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DIAGNOSIS AND TREATMENT OF PROXIMAL HUMERUS FRACTURES

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ABSTRACT Proximal humeral fractures typically occur in elderly patients and lead to significant functional disorders. There are many different nonsurgical and surgical treatment options for these injuries, including immobilization and early physical therapy, percutaneous K-wires fixation, plate osteosynthesis, intramedullary nailing and shoulder arthroplasty. The choice of treatment depends on the fracture type and severity, surgeon skill level, patient's age and health status. Today, there is no single algorithm for treating such injuries, there are no large randomized studies which allow it to be created. The aim of this article is to generalize various methods of treatment and diagnosis of fractures of the proximal humerus.

Keywords: fractures of the proximal humerus, treatment of fractures of the proximal humerus, osteosynthesis of humerus

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CT — computed tomography
ICL — index of the cortical layer
MRI — magnetic resonance imaging
RCS — rotator cuff of the shoulder

BACKGROUND

The fractures of the proximal humerus account for about 6% of all fractures in young patients and middle-aged patients and are the third most common among bone fractures in the elderly patients, second only to fractures in the proximal femur and distal radius.

Fractures of the proximal part have a strong influence on the function of the limb in the near and distant periods after trauma. Epidemiological studies indicate a constant increase in the incidence of such fractures and suggest a doubling of this number in patients over 80 in the next 20 years [1, 2].

The majority (87%) of fractures of the proximal humerus in patients of middle age occur as a result of an ordinary fall from the height of their own height [3]. Young patients are more likely to get these injuries as a result of high-energy trauma in road accidents and sports [1, 4]. In elderly patients, multifragmental fractures occur as a result of an indirect trauma with a slight effect of external forces against the background of existing osteoporosis [5, 6].

The results of treatment of fractures of the proximal humerus, as many authors note, are often unsatisfactory, especially in elderly patients, which leads to long-term rehabilitation and disability [7-10].

The aim is to study the treatment options of patients and summarize the results of methods for diagnosing and treating fractures of the proximal humerus.

DIAGNOSTICS

The clinical picture of the fracture of the proximal humerus is characterized by well-known signs, such as pain, swelling, bruising in the upper third of the humerus and shoulder joint. Usually patients keep the injured upper limb in a forced position, pressing it to the chest. It is mandatory to test blood circulation, motor and sensory functions at the periphery of the injured limb [11].

At the stages of examination of a patient, all unnecessary manipulations with a damaged limb should be avoided whenever possible. After each reposition or manipulation in the fracture region, it is necessary to evaluate pulsation in peripheral vessels and the neurological status of the injured limb. When fractures are combined with shoulder dislocations, the frequency of vascular and nerve damage reaches 30% [12].

When examining victims with injuries of the proximal humerus, additional diagnostic methods can not be avoided. A full radiological examination of the humerus and shoulder joint includes a true anteroposterior view, *Y* - and axial view. In complex fractures, additional information, such as the size and position of bone fragments, concomitant lesions of the

coracoid process of the scapula, can be obtained by performing computed tomography (CT) [11].

In addition to the X-ray method of examination and CT, other imaging methods, such as magnetic resonance imaging (MRI) and ultrasound are also used. MRI allows to estimate with a high degree of accuracy the state of components of the rotator cuff of the shoulder (RCS) [13].

However, considering the shortcomings of X-ray, CT and MRI (duration of studies and the need for special positions), many authors consider it rational to perform echography for the study of periarticular soft tissues. The main criterion for the diagnosis of damage to the RCS, according to N.M. Kondyreva et al. [14], is the lack of visualization of this cuff. This sign was detected in 25.8% of patients and was manifested in longitudinal and transverse scans at one or more projection points (depending on the size of the rupture) as the absence of echoshadow of the tendon complex of shoulder rotators. In this case, the articular bag with the deltoid muscle directly adjoins the head of the humerus, which indicates the divergence of the edges of the cuff under the action of the contracted muscles. In patients with partial injuries of RCS during ultrasound, the authors identified a diastasis of the tendons with the possible assessment of area of damage. In 55.8% of patients, they found effusion in the joint associated with the reaction of the capsule to irritation from the damaged rotators [14].

