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Surgical Treatment of Humeral Fracture-Dislocations: Mid-Term Results

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Abstract

Background. Fracture-dislocation of the proximal humerus is a severe injury that equally affects both young and old people. Such injuries are often accompanied by the high risk of neurocirculatory and other complications, which defines their great medical and social importance. ***The purposes of this study*** were: 1) to compare the mid-term results of the surgical treatment of the patients with dislocation-fractures of the proximal humerus when they were managed according to the standard algorithm or the new one developed by the authors of this study; 2) to evaluate the effectiveness of the proposed protocol in relation to the patients with neurological complications in order to elaborate a universal approach to the optimal treatment tactics. ***Patients and Methods.*** The treatment results of 73 patients with proximal humerus fracture-dislocation undergone the surgery from 2012 to 2018. The patients were divided into 2 groups, which were managed according to the traditional (control group) or the new algorithms (main group), differing in the time of the surgery, a set of diagnostic methods, and an approach to the prevention and treatment of complications. The patients' examination included taking patients' anamnesis, their physical examination, X-rays and multispiral computed tomography of the injured shoulder, electromyoneurography, ultrasound of the upper limb blood vessels, patients' questioning. ***Results.*** A year after the surgery, a statistically significant difference in the functional results was revealed in the patients of the main and control groups by the Constant Shoulder Score (p = 0.0063). In the control group, there was a statistically significant difference of the functional results by Constant Shoulder Score between the patients with and without neurological complications (p = 0.003). There was no statistically significant difference among such patients in the main group (p = 0.387). ***Conclusion.*** The main group patients, including those with neurological complications, achieved higher functional results in comparison with the control group. Thus, the authors' treatment algorithm showed its effectiveness. The surgery within 6 hours from the moment of admission of the patients with humerus fracture-dislocation, as well as the earliest possible diagnosis of neurological injury and treatment of complications significantly improved the prognosis and outcome the main group patients.

Keywords: fracture-dislocation of the humerus, plate osteosynthesis, neurological complications.

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Introduction

Proximal humerus fractures (PHF) are the second most frequent among all upper limb fractures, and in patients over 65 years old this pathology is ranked third place after femoral neck and distal radius fractures [1]. Among such injuries, the most severe are humerus fracture-dislocations[2]. Their frequency ranges from 2.6 to 14.5% among all proximal humerus injuries, also from 35.0 to 58.3% of fracture-dislocations of all localizations [3]. The vast majority of cases are anterior fracture-dislocations. Humerus head posterior dislocation – rare pathology occurring in 0.9% of cases [4].

The most common causes of this pathology are high-energy trauma (catatrauma, road accident and others) among young people and low-energy trauma among the elderly [5, 6]. Also, such injuries can be the result of electrical injury or epileptic seizure [7, 8].

As a rule, the Neer classification is used for PHF [9], based on the identification of four basic segments (head, greater and lesser tubercles, and humerus diaphysis) and their displacement. The classification is supplemented by fracture-dislocations and head splitting [10]. Criteria that determine the displacement: space between fragments is more than 1 cm and the angle is more than 45°. According to this classification, fracture-dislocations are referred to the sixth type of PHF and divided into anterior and posterior [9]. The most common are anterior two-fragment fracture-dislocations with avulsion of the greater tubercle, two-fragment fracture-dislocations with avulsion of the lesser tubercle are rare and result from posterior shoulder dislocation [10].

Often, associated injuries occur with proximal humerus (PH) fracture-dislocations, such as rotator cuff, nerves and blood vessels injuries, mainly the axillary artery or vein. They start at the time of injury or due to displacement of fragments and dislocation of the humerus with ongoing trauma to soft tissues and neurovascular structures. The injuries severity depends on the patient age , the injury energy, the fracture pattern and the time before fragments reduction [11]. So, according to various authors, the incidence of neurological injuries in fracture-dislocations ranges from 2 to 48% [11, 12]. However, this complication true prevalence is unknown due to the difficulty of early diagnosing [13].

After the closed dislocation reduction, provided a satisfactory stable fragments reduction, two-fragment fractures are successfully treated conservatively. In other cases, surgical treatment is necessary [14].

Conservative treatment of PH unstable multifragmental fractures and fracture- dislocations in the most cases leads to unsatisfactory results. Such injuries require open reduction and stable fixation [15, 16]. However, the exact indications for use one or another osteosynthesis method or shoulder replacement have not been determined and actively discussed in the literature [17].

Thus, despite the wide variety of treatment methods for patients with PH fracture-dislocations, there is no unified algorithm for patients examination and treatment. In Russian-language literature, there is not enough information on the effectiveness of patients with neurological injuries treatment, compared in large patients groups. Also there is no generally accepted criteria for the treatment methods choice.

Objectives of the study: 1) to compare the mid-term results of patients with PH fracture-dislocations surgical treatment managed according to standard algorithm or new algorithm developed by the authors of the study; 2) to evaluate the effectiveness of the proposed protocol in relation to patients with neurological complications in order to develop a universal approach to the treatment tactics choice.

