Original article

Treatment of pediatric forearm midshaft fractures: Is there a difference between types of orthopedic surgeon?


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A R T I C L E   I N F O

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A B S T R A C T

Purpose of the study: The objective of this study was to compare the clinical and radiological outcomes of pediatric forearm midshaft fractures treated operatively with titanium elastic nails (TENs) by pediatric orthopedists and non-pediatric orthopedists.

Material and methods: We conducted a prospective cohort study of 88 children of forearm midshaft fractures, who were randomized to operative stabilization either by pediatric orthopedists (Group A, 44 cases) or by non-pediatric orthopedists (Group B, 44 cases) from April 2013 to February 2014. At baseline, the groups were comparable with respect to age, sex, AO classification, injured side and interval from injury to surgery. We collected data on operative and radiation time, open reduction rate, length of hospitalization, bone union time, return to full physical activity time, complications, and measured clinical results using the Children’s Hospital of Philadelphia (CHOP) Forearm Fracture Fixation Outcome Classification.

Results: The mean follow-up period was 15.8 ± 3.3 months for Group A and 15.2 ± 4.2 months for Group B (P = 0.491). No significant difference existed in time to union (P = 0.282), the overall complication rate (P = 0.750), return to activity time (P = 0.408), and clinical outcomes according to CHOP classification (P = 0.508) between the two groups. However, the mean operating time and radiation time was significantly longer in Group B than in Group A (P = 0.001 and P = 0.001, respectively). In addition, there was a trend for patients of Group B to have a higher rate of open reduction (P = 0.035).

Discussions: Our results indicated that children forearm midshaft fractures treated surgically by pediatric orthopedists offered potential advantages including a shorter operating time and radiation time, a lower rate of open reduction. However, both pediatric and non-pediatric orthopedists had achieved satisfactory clinical results in treatment of these injuries.

Level of evidence: Level II prospective randomized study.

1. Introduction

Forearm fractures are common injuries in the pediatric population. They represent approximately 3 to 6% of all children’s fractures and about 30% of all upper extremity fractures [1]. Approximately 18% of pediatric forearm fractures occur in the middle third [1]. Surgical treatment is necessary for the irreducible or unstable forearm midshaft fractures [2,3]. The traditional internal fixation methods include open reduction and internal fixation with plate and screw fixation, which often can obtain satisfactory results [4,5]. In recent years, titanium elastic nails (TENs) as a minimally invasive technique has become increasingly popular among orthopedists [2,4,6–8].

With more young doctors and medical students giving up their career due to the relatively poor income and working environment [9,10], the great shortage of pediatric orthopedists becomes a serious problem. As a result, in some hospitals, only non-pediatric orthopedists are available to treat these injuries. Although pediatric orthopedists and non-pediatric orthopedists both report their good surgical results of treating forearm shaft fractures, no studies have confirmed whether the therapeutic effect is different in the two types of orthopedic surgeons.

This study was designed to compare the clinical and radiographic results of pediatric forearm midshaft fractures treated surgically by pediatric orthopedists and non-pediatric orthopedists. The hypotheses were that ulnar and radius fractures in
Table 1  
Demographics data and clinical characteristics.

<table>
<thead>
<tr>
<th>Demographics data</th>
<th>Group A (n = 44)</th>
<th>Group B (n = 44)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age (years)</td>
<td>8.9 ± 2.2</td>
<td>9.0 ± 2.3</td>
<td>0.835</td>
</tr>
<tr>
<td>Gender (M/F, n)</td>
<td>34:10</td>
<td>36:8</td>
<td>0.597</td>
</tr>
<tr>
<td>AO class</td>
<td>22:22</td>
<td>25:19</td>
<td>0.521</td>
</tr>
<tr>
<td>(22-D/4.1:22-D/S.1, n)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fracture side (left:right, n)</td>
<td>7:37</td>
<td>11:33</td>
<td>0.290</td>
</tr>
<tr>
<td>Injury to surgery time (d)</td>
<td>1.0 ± 0.5</td>
<td>1.0 ± 0.5</td>
<td>1</td>
</tr>
</tbody>
</table>

AO class: AO classification of pediatric long-bone fractures.

children managed surgically by pediatric orthopedists had fewer complications and more satisfactory functional outcomes versus by non-pediatric orthopedists.

2. Materials and methods

2.1. Study population and study design

We conducted a two-center clinical trial. This prospective study was approved by the Committee of Medical Ethics and the institutional review boards of the authors’ institutions. TENs were only performed if fracture alignment after closed reduction and cast immobilization was unacceptable. From April 2013 to February 2014, a total of 88 children with forearm shaft fractures were treated surgically with TENs by pediatric orthopedists (Group A, 44 cases) or by non-pediatric orthopedists (Group B, 44 cases) in two hospitals respectively.

