https://doi.org/10.5272/jimab.2021274.4072

Journal of IMAB
ISSN: 1312-773X
https://www.journal-imab-bg.org

Journal of IMAB - *Annual Proceeding (Scientific Papers)*. 2021 Oct-Dec;27(4)

Original article

RISK FACTORS FOR HUMERAL HEAD OSTEONECROSIS IN PATIENTS WITH PROXIMAL HUMERAL FRACTURES TREATED OPERATIVELY

Konstantin Totev[1], Georgi Dimitrov[1], Lyubomira Toteva[2], Svilen Todorov[1], Steliyan Lungarov[1]
1) *Department of orthopaedics and traumatology, Faculty of Medicine, Medical University - Pleven, Bulgaria.*
2) *Department of physical medicine, rehabilitation, ergotherapy and sport, Faculty of Public health, Medical University - Pleven, Bulgaria.*

ABSTRACT

Proximal humerus presents the second most frequent site of posttraumatic osteonecrosis. This complication is usually related to poor functional outcomes. The aim of this study is to identify and analyze the risk factors for posttraumatic humeral head osteonecrosis in surgically treated patients.

Ninety-one patients with 92 acute proximal humeral fractures were operated on for a period of 39 months. Operative methods include open reduction and internal fixation and closed reduction and percutaneous fixation. Fractures were classified according to Neer, AO and LEGO classifications. The mean age of patients was 60.9 years. From 91 operated patients for follow-up were available 82. The mean follow-up period was 15 months. Patient data was collected prospectively.

Functional results are present using age and gender adjusted Constant score. In 41 patients, the result is excellent, in 28-good, in 11-fair and in 3 poor.

Bone union was evident in all cases. No deep wound infections, nerve injuries, vascular injuries and implant failure were observed.

Osteonecrosis was seen in 5 (6.1%) patients. Patients with posttraumatic osteonecrosis had significant lower Constant results.

Analyzing the pre- and intraoperative factors in patients with osteonecrosis, we find that the most significant factors for this complication are increasing fracture severity and à combination of short medial metaphyseal extension and disrupted medial hinge.

Keywords: proximal humerus fracture, osteonecrosis, risk factors

INTRODUCTION.

Proximal humeral fractures (PHF) present about 5% of all fractures [1]. Their number is increasing nowadays, and they are about to triple by the year 2030 [2]. The severity of PHF is also increasing. In 1970 nondisplaced fractures present about 85% of all PHF [3]. In 2001 they present about 49% [1], and in 2009 nondisplaced fractures are only 36% [4]. This tendency is due to changing demographics and to more precise diagnostics. The number of patients with PHF treated by operative means is also increasing [2]. The reasons for this tendency are increased patients' expectations [5], development of surgical techniques and technologies and enhanced knowledge of predicting risk factors.

Treatment of displaced proximal humeral fractures still remains a challenge for orthopedic surgeons, and there is no widely accepted strategy for treating them. Blood supply of proximal humerus and its fracture related disruption are amongst the most important factors for treatment choice. Posttraumatic osteonecrosis of the humeral head is a relatively rare but disabling complication.

MATERIAL AND METHODS.

Ninety-one patients with 92 acute PHF were operated on at our department between November 2009 and December 2012. The mean age of patients at the time of surgery was 60.9 years (15-86). Seventy-four patients were female, and eighteen were male. The dominant extremity was affected in 38%. The mechanism of injury was defined as low energy in 90% (n=83) and high energy in 10% (n=9).

The diagnosis was based on true AP and lateral Y views. The axillary view was performed only in patients who were able to passively abduct the shoulder up to 40°. CT scan with 3D reconstruction was additionally made when X-ray data for fracture pattern was insufficient. Fractures were classified according to Neer, AO and LEGO with additional ischemia criteria [6] classifications. Our series includes 53 two-part, 24 three-part, 7 four-part fractures and 8 fracture-dislocations. Distribution according to AO classification was as follows: 32 type A, 50 type B and 10 type C fractures.

Indications for operative treatment were: varus dislocation > 20°, valgus dislocation >40°, head-shaft translation > 50%, great tuberosity displacement > 5 mm and all cases with medial comminution and fracture-dislocations.