Materials and Methods

Study design

A prospective two-center controlled non-randomized study of patients with PH frac-

ture-dislocation, underwent surgical treatment in the period from 2012 to 2018 at GKB No. 1 named after N.I. Pirogov and Podolsk City Clinical Hospital was evaluated. The duration of the study was 7 years - 2012–2019, including the follow-up period for patients who were injured in 2018. The follow-up period for patients in both groups was from one to seven years (on average, 3.3 ± 2.1 years). The minimal observation period was 12 months; the results of later observations were not included in this study. The dynamics of the function of the injured upper limb restoration with the performance of control radiographs and physical examination was monitored in all patients included in the study after 1, 3, 6 and 12 months after surgery.

The patients

The study included 73 patients - 42 (57.5%) men and 31 (42.5%) women - aged from 27 to 79 years. The inclusion criteria were patients over 18 years old with isolated closed two-, three- and four-fragment anterior fracture-dislocations with or without neurological injuries. The exclusion criteria were severe comorbidities and polytrauma, as well as the presence of posterior shoulder dislocation, closed dislocation reduction, and displacement of bone fragments less than 5 mm.

36 patients (49.3%) were injured as a result of high-energy trauma, 35 (47.9%) - low-energy trauma, and 2 (2.7%) - during an epileptic seizure. The distribution of patients by the type of PH fracture-dislocations according to the Neer classification is as follows: two-fragment - 21 (28.8%), three-fragment - 45 (61.6%), four-fragment - 7 (9.6%).

The material for the study was anamnestic data (complaints, mechanism of injury) and the results of studies: X-ray, CT, ENMG, vascular ultrasound, as well as questionnaire data. The patients were divided into two groups depending on the time period and were treated according to one of two algorithms (Table 1).

The main group included 41 (56.2%) patients treated in the period 2015–2018, aged from 27 to 77 years (average age - 53.78 ± 11.87 years). Among the patients, men predominated (23/41; 56.1%) up to 60 years old (25/41; 61%) with a peak at the age of 45–59 years (15/41; 37%). 20 (48.8%) patients were injuried as a result of high-energy trauma, 20 (48.8%) as a result of low-energy trauma, as a result of an epileptic seizure - 1 (2.4%). Surgical treatment was performed within 6 hours from the patient admission to the hospital. The hospitalization period ranged from 8 to 37 bed-days (on average, 12.37 ± 5.06 bed-days). By the type of fracture-dislocations, 11 (26.8%) patients were classified as two-fragment, 25 (61.0%)three-fragment, 5 (12.2%) four-fragment.

Table 1

Standard and new algorithms comparison

	Standard algorithm	New algorithm
X-ray in two projections	+	+
Closed dislocation reduction	–	–
CT	+/-	+
Surgical treatment: open reduction, locking plate fragments fixation	Delayed	Emergency (<6 h after accident)
Upper limb immobilization	Abduction splint/sling 3–4 weeks postoperatively	Abduction splint/sling 3–4 weeks postoperatively
ENMG	In follow-up period (min — 1 year after surgery, max — 3 years after surgery)	21 day after surgery

Patients of the main group examination and treatment were carried out according to the following protocol developed by the authors: performing standard radiographs in at least two projections and CT scan of the injured shoulder joint for all patients; ultrasound of the vessels of the injured upper limb; surgical treatment (open reduction, osteosynthesis with a plate) in the first 6 hours after the patient admission to the clinic; ENMG performance 3 weeks after surgical treatment; neurologist consultation if neurological injury is detected.

The control group consisted of 32 (43.8%) patients aged 32 to 79 years (mean age 50.81 ± 13.02 years) who were treated in 2012–2014. Among the patients, there were also more men (19/32; 59.4%) under 60 years old (24/32; 75%) with an age peak of 45–59 years (13/32; 41%). 16 (50.0%) patients were injuried by high-energy trauma, 15 (46.9%) low-energy trauma, and an epileptic seizure was registered in 1 (3.1%) case. The length of hospitalization varied from 13 to 22 bed-days (on average, 15.28 ± 1.63 bed-days). The distribution by PH fracture-dislocations types is as follows: two-fragment - 10 (31.2%), three-fragment - 20 (62.5%), four-fragment - 2 (6.2%).

Control group patients were treated according to the standard algorithm, including standard radiographs of the injured shoulder joint in two projections (if they were not informative, CT was performed), delayed surgical treatment in 4-7 days after the accident (on average, 3.4 ± 2.3 after the accident).

During surgery, two (2/73, 2.7%; 2/32, 6.25%) patients in the control group had brachial artery injury with a humerus head bone fragment during the reduction. In both cases, a vascular surgeon urgently sutured the damaged artery. Further treatment of these patients continued according to the standard protocol with the correction of therapy according to the vascular surgeon recommendations.

