Factors influencing the complication rate in pediatric supracondylar humerus fractures

Daniel Körner, Florian Laux, Ulrich Stöckle, Christoph Gonsor
Department of Traumatology and Reconstructive Surgery, BG Trauma Center Tübingen, Eberhard Karls University of Tübingen, Germany

Abstract

The aim of the study was to identify influencing factors on the complication rate in pediatric supracondylar humerus fractures (PSHF). 22 male and 19 female patients with an extension type PSHF underwent conservative and operative treatment at a single trauma department and were reviewed retrospectively. The complications were assessed and the groups of patients with and without complications were compared according to patient- and therapy-related factors. The overall complication rate was 19.5%. Two patients had a primary and 4 patients a postoperative neurological deficit. One patient developed a pin infection after open reduction and crossed pin fixation. One patient underwent early revision surgery because of insufficient initial reduction after closed reduction and crossed pin fixation. All complications appeared in the surgical treatment group. The appearance of complications was significantly associated with a higher Garlnd stage. The median time between trauma and operation was significantly longer in patients without compared to patients with complications. PSHF are associated with a high rate of neurological complications. The Garlnd stage and the necessity of surgical treatment are the major influencing factors on the complication rate.

Introduction

The majority (about 98%) of pediatric supracondylar humerus fractures (PSHF) are extension type fractures. Gartland established a classification for extension type PSHF with 3 fracture types in 1959 which is widely used until now. Type I fractures are not displaced with an intact periosteum circumferentially. Type II fractures are displaced but the posterior cortex is intact or hinged. On the lateral radiograph of the elbow the anterior humeral line (AHL) runs in front of the capitellum indicating the extension type displacement. Type III fractures represent a completely displaced fracture with no cortical contact. Extension and rotational instability are present and neurovascular injuries are common.

Wilkins subdivided type II fractures into subtypes IIA and IIB. Hereby, type IIA fractures have no rotational abnormality or fragment translation whereby IIB fractures do have these patterns indicating a higher degree of instability.

Several other classifications for PSHF do exist. In Europe the von Laer classification is also widely accepted because it takes the stability of the fracture into account. This classification divides PSHF into 4 types depending on the degree of dislocation – whereby type I fractures have no dislocation, type II fractures show a dislocation in 1 plane, type III fractures in 2 planes, and type IV fractures in 3 planes. Hereby, type I and II fractures represent stable fractures, type II fractures with a higher degree of dislocation represent a potentially unstable fracture, and the types III and IV represent unstable fractures.

The radiographic evaluation of PSHF includes an anteroposterior view of the distal humerus and a true lateral view of the elbow. In uninjured children the AHL passes through the middle third of the capitellum but in children younger than 4 years it passes nearly equally through the anterior or middle third of the capitellum at the lateral radiograph. The AHL helps to evaluate the fracture dislocation in the sagittal plane.

The Baumann angle (BA) is formed by the intersection of a line drawn down the humerus shaft and a line drawn through the capitellar physis on an anteroposterior radiograph. It is a measure for the fracture displacement in the coronal plane in PSHF. The mean BA in normal male and female children is stated to be 72±4 degrees, which was confirmed in further series. Other authors measure the BA by using a line perpendicular to the long axis of the humerus, which in fact means that you have to subtract the measured value from 90 degrees to compare them with values measured according to the first mentioned method. Hereby, the normal angle is stated to be in the range of 9 to 26 degrees.

PSHF are associated with a relatively high complication rate with consecutive harm for the young patients and their families. Primary or iatrogenic complications are nerve injuries, vascular compromise, compartment syndrome, infection and pin migration after surgical treatment, loss of reduction, malunion, persistent impairment of elbow motion, and cubitus varus.

Purpose of the study

The aim of this study was to identify influencing factors on the overall complication rate in patients with a PSHF after conservative and operative treatment.