Demographic data, co-morbidities and diagnostic radiographic measurements (preoperative head-shaft angle, combined cortical thickness and medial comminution) were collected for all patients. The average time from trauma to surgery was 1.6 days (0-12). Percutaneous fixation according to Jaberg technique was used in 27 patients, internal fixation with conventional plates in 9 patients, locking plates in 52 patients and screw fixation in 4 patients. The anterolateral deltoid splitting approach was used in 35 patients with open reduction and internal fixation (ORIF), and deltopectoral approach in 30 patients with ORIF. Bone grafting was performed in 5 (5.5%) patients.

In all cases at the end of the operation, fluoroscopy was used to assess fracture stability. In ORIF cases, the AP view was performed in neutral, maximal internal and external rotations to access the length of proximal locking screws and also another AP view in abduction to access the position of the implant in subacromial space. The wound was closed over a suction drain, which was removed the next day.

Postoperatively the arm was supported in a sling. Postoperative immobilization was from two to four weeks, depending on fracture type and achieved stability. Passive motions were allowed two weeks after surgery, active motions started five weeks after surgery.

The type of implant used, the state of the medial column, the state of the rotator cuff (when anterolateral approach used) and additional suture augmentation were collected from the operative report. Postoperatively the head-shaft angle, retroversion, the distance between the tip of the greater tuberosity (GT) and the proximal end of the plate, and the distance between the tip of the GT and the superior border of the articular surface (GT height) were measured.

Scheduled follow-up controls were performed at 1, 3, 6, 12 and 18 months. At every visit was performed X-ray examination and was accessed the functional outcome according to the Constant scale. Fracture healing was considered when fracture lines were missing, and cortico spongious bridging between the fragments was evident on X-rays. Radiographs were also assessed for signs of humeral head osteonecrosis, for implant position, for subacromial impingement and for glenohumeral osteoarthritis. Development of any complication was documented if indicated. The average follow-up was 15 months.

Statistical analyses were performed using SPSS software (SPSS, Chicago, Illinois). Statistical signiûcance was set at $p<0.05$.

RESULTS.

Constant score (CS) was calculated as age and gender adjusted results. Mean Constant scores are shown in Table 1. CS of the the injured shoulder was mean 83.9% (41%-99%) of CS of contralateral shoulder. The mean postoperative head-shaft angle was 134.6° (113° to 164°). The mean postoperative retroversion was 22.5° (-3° to 41°), mean GT height – 5.8 mm (0 to 12), mean distance plate – GT – 6.3 mm (0 to 13).

Table 1. Mean Constant score – age and gender adjusted results according to fracture type for followed-up patients

Adjusted Constant score	**All**	**Two-part**	**Three-part**	**Four-part**	**Fracture-dislocation**
	n= 82	n=48	n=22	n=7	n=5
3 months	*52*	*54 (33-81)*	*49 (30-72)*	*43 (30-59)*	*58 (44-66)*
6 months	*72*	*75 (36-95)*	*68 (40-96)*	*59 (46-80)*	*83 (75-94)*
12 months	*83*	*85 (39-100)*	*80 (58-100)*	*66 (49-81)*	*90 (82-100)*

The postoperative state of the medial column was as follows: without medial buttress – 26 patients, with medial buttress 59 patients (sixteen of them are with anatomical reduction).

Using the t-test to compare the final CS results we identify the following factors that significant influence the final results: age ($p=0.021$), co-morbidities ($p=0.008$), cortical thickness ($p=0.006$), postoperative medial buttress ($p=0.009$), GT height ($p=0.000$), fracture type in Neer ($p=0.043$) and AO classifications ($p=0.049$).

