The Treatment of the Proximal Humeral Fracture with the Use of the PHN Nailing System: the Importance of Reduction

Léčení zlomenin proximálního humeru pomocí PHN hřebovacího systému

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ABSTRACT

PURPOSE OF THE STUDY

Intramedullary nailing is a minimally invasive technique that respects humeral head. However, limited surgical approach does not permit an anatomical reduction. The significance of the reduction on the functional outcome has not been sufficiently investigated. The aim of the study was to examine the functional and radiological postoperative outcome in patients with proximal humeral fractures treated with intramedullary nailing and the significance of reduction.

MATERIALS AND METHODS

The study population consisted of 43 patients with proximal humeral fractures that were treated with the Proximal Humerus Nail System (Targon, Aesculap). Mean follow-up period was 23.2 months (SD: 8.9). Shoulder function was assessed with the Constant-Murley Score. Reduction was examined radiographically anteroposterior and true lateral plane. Radiographs of 50 healthy shoulders served as controls. Malreduction was analyzed for 10°, 15° and 20° in both planes.

RESULTS

The overall functional results were satisfying; mean CS of all patients at the last follow-up visit was 74.8 (SD: 19.3). Mean normalized CS for age and gender was 78.15 (SD 17.8). Fracture severity seemed to affect clinical outcome to a certain extent; 4-part fractures exhibited inferior results. Mean NSA was 126.5 (SD: 16.9) in anteroposterio and 137.4 (SD: 15.4) in true lateral view. The respective values in the control group were 134.1° (SD 7.1°) in anteroposterior and 133.7° (SD 12.8°) in true lateral view. A malreduction of >20° in the anteroposterior plane and >15° in both anteroposterior and true lateral planes resulted in significantly inferior clinical outcome. Thirteen complications were recorded, four of them being major.

DISCUSSION

The quality of reduction affected the postoperative outcome to a certain extent. Especially the anteroposterior reduction seemed to play a more important role in the postoperative function than reduction in the true lateral plane. However, this difference was statistically significant only after > 20° malreduction. The worst results in Constant Score were shown, as expected, in the group with malreduction in both planes; even a 15°malreduction resulted in statistically significant difference. The importance of anteroposterior reduction could be due to achievement of better ROM in the frontal plane, most probably because of better levers on the tuberosities. However an absolute anatomical reduction does not have to be achieved at all costs. The overall good results of the fractures in this study despite absence of anatomical reduction could partly result from the limited surgical approach.

CONCLUSIONS

The majority of the patients treated with closed reduction and internal fixation with PHN show good postoperative functional results. However, fracture malreduction reduction cannot be always avoided with the use of PHN. Nevertheless, the evaluation of the Constant-Murley score shows an absolute anatomical reduction in not necessary for satisfying functional outcome. The reduction in anteroposterior plane seems to play a more important role in the postsurgical functional outcome. A malreduction that exceeds 15° in both planes or a malreduction of more than 20° in either plane should be avoided.

Key words: humerus, fracture, PHN, intramedullary nailing, reduction.

INTRODUCTION

Proximal humeral fractures are the third most common extremity fractures after distal radius and hip fractures in elderly patients (3). Most of them can be sufficiently treated with conservative means (5), unless significant fragment dislocation (> 1cm), angulation (> 45°), rotational deformity and tuberosity involvement occur. In this case conservative treatment proves insufficient, as the inability to maintain an acceptably stable reduction results in mal-union and functional impairment (17, 22). The existing surgical options for the treatment of proximal humeral fractures are nowadays many. Balance between reduction and soft-tissue injuries with vascularity damages of the humeral head is not always easily achieved. Open reduction with the use of a plate offers a rigid internal fixation and good anatomical results. However, in some cases it is accompanied by wide soft-tissue exposure and blood supply deterioration of the fragments (7). Newer percutaneous plating techniques are promising but are still mainly applicable to uncomplicated fractures (15).

