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Original article

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Structure of elbow joint revision arthroplasty

A.G. Aliev✉, A.V. Ambrosenkov, A.A. Boyarov, G.I. Zhabin, S.Yu. Fedyunina, R.M. Tikhilov, I.I. Shubnyakov

Vreden National Medical Research Center of Traumatology and Orthopedics, Saint Petersburg, Russian Federation

Corresponding author: Alimurad G. Aliyev, mur23mur@yandex.ru

Abstract

Introduction Current operations of elbow arthroplasty are accompanied by an extremely high rate of complications in the early and long-term periods. Therefore, along with the widespread growth of primary arthroplasty, there is a growing need for revision interventions. Purpose To study the age groups of patients at the time of primary and revision arthroplasty, to investigate the reasons of the first and repeated revisions, the scope of interventions, as well as the time since the previous AP. **Materials and methods** A retrospective analysis of 133 cases of elbow revision arthroplasty (111 patients) treated from 2003 to 2019 was conducted. The rate of re-revisions was 16.5 %. The study investigated the age of patients, reasons for the first and repeated revisions, the scope of interventions, as well as the time passed since the previous elbow arthroplasty. **Results** In the structure of primary and revision arthroplasty, there was a significant dominance of patients aged 51 to 60 years (25.4 % and 33.3 %, respectively). However, the total rate of patients under 40 years old in the group of primary arthroplasty was 33.5 %, and in the revision group it was 34.2 %. The most frequent reason in the first and repeated revisions was aseptic loosening: 47 % and 50 %, respectively, followed by PJI (23 % in both groups), dislocation (10 % and 18 %, respectively) and breaks of the implant's components (8 % and 4 %). Other complications were less common (12 % and 5 %, respectively). Most of the revisions for PJI were performed in the first year since the previous arthroplasty (56.7 %). In terms of aseptic instability, early and late periods were identified. The ratio of early revisions to the total number of primary arthroplasty during the entire time of the surgical team's work decreased from 19.4 % to 3.5 %. **Discussion** The observed number of young people in the age structure of primary and revision AP in the long term is likely to lead to an increase in the number of patients with severe bone defects. The data of our study demonstrate a significant decrease in the number of revisions over the past 5 years performed for early loosening, despite the general increase in the number of primary APs. **Conclusion** The study identified a considerable number of young patients, which could potentially lead to an increase in the number of repeated revisions and related problems, including pronounced bone defects and recurrent infection. All this actualizes the need to improve the technique of revision arthroplasty.

Keywords: revision arthroplasty, elbow joint, causes of revisions, aseptic loosening, periprosthetic infection

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INTRODUCTION

The operation of replacement of the elbow joint with an artificial one was originally developed more than 70 years ago for patients with end-stage rheumatoid arthritis. However, over time, the indications for elbow joint arthroplasty (EJA) expanded and include consequences of severe injuries of the elbow joint (EJ), idiopathic arthritis, primary and metastatic tumors, as well as more rare systemic diseases such as juvenile idiopathic arthritis, hemophilic arthropathy, gouty arthritis, and some others.

Today, the orthopedic units that have accumulated sufficient experience in the EJA operations face a number of their complications: aseptic loosening, periprosthetic infection (PPI), dissociation and fatigue fracture of components, periprosthetic fracture, heterotopic ossification and soft tissue complications. The overall incidence of complications after primary EJA, according to various sources, ranges from 15 to 45 % [1]. Therefore, along with a widespread increase in the number of primary EJ arthroplasty, there is a growing need for revision interventions. In the studies that analyzed data from national registries of patients in the states of New York and California in the United States, the authors report a threefold increase in the number of primary EJ replacements performed for the consequences of injuries from 1993 to 2007, but the number of revisions during that period increased 5 times [2].