The patient demographics and fracture characteristics are shown in Table 1. The inclusion criteria were:

- age 5–12 years;
- unilateral midshaft both-bone forearm fracture;
- angulations of > 10 degrees after attempted closed reduction;
- malrotation of > 45 degrees (5–9 years) or malrotation of > 30 degrees (> 10 years) after attempted closed reduction;
- huge displacement (> 10 mm) after attempted closed reduction;
- no preoperative neurovascular injury;
- fresh closed fractures (within seven days from injury);
- at least 12 months of clinical and radiographic follow-up.

The following patients were excluded:

- ipsilateral or contralateral upper limb fractures and/or dislocation;
- pathological fractures;
- open fractures;
- comminuted forearm shaft fractures;
- associated with nerve or vascular injury requiring repair;
- combined with vital organs damage;
- metabolic bone disease;
- previous ipsilateral upper limb surgery;
- metaphyseal-diaphyseal junction fracture;
- radial head fracture;
- Monteggia and Galeazzi fractures.

There was no significant difference in the preoperative variables between the two groups.

2.2. Surgical procedures and postoperative management

All operations were performed by the two groups of surgeons. They all used the TENs produced by the same company (Synthes Paoli, PA, USA). The operative techniques applied in both groups were the same and similar to that previously described in the literature [6,11]. Appropriate antibiotic (Flucloxacillin 60 mg/kg) prophylaxis was only administered within half-hour before the surgery. Under general anesthesia, the patient was in a supine position on a standard radiolucent table. If the reduction was considered acceptable, two TENs were placed in a retrograde fashion through radius and in an antegrade fashion through the ulna respectively.

In general, the first bone to be fixed was the radius that was easiest to reduce. For the radius, the cortex at the point on the radial aspect of the distal metaphysis, 2 cm proximal to the physis was opened with a drill 1 mm larger than the size of the chosen nail. For the ulna, it was preferable to insert the pin through the proximal end, below the olecranon apophysis, through an incision on the lateral side in relation to the anconeus. The nails were attached to a T-handle and were inserted into the holes gently and rotationally. Closed reduction by manipulative traction was performed under fluoroscopic control. The skin incisions were sutured.

If failed attempts of closed reduction with closed manipulation were made for three times, open reduction with small approach was performed. After the open reduction was successful, we also used TENs to stabilize the fracture.

Postoperative treatments in both groups were the same. In all cases, full above elbow plaster cast was applied for 2 to 4 weeks after the injury in order to control pain.

2.3. Data collection and outcomes measurement

The patients were asked for follow-up at the 1st, 2nd and 4th weeks postoperatively and once a month thereafter. The total follow-up period ranged from 12 to 24 months for Group A and Group B. Demographic and preoperative data collected on the patients included age, gender, AO classification, injured side and interval from injury to surgery. Preoperative and postoperative radiographs were also examined. Preoperative radiographs were used to determine AO classification. At each postoperative follow-up visit, radiographs (anteroposterior [AP] and lateral images) were specifically analyzed by the operative surgeons and a radiologist. Outcome data collected also included operative and radiation time, the rate of open reduction, length of hospitalization, bone union time, return to full physical activity time and complications. For data collection, the operative time was defined as the time from the skin incision to skin closure. Fluoroscopy time was obtained from the fluoroscopy logger. Union was defined as the absence of pain and the presence of bridging callus in three of the four cortices seen on the AP and lateral radiographic views of the bone. Delayed union was defined as incomplete consolidation at 90 days as described by Schmittenecher et al. [12]. Incomplete healing by 6 months was considered a nonunion [8]. The range of rotation of the forearm was measured with the elbow flexed at 90 degrees and the arm adducted using a goniometer. The postoperative complications were assessed according to a modification of the Clavien-Dindo classification of surgical complications [13,14], namely, Grade I: complications were a deviation from a routine postoperative course without intervention; Grade II: complications resolved after outpatient management, pharmacologic treatment, or with close observation; Grade III: complications required inpatient care or reoperation; Grade IV: complications were limb threatening, life threatening or resulted in a permanent deficit; Grade V: death. Minor complications were considered Grade I and II complications. Major complications were considered Grade III, IV, V complications. At the last visit, the clinical results were assessed using Children's Hospital of Philadelphia (CHOP) Forearm Fracture Fixation Outcome Classification described by Flynn et al. [2]. An excellent result was noted if motion was full (<10 degrees loss of motion – supination and/or pronation) and no complications occurred. A fair result was <30 degrees loss of motion.
and/or a minor, resolving postoperative complication. A poor result was > 30 degrees loss of motion and/or a major postoperative complication. Only excellent was considered to be successful.