Postoperative patient management

In the postoperative period, all patients were treated according to the standard AO* rehabilitation protocol, which included upper limb immobilization with a sling or in abduction splint for 3-4 weeks (if necessary) and early activation from the first day after surgery under the physician supervision. Started from passive and pendulum-like movements, gradually expanding them to independent active movements, and the full load on the injured upper limb was allowed only after fracture consolidation was achieved. The restoration of the injuried upper limb function dynamics with the performance of control radiographs and physical examination were monitored in all patients 1, 3, 6 and 12 months after the surgery. To assess the integrity of the nerve trunks, the patients of the main group underwent ENMG 21 days after the injury. Patients of the comparison group underwent ENMG later during their observation, on average, after 5.7±4.4 months after injury (min-3 weeks, max-3 years 2 months).

Results assessment

The main comparable indicator is the shoulder joint function according to the Constant Shoulder Score (CSS) [18]. It is a 100-point multi-parameter scale designed to assess functional status after treatment of shoulder injuries. It contains 4 subsections: pain syndrome (15 points), daily activity (20 points), muscle strength (25 points) and range of motion (40 points): lifting, abduction, external and internal rotation in the shoulder joint. The higher the score, the higher the function [19]. 12 months after the surgery, result was considered excellent over 90 points, good - 90–80 points, satisfactory - 79–70 points, and unsatisfactory - less than 69 points.

Publication ethics

The study complies with the ethical standards of the bioethical committee, devel-

* Proximal humerus. Available from: https://www2.aofoundation.org/wps/portal/.

oped in accordance with the Declaration of Helsinki of the World Medical Association "Ethical principles of scientific medical research with human participation" and "Rules of clinical practice in the Russian Federation", approved by the the Ministry of Health of the Russian Federation Order in June 19, 2003 No. 266. All patients gave informed consent to participate in the study.

Statistical analysis

Statistical processing of the results was carried out using the programs Excel 2013 (Microsoft, USA), Statistica 10 (StatSoft, USA, 2010) and JMP 11 (SAS, USA, 2014). For quantitative indicators, the results are presented as absolute indicators, arithmetic mean values (M) and standard deviations (σ); for qualitative - relative indicators, expressed as a percentage (%). The critical level of significance (α) was taken equal to 0.05. When confirming the normal distribution of values, the statistical significance of the differences between the groups was assessed using the parametric Student's test (t) for independent samples. The Shapiro - Wilk test was used to check the distributions for normality, as well as a visual analysis of histograms; the equality of variances was checked using the Levene`s test. Comparisons of the two groups with abnormal distribution were carried out on the basis of the nonparametric Mann-Whitney test.

The analysis of the indicators dynamics in case of comparing two periods was carried out on the basis of the nonparametric Wilcoxon test, in the case of comparing three or more periods - on the basis of the nonparametric Friedman test.

The statistical significance of various values for binary and nominal indicators was determined using the Pearson's chi-squared test.

Results

Assessment of functional results by CSS

All 73 patients underwent open reduction and osteosynthesis of the PHF with a locking plate.

The comparative assessment of the treatment functional results in main and control groups by CSS was made according to the patients examination in terms of 1, 3, 6 and 12 months after surgery (Fig. 1, Table 2).

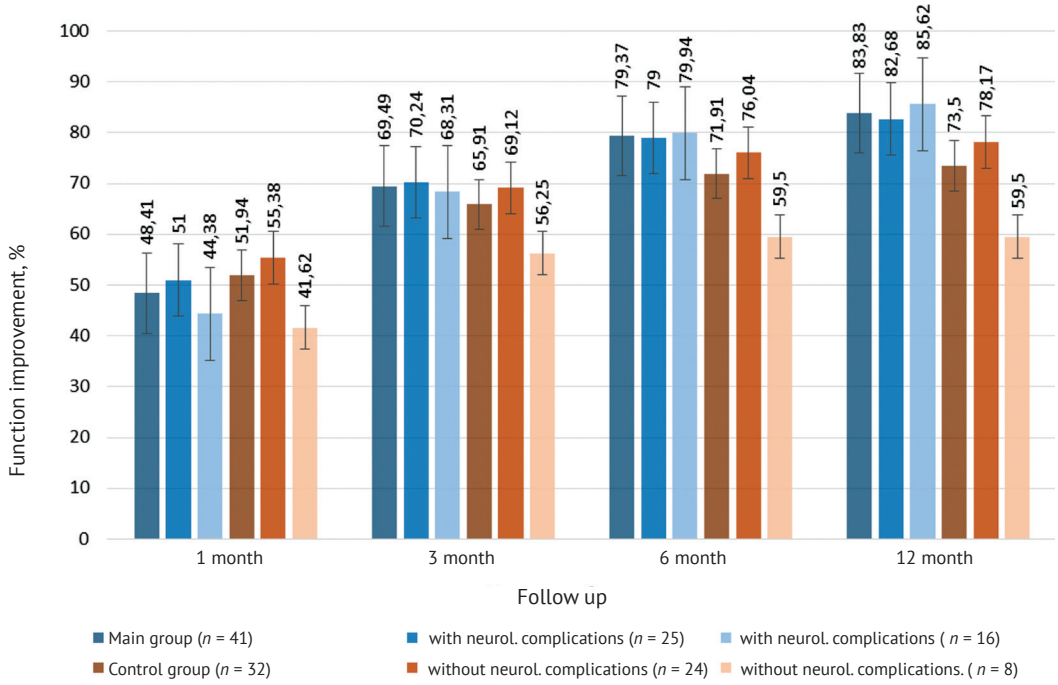

Figure 1. The functional state of the shoulder according to CSS in the patients of the both groups in 1, 3, 6 and 12 months after the treatment