The dynamics of publication activity reported in the Pubmed scientific base with a key word search "revision elbow arthroplasty" shows the emergence of interest in this topic since the beginning of the 80s, when the first articles appeared on the technological features of revision EJA for various complications of the primary one (Fig. 1). But since 2000 to the present time, there has been a multiple increase in the number of publications, reaching 140 papers in 2020.

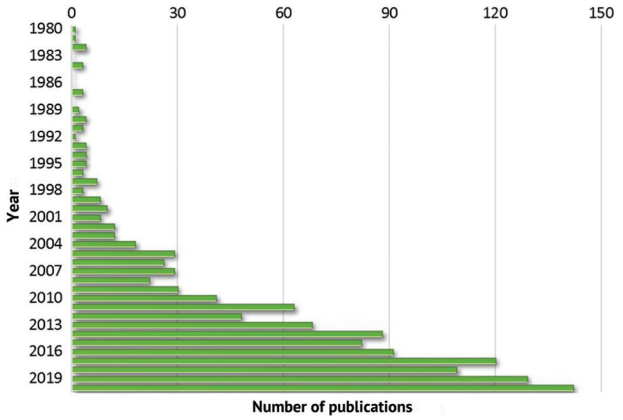

Fig. 1 Dynamics of publication activity in the scientific base Pubmed with a key word "revision elbow arthroplasty"

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Thus, in the recent decades, the need for revision operations after EJA has increased significantly in the world. The experience accumulated at the Vreden NMITS for TO on the performed interventions allowed us to formulate a number of questions this study aims to answer:

• At what age do patients undergo primary and revision EJA?

• What is the structure of the causes for primary EJA and its revision?

• Is there any regularity in the timing of the revision for aseptic loosening, PPI and other complications?

Purpose To assess the age groups of patients at the time of primary and revision arthroplasty, to study the reasons of the first and repeated revisions, the scope of interventions, as well as the time since the previous EJA.

MATERIAL AND METHODS

The database of the Vreden NMITS for TO contains information on 661 total EJAs performed in the period from 1993 to 2019: 528 (79.9 %) cases of primary arthroplasty and 133 cases (19.1 %) of revision arthroplasty (Table 1).

Table 1

Primary and repeated revisions

Intervention	Number of operations	
	No	%
Primary arthroplasty	528	79.9
First revision	111	16.8
Second revision	18	2.7
Third revision	4	0.6

Inclusion criteria were:

• Patient's from 18 years of age;

• Revision arthroplasty of the elbow joint.

Exclusion criteria:

• Contraindications for the intervention.

The retrospective study included 111 patients (133 interventions) who underwent revision EJA from 2003 to 2019: 44 (39.6 %) men and 67 (60.4 %) women (Table 2). The rate of repeated revisions was 16.5 % (n = 22). The average age of patients at the time of the intervention was 50.9 years (range, 21–80). All operations were performed by three surgeons. 104 patients (86 %) underwent primary EJA at the Vreden Center for TO, the remaining 17 (14 %) at other medical institutions of the North-West, South, North Caucasus and Central federal districts of the Russian Federation.

Table 2

General characteristics of patients included in the study

Data on 111 patients		
Gender	No.	%
Male	44	39.6
Female	67	60.4
Mean age, years	50.3 (21–80)	
Mean number of operations per patient	2.5 (1–8)	

Reasons for revisions were aseptic loosening of one or both components in 47 % (n = 63), PPI in 23 % (n = 30), dissociation of components with destruction of the elements of the connecting mechanism in 11 % (n = 15), fatigue fractures of a component in 7 % (n = 10), heterotopic ossification in 4 % (n = 5), periprosthetic fracture in 4 % (n = 5) and soft tissue complications in 4 % (n = 5), to which we attributed triceps tendon detachment (n = 1), neuropathy of the ulnar nerve (n = 1) and recurrent postoperative hematoma (n = 3). The diagnosed PPI was an indication for revision with implant retention (in manifestation of infection no later than 4 weeks after primary EJA) and two-stage revision. The latter was considered as one intervention performed.