2.4. Statistical analysis

Statistical analysis was performed using SPSS software version 12.0 (SPSS Inc., Chicago, IL, USA). Student’s t-test was used to compare continuous variables (age, injury to surgery time, operative time, X ray exposure time, duration of hospitalization, union time, resume to full physical activity time and follow-up period). A Chi-square test or a Fisher’s exact test was used to compare the differences in gender, AO classification, injured side, open reduction rate, clinical results and complications. In all analyses, significance was defined as $P < 0.05$.

3. Results

There was a significant difference between the two groups in the rate of open reduction (3/44 vs 10/44, $P = 0.035$). The mean follow-up period was 15.8 ± 3.3 months for Group A versus 15.2 ± 4.2 months for Group B ($P = 0.491$). Operation time and fluoroscopy time in Group B were significantly increased ($P = 0.001$ and $P = 0.001$, respectively). In addition, the length of hospitalization and the fracture union time did not show significant difference between the two groups ($P = 0.689$ and $P = 0.282$, respectively). All patients returned to full physical activity during the period of follow-up. All the details are illustrated in Table 2.

The complication rate was 14.6% (6 children) in the Group A, with 1 case of delayed union of the ulna which finally united at 5 months after operation without any further intervention and 1 case of perforation who had his TEN removed as early as 1.5 months because the nail became prominent with impending perforation of the skin. The complication rate in Group B was 14.7% (5 children); one child had delayed union of the ulna (united in a cast at 4.5 months postoperatively without intervention). We found similar complication rates between the groups ($P = 0.750$) (Table 3).

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Comparison of clinical data between two groups.</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Group A</td>
</tr>
<tr>
<td>Operating time (min)</td>
<td>36.2 ± 4.6</td>
</tr>
<tr>
<td>X ray exposure time (sec)</td>
<td>18.8 ± 4.0</td>
</tr>
<tr>
<td>Length of hospitalization (d)</td>
<td>5.0 ± 2.1</td>
</tr>
<tr>
<td>Union time (week)</td>
<td>7.6 ± 1.1</td>
</tr>
<tr>
<td>Open reduction rate (%)</td>
<td>3/44</td>
</tr>
<tr>
<td>Resume to full physical activity time (week)</td>
<td>11.3 ± 1.6</td>
</tr>
<tr>
<td>Follow-up period (m)</td>
<td>15.8 ± 3.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Postoperative complications between two groups.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group A (n = 41)</td>
</tr>
<tr>
<td>Grade I</td>
<td>Delayed union of ulna</td>
</tr>
<tr>
<td>Grade II</td>
<td>Nail entry site infection</td>
</tr>
<tr>
<td></td>
<td>Superficial radial nerve neurapraxia</td>
</tr>
<tr>
<td></td>
<td>Soft tissue irritation</td>
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<tr>
<td>Grade III</td>
<td>Fracture</td>
</tr>
<tr>
<td></td>
<td>Perforation of the nail</td>
</tr>
<tr>
<td></td>
<td>Nonunion of the ulna</td>
</tr>
<tr>
<td>Total complications</td>
<td>6</td>
</tr>
</tbody>
</table>

As for functional outcomes, normal forearm rotation was recorded in 60 forearms (80.0%). Four children (2 cases in each group) developed limitation of forearm rotation between 10° and 30° but this did not result in any functional disability. No children had limitation of forearm rotation of up to 30 degrees. When rating surgical results using the CHOP Forearm Fracture Fixation Outcome Classification, there was no significant difference between the groups (33/41 vs 27/34, $P = 0.908$) (Table 4).

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Functional outcomes between two groups.</th>
</tr>
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<tbody>
<tr>
<td>Patient outcome</td>
<td>Group A</td>
</tr>
<tr>
<td>Excellent</td>
<td>33</td>
</tr>
<tr>
<td>Fair</td>
<td>7</td>
</tr>
<tr>
<td>Poor</td>
<td>1</td>
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</table>

4. Discussion

Many Chinese hospitals have no specialized pediatric department of orthopedics and pediatric orthopedist. Therefore, in many hospitals, many operations associated with pediatric fractures are performed by non-pediatric orthopedists. Although both sides report their good results of their own group, it is unknown whether there is a difference between the two types of surgeons in surgical effect. Farley et al. demonstrated that both pediatric and non-pediatric orthopedists had sufficient ability to treat supracondylar humerus fractures and they had the same effect [15]. On the contrary, Dodds et al. found the pediatric orthopedists had a lower rate of open reduction and a lower rate of inadequate fracture fixation in the treatment of pediatric supracondylar humerus fractures [16].