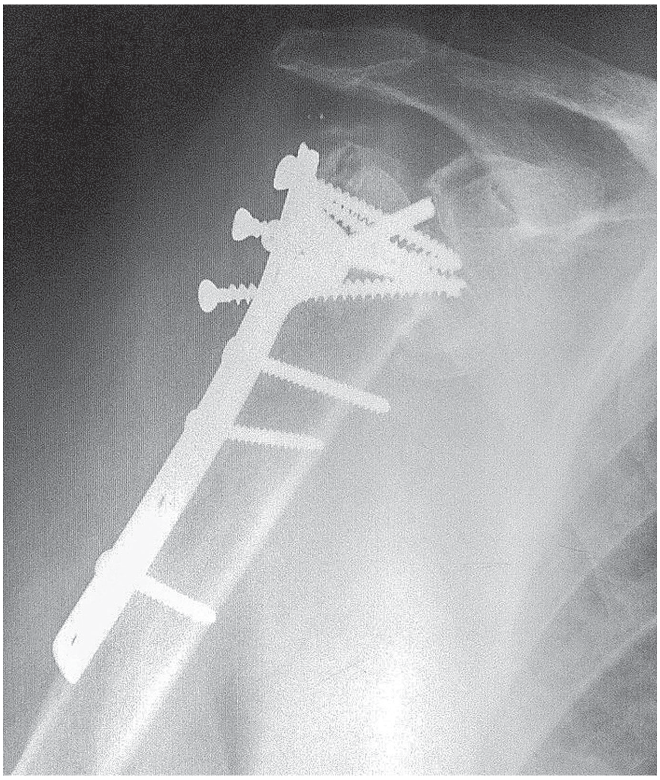
We did not have cases with nonunion. No deep wound infections, nerve injuries, vascular injuries and implant failure were observed.

COMPLICATIONS.

Complications were diagnosed in 38 patients. In 12 patients, only one complication was diagnosed, and in 26, more than one.

Osteonecrosis was evident in 5 (6.1%) patients. In four patients, osteonecrosis involved partially humeral head and, in one case, the whole head (Fig. 1). All cases with osteonecrosis were treated by ORIF. In all cases, the diagnosis was made before the first postoperative year. In three of the patients, osteonecrosis was followed by stiffness of the shoulder. The mean age of patients with osteonecrosis was 61.6 years. There was no correlation between patients' age and osteonecrosis of the humeral head ($p=0.159$). Medial comminution, as a potential factor for damage of posterior humeral circumflex artery, did not influence the development of osteonecrosis ($p=0.247$).

Fig. 1. Patient with total osteonecrosis 9 months postoperatively



Osteoarthritis was seen in 10 patients. The mean age of patients with osteoarthritis was 79.2 years. There was a strong correlation between osteoarthritis and age (p=0.004). Posttraumatic osteoarthritis is not a usual complication after proximal humerus fractures and is rarely included in follow-up criteria. Possible reasons for this are relatively favorable clinical presentation and a short follow-up period. Patients with posttraumatic osteoarthritis in our study had significant (p=0.006) lower Constant results than those without this complication.

Postoperative stiffness was diagnosed in 13 cases. Patients with stiffness had mean CS 65.4, whereas without stiffness – mean 90.3 (p=0.000). Stiffness usually was a consequence of another complication: in 2 cases after osteonecrosis; in 4 – after varus malunion; in 3 – after osteoarthritis; in 2 – after implant related subacromial impingement and only in two cases without any known reason. We could not found a relationship between fracture type and postoperative stiffness (Neer p=0.423, AO p=0.143).

Subacromial impingement was diagnosed when there was a coincidence between radiographic view and clinical symptoms. This complication was seen in 14 patients. In 2 cases, it was a result of too far cranial plate positioning, in 9 cases – of malreduction of GT and in 3 cases a combination of both factors. As a result of subacromial impingement was observed mainly decreased shoulder motion: flexion (p=0.016), abduction (p=0.002), external rotation (p=0.007) and internal rotation (p=0.001). Differences in pain were not significant (p=0.806) between patients with and without subacromial impingement. Mean CS in patients with subacromial impingement was 74.3 and in patients without this complication – 85.5 (p=0.003).

Varus malunion was accepted when bone union with head-shaft angle <120° was evident. This complication was seen in 15 patients. There was a strong correlation between the medial buttress and varus malunion (p=0.005). In 12 (80%) of patients with varus malunion, the medial buttress was missing. There was also a strong correlation between medial comminution and varus malunion (p=0.005). Preoperative head-shaft angle did not influence varus malunion (p=0.072). In 42.8% of patients with varus malunion, varus angulation was seen immediately after the surgery, and in the other 57.2% is a result of varus collapse as a result of fracture instability. Patients with varus malunion had a mean CS 73.4, whereas without this complication – 90.3 (p=0.002).

