Original article

Factors associated with a failed closed reduction for supracondylar fractures in children


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ABSTRACT

Purpose of the study: The aim of this retrospective study is to analyze the risk factors causing the failure of closed reduction of children supracondylar fracture.

Patients and methods: The children with supracondylar humerus fractures who were treated in our hospital from February 2008 to February 2013, were recorded as well as their age, sex, BMI, injured side, mechanism of injury, associated injuries, fracture type, delay from injury to surgery. Mean comparisons or Chi² test were used for univariate analysis of the above factors, and then multivariate logistic regression analysis was used to analyse the possible risk factors, in order to elicit the risk factors associated with a failed closed reduction for supracondylar fractures in children.

Results: Univariate analysis showed that BMI, fracture type, duration from injury to surgery, and mechanism of injury had statistically significant association with the failure of closed reduction for children supracondylar fracture (*P = 0.021, 0.044, 0.000 and 0.037 respectively). Multivariate logistic regression analysis demonstrated that fracture type (P = 0.027, OR = 1.177), time from injury to surgery (P = 0.022, OR = 2.003), and mechanism of injury (P = 0.044, OR = 4.182) were independent risk factors of a failed closed reduction for paediatric supracondylar fractures.

Discussions: Gartland type III supracondylar fractures, the peak period of soft tissue swelling and high-energy injury are significant risk factors to warrant open reduction. Treating surgeons should preoperatively carefully evaluate these risk factors and be prepared to treat these injuries accordingly.

Level of evidence: Level IV retrospective study.

1. Introduction

Pediatric supracondylar humerus fractures are the most common fractures around the pediatric elbow [1,2]. Because remodeling is limited, meticulous reduction and anatomic alignment are essential to restore normal elbow function and prevent future complications from malreduction and resultant abnormal joint kinematics. Closed reduction followed by stabilization with percutaneous Kirschner wires has been established as the standard treatment for unstable supracondylar fractures of the humerus in children, and a number of studies have shown satisfactory results with such treatment [1–5]. However, a totally displaced supracondylar humerus fracture is one of the most difficult fractures to manage because of marked soft tissues swelling and difficulty in achieving satisfactory reduction and maintaining reduction in the process of pinning. This means that a certain proportion of fractures cannot be reduced with the closed method, with the conversion rate to open reduction being between 3 and 15% [2,3,6]. Open reduction may have worse results than closed reduction as loss of motion, elbow stiffness, myositis ossificans, infection, scar formation and an increased risk of iatrogenic neurovascular injury are possible complications [6]. But few studies address some factors that may determine whether open reduction is performed when a closed reduction has failed.

The purpose of this retrospective study is to investigate the risk factors causing the failure of closed reduction of children supracondylar fractures. Some authors believed that the severity of the fracture and injury to surgery time might be associated with a higher rate of failed closed reduction [3,6]. Based on the views expressed above, we hypothesized that fracture type and time from injury to surgery were significant risk factors for the need for open reduction.


2. Patients and methods

2.1. Study population and study design

After approval from Institutional Review Board of our hospital, we retrospectively reviewed the records of consecutive patients with operatively treated pediatric supracondylar humerus fractures who were admitted between February 2008 and February 2013 at our clinic. The inclusion criteria were: age 5.0–13.0 years, fresh closed fractures, unstable Gartland II and all Gartland III fractures, all operations performed by the same group of doctors, and Blount’s technique failed or was contraindicated. The following patients were excluded: open fractures and old fractures, pathological fractures, combined with nerve or vascular injury, a history of ipsilateral elbow congenital malformations, associated with vital organs damage, and associated with fractures of other parts of the ipsilateral limb. In accordance with the inclusion criteria and exclusion criteria, a total of 104 patients with operatively treated supracondylar humerus fractures were identified.

2.2. Demographics of the study population

When Blount’s technique failed and closed reduction of the fracture was satisfactory, percutaneous pinning was performed. When closed reduction was not satisfactory, open reduction was performed. Among 104 patients, open reduction was performed in 21 cases, including 13 males and eight females, seven cases on the left and 14 cases on the right, with a median age of 8.43 ± 2.30 years. The average body mass index (BMI) of the patients was 28.62 ± 3.81 kg/m². It consisted of 3 cases of Gartland II fracture, 18 cases of Gartland III fracture. Causes of injuries were road traffic accidents in five patients, ground falls in nine and sports injuries in seven cases. We defined ground falls as low-energy injury and traffic accidents and sports injuries as high-energy injury. The time from injury to operation was < eight hours in five cases, eight hours to five days in 13 cases, five days to seven days in three cases. The remaining 83 cases were successfully reduced using the closed method, including 55 males and 28 females, 33 cases on the left and 50 cases on the right, with an average age of 8.90 ± 2.60 years. The BMI of the patients was 25.27 ± 3.93 kg/m². It included 31 cases of Gartland II fracture, 52 cases of Gartland III fracture. Causes of injuries were road traffic accidents in 12 patients, ground falls in 56 and sports injuries in 15 cases. The time from injury to operation was < eight hours in 44 cases, eight hours to five days in seven cases, five days to seven days in 32 cases.

