refracture after implant removal, which seems to be comparable.[15] Interestingly, the decision to remove implants can be controversial and is not universally performed. In the series by Shah et al., only 58% of plates were removed as compared to 100% of the intramedullary nails.[16] The authors did not specify why plates were removed, but the patients were immobilized for an average of 4 weeks after implant removal.[16] Smith et al. removed nails associated with complications such as implant prominence, migration, or bursitis.[17]

Single-Bone Fixation

Flynn and Waters first described single-bone fixation of both-bone forearm fractures[23] (Figure 2). This is mainly indicated in young children and is typically performed with FIN of the ulna, and closed reduction of the radius is acceptable if stable under rotation and stress with fluoroscopic imaging. The authors recommend that if the radial bow collapses, then standard dual fixation is necessary.[23] These findings were reinforced by subsequent studies.[24-26]

Figure 2. *Example of single-bone fixation*

Despite these reports, some authors have proposed a more nuanced conclusion with regard to single-bone fixation. Dietz et al. demonstrated that single-bone fixation is efficacious in younger children but expressed caution in older children or with open fractures due to greater risk for instability, soft tissue compromise, and re-displacement.[27] Similarly, Colaris et al. performed a multicenter randomized controlled trial of 24 children with unstable both-bone forearm fractures and demonstrated that re-displacement was more commonly noted with single-bone fixation.[28] However, the age of these patients that had re-displacement was unclear.

Westacott et al. performed a systematic review of single-bone fixation and concluded that few complications were noted when the second bone is left unfixed if it was deemed stable and reduced.[26] The authors also reported comparable outcomes between single- and dual-bone fixation methods. **Pearl: Consider long arm cast immobilization when performing single-bone fixation.**

Surgical Technique

Sequence of Fixation: Radius or Ulna?

The Nancy Manual on forearm nailing explains that reduction of the radius may prove to be difficult after fixation of the ulna and so the radius is typically the first bone to be addressed.[29] The subcutaneous position of the ulna facilitates an easier reduction, even following radial nailing. If the ulna is difficult to reduce, Lascombes et al. recommend pulling the retrograde radial nail back to just 1-2cm proximal to the radial fracture as this can create some motion and allow reduction of the ulna.[29]

In contrast, Waters and Bae recommend addressing the ulna first due to ease of ulnar rod placement and because restoration of ulnar length and fracture reduction will reduce the radius via ligamentotaxis and soft tissue connections.[30]

In a systematic review, Yong et al. failed to reach a conclusion regarding the sequence of bone fixation. The authors reinforce that the restoration of the radial bow is paramount for forearm stability and range of motion and is also helpful for ulnar reduction.[31] Lascombes et al. emphasize that surgeon preference and comfort level must ultimately dictate the sequence of bone fixation for both-bone forearm fractures.[29]

Implant Preparation

The radius and ulna will each accommodate one flexible nail. The ideal nail diameter of choice should be 40% of the intramedullary canal diameter at the isthmus of the bone. The narrowest diameter is best seen on the lateral view of the radius and ulna.[30] Placing the nail over the skin and assessing for length with a fluoroscopic x-ray can estimate the length of the nail. Concomitantly, the surgeon can also assess the curvature that needs to be applied to the nail. For stability, the apex of the curvature must be at the level of the fracture.

The tip of the nail is typically curved by the manufacturer to allow for a smooth turn at the metaphyseal-diaphyseal junction, facilitate passage across the fracture site, and rotation during insertion. **Pearl: Make sure that the offset of the nail to the curved tip is smaller than the diameter of the medullary canal; otherwise, it may need to be shortened.[29]** In addition, if the angle of the curvature of the nail tip is too small, it will be difficult to pass across the metaphyseal-diaphyseal junction.[29]

Figure 3. *In Figure A, the under-contoured flexible nail has displaced the distal radius fracture. Figure B demonstrates an appropriately contoured flexible nail that aids in reduction of the radius. Figures C and D demonstrate appropriate reduction. (Case courtesy Ken Noonan, MD, Madison, WI)*

Pitfall: When nailing fractures that are close to the insertion site, the risk of malunion as a result of nail contour exists. The nail may be plastically bent to a C-shaped pattern according to the surgeon's preference.[6] If the reduction is tenuous, this bend can be utilized for assisting in fracture reduction (Figure 3). Once the nail tip engages the slightly displaced far fragment, rotating the nail will further engage the fragment, and advancing the nail will help reduce the fracture against the contour of the nail.