Intraarticular implant penetration was evident in 14 cases. In 7 patients, there was K-wire penetration because of lack of stability and decreased bone density; in three patients, screw penetration was a sequel of osteonecrosis, in two patients – of varus malunion, and in two patients, the reason was an intraoperative technical mistake.

In total, 31 of 91 patients had second intervention within twelve months after the initial operation: 27 for routine K-wire extraction, one for extraction of the intraarticular screw and three for extraction of plate and screws after the bone union because of subacromial impingement.

DISCUSSION.

Proximal humeral fractures, regardless of the type of treatment, are the second most frequent site of osteonecrosis, second only to the hip [7]. The ratio of posttraumatic osteonecrosis in different studies is between 3% and 37% [8]. Understanding risk factors for humeral head osteonecrosis is related to three groups of facts:

1. Establishing the role of anterior and posterior circumflex humeral arteries in relation to humeral head vitality.

2. Detecting of predictive X-ray signs for humeral head osteonecrosis.

3. Establishing the possibility for humeral head revascularisation using sparing surgical technique, anatomical reduction and stable fixation.

Widely accepted in the past statement that the main blood supply of the humeral head comes from the anterior circumflex humeral artery (ACHA) has nowadays changed. ACHA is disrupted in most fracture patterns, and the posterior circumflex humeral artery (PCHA) is intact in 85% of cases. Quantity analysis of Hettrich [9] proves that 64% of the humeral head is supplied from PCHA. The authors conclude that surgical dissection posteromedially should be avoided for preserving the blood supply of the humeral head. The most important anastomosis between two main arteries are located in deep layers of the posteromedial capsule, thus all fractures with medial extension proximal to medial joint capsule insertion are at increased risk for osteonecrosis. Intraoperative humeral head perfusion can be evaluated by bleeding after bone drilling [6].

Changing the philosophy about the dominant artery of the proximal humerus is related to the development of radiographic criteria presenting the state of PCHA indirectly. These criteria can be evaluated on plaine X-ray views and have different predictive values. R. Hertel [6], in 2004, modifying Codman's classification, creates prognostic classification concerning humeral head ischemia. The most significant negative risk factors are: metaphyseal extension 8mm medial hinge dislocation 2mm and type of articular fracture. All cases in our study with osteonecrosis were with a metaphyseal head extension below 8 mm, and three of the cases were with a disrupted medial hinge (>2mm). When considering an individually metaphyseal extension and medial hinge, they are not statistically significant for osteonecrosis, but in cases, with both risk factors, we find osteonecrosis in 15% of patients. Other studies [10] also underline the importance of both predicting factors, but the authors find that additional imaging of the calcar area is indicated. Evaluating the different risk factors, Hertel et al. identify specific risk fracture patterns [6]. In our study, all five cases with osteonecrosis are from risk groups, described by Hertel.

Fracture displacement in the frontal plane is another predictive sign for humeral head ischemia. Medial diaphyseal displacement is with increased risk in comparison with lateral displacement [6]. Periosteal rupture starts in a mean of 9mm medial diaphyseal translation and in mean 6 mm. of lateral translation [11].

Humeral head dislocation is not related to an increased risk of ischemia [6]. Despite the small number of patients with fracture-dislocation in our study, there is no osteonecrosis in these patients.

Some studies find a strong correlation between fracture type and osteonecrosis ratio [12]. This complication is relatively rare in 3-part fractures, humeral head involvement is partial with minimal clinical signs, as opposed to 4-part fractures, where osteonecrosis is total with significant clinical presentation. The ratio of osteonecrosis after ORIF of 3-part fractures varies from 0% to 11 % and in 4-part fractures varies from 0% to 20 % [13]. Fracture type was a significant predictor for osteonecrosis in our study. We found a statistically significant relationship between fracture type and bone necrosis. In Neer classification, all fractures were four-part ($p=0.000$); in LEGO classification, two fractures were typed 2 and two were type 12 ($p=0.000$) and in AO classification three fractures were C3 and one was C2 ($p=0.000$).

Intraoperative factors have significant importance for osteonecrosis. They are the only factors that can be modified by the surgeon. Procedures using closed reduction are less invasive, but it is more difficult to achieve good reconstruction. On the other side, open techniques are more likely to obtain anatomical reduction and stronger fixation, but they have a higher risk of osteonecrosis of the humeral head because of soft tissue dissection and because of the fact that more severe cases are treated operatively. Sturzenegger [14] finds that osteonecrosis after ORIF is five times higher than in percutaneous techniques.