Materials and Methods

Study design

Between July 2009 and May 2018, 41 patients were treated with an acute extension type PSHF at a single university-based trauma department. The medical charts as well as the radiographs of the patients were reviewed retrospectively. Patients with conservative and operative treatment as well as in- and outpatients were included in the analysis. The groups of patients with and without complications were compared according to patient- and therapy-related factors. Missing documentation or radiographic images were not included in the analysis.

Results

The overall complication rate in patients with a PSHF after conservative and operative treatment as well as the radiographs of the patients were reviewed retrospectively. Patients with complications were compared according to patient- and therapy-related factors. Missing documentation or radiographic images were not included in the analysis.

Conclusions

The Garlnd stage and the necessity of surgical treatment are the major influencing factors on the overall complication rate. The radiographic evaluation of PSHF includes an anteroposterior view of the distal humerus and a true lateral view of the elbow. In uninjured children the AHL passes through the middle third of the capitellum but in children younger than 4 years it passes nearly equally through the anterior or middle third of the capitellum at the lateral radiograph. The AHL helps to evaluate the fracture dislocation in the sagittal plane.

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Conflict of interest: FL holds stocks of Fresenius SE and Johnson & Johnson. The other three authors declare that they have no conflict of interest.

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Correspondence: Daniel Körner, Department of Traumatology and Reconstructive Surgery, BG Trauma Center Tübingen, Schnarrenbergstr. 95, 72076 Tübingen, Germany. Tel.: +49.07071.6063842 - Fax: +49.07071.6061186 E-mail: dkoerner@bgu-tuebingen.de

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orthographs were defined as exclusion criteria.

The following factors were evaluated: age, gender, side of the injury, Garland stage, time of follow-up, concomitant injuries, treatment (conservative vs. operative), surgical technique, time between trauma and surgery, and the quality of the reposition in the patient population which received surgical treatment. Further, the occurrence of neurological and vascular complications, compartment syndrome, infection, and malunion, as well as the revision rate were assessed. Within the operated patient group, the quality of the reposition in the coronal plane was assessed using the BA and in the sagittal plane using the AHL. Hereby, a BA in the range of 64 and 80 degrees was considered to represent a sufficient reduction in the coronal plane. If the AHL passed through the anterior or middle third of the capitellum this was considered to indicate a sufficient reduction in the sagittal plane.

**Patient demographics**

Table 1 gives an overview about the patients’ characteristics.

**Outcome measures**

The overall complication rate was defined as the outcome measure.

**Statistical analysis**

The measured data was transferred into the software package JMP (SAS Institute Inc., JMP, Version 12.2.0, Cary, NC, USA). Data was screened for normality of distribution applying the Shapiro-Wilk-W-test. Descriptive statistics were carried out to calculate the means and standard deviations in case of normally distributed data or the medians and ranges in case of non-normally distributed data. The groups of patients with and without complications were compared. Hereby, the t-test was used for continuous data and the chi-square-test for categorical or ordinal data. A P<0.05 was considered statistically significant for all statistical tests.

**Results**

Within the entire study population 8 patients had a complication (19.5%). All complications appeared in the group of patients that underwent surgical treatment. Two patients had a primary and 4 patients a postoperative neurological deficit. The primary deficits presented as hypoesthesia in the median and ulnar nerve region in patients with Garland type III fractures, respectively. The hypoesthesia was improving in the early postoperative course in both cases in both cases. Figure 1 shows the radiographs.

| Table 1. Patients’ characteristics within the entire study population (n=41). |
|---------------------------------|-----------------|-----------------|
| Age (mean ± SD)                | 7.4 ± 2.1 years |
| Gender                         |                 |
| Male                           | 22              |
| Female                         | 19              |
| Side                           |                 |
| Right                          | 14              |
| Left                           | 27              |
| Garland type                   |                 |
| I                              | 3               |
| IIA                            | 8               |
| IIB                            | 13              |
| III                            | 17              |
| Follow-up (median, range)      | 37 days (1-345 days) |
| Concomitant injury             |                 |
| Distal metaphyseal radius fracture ipsilateral | 2 |
| Injury to the teeth            | 1               |