In most revision operations, the Coonrad-Morrey system was implanted (n = 94); however, in a few cases, other implants were used, including domestic products, such as Arete (n = 8), Sivash (n = 2), Ortho-L (n = 2), Japanese implant GSB-III (n = 2) and Mutars for an oncologic case (n = 1) (Table 3).

Table 3

Implants used for revision

Implant system	No.	%
Coonrad-Morrey	118	88.7
Arete	8	6.0
Sivash	2	1.5
Mutars	1	0.8
Orto-L	2	1.5
GSB-III	2	1.5
Total	133	100

The age of patients at the time of primary and revision arthroplasty was studied, including the average age by groups, depending on the revision cause. Reasons for the first and repeated revisions, the scope of interventions, as well as the term since the previous EJA were investigated. In addition, we evaluated the experience of the surgical team and the effect of this factor on the rate of early revisions.

Statistical processing

Accumulation, correction, systematization of the initial information and visualization of the obtained results were recorded in spreadsheets Microsoft Office Excel, 2016. Statistical analysis was carried out using the Past software (version 4.03). To characterize the study group, descriptive statistics methods were used (percentages, arithmetic mean, minimum and maximum values). The Mann-Whitney U-test was used to compare independent populations in cases where there was no normal data distribution. The calculated values of the Mann-Whitney U-test were compared with the critical ones at a significance level of $p < 0.05$: if the calculated U-value was equal to or less than the critical one, the statistical significance of the differences was recognized.

RESULTS

The analysis of the age in the patients that underwent primary EJA (Fig. 2) showed the prevalence of patients in the age range of 51 to 60 years (25.4 %). It can be explained, on the one hand, by high functional needs in this working-age group, and on the other hand, by the expediency of joint replacement at this age due to a relatively low survival rate of modern EJ implants. The number of patients of the younger age (up to 30, 31–40 and 41–50 years old) did not differ significantly in the groups, accounting for 15.9 %, 17.6 % and 16.9 % in the general structure of primary arthroplasty, respectively. In the revision EJA group, the proportion of patients aged 51 to 60 years was 29.7 %, among the younger contingent there was a prevalence of those operated at the age of 31 to 40 years (19.8 % versus 12.6 % under the age of 30 and 9.9 % from 41 to 50 years old). The total proportion of patients under 40 years of age in the group of primary EJA was 33.5 % and in the revision group it was 32.4 %.

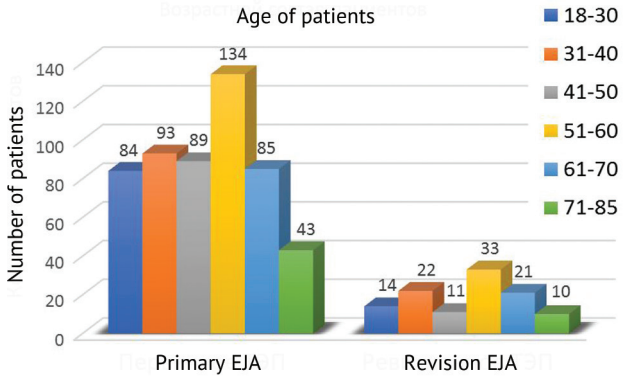

Fig. 2 Age distribution of patients who underwent primary and revision arthroplasty

When assessing the average age of patients, depending on the reason for revision, it turned out that the youngest were patients with dissociation of the implant components, whose average age was 46.4 years (31–80), followed by patients with PPI – 48.2 years old (22–74), aseptic loosening – 52.1 years (23–80) and break of components – 53.4 years (29–69). Despite the visible difference in the mean values, a comparative evaluation did not show statistically significant differences ($p = 0.1$); thus, we did not identify the relationship of this factor with a specific reason for revision.