Closed reduction with K-wires protects the blood supply but is often insufficient for fracture fixation (25). Joint replacement is indicated in cases of articular fractures in geriatric patients, where the risk of humeral head necrosis is high (14). Among these options stands closed reduction and internal fixation with the use of intramedullary nailing. This solution seems to combine advantages and disadvantages of the above mentioned techniques. Several nailing systems exist nowadays (24). The Proximal Humerus Nail System (Targon, Aesculap®, Tuttlingen, Germany) was designed in order to provide a stable fracture fixation with minimal soft-tissue exposure or periosteum-striping, while enabling a quick and safe rehabilitation (16). However, it seems that an anatomic closed fracture reduction with the implementation of intramedullary nailing is not easily feasible.

The impact of malreduction on the postoperative outcome of proximal humeral fractures has not been made clear. While reduction parameters, such as volar tilt and radial inclination are well defined for distal radius fractures (1), such absolute measurements are not common place for proximal humeral fractures. The aim of this study was to examine the therapeutic outcome in patients with proximal humeral fractures with the use of PHN, as well as, to evaluate the significance of reduction in the postsurgical outcome in terms of shoulder function and range of motion.

PATIENTS AND METHODS

Study population

We retrospectively evaluated 43 proximal humeral fractures, treated with PHN over a 2-year period. For patients characteristics see table 1. All 2- to 4-part (II-IV according to Neer classification) proximal humeral fractures that presented in our clinic with a > 45° angulation, > 1 cm humeral head displacement and instability at 90° abduction under image intensifier control were treated operatively with PHN.

The operation was performed within 24 h (n = 33) in 76.7% of the cases; the remaining patients were treated within 7 days (n = 10) from the accident because of comorbidities or secondary admission after initial treatment in other hospitals. None of the patients had any preexisting pathology or concomitant fracture of the ipsilateral extremity. The rehabilitation protocol consisted of active assisted exercises of the shoulder under physiotherapeutic guidance for 6 weeks up to 90 degrees abduction or elevation. Mean hospital stay was 11 days (SD 4.4 days). Mean follow-up was 23.2 months (SD 8.92).

Operation technique

The standard PHN system (Targon, Aesculap®, Tuttlingen, Germany) (150 mm, 8 mm) was used in the present study. PHN is designed for the treatment of proximal humeral fractures and can be used in the case of two-, three- and four-part humeral fractures. It offers four proximal and two distal locking options. The proximal locking options permit the fixation of greater tuberosity with two screws, the fixation of minor tuberosity with another screw and the fixation of a fifth dorsal fragment with one last screw. This fifth fragment is a splitter dorsal greater tuberosity fragment. As the entry point of the nail is located in the joint surface, the humeral head is subchondrally fixed by the nail itself (Fig. 1). An intraoperative single-shot antibiotic prophylaxis was used in all patients. Closed reduction was performed indirectly by traction and the nail was inserted with its insertion handle over an anterolateral deltoid-split approach. If necessary, K-wires, used as joystick, were drilled in the joint surface or a raspatory was inserted between the tuberosities over the skin incision for the proximal interlocking screw, in order to manipulate reduction. The tuberosities could be reduced

Fig. 1. Clinical case of a 78-year-old patient with a two-part fracture of the proximal humerus: post-traumatic and post-operative x-rays, as well as, x-rays (a.p. and lateral) at one-year follow-up. The post-traumatic lateral x-ray was not perfectly performed. Excellent mobility of the shoulder with a CS of 85 one year after trauma.