ASSESSMENT OF BONE TISSUE

It is important to assess the quality of bone tissue before surgery, based not only on the age of the patient correlating with his/here physiological state, but also on the analysis of radiographs, in particular, on the thickness of the patient's cortical bone. *Tingart et al.* [15] proposed a convenient and reproducible method for assessing bone mineral density in the proximal humerus. They noted that the thickness of the cortical bone less than 4 mm is a marker of its low mineral density. The thickness of the cortex was measured at two levels. Level 1 was defined as the most proximal portion of the diaphysis of the humerus, in which the boundaries of the endosteum of the medial and lateral cortical layers are parallel to each other. Level 2 was 2 cm distal to the level 1. The total thickness of the cortical layer was measured taking into account the degree of magnification of the image. Then the average values of the thickness of the cortical layer at each of the two levels were summarized [15]. Thus, the thickness of the cortical layer, or the index of the cortical layer (ICL) is the arithmetic average of the thickness of four cortical layers at two levels. ICL more than 4 mm was normal, and ICL less than 4 mm meant reduced bone mineral density, muscle system hypotrophy and decreased vital activity [16].

ASSESSMENT OF VASCULARIZATION OF THE HEAD OF THE HUMERUS

In fractures of the head of the humerus, vascularization, dislocation and cartilage damage can occur, followed by necrosis of the head, which, according to some studies, occurs in 30-100% of cases after comminuted fractures consisting of 3 and 4 fragments. For complex injuries of the proximal humerus, such as three or more fragmentary fractures of the head and surgical neck of the humerus, the results of osteosynthesis are not always satisfactory, because avascular necrosis, followed by osteoarthrosis of the shoulder joint develops, which is associated with age-related changes in the blood supply of the humeral head and blood circulation disorders as a result of trauma [17].

Another important parameter for assessing the fracture of the proximal humerus is the blood supply to its head. Avascular necrosis of the head of the humerus (as a complication of the fracture of the proximal humerus) is observed in 21-75% of cases [18, 19]. Nonunion and resorption of tubercles of the humerus can also be associated with impaired blood flow.

Hertel et al. suggested a number of criteria that are markers of ischemia of the humeral head with fractures of its proximal part. These authors see the tubercles of the humerus as an intermediate segment between the head and the diaphysis of the humerus, while in standard classifications the tubercles are represented by the protuberances of metaepiphysis. To determine the degree of reduction in the blood supply to the head in fractures, it is necessary to answer 5 basic and 7 additional questions. The main questions concern the location of the fracture, additional ones are aimed at differentiating the extent of the posterior medial metaphyseal fragments, the degree of displacement, the presence or absence of dislocation and splitting of the head [20].

CLASSIFICATIONS

One of the most commonly used classifications of fractures of the proximal humerus is the classification presented by *C.S. Neer* in 1970, which distinguishes several main areas in this department: the joint part, the large and small tubercles and the diaphysis of the humerus. These areas can be divided by fracture lines, but the true fragments are those ones displaced more than 1 cm or at an angular deformation of more than 45°. Depending on the number of displaced fragments, fractures are subdivided into single, double, triple and fourfragmentary fractures. Each of these types of fractures can potentially be combined with a dislocation of the humeral head [21].

Neer classification does not take into account the blood supply to the head of the humerus, which is noted in another widespread AO classification by Maurice E. Muller et al. in 1991 and modified in 2007 in the classification of fractures of tubular bones. Here the fractures are divided into 3 types (*A*, *B*, *C*), which are divided into 3 groups, each of which

consists of 3 subgroups. Type *A* includes extra-articulate unifocal fractures with intact blood supply, type *B* includes extra-articular bifocal fractures with a risk of impaired blood supply to the head of the humerus, and type *C* includes intra-articular fractures with a high probability of impaired blood supply to the head of the humerus [22]. The blood supply of the proximal humerus is very similar to the blood supply of the proximal femur, and its violation can lead to avascular necrosis of the head. The blood supply to the head of the humerus is mainly gained through the arcuate artery, which branches off from the ascending branch of the anterior circumflex humerus artery. This artery is immersed in the humerus in the intertubercular sulcus, giving the branches to both tubercles and the head. If the arcuate artery is damaged, the blood supply to the head can not be compensated by other sources, which leads to avascular necrosis of the humeral head [22].