2.3. Data collection

All demographic and outcome data were gathered by two authors and stored anonymously in a database. Demographic information recorded at the time of the original injury included age, sex, BMI, fracture type, mechanism of injury, and the time from injury to operation. Fracture was classified using Gartland fracture classification system. The main outcome variable was the need for open reduction. Indications for open reduction were a fracture irreducible by closed reduction or a fracture with unacceptable reduction. An unacceptable reduction was defined as excessive translational or rotational malalignment. Translational malalignment was defined on a lateral radiograph when less than 50% cortical contact existed between the proximal and distal fragments (Fig. 1). Rotational malalignment was defined on a lateral radiograph when a 2 to 3 mm difference existed in the width of the bone at the fracture site between the proximal and distal fragments (Fig. 2). Greater angular malalignment was accepted because this has a greater potential for correction through remodeling.

2.4. Statistical analysis

Distributions of data were checked. Percentages were used for categorical data, and means or medians were used for continuous data. Student’s t test was used for the comparison of continuous variables and the Chi² test for the comparison of categorical variables. The open reduction group was compared with closed reduction patients on collected variables. To determine whether factors were independently associated with risk of open reduction, a multivariate logistic model was fit predicting open reduction status. All variables were included as possible predictors and a final model was found using stepwise elimination. Final modeling results are reported with odds ratios (OR) and 95% confidence intervals (CIs). All analyses were performed using SPSS software, version 11.0 (SPSS, Inc., Chicago, IL, USA). The level of significance was set at P < 0.05.
Table 1
Baseline characteristics of all operated patients.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Open reduction</th>
<th>Closed reduction</th>
<th>( \chi^2(1) )</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>8.43 ± 2.30</td>
<td>8.90 ± 2.60</td>
<td>-0.767</td>
<td>0.445</td>
</tr>
<tr>
<td>Sex (male: female, n)</td>
<td>13:8</td>
<td>55:28</td>
<td>0.141</td>
<td>0.708</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>28.62 ± 3.81</td>
<td>25.27 ± 3.93</td>
<td>2.512</td>
<td>0.021</td>
</tr>
<tr>
<td>Fracture side (left:right, n)</td>
<td>7:14</td>
<td>33:50</td>
<td>0.292</td>
<td>0.589</td>
</tr>
<tr>
<td>Fracture type (Gartland II:Gartland III, n)</td>
<td>3:18</td>
<td>31:52</td>
<td>4.051</td>
<td>0.044</td>
</tr>
<tr>
<td>Cause of injury (low-energy:high-energy, n)</td>
<td>9:12</td>
<td>56:27</td>
<td>4.332</td>
<td>0.037</td>
</tr>
<tr>
<td>Injury to surgery time (&lt;8 h:8–5 days:5–7 days, n)</td>
<td>5:13:3</td>
<td>44:7:32</td>
<td>30.884</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Table 2
Multivariate logistic regression analysis.

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Regression coefficient, B</th>
<th>Wald Statistic</th>
<th>( P ) value of Wald Statistic</th>
<th>Standard error of B</th>
<th>Odds Ratio Exp (B) (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td>0.485</td>
<td>2.226</td>
<td>0.136</td>
<td>0.325</td>
<td>1.624 (0.859–3.072)</td>
</tr>
<tr>
<td>Fracture type</td>
<td>0.163</td>
<td>4.899</td>
<td>0.027</td>
<td>0.074</td>
<td>1.177 (1.019–1.359)</td>
</tr>
<tr>
<td>Cause of injury</td>
<td>1.431</td>
<td>4.074</td>
<td>0.044</td>
<td>0.709</td>
<td>4.182 (1.042–16.784)</td>
</tr>
<tr>
<td>Injury to surgery</td>
<td>0.695</td>
<td>5.210</td>
<td>0.022</td>
<td>0.304</td>
<td>2.003 (1.103–3.636)</td>
</tr>
</tbody>
</table>

3. Results

Of the 104 patients who were at least five years of age, closed reduction failed in 21 patients, representing a risk of 20.2%. BMI \((P = 0.021)\), fracture type \((P = 0.044)\), time from injury to operation \((P = 0.000)\) and mechanism of injury \((P = 0.037)\) were associated with increased risk of a failed closed reduction on univariate analysis (Table 1) and were considered in the multivariate model. Results from the logistic modeling showed that none of the following were significantly related to predicting the risk of open resection: age, sex, BMI and injured side. Only the categorical variables of fracture type \((P = 0.027, \ OR = 1.177)\), time from injury to operation \((P = 0.022, \ OR = 2.003)\), and mechanism of injury \((P = 0.044, \ OR = 4.182)\) remained independently predictive (Table 2).