Table 2

Assessment of shoulder joint function in all patients of both groups by CSS after 12 months

CSS score	Main group (M±σ = 83,83±11,26)		Control group (M±σ = 73,5±16,7)	
	absolute number (%)	average CSS score	absolute number (%)	average CSS scoreSS
Excellent	11 (26,8)	95,64±3,31	5 (15,6)	93,00±2,10
Good	17 (41,5)	84,74±3,29	12 (37,5)	82,64±1,37
Satisfactory	10 (24,4)	74,00±2,36	9 (28,1)	73,71±2,49
Unsatisfactory	3 (7,3)	53,50±13,50	6 (18,8)	51,33±12,09

Despite the lower CSS after 1 month in the main group, the further rate of recovery of the function of the shoulder joint, range of motion, and the increase in the CSS indicator were significantly higher in patients who were treated according to our proposed algorithm. So, after 12 months after surgery, a statistically significant difference has been identified in terms of flexion and abduction (p = 0.0194 and p = 0.0215, respectively), the average CSS score (p = 0.0063), and the rate of increase in the CSS score in periods 1–3, 1–6, and 1–12 months. (p <0.001) (Fig. 2).

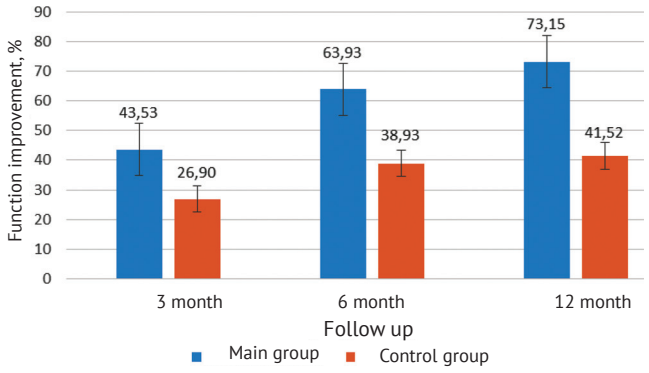

Figure 2. The dynamics of function improvement by Constant Shoulder Score, %

Complications

Complications identified in the course of treatment and postoperative follow-up are presented in Table 3.

Thus, in the compared groups, the risk of associated injuries did not depend on the patient management algorithm (p = 0.436), and neurological injuries accounted for up to 1/3 of all complications associated with PH fracture-dislocations. The structure of neurological complications is presented in Table 4. There was no statistical difference in the number of nerve injuries between the compared groups (p> 0.05).

The greater number of neurological complications in the study group can be explained by the earlier timing of the damaged nerves identification (ENMG was performed in all patients after 21 days), which made it possible to immediately start treatment of these disorders and led to partial or complete regression of neurological symptoms and, in most cases, to good recovery of damaged shoulder joint function: mean CSS score 85.62 ± 14.38 at 12 months. Patients in the control group showed persistent damage to peripheral nerves (ENMG was performed later than 3 weeks after the injury), and the therapy was no longer able to correct such long-term disorders, which led to the worst functional results: mean CSS score 59.50 ± 13.96 after 12 months.

The study revealed that isolated damage to the axillary nerve was rare, more often in combination with other nerves.

Causes of damage to the brachial artery in patients of the control group, in both cases, probably age over 50 years old (p = 0.0408; decreased elasticity of the arteries on the background of atherosclerosis), delayed surgery (scar formation, altered anatomy after trauma) and the fracture-dislocation pattern (three-fragment type according to the Neer classification).

Table 3

Structure of complications identified in PHF patients

Complication	Absolute number of complications (%)		
	both groups	main group	control groupa
Aseptic necrosis of the humerus head	7 (9,6)	5 (12,2)	2 (6,2)
Hardware migration	5 (6,8)	2 (4,9)	3 (9,4)
Brachial artery lesion	2 (2,7)	0	2 (6,2)
Nerves lesion	24 (32,9)	16 (39,0)	8 (25,0)

Table 4

Structure of neurological complications identified in PHF patients

Neurological complications	Absolute number of complications (%)		
	both groups	main group	control groupa
N. axillaris	10 (13,7)	4 (9,8)	6 (19,4)
Nn. axillaris, radialis et musculocutaneus	2 (2,8)	2 (4,9)	0
Nn. axillaris, radialis, musculocutaneus, medianus et ulnaris	3 (4,2)	2 (4,9)	1 (4,2)
Nn. axillaris et suprascapularis	1 (1,4)	0	1 (3,2)
Nn. axillaris, suprascapularis, musculocutaneus et radialis	8 (11,1)	8 (19,5)	0
Total	24 (32,9)	16 (39,0)	8 (25,0)