Both of the above classifications are static and have low reproducibility in the initial and repeated evaluation of X-rays, and the same doctor gives conflicting conclusions in 30% of observations. A.V. Skoroglyadova et al. say that the tactics of treatment in this case may vary, and for a clearer evaluation it is advisable to perform CT, which results change the treatment plan in 20% of patients [23].

When evaluating X-ray images and CT, many criteria must be taken into account. With the increase in the number of fracture characteristics, the classification becomes more complex. At the same time, the amount of information that can be obtained about a fracture from the database increases, and it becomes possible to decide more quickly and accurately about the method of treatment. An updated classification system based on the fracture characteristic and *E.A. Codman's* graphical classification, is a protocol of images analysis with 21 item fracture characteristics, which are divided into 5 groups. In this classification, the following letter symbols are used: *C* — a fragment of the humeral head, covered with cartilage; *T* — a large tubercle; *t* — a small tubercle; *D* — diaphysis of humerus; / — a fracture without displacement; // — a fracture with displacement [24].

For example, the displacement "head-diaphysis" is denoted "*CTt//D*". The fracture is considered to have a displacement if the diaphysis in the anterior-posterior or lateral directions is more than 1 cm, or the angular displacement is more than 3° (in comparison with the cervico-diaphyseal angle of the healthy limb). The angulation more than 30° is angular displacement (in comparison with the neck-diaphyseal angle of the healthy limb). Fractures of the small tubercle are classified as fractures with displacement if its displacement relative to the head is more than 1 cm. The fracture of the large tubercle is classified as a fracture with displacement if its displacement relative to the head is more than 5 mm. Impression fractures are divided into several types: type 1 — not more than 20% of the joint surface is damaged, type 2 — 20 to 50% of the joint surface is damaged, type 3 — more than 50% of the articular surface is damaged [24].

TREATMENT

Today, clear recommendations based on the principles of evidence-based medicine regarding the choice of tactics for treating fractures of the proximal humerus do not exist [21]. Despite the high incidence of these fractures, the number of randomized trials devoted to the treatment is relatively small. This is due to a large number of variants of fractures and methods of treatment, from conservative therapy and many modifications of surgeries to the prosthetic joint [11].

The indications for surgical treatment of fractures with a moderate displacement of fragments, which used to be treated mainly conservatively, are expanding. Despite the literature data that 60-80% of fractures of the proximal humerus without displacement or with moderate displacement can be treated conservatively, most of these fractures are now treated operatively [25].

For a long time, the advantage in the treatment of fractures of the proximal arm was retained by the conservative method of prolonged immobilization, but this technique is characterized by a large number of complications, mainly contractures. A functional approach to conservative treatment was proposed by V.V. Gorinevskaya and E.F. Dreving (1940). In the treatment of fractures of the surgical neck of the humerus, the conventional methods of immobilization are excluded by the functional method, there is no rigid fixation of the fracture, and self-extension is used for the gradual reposition of the fragments under the weight of the hanging arm. Therapeutic gymnastics is indicated to victims starting from day 2-3, it is divided into 3 periods, with a gradual increase in the number and intensity of exercise [26, 27].

Some authors recommend surgery as the method of choice in the treatment of young patients when the displacement of fragments is more than 5 mm, angular displacement of more than 20° and displacement of the tubercles of the humerus is more than 2 mm [28]. For elderly patients, the threshold values for the *Neer* classification of the fracture are a displacement of more than 1 cm or an angular deformation of more than 45° [11].

It is generally accepted that fractures without displacement can be cured conservatively. Thus surrounding soft tissues are relatively intact and contribute to stabilization of fragments. Some authors extend the evidence to conservative treatment and believe that it is a safe method of treating fractures of the proximal humerus of varying complexity, giving acceptable results with a small number of complications [29]. Other authors consider conservative treatment is indicated in fractures without displacement and fractures of the large tubercle with a displacement of less than 5 mm upward and less than 10 mm posteriorly [30]. In addition to fractures without displacement, valgus impacted

fractures also have a good prognosis with conservative treatment. It makes it possible to achieve 85% of the volume of movements in the shoulder joint of the injured limb in comparison with the opposite side. In this case, the main complications of this treatment are rigid shoulder joint, necrosis of the head of the humerus, pain, subacromial impingement due to the displacement of the large tubercle and the formation of a false joint. The traditional scheme of conservative treatment is immobilization in the *Gilchrist* bandage for one week, pendular movements by hand for the next 2-3 weeks, abduction in the shoulder joint to 90° with external help by week 4-5, and free movement of the hand starting from the 7th week [11].