The most frequent reason of the first performed and repeated revision was aseptic instability: 47 and 50 %, respectively (Fig. 3). Out of 63 revisions performed for this complication, both EA components were replaced in 34 cases (54 %), only the humeral component in 25 (39.7 %) and in 4 cases (6.3 %) the ulnar component was changed. Nine patients (14.3 %) had pronounced defects of the distal humerus with the loss of both epicondyles, which required grafting. A diaphyseal tubular allograft of the tibial diaphysis was used in 5 cases, a cancellous composite formed from the head of the femur in 3 cases, and an autograft taken from the iliac crest in one patient. Due to a pronounced cavitary defect of the humerus, 13 patients (20.6 %) required impaction plasty with crushed cancellous grafts.

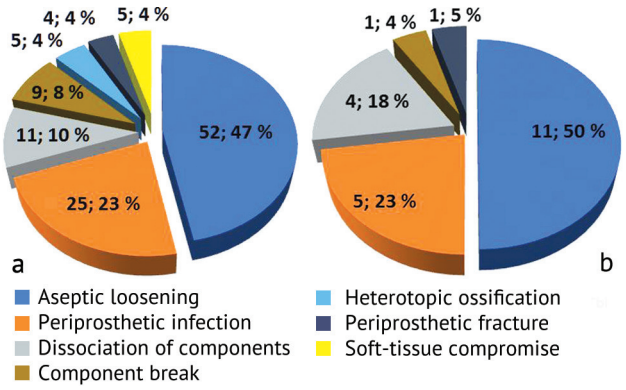

Fig. 3 The structure of the reasons for the first (a) and repeated revisions (b)

The second most frequent indication for revision was PPI (23 % in both groups). The diagnosis of deep infection was established based on clinical manifestations (pain, sinuses, fever, local signs of inflammation), laboratory data (leukocytosis, shift of the leukocyte formula to the left, erythrocyte sedimentation rate, the level of C-reactive protein, leukocyte esterase and other nonspecific markers of inflammation), X-rays and the result of synovial fluid punctate culture [3].

In total, out of 30 cases of diagnosed PPI, 29 underwent two-stage revision and one was one-stage with implant retention since the infection occurred in the early postoperative period. However, despite the timely intervention, the patient had a infection recurrence which required two-stage revision. The first stage of the infectious revision involves the implementation of a radical debridement of the focus of infection and the installation of an antibacterial spacer (Fig. 4). After at least 3 months, upon confirmation of infection arrest, the second stage of the revision is performed, the antimicrobial spacer is removed and the components of a larger size are implanted.

Fig. 4 Antimicrobial spacer of the elbow joint, implanted in the patient at the first stage for periprosthetic infection; congruent surfaces were modeled on the surfaces of the humeral and ulna components of the spacer for mobilizing the limb during the waiting period for second stage of the revision

The third place in terms of the incidence rate was occupied by the dissociation of the components of the endoprosthesis in both groups (10 % in the group of the first-time revision and 18 % among repeated revisions). This complication occurs due to the critical wear of the polyethylene bushings in the friction pair and the subsequent metal-to-metal contact, which eventually leads to a fatigue fracture of the elements of the connecting mechanism. We replaced the polyethylene liners and connecting elements.

Fatigue fracture of the components ranks fourth in the structure of the first-time and repeated revisions (8 % and 4 %, respectively). Six cases were breaks of the humeral component of the Arete system in its condylar part, which required replacement of both components (Coonrad-Morrey implant), since the production of the previous implant system had been discontinued by the time the revision was performed. Four patients had a fatigue fracture of the Coonrad-Morrey ulnar component in its proximal part. At the same time, a zone of focal osteolysis was visualized on radiographs in the area of the fracture in all those observations which probably developed due to polyethylene wear.

Complications requiring intervention without replacing the components (periprosthetic fracture, heterotopic ossification, and soft tissue complications) occur in a significantly smaller number in the revision structure (12 % in the first group, 9 % in the second). Due to a small number of cases, these complications were excluded from the comparative analysis.