In patients with two-fragment fracture-dislocations in both groups, only neurological complications were revealed. The incidence of complications such as aseptic necrosis of the humerus head and hardwade migration is statistically higher in patients with three- and four-fragment fracture-dislocations ($p < 0.001$). Also, patients with four-fragment PHF have a significantly higher risk of peripheral nerve damage($p = 0.0089$). At the same time, in 10 (13.7%) patients with three- and four-fragment fractures (5 from each group), a combination of two, less often - three complications was observed. In the main group, three cases (7.3%) revealed a combination of aseptic necrosis of the humerus head and neurological complications, in one (2.4%) case - aseptic necrosis and hardware migration, in one (2.4%) case - aseptic necrosis, hardware migration and nerve damage. In the control group, 2 (6.3%) cases of neurological complications with brachial artery lesion were registered, 2 (6.3%) cases of the humerus head aseptic necrosis in combination with the hardware migration, 1 (3.1%) - neurological damage and hardware migration.

In early postoperative period in all patients, postoperative wounds healed by primary intention, the sutures were removed by 12–14th day after surgery. There were no infectious complications in early and late postoperative periods. The average duration of patients hospitalization in the main group is statistically less than in the control group ($p < 0.001$).

The functional CSS score in patients with neurological complications in the control group was statistically lower than in patients of the same group without nerve damage ($p = 0.003$), as well as compared to the average result of the entire group. There were no statistically significant differences among patients with and without neurological complications in the study group ($p = 0.387$) (Fig. 1).

During the patients with neurological complications observation, a significant difference was found in the damaged joint function restoration in the compared groups: throughout the observation period, the range of motion indicators and dynamics increased (flexion, extension, abduction, adduction, internal and external rotation), as well as indicators for CSS were higher in the main group ($p < 0.05$) (Table 5, Fig. 3). Average CSS score after 12 months was statistically significantly higher in the main group ($p < 0.001$).

Table 5

CSS assessment of patients with neurological disorders in the main and control groups after 12 months.

CSS score	Main group (M±σ = 85,62±14,38)		Control group (M±σ = 59,5±13,96)	
	absolute number (%)	average CSS score	absolute number (%)	average CSS score
Excellent	4 (25)	95,6±3,31	0 (0)	0
Good	6 (37,5)	84,4±3,29	1 (12,5)	81,50
Satisfactory	4 (25)	76±2,36	4 (50,0)	66,50±1,69
Unsatisfactory	2 (12,5)	53,5±5,08	3 (37,5)	43,30±3,47

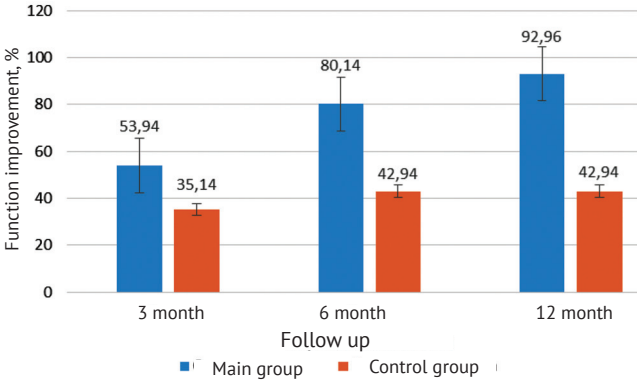

Figure 3. The dynamics of function increase by Constant Shoulder Score in the patients with neurological complications, %

Discussion

The literature describes a variety of methods for treating patients with PH skeletal injuries, and in several case-reports there were presented algorithms for managing PH fracture-dislocations patients with various complications. However, a unified management algorithm has not yet been developed. The high risk of complications, especially neurological complications, leads to patients disability, which is colossal medical and social problem.

Many authors follow strategy of closed dislocation reduction after radiography and/or CT of the damaged PH in patients with two-fragments fracture-dislocations [7, 10, 20, 21]. In most cases, it is possible to achieve a good stable reduction of the greater / lesser tubercle, then patients are successfully treated conservatively. An exception is persistent displacement more than 5 mm [10, 11, 20] and displacement up to 3 mm in young active patients, athletes and manual labor workers[21].

For anterior and posterior three-fragment fracture-dislocations, C. Filippo et al. performed PH CT for preoperative planning, and further surgical tactics (endoprosthetics or osteosynthesis) depended on the patient's age, bone quality, bone size, and severity of soft tissue injuries [10].

Four-fragment fracture-dislocations - severe complex injuries, which treatment tactics are still being discussed [7, 8, 22,23, 24]. A common problem of this pathology is blood supply violation and, as a consequence, humerus head ischemia [25, 26].

Various studies indicates on the high risk of the humerus head aseptic necrosis development [8, 10, 11, 22, 27, 28]. Based on these

observations, in middle-aged and elderly patients, arthroplasty is preferred, and osteosynthesis is recommended only for the young [10].

The data on the brachial plexus lesions frequency in PH fracture-dislocations varies widely. So, C.M. Robinson et al. reported 13.5% of nerve lesions due to anterior fracture-dislocations in 3,633 patients. With the ENMG help, it was revealed that the axillary nerve is injured more often than others [11].