Strategies for Radial Nailing

Insertion of the radial nail is typically performed in a retrograde fashion (distal-to-proximal). Care must be taken to protect the distal radial physis. The surgeon can mark the physis over the skin with the use of a fluoroscopic x-ray intraoperatively to avoid inadvertent implant penetration.

Dolan and Waters clearly describe the different entry points into the radial metaphysis.[6] The standard entry is on the radial aspect about one centimeter proximal to the distal radial physis (Figure 4). The insertion is located volar to the brachioradialis tendon. Care must be taken to avoid the superficial radial sensory nerve and the 1st and 2nd dorsal extensor compartments. **Pearl: Use of an awl may be safer than a drill as the APL and EPB tendons can be wrapped up in the drill if not adequately protected.** If the entry awl is aimed volar, it can slip and injure the radial artery. Thus, it is paramount to aim the awl dorsal to avoid this complication. Since the awl should be inserted obliquely into the metaphysis (distal radial to proximal ulnar), the skin incision should be extended distally. To avoid inadvertent injury to the superficial radial sensory nerve, some authors have described the use of a central entry point (see cross on Figure 4). This is located proximal to Lister's tubercle. Care must be taken to protect the thumb and digital extensor tendons. Lastly, an ulnar sided insertion can be opted for between the fourth and fifth dorsal compartments.

After the entry hole is made, the pre-contoured radial nail is inserted and slowly advanced across the fracture. If the nail gets jammed and does not advance even after rotation, shortening the curvature of the tip is advised. Reduction and wire passage across the fracture is checked on multiplaner fluoroscopy. The F-Tool can be utilized to assist in reduction and can hold the reduction while checking fluoroscopic x-rays, thereby avoiding radiation to the surgeon's hands.[6] Once the nail is passed to the level of the bicipital tuberosity, the concave side should face the ulna, which helps restore the radial bow and tensions the interosseous membrane. The nail should be trimmed and bent if the plan is to bury within the skin to avoid skin irritation. The nail ends can be left outside of the skin as well, based on surgeon preference.[30]

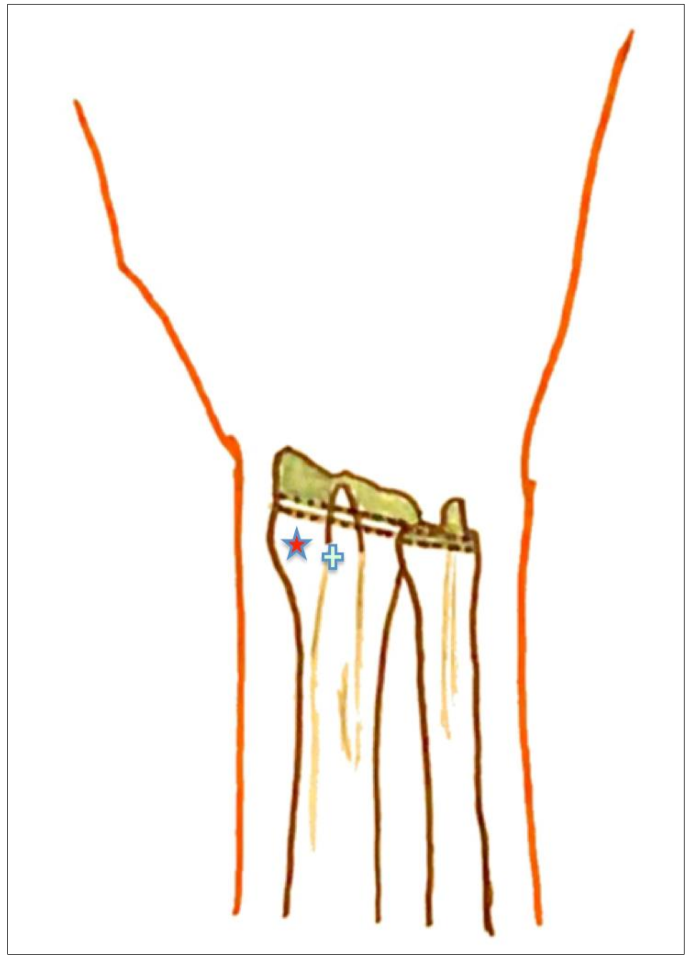

Figure 4. *Diagram of the distal radius entry points. Star represents the standard entry point proximal to the radial physis and between the 1st and 2nd extensor tendon compartments. Cross represents the central entry on the radial aspect of Lister's tubercle.*

Strategies for Ulnar Nailing

Antegrade nailing (proximal to distal) of the ulna is more frequently utilized than retrograde nailing (distal to proximal). A posteromedial entry is precarious due to the risk of injury to the ulnar nerve. The preferred entry point for antegrade nailing is through the anconeus on the posterolateral aspect of the olecranon (Figure 5). An entry point over the olecranon tip is often easier to place, but the nail can become prominent and painful when the elbow rests on surfaces. **Pearl: with a posterolateral entry, the nail end can be buried within the anconeus muscle and is much less bothersome than a nail placed down the tip of the ulna.[29]** If the nail is to be left out and removed in clinic, the tip of the olecranon is easier than the anconeus approach.

