Rate of avascular necrosis after fracture dislocations of the proximal humerus

Timing of surgery

The treatment of dislocation fractures of the proximal humerus is challenging. Complications such as avascular necrosis of the humeral head can lead to worse outcomes. The relationship between timing of surgery and the development of the avascular necrosis in dislocation fractures of the proximal humerus has not been investigated thoroughly to date.

Introduction

The fracture dislocation of the proximal humerus represents a rare injury, and in these patients operative treatment is required owing to dislocation of the humeral head [9,20]. High rates of complications after reconstruction of proximal humerus fractures regardless of the method of fixation are reported [18,19]. Avascular necrosis (AVN) of the humeral head is one of the most feared short-term complications after reconstructive surgery of proximal humerus fractures [6,7]. AVN leads to worse clinical outcome and subsequent revision surgery in most patients [13]. In fracture dislocations an even higher risk of AVN might be considered owing to the limited blood supply of the humeral head [7]. Therefore, the time spent waiting for surgery might be one important aspect in fracture dislocations of the humeral head with respect to AVN rate. Several authors have postulated that stable internal fixation promotes revascularization of the humeral head after fracture [7,21]. Early stabilization of these fractures could therefore be expected to reduce ischemic time for the humeral head and perhaps the rate of AVN. Thus, the aim of the current study was to investigate the correlation between time to surgery and AVN rate in fracture dislocations of the proximal humerus. We hypothesized that patients with early reconstructive surgery within 48 h of trauma could have significantly lower rates of AVN of the humeral head compared with patients who underwent late surgery (>48 h).

Methods

This retrospective study was enrolled at a level I trauma center after approval of the local ethics committee (No. 837.503.14/9742). Inclusion criteria were age ≥18 years, dislocation fracture of the humeral head type B3 or C3 according to the AO/Orthopaedic Trauma Association (OTA) classification system [10], treatment with locking plate fixation (PHILOS, Synthes, Davos, Switzerland), a minimum follow-up of 1 year, and written informed consent. According to the classification system, patients were only included in the case of complete dislocation of the humeral head from the glenoid. Between January 2008 and October 2014, 39 patients were identified. Nine patients could not be reached or were not able to come to the follow-up examination. Finally, 30 patients (77%) were included in this study.

The mean age of the study population was 63 ± 14 years (range: 34–86 years); 12 patients (40%) were male and 18 patients (60%) were female. The right side was injured in 14 patients (47%) and the left side in 16 patients (53%). According to the AO/OTA classification system, 28 patients (93%) had an 11C3 fracture type and two patients (7%) had an 11B3 fracture type. Of the patients, 13 (43%) had at least one comorbidity, with the most frequent being hypertension (n = 11; 37%) and diabetes (n = 4; 13%).

Treatment protocol and timing of surgery

In all patients, a surgical approach was required to reduce the dislocated humeral head and to repair the fracture. The surgical treatment was planned as soon as possible for all patients. However, five patients underwent surgery with open reduction more than 48 h after trauma, as they were referred late from another hospital. In these five patients, closed reduction was not performed or not possible before surgical treatment. We therefore divided the study population into patients with early surgery (within 48 h of trauma) and those with late surgery (>48 h after trauma).

In all patients, operative treatment was performed with a locking plate fixation (PHILOS, Synthes, Davos, Switzerland) through a deltoideal pectoral approach. The plate was positioned 3–5 mm laterally...
of the long head of the biceps. The cho-

of early and late surgery

Complication, n (%)  

| Early surgery (n = 25) | Late surgery (n = 5) |
|-----------------------|---------------------|
| Avascular necrosis    | 5 (20)              |
|                      | 5 (100)             |
| Infection             | 0                   |
|                      | 1 (20)              |
| Non-union             | 2 (8)               |
|                      | 0                   |
| Secondary fracture dislocation | 5 (20) |
|                      | 1 (20)              |
| Revision surgery, n (%) | 2 (8)          |
|                      | 4 (80)              |
| Implant removal with open surgical release | 3 (12) |
|                      | 1 (20)              |