C.P. Visser et al. in a prospective study of 77 patients with PH fracture-dislocations described the loss of axonal connection in 48% of cases. Axillary nerve damage was 42%. The authors suggested that more frequent damage to this particular nerve is due to its anatomical position, which makes it prone to overstretching or compression by the humerus head [12]. That is why, with inferior dislocations the frequency of nerve damage increases to 60%, and with posterior dislocations it is less than 5% [17]. Also, researchers pay attention to a significant injured shoulder joint dysfunction, despite the almost complete restoration of electroneuroconductivity according to the ENMG results and muscle strength in patients with damage to the axillary and suprascapular nerves [9].

In another study, C.P. Visser et al. reported about 142 patients with PHF. All patients underwent ENMG. As a result, neurological damage was detected in 67% of cases. In most cases, the axillary and suprascapular nerves were both injured. In displaced fractures cases, such injuries were 86%, with nondisplaced fractures - 72%. In 9 patients, pronounced shoulder inferior subluxation developed as a result of strength loss in the deltoid muscle and rotator cuff as a result of neurological damage. Later, subluxation spontaneously recovered in all cases [13].

S.V. Gulnazarova et al. give the results of surgical treatment of 69 patients with chronic PH fractures and fracture-dislocations. According to ENMG data, peripheral nerve neuropathy was detected in 89% of cases. The result of such damage was the migration of the endoprosthesis head or its instability [29].

At the same time, G. Gasbarro et al. came to the conclusion that nerve damage in PHF cannot be an absolute contraindication to reverse total shoulder arthroplasty, since in most cases, in patients with obvious nerve damage or without it, reverse shoulder total arthroplasty made it possible to restore joint function and led to good or excellent treatment result. Deep nerves paralysis did not lead to higher complication rates, including dislocation of the endoprosthesis components. Despite greater disability and less satisfaction with treatment, complete or partial nerve recovery can be expected in most patients [30].

In some of research works, the factors of the greatest risk of nerve damage (usually axillary nerve) in case of shoulder joint injury were identified: displaced fractures, fracture-dislocations, concomitant hematoma at the fracture site and age over 65 years. In this case, the authors report on the complete or partial injured nerves recovery [12, 30, 31, 32].

In addition to the brachial artery lesion, rare cases of the axillary artery lesion are described in the literature [33, 34]. This usually occurs when the humerus diaphysis is displaced medially, and this lesion is often diagnosed with a delay. More than 90% of reported cases of vascular injury after shoulder joint trauma occur in patients aged 50 years and over. Older adults are thought to be at increased risk of vascular injury due to reduced elasticity of the arteries in atherosclerosis.

S.J. Cotman et al. proposed an algorithm for the management of patients with PH fracture-dislocations and associated plexopathy and axillary artery rupture. Given the high risk of such injuries, the authors propose to pay more attention to the neurovascular structures study right after trauma, as well as to non-invasive studies of blood vessels and consultation with a vascular surgeon in patients with suspected vascular injury. In such

cases, the authors of the study recommend to refuse closed dislocation reduction and, if possible, immediately go to open reduction. Researchers make very cautious prognosis for such patients, even despite the timely detection and treatment of such injuries [34].

K.S. Wronka et al. proposed a pragmatic approach to the treatment of PH fracture-dislocations in acute period, dividing patients into 3 groups: 1 - anterior shoulder dislocation with the greater tubercle avulsion 2 - anterior dislocation with humerus surgical neck fracture and with / without avulsion of the greater tubercle, 3 - posterior shoulder dislocation and PHF. The authors concluded that emergency closed dislocation reduction under sedation was effective in 94% of patients in group 1, thus not a single case of re-displacement or fracture site spread was detected. Patients in group 2 are advised to careful closed dislocation reduction under general anesthesia with complete muscle relaxation or to perform primary open fracture-dislocation reduction and internal fixation. This is due to the high risk of devascularization of bone fragments and development of aseptic necrosis during reduction, as well as redisplacement of fragments and/or fracture site spread (40%). In group 3 patients, the authors suggest to refuse closed dislocation reduction under sedation and to use general anesthesia (although in their study the authors did not attempt to closed dislocation reduction under sedation in patients of this group) [35].

In our study, patients with three-fragment fracture-dislocations prevailed (61.6%), since most of the patients with two-fragment fractures underwent closed dislocation reduction (which is an excluding criteria of this study), and, as a rule, they were treated conservatively. In order to maintain equal terms for comparative analysis, our study included only patients who underwent osteosynthesis with a plate. Patients of both compared groups with three- and four-fragment PHF underwent CT of the injured joint. The incidence of neurological complications ranged from 25 to 39% and, on average, was found in one third of all patients. Isolated damage n. axillaris was observed in 41.7% of all neurological complications. In our practice, 2 cases of intraoperative brachial artery lesion were registered in patients over 60 years old from the control group at the time of the humeral head extraction from soft tissues, in both cases the problem was solved with the vascular surgeons participation.