The distal ulnar physis is marked on the skin under fluoroscopic x-ray in order to avoid violation with the leading end of the antegrade nail. A small incision is made just radial to the tip of the olecranon process, and dissection is carried down to bone. The entry point is typically more dorsal than expected. An awl is utilized to make an oblique entry (proximal to distal), and a pre-contoured nail is inserted as the awl is removed so that the nail travels through the same soft tissue path.[29] The nail is advanced past the fracture and stopped 5-10mm proximal to the distal ulnar physis. **Pitfall: Violation of the distal ulna physis could lead to growth arrest.** If reduction of the ulnar fracture proves to be difficult, pulling back the radial nail to just 1-2cm past the radial fracture can create enough motion to allow for ulnar fracture reduction and ulnar nail passage.[29] Following appropriate placement of the ulnar nail, the concave side of the nail should face radially to create stability and tension the interosseous membrane.

Retrograde nailing of the ulna has been described for more distal ulnar fractures and for ease of fluoroscopic imaging[32] (Figure 5). The distal ulnar physis is marked on the skin in standard fashion, and a small longitudinal incision is made along the ulnar border of the distal ulna proximal to the physis. Dissection is carried out between the flexor carpi ulnaris and extensor carpi ulnaris. Care is taken to protect the tendons and the dorsal sensory branch of the ulnar nerve. An awl is utilized to make an oblique hole (distal to proximal) into the distal ulna, making sure it is proximal to the distal ulnar physis. The nail is then passed in a similar fashion as described above.[32]

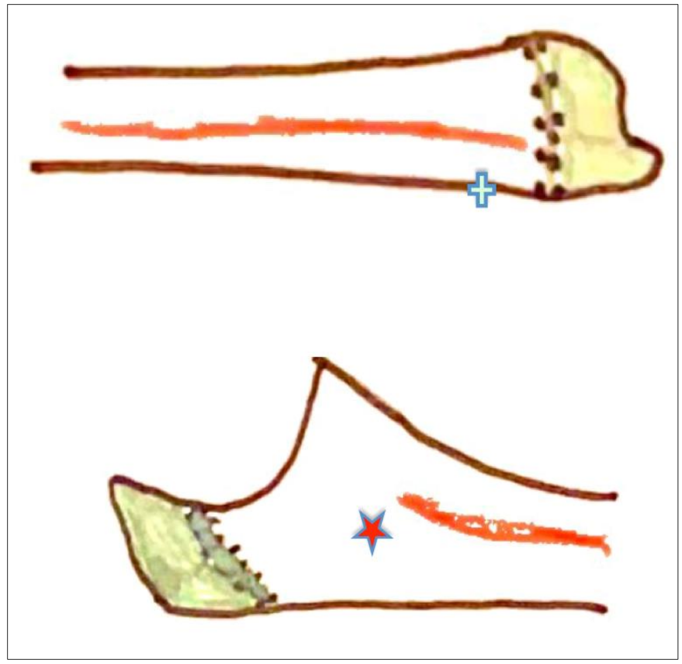

Figure 5. *Diagram of proximal ulnar nailing entry points. Star represents the antegrade nailing entry point on the posterolateral aspect of the olecranon. Cross represents the retrograde nailing entry point along the ulnar border of the distal ulna proximal to the physis.*

Johnson et al. compared outcomes between antegrade and retrograde ulnar nailing.[32] They demonstrated a radiographic union in all patients and that the nail insertion technique was not associated with time to bony union, implant removal, or postoperative range of motion parameters. Antegrade nailing was associated with nearly four times the rate of symptomatic implants than retrograde nailing. The authors concluded that local implant irritation at the insertion site and by the nail end was likely the source of the complications. The authors left the nail end protruding for ease of removal with both techniques.[32] Ultimately, surgeon preference, fracture pattern, and ease of use should determine the optimal technique for ulnar nailing.

Indications for Open Reduction

In cases of difficult fracture reduction, our practice is to open the fracture site after two attempts at closed reduction intraoperatively in an effort to mitigate the risk for compartment syndrome.[32] Yuan et al. assessed the risk of compartment syndrome associated with intramedullary nailing of pediatric forearm fractures.[33] The authors demonstrated a compartment syndrome rate of 6-10% and correlated this with longer operative times and increased intraoperative fluoroscopy burden. Prolonged repetitive manipulations with wire passage attempts can increase compartment inflammation, hematoma formation, and compartment syndrome risk.

