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Features of the Rehabilitation of Patients with Fractures of the Humeral Diaphysis after Osteosynthesis

Cechy rehabilitacji pacjentów ze złamaniami trzonu kości ramiennej po osteosyntezie

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SUMMARY

Aim: Determination of the target criteria of physical rehabilitation and the optimal time of their implementation depending on the methods of fixation of fractures of the humeral diaphysis.

Materials and methods: The results of treatment of 59 patients with diaphyseal humeral fractures have been studied. All patients underwent extra- or intramedullary osteosynthesis.

Results: In the absence of satisfactory stability of fracture fixation (Group A), passive movements and no active movements are recommended, especially in the presence of free bone fragments that serve as a site for muscle insertion (Group A1). The presence of free fragments with stable fixation (Groups B1 and B2) determined the possibility of active adduction and abduction movements of the shoulder. Complexes of physical rehabilitation exercises with the exclusion or prohibition of active rotational movements have been chosen for patients of Groups C1 and C2.

Conclusions: The proposed system of distribution of physical load during the rehabilitation period according to the "ABC" type provides a biomechanically based approach to the rehabilitation process.

Key words: rehabilitation, humeral fracture, diaphysis, shoulder muscles

Słowa kluczowe: rehabilitacja, złamanie kości ramiennej, trzon, mięśnie barku

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INTRODUCTION

Scientific publications report that diaphyseal humeral fractures account for 3.0% of all skeletal bone fractures in the adult population [1, 2].

The largest number of high-energy injuries of the humerus is observed in young people with high occupational and social activity [3].

It is known that the consolidation of a diaphyseal humeral fracture can be achieved by the conservative treatment, though surgical intervention can accelerate this process, as well as rehabilitation [4, 5].

It has been reported that the percentage of complications in the treatment of fractures of the distal segment of the humeral diaphysis reaches 8.3-67% and subsequently can lead to a loss of work capacity, the ability to self-care and disability [6].

Shoulder and elbow joints are the areas formed with the participation of the humerus, which, due to anatomical and biomechanical features, are most prone to the development of a chain of complications, among which the contractures are rating first that require an individual rehabilitation protocol [7, 8].

There are various methods of contracture treatment: therapeutic exercises, stretching, strengthening exercises, continuous passive movements, use of electrotherapeutic methods, static progressive splinting. Recently, clinical studies have proved the effectiveness of the muscle energy technique and its therapeutic mechanisms. Muscle energy techniques are the group of relatively painless mobilization techniques used to restore mobility, reduce tissue swelling, reduce muscle spasm, stretch fibrous tissue, and restore stabilizing function of intersegmental muscles [9, 10].

Notably, in the contemporary scientific literature, attention is not sufficiently focused on measures to prevent contractures of the shoulder and elbow joints in case of damage to the humeral diaphysis at various stages of medical care, and the use of well-known postoperative rehabilitation schemes does not always solve the issue of achieving the recovery of function in certain cases [11, 12].

Since no generally accepted treatment algorithm exists to date, it must be individualized and agreed upon in the process of joint decision-making with each patient [13].

AIM

Determination of the target criteria of physical rehabilitation and the optimal time of their implementation depending on the methods of fixation of fractures of the humeral diaphysis.

MATERIALS AND METHODS

59 patients with fractures of the humeral diaphysis aged 16 to 85 years have been involved into the study. Among them, according to the gender distribution, women prevailed (69.5% (41)). The average age among female and male patients was 60.4 and 46.3 years, respectively.

The period of hospitalization ranged from 2 hours to 25 days from the moment of injury. In the period from 2 to 6 hours, 5% (3) of patients were hospitalized. During the first day after exposure to the traumatic factor 17% (10) of patients were hospitalized. 78% (46) of patients were hospitalized more than one day since the injury.

In 52.5% (31) of patients, the reason for fracture of the humeral diaphysis was a low-energy injury occurred as a result of a fall from own height. In 47.5% (28) of patients the injury was a high-energy and resulted from a traffic accident, an occupational injury, a fall from a height, and random violence.

Closed fractures of the humeral diaphysis were diagnosed in 100% of patients. According to the AO Classification, fractures were distributed as follows:

- 12A – 28,8%
- 12B – 44,1%
- 13C – 27,1%

The detailed description of the nature of fractures according to the AO Classification is presented in Table 1.