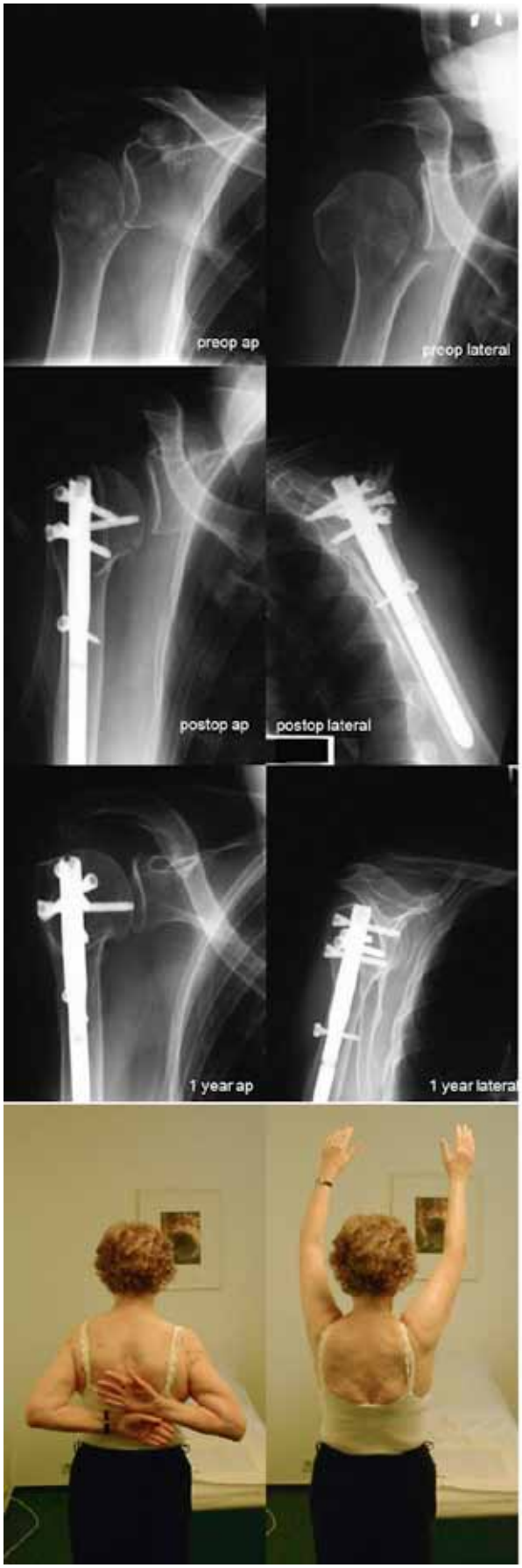

Fig. 2. Measurement of the Neck-Shaft-Angle (NSA) in AP (left) and TL view (right).

Table 1. Population characteristics

Fracture type	
2-Part	10 (23.2%)
3-Part	23 (53.5%)
4-Part	10 (23.2%)
Gender	
male	5 (11.6%)
female	38 (88.4%)
Affected side	
left	23 (53.5%)
right	20 (46.5%)
Mechanism of injury	
fall	41 (95.3%)
traffic accident	2 (4.7%)
Age	
68.56 y (19–89)	

directly through the approach. The exact operation technique is described elsewhere (16). Postoperatively the shoulder was immobilized in a Gilchrist-shoulder-immobilizer and neurovascular status was controlled. Rehabilitation protocol consisted of active assisted exercises of the shoulder under physiotherapeutic guidance for 6 weeks up to 90 degrees abduction or elevation.

Radiographic analysis

Postoperative reduction was radiographically evaluated and consisted of neck-shaft-angle (NSA) measurement in anteroposterior (AP) and true lateral view (TL) (Fig. 2). Subjective clinical outcome was assessed with Constant-Murley score (CS) (2). Complications were recorded. For the means of this radiographic examination, 50 x-rays of proximal humeri from pathology-free, age- and gender- matched subjects from the radiological databank of our hospital served as control group.

Postoperative malreduction of 10° in either plane compared to the control group was defined as minimal malreduction level. Malreduction was further analyzed in AP and TL. Subgroups with different amounts of postoperative malreduction were formed; greater than 20°, greater than 15°, and greater than 10° degrees in AP, TL, and in both planes simultaneously. These subgroups were compared to the rest of the fractures in terms of CS.

Statistical analysis

Continuous variables were expressed as mean and standard deviation (SD). Nominal data were presented as percentages. The data were examined for normality with Kolmogorov-Smirnov Test. Student´s t-test or Wilcoxon-Mann-Whitney test were appropriately used for comparison of continuous independent variables between two groups. Statistical significance was set at $p < 0.05$.