Research limitations

This study has a number of limitations that reduce its quality and statistical significance. Thus, the control group patients were evaluated retrospectively, while the experimental group patients were examined prospectively. The study included only patients who underwent open reduction and osteosynthesis with a plate. The observation period for the patients was 12 months, which is not enough to assess the long-term treatment results.

Research prospects

It is planned to track in the future the long-term results of surgically treated patients with fracture-dislocations in the compared groups, as well as to compare used various surgical methods, and to determine the optimal patients management algorithm depending on the fracture-dislocation pattern and associated injuries.

Conclusion

The analysis of early and mid-term results of surgical treatment confirmed the need for timely detection and treatment of such a key complication as damage to the brachial plexus nerves, which can be the result of both an already existing trauma and the ongoing trauma of the neurovascular bundle by the head of the humerus as a result of fracture-dislocation. Surgical treatment within 6 hours from the moment the patient was admitted to the hospital, as well as the early neurological

damage detection and treatment of complications, significantly improved the prognosis and outcome of injured shoulder joint treatment in patients of the main group. Thus, the algorithm for the management of patients with PH fracture-dislocations, developed and introduced into hospitals practice, proved its effectiveness and made it possible to reduce the frequency of unsatisfactory functional results by more than 2 times, and also reduce patients hospitalization period.

References

1. Baron J.A., Barrett J.A., Karagas M.R. The epidemiology of peripheral fractures. *Bone*. 1996;18(suppl):209-213. doi: 10.1016/8756-3282(95)00504-8.
2. Kwon Y.W., Zuckerman J.D. Outcome after treatment of proximal humeral fractures with humeral head replacement. *Instr Course Lect*. 2005;54:363-369.
3. Krasnov A.F., Akhmedzyanov R.B. [Shoulder dislocations]. Moscow: Medicine; 1982. p. 160. (In Russian).
4. Shen L., Jiang C., An Z. Open reduction through a posterior incision in the surgical treatment of shoulder posterior dislocation associated with proximal humeral fractures. *ANZ J Surg*. 2019; 89(4):334-338. doi: 10.1111/ans.15147.
5. Court-Brown C.M., Garg A., McQueen M.M. The epidemiology of proximal humeral fractures. *Acta Orthop Scand*. 2001;72(4):365-371.
6. Chun J.M., Groh G.I., Rockwood C.A.Jr. Two-part fractures of the proximal humerus. J Shoulder Elbow Surg. 1994;(5):273-287. doi: 10.1016/S1058-2746(09)80071-2.
7. Bigliani L.U. Fractures of the proximal humerus. In: Rockwood C.A., Matsen F.A. (eds). The shoulder, 2nd edn. WB Saunders, Philadelphia; 1998. p. 278-334.
8. Duparc J., Largier A. Les luxations-fractures de l'extrémité supérieure de l'humérus [Fracture-dislocations of the upper end of the humerus]. *Rev Chir Orthop Reparatrice Appar Mot*. 1976;62(1):91-110. (In French).
9. Neer C.S. Displaced proximal humeral fractures: I. Classification and evolution. *J Bone Joint Surg Am*. 1970;52:1077-1089.
10. Filippo C., Davide B., Marco A. Simple and Complex Fractures of the Humerus. Springer-Verlag Mailand; 2015; p. 177-179. doi: 10.1007/978-88-470-5307-6.
11. Robinson C.M., Akhtar A., Mitchell M., Beavis C. Complex posterior fracture – dislocations of the shoulder. Epidemiology, injury patterns, and results of operative treatment. *J Bone Joint Surg Am*. 2007;89:1454-1466.
12. Visser C.P., Coene L.N., Brand R., Tavy D.L. The incidence of nerve injury in anterior dislocation of the shoulder and its influence on functional recovery. A prospective clinical and EMG study. *J Bone Joint Surg Br*. 1999;81(4):679-685. doi: 10.1302/0301-620x.81b4.9005.
13. Visser C.P., Coene L.N., Brand R., Tavy D.L. Nerve lesions in proximal humeral fractures. *J Shoulder Elbow Surg*. 2001;10(5):421-427. doi: 10.1067/mse.2001.118002.
14. Hems T.E., Mahmood F. Injuries of the terminal branches of the infraclavicular brachial plexus: patterns of injury, management and outcome. *J Bone Joint Surg Br*. 2012;94(6):799-804.doi:10.1302/0301-620X.94B6.28286
15. Fric V., Pazdírek P., Bartonícek J. Nepredvrtané zajistěné nitrodrenové hrebování zlomenin humeru--základní hodnocení souboru [Unreamed locking intramedullary nailing of humeral fractures--basic evaluation of a patient group]. *Acta Chir Orthop Traumatol Cech*. 2001;68(6):345-356. (In Czech).
16. Wijgman A.J., Roolker W., Patt T.W., Raaymakers E.L., Marti R.K. Open reduction and internal fixation of three and four-part fractures of the proximal part of the humerus. *J Bone Joint Surg Am*. 2002;84(11):1919-1925.
17. Sun J.C., Li Y.L., Ning G.Z., Wu Q., Feng S.Q. Treatment of three- and four-part proximal humeral fractures with locking proximal humerus plate. *Eur J Orthop Surg Traumatol*. 2013;23(6):699-704. doi: 10.1007/s00590-012-1040-x.
18. Conboy V.B., Morris R.W., Kiss J., Carr A.J. An evaluation of the constant-Murley shoulder assessment. *J Bone Joint Surg Br*. 1996;78(2):229-232.
19. Hirschmann M.T., Wind B., Amsler F., Gross T. Reliability of shoulder abduction strength measure for the Constant-Murley score. *Clin Orthop Relat Res*. 2010;468(6):1565-1571. doi: 10.1007/s11999-009-1007-3.
20. Park T.S., Choi I.Y., Kim Y. Park M.R., Shon J.H., Kim S.I. A new suggestion for the treatment of minimally displaced fractures of the greater tuberosity of the proximal humerus. *Bull Hosp Jt Dis*. 1997;56(3):171-176.
21. Resch H., Thoni H. [Dislocation fractures of the shoulder. Special status and therapeutic concepts]. *Orthopade*. 1992;21(2):131-139. (In German).
22. Ackermann C., Lam Q., Linder P., Kull C., Regazzoni P. [Problems in classification of fractures of the proximal humerus]. *Z Unfallchir Versicherungsmed Berufskr*. 1986;79:209-215. (In German).
23. Shrader M.W., Sanchez–Sotelo J., Sperling J.W., Rowland C.M., Cofield R.H. Understanding proximal humerus fractures: image analysis, classification, and treatment. *J Shoulder Elbow Surg*. 2005;14:497-505. doi: 10.1016/j.jse.2005.02.014.
24. Hertel R., Hempfing A., Stiehler M., Leunig M. Predictors of humeral head ishemia after intracapsular fracture of the proximal humerus. *J Shoulder Elbow Surg*. 2004;13:427-433.
25. Gerber C., Schneeberger A.G., Vinh T.S. The arterial vascularization of the humeral head. An anatomical study. *J Bone Joint Surg Am*. 1990;72:1486-1494.
26. Meyer C., Alt V., Hassanin H. Heiss C., Stahl J.P., Giebel G. et al. The arteries of the humeral head and their relevance in fracture treatment. *Surg Radiol Anat*. 2005;27:232-237. doi: 10.1007/s00276-005-0318-7.
27. Auffarth A., Mayer M., Kofler B., Hitzl W., Bogner R., Moroder P. et al. The interobserver reliability in diagnosing osseous lesions after first – time anterior shoulder dislocation comparting plain radiographs with computed tomography scans. *J Shoulder Elbow Surg*. 2013;22(11):1507-1513. doi: 10.1016/j.jse.2013.04.020.
28. Russo R., Cautiero F., Della Rotonda G. The classification of complex 4-part fracture revisited: the missing fifth fragment and indication for surgery. *Musculoskelet Surg*. 2012;96(suppl 1):S13-19. doi: 10.1007/s12306-012-0195-2.