Surgical treatment methods were used in 100% of patients. Traditional locking-plate osteosynthesis using the LCP was performed in 57.6% (34) of patients. Antegrade blocking intramedullary osteosynthesis with a pin was used in 35.6% (21) of patients, retrograde blocking intramedullary osteosynthesis with a pin was performed in 6.8% (4) of patients.

At the preoperative and postoperative stages of treatment, in order to choose the optimal tactics and scheme of the follo-up physical rehabilitation, all patients underwent radiography of the damaged segment in two projections. Of these, 28.8% (17) patients underwent computed tomography of the injured segment of the humeral diaphysis using anatomical 3D modeling at the stage of preoperative planning.

A comparative analysis of the position of bone fragments, the degree of their displacement relative to the normal axis of the humerus, and the anatomical fixation before and after the use of the surgical treatment methods was performed.

The nature of displacement and possible postoperative complications at the stage of medical rehabilitation were evaluated based on the scheme of typical contact relationships between the bone and muscle tissues of the studied area of the humerus.

The nature of the fracture, the presence of bone fragments and their relationship with the sites of insertion of the deltoid, pectoralis major, teres major, humerus muscles and the latissimus dorsi muscle, the degree and stability of their fixation with internal metal fixators had a key influence on the choice of tactics for the follow-up physical rehabilitation and patients' assignment to the groups.

According to the conclusions of the Ethics Commission of the PSMU, the paper meets the requirements of the Helsinki Commission. Patients, assigned in the clinical groups, participated with informed consent.

RESULTS

After detailed processing and analysis of the data, preoperative and postoperative radiographs, anatomical 3D models, 6 clinical groups of physical rehabilitation of patients have been formed depending on the existing bone fragments, the degree of their displacement and the method of fixation, the relationship with the sites of insertion of the muscle component of the humeral diaphysis and motor activity of the damaged limb segment and adjacent joints.

The distribution of clinical groups of physical rehabilitation depending on the method of fracture fixation, fixation stability, the presence of bone fragments and their relationship with the sites of muscle insertion is shown in Table 2.

Group A1 involved 7 patients (11.9%) with high- and low-energy injuries with the presence of bone fragments. Fractures of 12B1 type were detected in 1 (1.7%) patient, 12B3 type – in 3 (5.1%) patients, 12C3 type – in 3 (5.1%) patients. Blocking intramedullary osteosynthesis with a pin was performed in 1 (1.7%) patient, locking-plate osteosynthesis with LCP – in 6

Table 1. The description of fractures of the humeral diaphysis in the subjects according to the AO Classification

No.	The type of AO Fracture Classification	Number of patients, persons (%)
1.	12 A1	6 (10,2)
2.	12 A2	6 (10,2)
3.	12 A3	5 (8,5)
4.	12 B1	7 (11,8)
5.	12 B2	14 (23,7)
6.	12 B3	5 (8,5)
7.	12 C1	5 (8,5)
8.	12 C2	1 (1,7)
9.	12 C3	10 (16,9)

Table 2. Distribution of clinical groups of physical rehabilitation of patients with fractures of the humeral diaphysis after osteosynthesis depending on the target criteria for selecting physical rehabilitation methods

Group No.	Group name	Fracture fixation method	Fixation stability	The presence of bone fragments	Relationship of bone fragments with muscle insertion sites
1.	A1	blocking intramedullary osteosynthesis, locking-plate osteosynthesis	No	Yes	Yes
2.	A2	blocking intramedullary osteosynthesis, locking-plate osteosynthesis	No	Yes	No
3.	B1	blocking intramedullary osteosynthesis, locking-plate osteosynthesis	Yes	Yes	No
4.	B2	blocking intramedullary osteosynthesis, locking-plate osteosynthesis	Yes	Yes	No
5.	C1	locking-plate osteosynthesis	Yes	No	–
6.	C2	blocking intramedullary osteosynthesis	Yes	No	–

(10.2%) patients. Fixation stability in all patients of this group was unsatisfactory. The bone fragments served as insertion points of the humerus muscles in the proximal and distal parts of the diaphyseal segment.