The need for open reduction in difficult situations may be necessary in 10-30% cases.[6, 34] Makki et al. assessed the rate of open reduction with intramedullary nailing and demonstrated that 33% of cases required an open reduction.[34] The authors also demonstrated that single bone fractures were associated with a significantly higher open reduction rate than both-bone fractures (52% vs. 27%, respectively). **Pearl: A small open approach to facilitate passage of the nail across a difficult fracture is not the sign of poor technique but the practice of a wise surgeon.**

Utilizing the brachioradialis-flexor carpi radialis interval can facilitate open reduction of a diaphyseal radius fracture. An alternative is to perform dissection within the brachioradialis and pronator teres interval distally and proximally.[30] Waters and Bae recommend that if an open reduction is executed, a prophylactic fasciotomy be performed of the forearm fascia.[30] Open reduction of the ulna fracture is typically performed with palpation of the subcutaneous border of the ulna and centering the incision and dissection over the ulnar fracture.

Bartlett et al. assessed the utility of a forearm traction table to help reduce the radius fracture prior to radial nailing.[35] The fingers are attached to finger traps with equal weight, and an axillary post provides counter-resistance to the forearm. This traction set up is conceptually similar to that used for femur fracture intramedullary nailing. After radial nailing, the traction is released, and the elbow is flexed to facilitate ulnar implantation.[35] This technique may reduce the need for prolonged, repetitive closed reduction attempts.

Complications

The minimally invasive nature of FIN has promoted widespread utilization for unstable both-bone forearm fractures. However, this must be coupled with caution and review of the pitfalls associated with this technique. Fernandez et al. published a large retrospective series that categorized the complications associated with forearm FIN.[36] The most common complications were refracture (4.8%), delayed union/nonunion (3.8%), injury to the superficial radial nerve (2.7%), and infection (1%).[36]

Refracture

Refractures can occur after intramedullary nailing with the nails in place (refracture in-situ) or after intramedullary nail removal. Lascombes et al. noted in their series that intramedullary implants should not be removed before 6 months post-insertion to allow for adequate cortical remodeling.[9] When the authors removed the implants at 4 months, they noted cases of refracture in the forearm, which did not occur after a change in practice in which they removed implants after 6 months. Based on biomechanical findings, the recommended time for implant removal is 4-6 months based on typical fracture healing and to minimize risk for refracture.[37, 38] However, most authors have advocated for waiting until 6 months post-insertion for forearm fractures. Fernandez et al. demonstrated that the vast majority of refractures occurred within 1 year of implant removal (performed at 6-8 months after insertion).[36]

The risk factors for refracture have been scrutinized; Han et al. demonstrated that male gender and a more distal fracture location were risk factors for refracture.[39] Rousset et al. demonstrated that age under 7 years, slimmer patients under 24 kilograms, radial medullary diameter <4.7mm, and ulnar medullary diameter <3.6mm were risk factors for refracture.[40]

Management of refractures can be debated. If the fracture is unstable and requires reoperation due to unacceptable angulation, passing of new intramedullary nails can be difficult across the callous or hypertrophic bone. As such, open reduction with compression plating is more often recommended.[7] In contrast, if a refracture is closed reduced and is deemed stable in a cast, this can be treated definitively if the reduction is acceptable through weekly follow-up. This is often not the case, particularly in older children.

Refracture in-situ can be a difficult scenario to manage (Figure 6). In their large series, Fernandez et al. reported a 2.5% rate of in-situ refractures.[36] Various treatment strategies have been reported with no general consensus regarding best treatment method.[41] Closed reduction and controlled rebending of the implants can be attempted if deemed safe. This treatment can be definitive if the residual angulation is acceptable.[42, 43] The patient and family must be instructed that the mechanical stability of the implants will be significantly reduced, and therefore, casting along with activity modification is paramount.[43] If the patient is older and if the fracture angulation is unacceptable, Keely et al. recommend nail removal with revision open reduction and internal fixation with plate osteosynthesis[41] (Figure 7).

Figure 6. *Two case examples of refracture in-situ*

Nonunion and Delayed Union

Nonunion is defined as no bony consolidation after 6 months, and delayed union is considered if no bony consolidation is noted at 12 weeks.[36] In the review by Fernandez et al., all cases of nonunion were limited to the ulna. This was similar to the findings noted by other authors.[20, 21] The majority of these cases healed after revision surgery with plate osteosynthesis. In cases of delayed union, watchful waiting up to the 16th week proved effective, and the authors noted bony consolidation at that time.