29. Giul'nazarova S.V., Mamaev V.I., Zubareva T.V. [Complications of the shoulder arthroplasty in patients with inveterate fractures and fracture-dislocations of the proximal humerus]. *Genij ortopedii*. 2016;(1):48-51. (In Russian).
30. Gasbarro G., Crasto J.A., Rocha J., Henry S., Kano D., Tarkin I.S. Reverse Total Shoulder Arthroplasty for Geriatric Proximal Humerus Fracture Dislocation With Concomitant Nerve Injury. *Geriatr Orthop Surg Rehabil*. 2019;10:2151459319855318. doi: 10.1177/2151459319855318.
31. Lopiz Y., Garcıa-Coiradas J., Serrano-Mateo L., Garcıa-Fernandezdez C., Marco F. Reverse shoulder arthroplasty for acute proximal humeral fractures in the geriatric patient: results, health-related quality of life and complication rates. *Int Orthop*. 2016;40:771-781. doi: 10.1007/s00264-015-3085-z.
32. Day J.S., Scott Paxton E., Lau E., Gordon V.A., Abboud J.A., Williams G.R. Use of reverse total shoulder arthroplasty in the Medicare population. *J Shoulder Elb Surg*. 2015;24:766-772. doi: 10.1016/j.jse.2014.12.023.
33. Menendez M.E., Ring D., Heng M. Proximal humerus fracture with injury to the axillary artery: a population-based study. *Injury*. 2015;46:1367-1371. doi: 10.1016/j.injury.2015.04.026.
34. Cotman S.J., Trinh T.Q., Vincent S., Backes J.R. Proximal Humerus Fracture-Dislocation with Laceration of the Axillary Artery: A Case Report. *Iowa Orthop J*. 2017;37:53-55.
35. Wronka K.S., Ved A., Mohanty K. When is it safe to reduce fracture dislocation of shoulder under sedation? Proposed treatment algorithm. *Eur J Orthop Surg Traumatol*. 2017;27(3):335-340. doi: 10.1007/s00590-016-1899-z.

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