RESULTS

Mean CS of all patients at the last follow-up visit was 74.8 (SD 19.3). Mean normalized CS for age and gender was 78.15 (SD 17.8). Fracture severity seemed to affect clinical outcome to a certain extent; 4-part fractures ex-

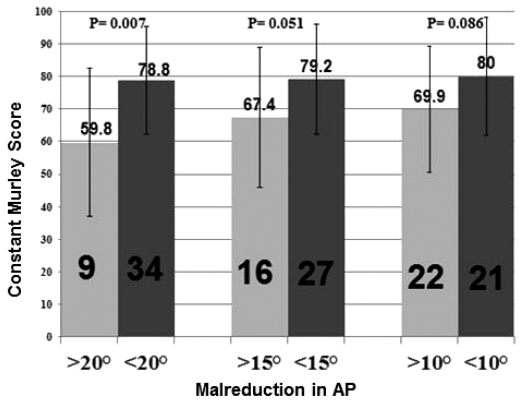

Fig. 3. Comparison of malreduced fractures to the rest in anteroposterior plane. On the x axis the degrees of malreduction are shown. The patients are grouped according to the degree of malreduction. On the y axis the Constant-Murley Score (CS) is shown. A malreduction over 20° resulted in statistical significant difference in the CS.

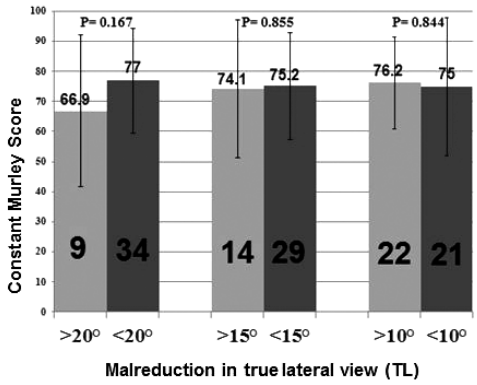

Fig. 4. Comparison of malreduced fractures in true lateral plane. On the x axis the degrees of malreduction are shown. The patients are grouped according to the degree of malreduction. On the y axis the CS is shown. The malreduction in the lateral plane did not affect the CS significantly.

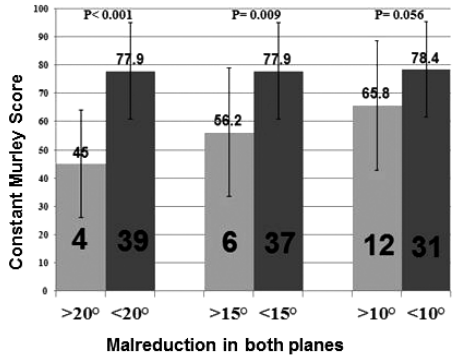

Fig. 5. Comparison of malreduced fractures in both planes. On the x axis the degrees of malreduction are shown. The patients are grouped according to the degree of malreduction. On the y axis the CS is shown. A malreduction of more than 15° resulted in statistically significant lower values of CS.

hibited inferior results. Mean NSA was 126.5° (SD 16.9°) in AP and 137.4° (SD 15.4°) in TL (Table 2). The respective values in the control group were 134.1° (SD 7.1°) in AP and 133.7° (SD 12.8°) in TL. The postoperative shoulder anteversion and abduction were satisfying.

A malreduction of >10° in AP was seen in 22 cases; in TL in other 22 fractures. In 12 of these cases > 10° malreduction in both planes was present. The closer the NSA angle of the patients was to that of the control group, the higher the CS was. This was observed for all NSA (AP, TL and both views). Malreduction of at least 20° in AP ($p = 0.007$), as well as, of at least 15° ($p = 0.009$) and 20° ($p < 0.001$) in both planes resulted in statistically significantly lower CS values. Malreduction in TL up to 15° resulted also in inferior CS results; however, this difference was not statistically significant. The other malreduced angles showed no statistically significant reduction of CS (Figs 3, 4 and 5).