| Table 2. Comparison of the patients with (group A) and without complications (group B) within the entire study population (n=41). |
|-------------------------------------------------|-----------------|-----------------|
| Age (mean ± SD)                                | 7.75 ± 2.05 years | 7.30 ± 2.19 years |
| Gender                                         |                 |                 |
| Male                                           | 4               | 18              |
| Female                                         | 4               | 15              |
| Side                                           |                 |                 |
| Right                                          | 2               | 12              |
| Left                                           | 6               | 21              |
| Garland stage                                  |                 |                 |
| I                                              | 0               | 3               |
| IIA                                            | 1               | 7               |
| IIB                                            | 0               | 13              |
| III                                            | 7               | 10              |
| Treatment                                      |                 |                 |
| Conservative                                   | 0               | 4               |
| Operative                                      | 8               | 29              |

| P-values                                       |
|------------------------------------------------|
| 0.596 (t-test)                                |
| 0.817 (chi-square-test)                       |
| 0.543 (chi-square-test)                       |
| 0.027* (chi-square-test)                      |
| 0.300 (chi-square-test)                       |

* indicates statistical significance.

| Table 3. Comparison of the patients with and without complications within the group of operated patients (n=37). |
|-------------------------------------------------|-----------------|-----------------|
| Surgical technique                             |                 |                 |
| Closed reduction, crossed pin fixation         | 2               | 16              |
| Open reduction, crossed pin fixation           | 6               | 13              |
| Time between trauma and operation (median, range) | 0 days | 0 days (0-14 days) | 0.039* (t-test) |
| Coronary reposition sufficient (BA)            |                 |                 |
| Yes                                            | 6               | 25              |
| No                                             | 1               | 2               |
| NA                                             | 1               | 2               |
| Sagittal reposition sufficient (AHL)           |                 |                 |
| Yes                                            | 28              | 8               |
| No                                             | 0               | 0               |
| NA                                             | 0               | 1               |

* indicates statistical significance. BA – Baumann angle, AHL – Anterior humeral line, NA – non-applicable.
ographs of the patient with a primary median nerve lesion.

The new postoperative deficits affected the ulnar nerve in 2 and the radial nerve in 2 cases. All postoperative nerve lesions affected the motor and sensory function. One patient with a postoperative ulnar nerve lesion had a Gartland type IIA fracture and received closed reduction and crossed pin fixation and the remaining 3 patients received open reduction and crossed pin fixation for a Gartland type III fracture.

One patient developed a pin infection with Staphylococcus aureus after open reduction and crossed pin fixation with 1 ulnar and 2 radial pins. In this case all pins were removed 23 days after the initial operation and the patient received antibiotic treatment and an additional upper arm splint for 2 more weeks. The further course was uncomplicated.

Furthermore, 1 patient underwent early revision surgery 2 days after the first operation because of insufficient initial reduction after closed reduction and crossed pin fixation.

There were not detected any delayed unions within the population.

Table 2 shows the comparison of the groups with and without complications within the entire study population according to the factors age, gender, side of the injury, Gartland stage, and treatment (conservative vs. operative). The appearance of complications was significantly associated with a higher Gartland stage (Figure 2).

Table 3 shows the comparison of the operated patients with and without complications according to the surgical technique, the time between trauma and operation, and the quality of the reposition according to the BA and the AHL. All operated patients were treated either with closed or open reduction and crossed pin fixation. The median time between trauma and operation was signifi-

Figure 1. Radiographs of a 5-year old girl with a Gartland type III supracondylar humerus fracture with a primary sensory median nerve lesion. The initial anteroposterior radiograph (A) shows the comminution of the medial collum whereby the lateral view (B) demonstrates the extension type displacement in the sagittal plane. The patient underwent open reduction and crossed pin fixation (C anteroposterior, D lateral view). The hypoesthesia improved within the early postoperative course.

Figure 2. Mosaic plot showing the rate of complications according to the Gartland stage within the entire study population (n=41).