Figure 7. *Example of refracture in-situ after revision fixation with implant removal and plate osteosynthesis.*

The ulna is described to have a relative "watershed-zone" with regards to its blood supply in the middle third portion, which may predispose it to increased rates of nonunion and delayed union, relative to the radius.[36, 44] Another explanation is that open reduction of the ulna may remove the fracture hematoma and cause periosteal stripping, which may also predispose it to delayed healing or nonunion. **Pitfall: There is a visceral desire to place a large diameter nail in the ulna which can occasionally distract the fracture site when hammered in and may contribute to delayed healing.**

Wound Complications

Overt wound infections are rare and most commonly manifest as skin irritation or breakdown. Fernandez et al. reported a 1% rate of infection/wound complications. This can manifest as skin contusions due to small surgical incision, painful bursa at the olecranon insertion, or complications of open fractures.[36] At the distal radial insertion site, ensuring proper exposure by extending the incision distally can optimize soft tissue handling. This will prevent stretching of the skin and soft tissue in order to accommodate an obliquely inserted nail. At the olecranon insertion site, care must be taken to ensure that the nail tip will not be prominent against resting surfaces.

Bending the end of the nail is also encouraged if the nail end is to be retained within the wound. Lascombes et al. recommend bending the tip at 90 degrees and cutting it 5mm from the bone.[29] If it is still prominent, the authors recommend slightly burying the nail. Gibon et al. have further investigated this theory and assessed the incidence of skin irritation with nail ends bent at 90 degrees compared to those bent at 180 degrees.[45] The authors reported no complications with nail ends bent at 180 degrees. Whereas, nails with 90-degree bends were correlated with skin irritation issues.[45]

Extensor Pollicis Longus Tendon (EPL) Rupture

EPL tendon rupture can be seen with insertion of the radial nail via the central (dorsal) entry site proximal to Lister's tubercle (Figure 8). Care must be taken to protect this tendon during dissection and nail insertion. Another source of tendon injury is a prominent radial nail end that creates repetitive abrasion and causes attritional rupture of the EPL tendon. In such situations, the nail should be removed, and a tendon reconstruction can be performed. Sproule et al. report good outcomes with an extensor indicis propius to extensor pollicis longus tendon transfer in this situation.[46] Murphy et al. performed a review of the literature and concluded that the radial entry site for the radial nail is a safer alternative to avoid EPL tendon injury while keeping in mind that the superficial branch of the radial nerve needs to be avoided.[47]

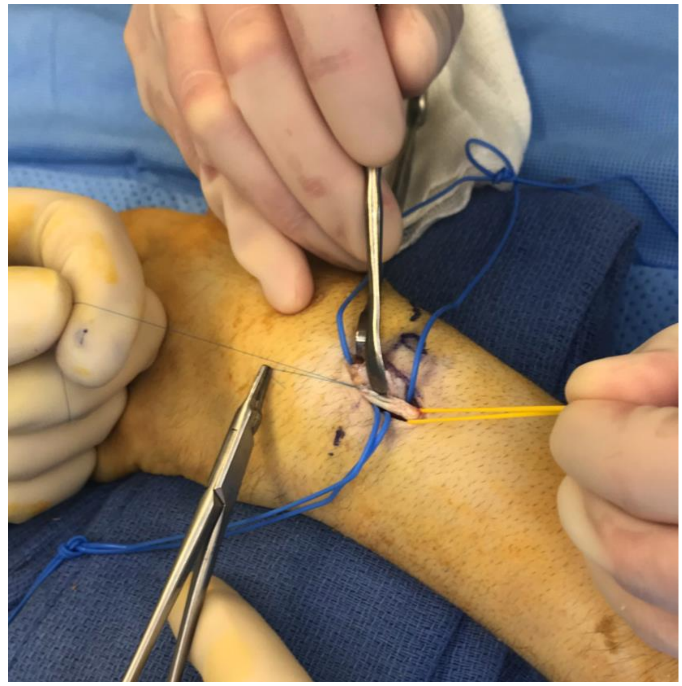

Figure 8. *Example of extensor tendon injury from dorsal insertion of flexible nail in the radius.*

Conclusion

Flexible intramedullary nailing is an efficient and useful technique for the management of unstable pediatric forearm fractures. It is minimally invasive and has gained widespread popularity. However, care must be taken to review the technical pearls and pitfalls associated with forearm intramedullary nailing in an effort to mitigate complications.

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