TSA total shoulder arthroplasty, RSA reverse shoulder arthroplasty

Results

of 110–150°, <5 mm head-shaft dislo-

gles of 110–150°, <5 mm head-shaft dis-
location, and <5 mm displacement of the
major tubercle on the postoperative ra-
diographs. In the case of varus <110° or
valgus >150°, >5 mm head-shaft disloca-
tion, or >5 mm displacement of the ma-
jor tubercle, the reposition was defined
as poor quality of reduction. At final fol-
low-up, radiographs were obtained if the
patient reported pain, or if a decrease in
range of motion or a low functional re-
sult was identified with respect to ethics
committee objections. The follow-up ra-
diographs were analyzed for complica-
tions related to the fracture fixation such
as AVN, secondary fracture dislocation,
screw cut out, or non-union. The AVN
was classified according to the system of
Crues [5].

Follow-up protocol

The clinical examination was performed
by one independent examiner. In all
patients the range of motion, Constant
score (CS), and the Disabilities of the
Arm, Shoulder, and Hand (DASH) score
were investigated at final follow-up.

The surgical revision rates and reasons
were also recorded. The influence of the
timing of surgery was analyzed: Surgery
within 48 h of trauma was defined as early
and surgery after >48 h was defined as late according to previous studies [11, 16]. The immediate postoperative radi-
graphs were analyzed with regard to the
quality of fracture and humeral head re-
duction according to a previous study
from our study group [15]. Briefly, the
reduction of the head–shaft angle (nor-
mal, varus, valgus), head–shaft disloca-
tion (no, <5 mm, >5 mm), and displace-
ment of the major tubercle (no, <5 mm,
>5 mm) were analyzed. Overall, the re-
position was defined as anatomical quality of reduction in cases of head-shaft an-
gles of 110–150°, <5 mm head-shaft dis-
location, and <5 mm displacement of the
major tubercle on the postoperative ra-
diographs. In the case of varus <110° or
valgus >150°, >5 mm head-shaft disloca-
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screw cut out, or non-union. The AVN
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Crues [5].

Statistical analysis

Mean and standard deviation (SD) were
calculated for continuous variables. Dif-
fferences between the two groups of pa-
tients were calculated using the Mann-
Whitney U test. To identify prognostic
factors for the development of AVN or
the need for revision surgeries, relative
risk (RR) and the results of Fisher’s ex-
tact test were determined for the time of
surgery (late surgery >48 h). In addition,
the influence of four independent factors
(female gender, age >65 years, >1 comor-
bidity, poor fracture reduction) on the
occurrence of AVN and the need for re-
vision surgery was determined. A two-
tailed p value of <0.05 was considered to
show a significant difference. SPSS soft-
ware (version 23.0; IBM) was used for
the analysis.

At final-follow up after 37 months (range:
12–66 months), the mean CS was 52 ± 22
(range: 20–77), the DASH score was 60 ± 24
(range: 27–100), and the DASH score
was 32 ± 24 (range: 2–73). Mean ab-
duction was 83° ± 42 (range: 15–165°),
flexion was 95° ± 37 (range: 45–165°),
and external rotation was 17° ± 17 (range:
0–40°). Ten patients (33%) developed an
AVN of the humeral head and ten pa-
tients (33%) underwent revision surgery
(Table 1).

Patients with AVN of the humeral
head presented clinically with increased
pain, and the diagnosis was made on the
basis of such clinical signs and a change
on the radiographs, which showed AVN
stage II in three patients, stage III in
five patients (Fig. 1), and stage IV in
two patients. Detailed results of patients
with AVN are shown in Table 2.