Figure 3. Box plot showing the time between trauma and operation within the patient groups with (n=8) and without (n=33) complications.
On the other hand, only 1 of the 21 Gartland conservative treated patients. Furthermore, this significant because of the low number of complications (Figure 3). The mean BA within the group of operated patients was 69.9±5.4 degrees, in the group of patients with complications it was 72.0±6.6 degrees and in the group of patients without complications it was 69.3±5.1 degrees. In 3 patients the Baumann angle and in 1 patient the AHL were non-applicable because of insufficient quality of the radiographs.

**Discussion**

Nerve injuries are common with PSHF with a reported rate of traumatic neurapraxia of approximately 12.7% of all patients presenting with extension type fractures. Hereby, the anterior interosseous nerve is predominantly affected followed by the radial and the median nerve. Within our study population 2 patients (4.9%) presented with a primary neurological deficit – in 1 case the median and in 1 case the ulnar nerve were affected.

Further, iatrogenic neurapraxia after lateral-only and lateral/medial pinning is reported to be 3.9%, whereby medial pinning increases the risk of ulnar nerve injury. Several studies focus on the best pin configuration in the surgical treatment of PSHF. Recent findings suggest that the lateral-only pin placement seems to offer similar stability compared to the crossed pin technique but is associated with a lower risk of iatrogenic ulnar nerve injury. The probability of an iatrogenic ulnar nerve injury has been reported to be 5.04 times higher with medial/lateral entry than with lateral entry pinning.

We have seen 4 postoperative neurological complications (9.8%) within our study population affecting the ulnar nerve in 2 and the radial nerve in 2 cases. All of these patients received crossed pin fixation, whereby 3 patients underwent open reduction.

We found out, that the most important influencing factor on the presence of a primary or iatrogenic nerve injury is the Gartland stage, which indicates the grade of displacement. Moreover, surgical treatment was an influencing factor for the overall complication rate and especially for neurological complications, even though the difference between the conservative and surgical treated patients according to the overall complication rate was not statistically significant because of the low number of conservative treated patients. Furthermore, this finding is biased by the fact, that only displaced fractures needed surgical treatment. On the other hand, only 1 of the 21 Gartland type IIA and B fractures had an iatrogenic nerve injury.

PSHF can be associated with vascular complications leading to pulseless hand with (pink pulseless hand) or without sufficient perfusion. There are reported rates of pulseless hand with PSHF patients of up to 20%. The risk of compartment syndrome is low with PSHF. The reported rates are below 1%, but increase with the presence of a concomitant forearm fracture. We have not seen any patient with a pulseless hand or a compartment syndrome within our study population.

The reported rates of therapy-associated infections with PSHF are inconsistent within the literature. In a large study focusing on the complications after pinning of PSHF with 622 patients, 1 patient developed a deep wound infection with septic arthritis and osteomyelitis and 5 patients had a superficial skin infection. Further series reported pin tract infection rates of up to 2.5%. But there are also studies with reported rates of pin tract infection of 35.6%. We underline the low rate of pin infection with one case within our series.

The statistical analysis revealed, that the median time between trauma and operation was significantly longer in the patient group without compared to the group with complications. The reason is, that the patients with complications mainly had fractures with a high degree of dislocation, which led to an immediate surgical care at the day of presentation. Further, the group without complications contained 2 patients with delayed surgical care within our institution 14 days after the trauma, respectively. One of these patients presented delayed and thus was diagnosed delayed. The other patient presented after insufficient K-wire fixation in another hospital and underwent a second operation within our institution. The statistical analysis has to be interpreted beyond this background.

The quality of the reposition in the coronary plane was assessed using the BA in the group of operated patients. The measured values were consistent with those reported in the literature. However, the quality of the angle measurement depends on the quality of the radiographs. Incomplete extension in the elbow joint and a different degree of humeral rotation between the different radiographs are both possible reasons for the variance of the measured values. The AHL is easy to assess even though incorrect lateral projection and humeral rotation might impair measurement quality.

**Conclusions**

PSHF are associated with a high rate of primary and iatrogenic neurological complications. The Gartland stage and the necessity of surgical treatment are the major influencing factors on the overall complication rate.

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