In patients of Group A1, passive flexion and extension of the humerus was performed in the range of 110°-155° and 25°-45°, respectively; passive flexion and extension of the forearm was made in the range of 45°-80° and 140°-160°, respectively; combinative passive rotational movements of the forearm: pronation – 110°-150°, supination – 95°-135°.

Group A2 involved 8 (13.6%) patients with fragmentary fractures. Among them, type 12B1 fractures were diagnosed in 2 (3.4%) patients, 12B2 – in 2 patients (3.4%), 12B3 – in 1 (1.7%) patient, 12C1 – in 1 patient (1.7%), 12C3 – in 2 (3.4%) patients. Blocking intramedullary osteosynthesis with a pin was performed in 2 (3.4%) patients, locking-plate osteosynthesis with LCP was performed in 6 (10.2%) patients. The stability of fixation of bone fragments was unsatisfactory. The bone fragments did not serve as a point of muscle insertion and were located in the middle third of the humeral diaphysis.

Patients of group A2 performed passive adduction and abduction movements of the humerus 110°-140° in combination with a set of exercises of Group A1.

Group B1 involved 14 (23.7%) patients with fragmentary fractures. 12B1 fractures were detected in 3 (5.1%) patients, 12B2 type – in 4 (6.75%) patients, 12C1 – in 4 (6.75%) patients, 12C3 – in 3 (5.1%) patients. Locking-plate osteosynthesis with LCP was performed in 9 (15.3%) cases, blocking intramedullary osteosynthesis with a pin – in 5 (8.4%) cases. The stability of fixation of bone fragments in patients of this group was satisfactory. Bone fragments served as insertion points of the muscular component of the humerus and were localized in the proximal and distal diaphyseal segments.

Patients of Group B1 performed active forearm flexion and extension within 30°-79° and 149°-180°, respectively; active rotational movements of the forearm: pronation - 136°-180°, supination - 136°-180° in combination with a set of Group A exercises.

Group B2 involved 13 (22%) patients with fragmentary fractures of the diaphyseal segment of the humerus. Fracture type 12B2 according to the AO Classification was diagnosed in 9 (15.2%) patients, type 12B3 – in 1 (1.7%) patient, 12C2 – in 1 (1.7%) patient, 12C3 – in 2 (3.4 %) of patients. Blocking intramedullary osteosynthesis with a pin was performed in 7 (11.7%) patients, traditional locking-plate osteosynthesis with LCP – in 6 (10.1%) patients. The stability of fixation of bone fragments was satisfactory. The bone fragments were located in the middle third of the diaphyseal segment of the humerus and did not serve as a site of muscle attachment.

In Group B2 patients, active flexion and extension movements of the shoulder in the range of 110°-155° and 25°-45°, respectively, as well as passive rotational movements of the shoulder were added to the previous set of exercises.

Group C1 involved 7 (11.9%) patients with bifragmentary fractures of the humeral diaphysis, the method of choice for treatment of which was locking-plate osteosynthesis with LCP. According to the AO Classification, type 12A1 fractures were diagnosed in 6 (10.2%) patients, 12A2 – in 1 (1.7%) patient. Fixation of the fracture in patients of group C1 was stable.

In patients of Group C1, active adduction and abduction movements of the shoulder 115°-175° were added to the complex of active and passive exercises.

Group C2 involved 10 (16.9%) patients with simple bifragmentary fractures. Patients of this group were operated using the method of blocking intramedullary osteosynthesis with pins. Fractures of type 12A2 and 12A3 were equally distributed. Fixation of the fracture of the diaphyseal segment of the humerus with an intramedullary pin was stable.

Patients of group C2 were engaged in a complex of active exercises of the previous groups with addition of active shoulder rotational movements.

The distribution of physical rehabilitation groups depending on passive and active motor activity of the damaged segment and adjacent joints is shown in Table 3.

DISCUSSION

Among the patients of all clinical groups, medical rehabilitation was started immediately after the surgical intervention and at the end of the anesthetic methods application. The complex of exercises was performed with

Table 3. Description of clinical groups of physical rehabilitation depending on the type of active or passive physical activity

Group name Physical activity	A1	A2	B1	B2	C1	C2
Passive flexion and extension movements of the forearm	+	+	+	+	+	+
Passive rotational movements of the forearm	+	+	+	+	+	+
Passive flexion and extension movements of the shoulder	+	+	+	+	+	+
Passive adduction and abduction movements of the shoulder	–	+	+	+	+	+
Active flexion and extension movements of the forearm	–	–	+	+	+	+
Active rotational movements of the forearm	–	–	+	+	+	+
Active flexion and extension movements of the shoulder	–	–	–	+	+	+
Passive rotational movements of the shoulder	–	–	–	+	+	+
Active adduction and abduction movements of the shoulder	–	–	–	–	+	+
Active rotational movements of the shoulder	–	–	–	–	–	+

the help and under the supervision of medical personnel, as well as independently by the patient after his/her training and continued until the onset of consolidation of the fracture.