As for perioperative variables, the Group B needed longer operation and radiation time than Group A ($P = 0.001$ and $P = 0.001$, respectively). The operation time was mainly related to fracture reduction and technique of insertion of TENs and the radiation time was likewise. The success rate of fracture reduction and nails insertion technique was intimately associated with skill level and experience of the surgeon. Every year, pediatric orthopedists treated more children forearm fractures than non-pediatric orthopedists, so they had a richer experience in dealing with such fractures. It was more conducive to reviewing their experience and lessons and improving the efficiency of operation. Moreover, pediatric orthopedists usually received a lot of formal training and their operation procedure might be more standard. In other words, pediatric orthopedists might have more sufficient training, skill, and experience than their counterparts. Several studies demonstrated that the presence of a senior surgeon resulted in a 36–40% decrease in the amount of radiation and radiation exposure time during surgical procedures [17,18]. Moreover, some tips also could help to reduce operation time and radiation dose. Garg et al. suggested that the nail required suitable pre-bending to allow it to pass easily through the medullary canal [6]. Furthermore, when advancing the nail to proximal metaphysis, gently rotating the T-handle can make reduction smoothly and reduce the radiation dose [8].

Compared with non-pediatric orthopedists, pediatric orthopedics doctors also have the advantages mentioned above, which lead to a lower open reduction rate. Dodds et al. reported higher rates of open reduction in patients treated by non-pediatric orthopedists [16]. However, they thought the clinical impact of the difference in open reduction rate between pediatric and non-pediatric orthopedists might be minimal. Interestingly, Farley et al. found that the pediatric orthopedists had a significantly higher rate of treating the severe fractures with an open reduction. It was mainly because their series were not well matched by fracture type [15]. To avoid this handicap, the AO classification between the two groups
was comparable. Our series had an open reduction rate of 14.7%, which was similar to previous series [2,8,19]. Besides, no significant difference between the two groups was found in length of hospitalization, union time and return to full physical activity time. This indicated that children treated by both pediatric and non-pediatric orthopedists achieved similar clinical outcomes.

Based on the Clavien-Dindo classification, there were no significant differences in the postoperative complication between two groups. No complications, such as osteomyelitis, misplacement of TEN, permanent nerve palsy, radio-ulnar synostosis, tendon rupture or compartment syndrome, occurred in either group. Skin irritation at nail insertion sites was relatively common in our series. The incidence of nail-tip irritation in published reports ranged from 4.5% to 12% [3,20–22]. We encountered two patients (4.9%) with nail-tip irritations in Group A and three (8.8%) in Group B. No significant differences were found between the groups for nail-tip irritation rate (P = 0.828). Similarly, we found that delayed union, superficial wound infection, superficial radial nerve neurapraxia and perforation of nail rates were similar between the two groups (P = 0.558, P = 0.925, P = 0.558, P = 0.925, respectively). Additionally, complication rates in our study were comparable to those of other published series [3,6,8,12,21,22]. In summary, this study did not demonstrate differences in the rates of complications between patients treated by pediatric orthopedists and those treated by non-pediatric orthopedists.

The reported CHOP Forearm Fracture Fixation Outcome Classification results were 77–95.2% [2,4,7]. The scores of our series were all within the scope of the data reported in the previous papers [2,4,7]. We also found the clinical outcomes revealed no significant difference between the two groups (Table 4). From this, we could conclude the functional results treated by pediatric orthopedists and non-pediatric orthopedists were comparable.

The resolution of pediatric orthopedic surgical training problem and the shortages of pediatric orthopedists remains an uphill journey but we can still do something. First, the universities should set up an independent pediatric orthopedic specialty and recruit more pediatric orthopedic students. This is the key to the solution of the problem. Second, the salary of pediatric orthopedic surgeons should be improved to attract them to stay at their original post. Third, hospitals should set up pediatric orthopedic department and carry out relevant professional training to meet clinical needs. Pediatric orthopedic training is improved by providing a platform for primary pediatricians to study at large children’s hospitals. Similarly, a consummate system is the key to the standardized training of specialist pediatric orthopedists.

The present study is not without limitations. First, this is a two-center clinical trial which enrolled only a small number of patients. To further convince these results, high quality randomized controlled trials with larger sample size are still needed. Second, parents will be more inclined to choose pediatric orthopedists to treat their children, which might influence the results. Third, in order to simplify our research, we only incorporated midshaft both-bone forearm fracture in the present study. Consequently, the advantages of pediatric orthopedists could not be fully reflected due to lack of severe fractures.

5. Conclusion

Our results indicated that children forearm shaft fractures treated surgically by pediatric orthopedists had a shorter operating time and radiation time, a lower rate of open reduction. However, both pediatric and non-pediatric orthopedists had achieved satisfactory clinical results in treatment of these injuries.

Ethical approval

Each author certifies that his or her institution has approved the reporting of this case and that all investigations were conducted in conformity with ethical principles of research.

Disclosure of interest

The authors declare that they have no competing interest.

References