Thirteen complications (30.2%) were postoperatively recorded (Table 3). Two non-unions in 2-part fractures were treated with corticospongiosal interposition and plating. One case of AVN after an anatomical humeral neck fracture was treated with a hemiprosthesis. One superficial infection was treated successfully by surgical debridement and antibiotic therapy. Nine patients required reoperation due to implant removal or arthrolysis that were caused by shoulder stiffness and/or pain due to over-standing implants. An implant removal of four nails and four screws had to be performed earlier than planned, because of an intraarticular implant position. Loosening of ten screws was also observed; however, no therapeutic actions had to be taken. Four patients showed rotator-cuff signs at the last clinical follow up examination. A periprosthetic fracture after fall was reoperated with a long intramedullary nail. In the group of patients with complications there were only 3-part ($n = 7$) and 4-part fractures ($n = 6$). Four of them showed inadequate postoperative reduction in both planes, while two of them only in TL. Mean NSA for the complication group was 132.6° (SD: 18.5°) in AP and 137.1° (SD 15.7°) in TL. The CS of the patients that suffered complications was 71.9 and did not differ significantly compared to the overall patient collective.

DISCUSSION

Humeral head fractures are often difficult to reduce, difficult to fixate and have a high risk of secondary loss of reduction. Reduction methods are indirect or direct, independent of the approach (21). The importance of anatomical reduction for other fractures is well known and well analyzed (1). In distal radial fractures defined anatomic angles for reduction control exist for quite a long time (13). For proximal humeral fractures such anatomic angles have not been commonly defined, and the necessary thresholds for successful reduction are still not absolutely clear. Based on the belief that the humeroscapular compensation is more important in the case of proximal humeral fractures, the adequate reduction of proximal humerus fractures has not been defined in the literature. This

probably resulted also from difficulties in retention of the reduction. While some authors advocate absolute anatomical reduction for the achievement of good postoperative outcome (4, 6), others suggest that a residual deformity might be acceptable (8, 20). In the present study fracture severity affected the functional outcome to a certain extent, as evaluated with CS. The 4-part fractures resulted in inferior postoperative outcome. These results were comparable to those reported in the literature (12, 16). The quality of reduction also affected the postoperative outcome. Especially the AP reduction seemed to play a more important role in the postoperative function than TL reduction. However, only after > 20° malreduction was this difference statistically significant. The worst results in CS were shown, as expected, in the group with malreduction in both planes; even a 15°malreduction resulted in statistically significant difference. It was interesting to see that the present study confirmed the notion that increasing malreduction results in worse CS and therefore worse functional outcome. The limit of malreduction is different for the two planes, lower in AP than in TL. The importance of AP reduction could be due to achievement of better ROM in the frontal plane, most probably because of better levers on the tuberosities. However, an absolute anatomical reduction must not be achieved at all costs. The overall good results of the fractures in this study despite absence of anatomical reduction could partly result from the limited surgical approach.

There has been much discussion about the risk of avascular necrosis (AVN) of the humeral head, as well as, of the soft-tissue damage caused by wide devastation due to extended surgical approaches (10). As PHN is minimally invasively inserted through a delta-split approach, it theoretically protects the vascular humeral head supply and lowers the risk of AVN. There was one observed case of AVN in our collective. Interestingly, this AVN occurred in a severely dislocated 2-part fracture of the anatomical neck and probably resulted from the fracture site and fragment displacement. The rate of AVN was in accordance with the literature (9, 23). Furthermore, the good biomechanical characteristics of PHN and the stable fracture fixation permit short immobilization and earlier rehabilitation in order to avoid shoulder stiffness. It has been shown that no significant difference in the biomechanical behavior between intramedullary nailing and locked-plate fixation in means of several biomechanical parameters exist (11).