Passive movements and no active movements during physical rehabilitation of patients from Groups A1 and A2 are advocated due to the lack of satisfactory stability of fracture fixation. The presence of free bone fragments serving as the site of insertion of muscles (group A1) makes it impossible to perform active movements of the limb without their secondary displacement and traumatization of paraosseous soft tissue structures, such as the nerves, vessels and muscles, and provokes the formation of a secondary intermuscular hematoma.

In patients of Groups B1 and B2, fixation of fractures was satisfactory, which enabled the diverse active movements during physical rehabilitation. Active adduction and abduction movements of the shoulder are excluded in patients of group B1 due to the presence of bone fragments that serve as the site of insertion of the muscles of the proximal segment of the humeral diaphysis. Activation of these movements increases the risk of secondary displacement of bone fragments and compromising the stability of osteosynthesis.

The complex of physical rehabilitation exercises in patients of Groups C1 and C2 began with active movements, which was determined by the absence of bone fragments and the stability of the performed osteosynthesis. Exclusion of active rotational movements in patients of Group C1 was associated with the prevention of the development of foci of local osteoporosis and migration/damage of metal fixators.

The assessment of the functional activity of the elbow and shoulder joints was carried out within 8-10 weeks after the surgical intervention and after the onset of consolidation of the fracture of the diaphyseal segment of the humerus using the MEPI and CMS scales, respectively.

According to the MEPI scale, the functional activity of the elbow joint in patients of Group A1 and A2 ranged from 82 to 89 points and was rated as good. Functional activity of the elbow joint according to the above scale in patients of Group B1, B2, C1, C2 ranged from 90 to 99 points and was assessed as excellent.

According to the CMS scale, the difference in the functional activity of the shoulder joint on the injured and healthy side in patients of Group A1 and A2 ranged from 12 to 18 points and indicated a good result. The functional activity of the shoulder joint of the injured limb in patients of Group B1, B2, C1, C2 had a score of 17 to 8 points compared to the healthy one, which indicated a good and excellent result.

CONCLUSIONS

The proposed system of distribution of physical load during the rehabilitation period according to the "ABC" type provides a biomechanically grounded approach to the rehabilitation process and allows to prevent the occurrence of iatrogenic complications in the early and remote postoperative periods, prevents disfunction of the shoulder and elbow joints.

The concern in the target criteria for choosing physical rehabilitation tactics for patients with humeral diaphysis fractures after osteosynthesis, as well as the concern in the biomechanical features of bone fragments, which are caused by the contact relationship between bone and muscle tissues, enables choosing the optimal physical exercises for each patient. This determines the early start of physical rehabilitation in patients with fractures of the humeral diaphysis to increase the functional activity of adjacent joints, reduce the risk of contractures, improve the patient's quality of life and reduce the period of incapacity.

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Info

POLISH ASSOCIATION OF HEALTH RESORT PATIENTS

On the initiative of Professor Irena Ponikowska, the Polish Association of Health Resort Patients was established in 2019. The Association aims to integrate patients using health resort treatment, increase the availability of health resort treatment for subjects in need, improve the quality of services provided in the health resort treatment sector, cooperate with doctors and health resort treatment facilities, and involve in patient education.

Each member of the Association will be able to benefit from discounts in fees for stay and treatment, during commercial stays in selected health resort treatment facilities, and take part in conferences, workshops, and consultations organized by the Association.

Natural and legal persons may be members of the Association. Membership in the Association for natural persons is free, whereas legal persons may become supporting members.

We invite both patients and companies operating in the field of health resort medicine to work together.

Please visit the website of the Association udrowiskowi.eu where you will find more information as well as a declaration of joining the Association.

The Board of the Polish Association of Health Resort Patients