It is possible to use various bandages in the conservative treatment of fractures of the surgical neck of the humerus for immobilization of the shoulder joint. When comparing spica (*Dezo* bandage) and *Gilchrist* bandage, difference in the incidence of adhesions and functional results was not revealed. However, when using the *Gilchrist* bandage, patients experienced less discomfort and pain, and also noted fewer irritations on the skin [31].

When choosing tactics of treatment, it is necessary to take into account the age of the victim, since the difference between conservative treatment and hemiarthroplasty was not revealed when comparing the functional results of treatment of fractures of the proximal humerus in elderly patients [32].

The decision in favor of surgical treatment and the choice of a specific surgical procedure for fractures of the proximal humerus largely depends on the type of the fracture. The most widespread classifications are based on the analysis of X-ray images. In the original study, two views were needed to classify fractures according to *Neer*: a true anteroposterior and an *Y* view. Three-dimensional recostruction at CT in most cases allows to significantly improve understanding of a complex fracture [22].

In one of the meta-analyzes, comparing conservative and operative treatment of comminuted fractures of the proximal humerus in elderly patients, conservative treatment significantly reduced the incidence of complications and risks associated with the operation itself. There were no statistically significant differences in clinical results in both groups [33]. At present, there are no studies with reliable evidence of a better functional result in elderly patients after the operative treatment of these fractures [33].

Surgical treatments for fractures of the proximal humerus may consist of the following:

- closed reposition and percutaneous fixation with wires;
- extra-focal fixation;
- open reposition and internal fixation by a plate;
- open reposition and fixation by the tightening loop method;
- intramedullar fixation;
- hemiarthroplasty (prosthetics of the humeral head);
- total replacement of the shoulder joint (anatomical or reversible) [21].

In the case of treatment of fractures of the proximal humerus, combined with dislocation of the shoulder, the elimination of dislocation with intravenous sedation is recommended only in case of anterior dislocation with fracture of the large tubercle of the humerus. In other cases it is recommended to eliminate dislocation and perform osteosynthesis (if necessary) under general anesthesia. Closed reposition of the surgical neck of the humerus can cause additional trauma to blood vessels that supply blood to the head. Moreover, the displacement of fragments may occur with a frequency of 45% [34].

When choosing an operative method of treatment, the time of performing is important. Delaying the osteosynthesis of the proximal humerus for more than 5 days from the time of trauma leads to a significant increase in the number of complications, such as avascular necrosis of the head and secondary displacement of fragments. In cases with splitting of the humeral head and fractures in combination with dislocation, anatomic repositioning should be performed no later than 48 hours after the trauma, which reduces the risk of avascular necrosis of the humeral head [35].

The choice between a plate and a wire for fixing fractures of the proximal metaepiphysis of the humerus remains unsolved. According to many studies, when comparing the osteosynthesis of even three- and four-fragmentary fractures of the proximal humerus with the blocked plate and the blocked wire, no significant differences in the fixation stability and the results of treatment have been revealed, however, wire osteosynthesis may be performed less invasively [36, 37].

In one study, a comparison was made between different methods of treating fractures of the proximal humerus with displacement of fragments. The authors found that osteosynthesis with wires gave better functional results in patients of all ages compared with conservative treatment, especially in patients with two-fragment fractures. Osteosynthesis with a nail or wires in young patients gave a better result than the conservative treatment. In elderly patients, the best results were obtained with wires osteosynthesis than with nailing. When comparing osteosynthesis with a plate and conservative treatment, no differences were found in all groups of patients [38].

Osteosynthesis with wires in fractures of the proximal humerus has many advantages, such as minimal blood loss, a short operation time, the least injury to soft tissue and low cost. This method of osteosynthesis also has complications, and the most frequent are development of infection in the area of the wires insertion, poor quality of reposition,

nonunion and migration of wires [39]. Osteosynthesis with wires is relatively safe and is especially useful for patients with a variety of concomitant diseases where open osteosynthesis is contraindicated. However, it must be taken into account that the use of osteosynthesis with wires in conditions of osteoporosis worsens the quality of reposition and increases the frequency of wires migration [40].