On the contrary, disadvantages also exist. The incision of the supraspinatus tendon can cause rotator cuff pathology. Most of the subacromial pathology, i.e. impingement and rotator cuff pathology in the present study was associated with implant malposition, either by a primary malposition or by secondary nail migration. Although the approach is through the rotator cuff, we observed only 4 cases of rotator cuff pathologies, in the present collective. Additionally, the subchondral nail placement bears the risk of intra-articular protrusion and can lead to impingement, pain, and extensive arthritis. Even in the case of state-of-the-art nail placement the risk of implant migration is a well-known problem of PHN, and almost of every other implant used in the humeral head. The effort is to place the nail and the screws as close as possible to the subchondral bone, as the best bone stock in osteoporotic humeral heads lies here. Due to the spheric shape of the humeral head and the 2-dimensional intraoperative fluoroscopic view, this can result in a primary intra-articular malposition. In order to overcome this major problem, the intraoperative fluoroscopic control of the nail in multiple planes is of outmost importance. Motion at the fracture site in the postoperative phase can lead to screw migration towards or outwards the joint and cause secondary intra-articular malposition.

Additionally, poor bone stock, which tends to collapse, can lead primary well-placed nail and screws to protrude the joint without implant migration. These facts decrease the good fixation possibilities in the head. This problem was addressed by a peek inlay in the nail to increase friction between the implant and hinder its migration in the newer generation of these implants. Those complications occurred in our collective too. Intra-articular isolated screws have to be removed as soon as possible, whereas nail removal should only be performed, when the fracture is safely healed. These operations can

Table 2. Constant Score, anteversion and abduction of the shoulder and the NSA of the healed proximal humerus fractures at follow-up visit. NSA of the control group: 50 proximal humeri without fracture

Group	Constant Score	Anteversion	Abduction	NSA in TL	NSA in AP
all	74.8 ± 19.3	119.1° ± 42.2°	116.8° ±41.4°	137.4° ± 15.4°	126.5° ± 16.9°
2-part (n = 10)	74.6 ± 23.4	115.5° ± 55.8°	116.0° ± 52.0°	138.8° ± 13.9°	130.8° ± 21.2°
3-part (n = 23)	78.3 ± 17.0	128.1° ± 34.3°	123.2° ± 36.6°	135.7° ± 14.2°	128.4° ± 14.3°
4-part (n = 10)	67.2 ± 19.8	102.0° ± 42.1°	103.0° ± 41.3°	140.5° ± 21.0°	117.9° ± 16.7°
Control (n = 50)	-	-	-	133.7° ± 12.8°	134.1° ± 7.1°

Table 3. Complications of all treated fractures

Complications	2-part	3-part	4-part
Non union	2	0	0
Infection	0	1	0
Implant associated (intraarticularmalpostion, pain, shoulder stiffness)	1	6	2
Avascular necrosis	1	0	0
All	n = 13 (30.2%)		

be combined with intraoperative shoulder mobilization. Overall, no early arthritis was found in the present population in the follow-up period.

Another reported risk, which is associated with the use of intramedullary nailing, is the injury of the axillary nerve during guided locking (19). Despite the fact that PHN has been found to be a relatively low-risk implant (18), this risk is higher if a second proximal locking screw is used. No injury of the axillary nerve was observed in our study. The overall complication rate of 30.2% in our study is higher compared to the literature (26). However, more than half of them were minor complications that were successfully addressed with implant removal. The complication rates reported in the literature do not always refer to minor complications, such as pain or minimal shoulder stiffness. The problem of standing implants still exists in the case of PHN and newer designs for better subchondral positioning of the nail in the humeral head are needed.

CONCLUSIONS

Conclusively, the results of this study suggest that the majority of the patients treated with closed reduction and internal fixation with PHN show good postoperative functional results. However, fracture malreduction cannot be always avoided with the use of PHN. Nevertheless, the evaluation of the Constant-Murley score shows an absolute anatomical reduction in not necessary for satisfying functional oucome. The reduction in AP seems to play a more important role in the postsurgical functional outcome. A malreduction that exceeds 15° in both planes or a malreduction of more than 20° in either plane should be avoided.

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