In all, 25 patients (83%) under-
went early surgery within 48 h of trauma
(range: 0–2 days) and five patients (17%)
had late surgery, >48 h after trauma
(range: 3–7 days). Patients with late
surgery had more complications (100% vs.
48%; p = 0.042) and underwent more revision surgeries (100% vs. 20%;
p = 0.018). In the late surgery group,
five of five patients (100%) developed an
AVN of the humeral head, and in the
early group, five of 25 patients (20%) de-
veloped an AVN of the humeral head
(p = 0.002; Table 3). Overall, surgery
was performed after an average period
of 1.3 ± 2.1 days after trauma. Patients with
subsequent AVN underwent surgery af-
after an average of 3.0 ± 3.0 days (range:
0–7 days) and patients without subse-
quent AVN after 0.4 ± 0.6 days (range:
0–2 days; p = 0.007).

According to our proposed criteria for
quality of fracture reduction, anatomical
reconstruction was achieved in ten pa-
tients (33%), whereas 20 patients (67%)
had a poor quality of reduction. Nine out
of 20 patients (45%) with poor quality
of fracture reduction and one out
of ten patients (10%) with anatomical
fracture reduction developed an AVN
of the humeral head. Overall, two out
of ten patients with anatomical reduc-
tion developed complications (20%) and
Abstract

Background. Avascular necrosis (AVN) of the humeral head is a severe complication after proximal humerus fracture dislocations, and leads to a poorer clinical outcome and subsequent revision surgeries. The aim of the current study was to analyze the influence of time to surgery on the AVN rate after locked plating of dislocation fractures of the proximal humerus.

Patients and methods. This retrospective study included 30 patients with a mean age of 63 ± 14 years with dislocation fractures of the proximal humerus type B3 or C3 according to the AO/OTA classification. The rates of AVN of the humeral head were determined clinically and radiographically. In addition, the clinical outcome was determined using the Constant score (CS), the age- and sex-adjusted Constant score (CS5%), Disabilities of the Arm, Shoulder, and Hand (DASH) score, the range of motion, and complication and revision rates. Patients were subdivided into groups of subjects operated on early (<48 h after trauma) and those with late surgery (>48 h after trauma), and the relative risk (RR) for complications and revisions was determined for both groups.

Results. After a mean follow-up of 37 months (range: 12–66 months) the mean CS5% was 60 ± 24 and the mean DASH score was 32 ± 24 points. Ten patients (33%) developed a symptomatic AVN, and ten patients underwent revision surgery. Early surgery was performed on 25 patients while five patients underwent late surgery. After late surgery, all five patients developed AVN, and patients had a fivefold increased RR for AVN (p = 0.002) and subsequent associated surgical revision (RR = 3.3, p = 0.031).

Conclusion. In fracture dislocations of the proximal humerus, early surgery within 48 h of trauma significantly decreases the risk of AVN and subsequent surgery.

Keywords

Osteonecrosis · Shoulder fractures · Shoulder joint · Treatment outcome · Revision surgery
A 50-year-old patient with a dislocation fracture type 11C3 on the left side (a). Surgery was performed 3 days after trauma. Intraoperatively, the humeral head was completely dislocated from the glenoid. The intraoperative radiographs confirmed an anatomical fracture reduction (b, c). After 3 months, the patient complained of pain on movement and the radiograph showed a stage III avascular necrosis of the inferior part of the humeral head (d). The patient underwent revision surgery with implant removal alone (e).

Fig. 1 A 50-year-old patient with a dislocation fracture type 11C3 on the left side (a). Surgery was performed 3 days after trauma. Intraoperatively, the humeral head was completely dislocated from the glenoid. The intraoperative radiographs confirmed an anatomical fracture reduction (b, c). After 3 months, the patient complained of pain on movement and the radiograph showed a stage III avascular necrosis of the inferior part of the humeral head (d). The patient underwent revision surgery with implant removal alone (e).