The incentive for the development of antegrade technique of fixing the fractures of the proximal humerus by the nail are such advantages of the method as the reliable fixation in combination with the small invasiveness. The earliest versions of intramedullary rods, such as the *Rush* rod, did not provide adequate stability of fixation, including the rotational one, which led to migration of fixatives and required repeated surgical interventions. The idea of using blocked nails for osteosynthesis of the humerus appeared as a result of the experience of using such fixatives on the tibia. The weak point of the blocked second-generation nails, such as *Polarus nail* and *Targon PH*, was a weak fixation with proximal locking screws, which led to migration. The 3rd generation nails, such as *Stryker T2 Proximal Humeral Nail* and *Synthes Proximal Humeral Nail*, already have sufficient fixation strength and stability of proximal locking screws. To solve the problems of migration, such approaches as "screw in screw", "spiral blade" and others [41] were used.

The use of the proximal shoulder nail allows the osteosynthesis to be performed minimally invasively and with the least risk of infectious complications compared to other surgical methods of treatment [42]. However, osteosynthesis with a standard proximal shoulder nail can damage the tendons of the rotator cuff and cause postoperative pain in the shoulder joint [43].

The proximal blocking plate is good for fixing fractures in young patients, but remains problematic for fixing fractures in patients with osteoporosis. Up to 40% of complications with the use of plates are associated with errors in the surgical technique, including such as intraoperative perforation of the head of the humerus with screws. Fractures of the plate occur in 1.9%, impingement occurs in 2.6%, formation of false joint is revealed in 2.6%, wound infection develops in 3.9%, loss of reposition occurs in 7.1% and necrosis of the humeral head - in 3.9% of cases [44].

The emergence of such complications as impingement, migration and "eruption" of screws is associated with the technique of installing the plate and screws, as well as with the type of a fracture [45]. At present, according to some authors, the main indications for the use of proximal blocked plates are two-, three- and fourfragmental fractures, false joints of the humerus, and fractures in the background of osteoporosis [30, 46].

On X-rays of patients with fractures of the proximal humerus, the incomplete dislocation of the humeral head is often determined. Transitory subluxation of the head of the humerus may be observed both after trauma and after suturing RCS, osteosynthesis of the proximal humerus and prosthetics of the shoulder joint.

For the first time, the lower subluxation of the humerus was reported in 1921 by *F.J. Cotton*. This condition should be differentiated with a dislocation of the humerus. With anterior dislocation, the head is displaced medial to the articular cavity of the scapula, with the posterior dislocation the joint gap may appear normal at first glance, while with the lower subluxation the head of the humerus is displaced downwards and outward, the joint slot and subacromial space widen. The reason for this phenomenon is a change in the anatomy and physiology of the RCS and deltoid muscle. An additional factor is the loss of negative pressure in the cavity of the shoulder joint. After restoration of the muscle tone, the subluxation regresses. In 92% of patients with fractures of the proximal humerus, subluxation of the humerus regressed by the 6th week after the injury [47].

Despite the presence of a wide range of fixatives, osteosynthesis of many fractures of the proximal humerus can not be performed. A number of authors believe that shoulder joint prosthesis is indicated in three- and four-fragment fractures of the proximal humerus if the articular surface is fragmented or represents only the cortical bone due to loss of the spongy bone and also in cases of unsuccessful previous osteosynthesis in the absence of the prospect of saving the humeral head. Despite the development of prosthetic technologies, the functional results of shoulder joint prosthesis in fractures remain poor, but the pain in the shoulder joint do not bother most of such patients [11, 48, 49].

CONCLUSION

The treatment of patients with fractures of the proximal humerus is an urgent problem and requires preliminary evaluation of the factors associated with the patient (such as age and activity level), as well as those directly related to the fracture (such as bone quality, fracture, degree of commotion and others). The goal of treatment is painless movements in the shoulder joint and restoration of the former function [50].

Currently, there are no generally accepted standard protocols and treatment regimens for patients with fractures of the proximal humerus, and existing studies are not sufficient to create such an algorithm. Despite the increasing role of evidence-based medicine, the decision to choose the treatment tactics for this category of patients is mainly based on the experience of an orthopedic trauma specialist and consultation with the patient [11].

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