4. Discussion

There are many factors associated with a failed closed reduction for supracondylar fractures in children. Past simple correlation analysis did not reveal the real situation and was easy to draw wrong conclusions. In order to avoid mutual interference between the various factors, the current study used univariate analysis combined with multivariate Logistic regression analysis to investigate the risk factors for failed closed reduction of pediatric supracondylar humerus fractures. The results showed the variables that significantly and independently influenced the need for open reduction were Gartland type III fracture \((P = 0.027, \ OR = 1.177)\) and time from injury to surgery \((P = 0.022, \ OR = 2.003)\), which confirmed our initial hypothesis. In addition, we found that the mechanism of injury \((P = 0.044, \ OR = 4.182)\) also was an independent risk factor.

The surgical treatment of Gartland type III fracture is complicated and entails technically difficult procedures for orthopaedic surgeons. The fracture pattern generally presents no cortical contact and completely detaches peristeum. Furthermore, due to interposition of structures such as the brachialis muscle, median nerve or brachial artery, severely displaced Gartland type III fractures often can not achieve good alignment simply using closed reduction [7]. The current study also showed Gartland type III fracture was one of independent risk factors associated with a failed closed reduction. Therefore, we recommend closed reduction should routinely be performed for Gartland type II fractures while for Gartland type III fractures it needs careful consideration. We suggest starting with a closed reduction technique for Gartland type III fractures unless some special circumstances are present. If an anatomical reduction cannot be obtained after one or two closed attempts, an open reduction should be performed because repetitive manipulations could increase the probability of neurovascular injury, promote compartment syndrome, and produce adverse effects on the epiphysis and also lead to myositis ossificans [4,8].

Timing of surgery remains a controversial issue in the treatment of supracondylar fractures of the humerus. In a multivariate analysis of 198 patients, Mehman et al. [9] found no significant difference in need for open reduction, pin track infection or iatrogenic nerve injury between groups of patients treated within or after eight hours. Other retrospective studies [10–12] also found no increase in complications or rate of open reduction when these fractures were delayed for more than 12 hours. However, Walmsley et al. [13] and Carmichael et al. [14] found delaying surgery more than eight hours was associated with an increased rate of open reduction. The overall rate of open reduction reported in the literature varied from 1 to 46% [9–11,13–17]. Our figures showed that the rate of open reduction increased from 10.2 to 29.1% if surgery was delayed for more than eight hours. In particular, the rate was up to 65% if surgery was performed between eight hours and five days after injury. This might be due to the severity of swelling of local soft tissue after fracture. Significant swelling made fracture fragments not easy to palpated and interfered with the surgeon’s judgment on landmarks. Consequently, manipulative reduction of fractures and subsequent surgical procedures were hampered. Even if satisfactory alignment could temporarily be achieved with closed reduction, loss of reduction often occurred in the pinning process. Based on this evidence and our own experience, we suggest that if the patient’s own situation and surgical conditions permit, the patient should be operated within eight hours. If conditions are not available, operation can be performed five to seven days after injury when swelling begins to subside, or it may increase the rate of open reduction. This is consistent with the findings of Heras et al. [5].

In this study, we also found high-energy injury was an independent risk factor associated with a failed closed reduction. High-energy injury causes soft tissue to swell more seriously which increases the difficulty of closed reduction. Additionally, high-energy injury usually leads to a more serious and more unstable fracture with a larger initial fracture displacement. Fracture displacement, especially rotational displacement, had a direct impact on a successful closed reduction [18]. So when we choose surgical methods for supracondylar humerus fractures in children, it is necessary to fully assess the effect of high-energy injury on closed reduction. If a severe fracture caused by high-energy injury is present, the possibility of open reduction should be emphasized during preoperative planning for these fractures. Although the need to convert to open treatment is a possibility for any
surgically treated supracondylar humerus fracture, the treating surgeon should be aware of the increased likelihood in patients with a severe fracture resulting from high-energy injury. Limitations of the current study included the study design in which injury and results data were obtained retrospectively, therefore, the final numbers depended on the accuracy of documentation. Second, our study did not include patients with nerve or vascular injury or with vital organs damage. However, associated injuries may be one of the risk factors of failure of closed reduction [18]. Third, a selection bias was likely present because patients with more difficult fracture patterns would have been sent to pediatric-trained orthopedic surgeons if available.

5. Conclusion

Gartland type III supracondylar humerus fractures, high-energy injury, and time from injury to surgery were significant risk factors for the need for open reduction. Surgeons should be aware of the patients with one or more risk factor and be prepared to treat these injuries accordingly in order to obtain better results.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References