In 2015, Siebenbürger et al. published the first study that investigated the correlation between timing of surgery and the general rate of complications in operative treatment of proximal humerus fractures [16]. This study evaluated the data of 329 patients and most of them were classified as having two-part ($n = 126$) and three-part fractures ($n = 136$). In their study, 13 patients had a fracture dislocation, which was the smallest group of patients. All patients were treated with open reduction and locking plate fixation, comparable to the current study. The authors found that patients with early surgery (<48 h) and intermediate surgery (>48 h to 5 days) did not exhibit a reduced rate of complications. However, late surgery (>5 days) was associated with a higher rate of loss of fixation and AVN (odds ratio: 1.6). Overall, in 6.4% of cases, AVN of the humeral head was evident.

Two studies have been published that investigated the influence of timing on the rate of AVN after surgical reconstruction of proximal humerus fractures. Boesmuller et al. enrolled 154 patients in their study including nine patients (5.8%) with a fracture dislocation [4]. Mean time to surgery was 5.28 days (range: 0–48 days) and the authors found that time to surgery had no influence on the AVN rate. In the second study, Archer et al. evaluated the data of 19 patients without fracture dislocations [2]. The authors also did not find a correlation between time to surgery and development of AVN. It should be noted that in both studies, patients with fracture dislocations were not analyzed separately.

According to the literature, the prevalence of ischemic head necrosis after operative reconstruction of the humeral head is 3–35% [1, 7, 8, 19]. The rate of AVN in the current study is particularly high at 33%. A number of risk factors for the development of post-traumatic AVN have been previously been reported in the literature. According to Hertel et al., there are three main factors that increase the risk of development of AVN in a proximal humerus frac-
Table 2  Detailed results for patients with and without AVN

|                  | With AVN (n = 10) | Without AVN (n = 20) |
|------------------|------------------|---------------------|
| **Age (mean; range)** | 64 (43–83)       | 62 (34–86)          |
| **Time to surgery (n)** |                |                     |
| <48 h             | 5               | 20                  |
| >48 h             | 5               | 0                   |
| **Time to surgery (mean ± SD)** | 3.0 ± 3.0       | 0.4 ± 0.6           |
| **Quality of reduction (n)** |                |                     |
| Anatomical        | 1               | 9                   |
| Poor              | 9               | 11                  |
| **Range of motion (°, range)** |                |                     |
| Abduction         | 65 (45–105)     | 88 (45–165)         |
| Flexion           | 75 (25–115)     | 101 (45–165)        |
| External rotation | 13 (0–40)       | 18 (0–40)           |
| CS% (mean ± SD)   | 49 ± 7          | 64 ± 26             |
| **Complications (n)** | 10              | 5                   |
| **Revision surgery (n)** | 7               | 3                   |

AVN avascular necrosis, CS% age- and sex-adjusted Constant score, SD standard deviation

Eight of ten initially ischemic heads did not develop AVN. This was ascribed to a stable, anatomic reduction, which allowed for revascularization. In the current study, poor fracture reduction led to higher complications rates (20% vs. 65%), and patients with poor fracture reduction underwent significantly more revision surgeries (50% vs. 0%; p = 0.011). The number of patients with poor fracture reduction was particularly high: 20 of 30 patients. However, the proposed criteria for fracture reduction were very strictly defined. Other factors such as female gender, age >65, and more than one comorbidity did not increase the risk for complications or revision surgeries.

Limitations

This study was limited by its retrospective design. There was no control group, and a power analysis was not performed. Owing to the small sample size, the study was purely exploratory in design, and multiple tests without adjustment for multiplicity were performed. The p values reported here can only be interpreted descriptively. It should be further noted that the clinical scores were investigated at final follow-up after potential revision surgery.

Practical conclusion

- In dislocation fractures of the humeral head, early reconstructive surgery within 48 h of trauma and anatomical reduction significantly decreases the risk of AVN.
- In the case of a fracture dislocation of the proximal humerus, the operative surgeon should be aware of these facts and early surgery should be performed to decrease the risk of AVN.
Compliance with ethical guidelines

Conflict of interest. M. Schnetzke, J. Bockmeyer, M. Loew, S. Studier-Fischer, P.-A. Grützner, and T. Guehring declare that they have no competing interests.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

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