One factor related to posttraumatic osteonecrosis is the surgical approach. Historically, the deltopectoral approach (DPA) has been used for fracture fixation. Another approach for proximal humerus fixation is the anterolateral approach (ALA), which, in our opinion, has a few benefits. Using DPA is related to an increased risk of lesion of ACHA [15] and PCHA [16] during its passing through quadrilateral space. Other benefits of ALA are the better visualization of fracture site [17], easier reduction of the greater tuberosity and easier angular plate fixation because of the same plane of screw positioning and surgical approach.

Ischemia is not related to osteonecrosis in cases with stable fixation [18] because of possible revascularisation. There are different strategies for increasing construct stability. These are using intramedullar fibular grafts and infromedial calcar screws [19]. In our study, the medial buttress is the only factor, which could be modified by the surgeon that statistically significant influences the final results.

Considerable question is if osteonecrosis is clinically significant. Gerber [20], following 25 patients with osteonecrosis after proximal humeral fracture for a mean of 7.5 years, found a mean CS of 46. On the other side, some authors reported a small number of patients with osteonecrosis and good functional results. Nowadays, most of the authors agree that posttraumatic osteonecrosis is related to poor functional results [21]. In our study, we found a significant difference in final results ($p=0.002$ t-test) between patients with osteonecrosis and those without this complication. Except for the pain, another reason for poor results was shoulder stiffness, seen in 3 (75%) of patients with osteonecrosis.

CONCLUSION

Posttraumatic osteonecrosis of the humeral head in our study was seen in 6.1% of patients, which is lower than the 10% ratio published in a systematic review by Sproul [22]. A possible reason is that in cases with anatomic reduction and stable fixation, revascularization and bone reparation are possible. Another reason is relatively short follow-up. Of evaluated different risk factors, more significant are fracture severity and radiographic signs for humeral head ischemia. The value of some risk factors can not be estimated, thus longer follow-up studies with a greater population with osteonecrosis are needed to analyze possible risk factors for humeral head necrosis.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of the article. The authors state that there are no conflicts of interest.

REFERENCES:

1. Court-Brown CM, Garg A, McQueen MM. The epidemiology of proximal humeral fractures. *Acta Orthop Scand.* 2001 Aug; 72(4):365-371. [PubMed]
2. Palvanen M, Kannus P, Niemi S, Parkkari J. Update in the epidemiology of proximal humeral fractures. *Clin Orthop Relat Res.* 2006 Jan;442:87-92. [PubMed]
3. Neer CS 2nd. Displaced proximal humeral fractures. I. Classification and evaluation. *J Bone Joint Surg Am.* 1970 Sep;52(6):1077-89. [PubMed]
4. Tamai K, Ishige N, Kuroda S, Ohno W, Itoh H, Hashiguchi H, et al. Four-segment classification of proximal humeral fractures revisited: A multicenter study on 509 cases. *J Shoulder Elbow Surg*. 2009 Nov-Dec; 18(6):845-50. [PubMed]
5. Robinson CM, Stirling PH, Goudie EB, MacDonald DJ, Strelzow JA. Complications and long-term outcomes of open reduction and plate fixation of proximal humeral fractures. *J Bone Joint Surg Am.* 2019 Dec 4;101(23):2129-2139. [PubMed]
6. Hertel R, Hempfing A, Stiehler M, Leunig M. Predictors of humeral head ischemia after intracapsular fracture of the proximal humerus. *J Shoulder Elbow Surg*. 2004 Jul-Aug;13(4): 427-33. [PubMed]
7. Large TM, Adams MR, Loeffler BJ, Gardner MJ. Posttraumatic Avascular Necrosis After Proximal Femur, Proximal Humerus, Talar Neck, and Scaphoid Fractures. *J Am Acad Orthop Surg*. 2019 Nov 1;27(21):794-805. [PubMed]
8. Patel S, Colaco HB, Elvey ME, Lee MH. Post-traumatic osteonecrosis of the proximal humerus. Injury. 2015 Oct;46(10):1878-84. [PubMed]
9. Hettrich CM, Boraiah S, Dyke JP, Neviaser A, Helfet DL, Lorich DG. Quantitative assessment of the vascularity of the proximal part of the humerus. *J Bone Joint Surg Am.* 2010 Apr;92(4):943-8. [PubMed]
10. Campochiaro G, Rebuzzi M, Baudi P, Catani F. Complex proximal humerus fractures: Hertel's criteria reliability to predict head necrosis *Musculoskelet Surg*. 2015 Sep;99 Suppl 1:S9-15. [PubMed]
11. Resch H, Aschauer E, Povacz P, Ritter E. Closed Reduction and Fixation of Articular Fractures of the Humeral Head. *Techniques in Shoulder &Elbow Surgery.* 2000 Sep; 1(3):154-162.
12. Beeres FJP, Hallensleben NDL, Rhemrev SJ, Goslings JC, Oehme F, Meylaerts SAG, et al. Plate fixation of the proximal humerus: an international multicentre comparative study of postoperative complications. *Arch Orthop Trauma Surg.* 2017 Dec;137(12):1685-1692. [PubMed]
13. Court-Brown C, McQueen M, Tornetta P. Trauma (Orthopaedic Surgery Essentials Series) 1st Edition. Lippincott Williams & Wilkins. January 1, 2006. p.99 [Internet]
14. Sturzenegger M, Fornado E, Jacob R. Results of surgical treatment of multifragmented fractures of the humeral head. *Arch Orthop Trauma Surg.* 1982; 100 (4):249-259. [PubMed]
15. Gardner MJ, Griffith MH, Dines JS, Briggs SM, Weiland AJ, Lorich DG. The extended anterolateral acromial approach allows minimally invasive access to the proximal humerus. *Clin Orthop Relat Res.* 2005 May;434:123-9. [PubMed]
16. Frankle MA, Greenwald DP, Markee BA, Ondrovic LE, Lee WE 3rd. Biomechanical effects of malposition of tuberosity fragments on the humeral prosthetic reconstruction for four-part proximal humerus fractures. *J Shoulder Elbow Surg.* 2001 Jul-Aug;10(4): 321-6. [PubMed]
17. Dimitrov G, Totev K, Simeonov M, Ivanov I, Asparouhov A. Anterolateral approach to the proxilal humerus. *Ortop Trauma* 2011; 3(48):104-110
18. Bastian JD, Hertel R. Initial postfracture humeral head ischemia does not predict development of necrosis. *J Shoulder Elbow Surg*. 2008 Jan-Feb;17(1):2-8. [PubMed]
19. Padegimas EM, Zmistowski B, Lawrence C, Palmquist A, Nicholson TA, Namdari S. Defining optimal calcar screw positioning in proximal humerus fracture fixation. *J Shoulder Elbow Surg*. 2017 Nov;26(11):1931-7. [PubMed]
20. Gerber C, Lambert SM, Hoogewoud HM. Absence of avascular necrosis of the humeral head after posttraumatic rupture of the anterior and posterior humeral circumûex arteries. A case report. *J Bone Joint Surg.* 1996 Aug;78(8):1256-9. [PubMed]
21. Belayneh R, Lott A, Haglin J, Konda S, Zuckerman JD, Egol KA. Osteonecrosis after surgically repaired proximal humerus fractures is a predictor of poor outcomes. *J Orthop Trauma.* 2018 Oct;32(10):e387-e393. [PubMed]
22. Sproul RC, Iyengar JI, Devcic Z, Feeley BT. A systematic review of locking plate fixation of proximal humerus fractures. *Injury.* 2011 Apr;42(4):408-13. [PubMed]

Please cite this article as: Totev K, Dimitrov G, Toteva L, Todorov S, Lungarov S. Risk factors for humeral head osteonecrosis in patients with proximal humeral fractures treated operatively. *J of IMAB.* 2021 Oct-Dec;27(4):4072-4076. DOI: https://doi.org/10.5272/jimab.2021274.4072

Received: 26/03/2021; Published online: 28/10/2021

Address for correspondence:
Konstantin Totev, MD, PhD
Department of orthopaedics and traumatology, Faculty of Medicine, Medical University, Pleven, Bulgaria
89, Ruse Blv., Pleven 5800, Bulgaria
E-mail: kztotev@abv.bg