Table 4

Causes of revision according to etiology, n (%)

Cause	Etiology			
	Rheumatoid arthritis	Consequences of injuries	Tumors	Total
Loosening	12 (66.7)	40 (44.9)	–	52 (46.8)
Infection	2 (11.1)	22 (24.7)	1 (25)	24 (21.6)
Dissociation of components	1 (0.5)	8 (9.0)	2 (50)	11 (9.9)
Break of components	2 (11.1)	7 (7.9)	–	9 (8.1)
Ossification	–	5 (5.6)	–	5 (4.5)
Periprosthetic fracture	–	3 (3.4)	1 (25)	4 (3.6)
Soft tissue complications	1 (0.5)	4 (4.5)	–	4 (3.6)
Total	18 (16.2)	89 (80.2)	4 (3.6)	111 (100)

The causes of revisions, depending on the etiology, showed that in patients who underwent primary EJA due to the consequences of previous EJ injuries, the PPI revision was two times higher than in patients with rheumatoid arthritis (24.7 % and 11.1 %, respectively) (Table 4). Of considerable interest is a significantly higher percentage of component dissociation among patients with post-traumatic conditions (9.0 % compared to 0.5 % in patients with rheumatoid arthritis), since this complication develops due to an increase in the varus-valgus range of motion in case of defects of the humeral epicondyles, usually observed after injuries and interventions. In the future, critical wear of the friction pair develops, leading to metal-on-metal contact and subsequent fatigue fracture of the connecting pin [4].

Analyzing the dynamics of the revision operations by time from the moment of the previous EJA, we observed a significant difference in relation to aseptic loosening and deep infection (Fig. 5). Most of the revisions performed due to PPI occur in the first year since the previous EJA (56.7 %). In subsequent years, there is a multiple decrease (20 % in the second year, 6.7 % in the third year). Thus, the greatest risk of developing pyoinflammatory complications after EJA occurs in the first three years after the previous intervention. Further on, the likelihood of PPI decreases sharply.

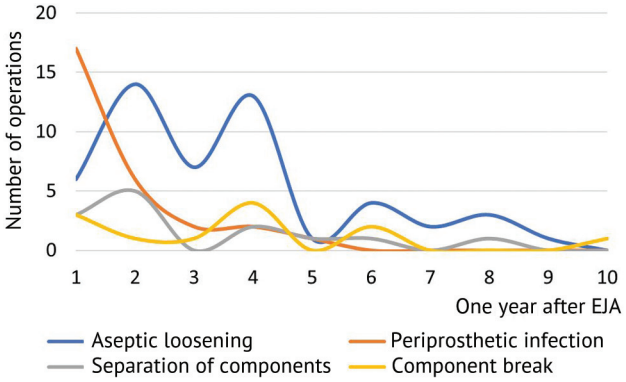

Fig. 5 Distribution of revisions by terms from the previous operation

In the revisions performed for aseptic instability, two periods can be distinguished: an early one (from 1 to 4 years after the previous intervention), which accounts for 2/3 of revisions, and remote one (from 5 to 10 years). Looseness of components that occurs in the early period is more likely associated with defects in the EJA performance, namely, incorrect positioning of components, inadequate cementation, selection of an inappropriate size of components, bone defects, and others. In the long-term period, the role of mechanical factors associated with the constitutional and behavioral characteristics of patients increases which include wear of the friction pair and subsequent osteolysis, obesity, increased loads on the operated limb in patients with a high level of physical activity. In an attempt to determine the possible reason for the significant predominance of early revisions performed for aseptic in stability, we assessed the experience of the surgical team. Table 5 shows the ratio of the number of early revisions to the total number of primary EJA at different time intervals (Table 5). The period from 1997 to 2002 is characterized by the highest percentage of revisions (19.4 %) due to mastering the EJA technique. In subsequent five-year periods, this rate is 8.8 % and 14.7 %, respectively. And only after 2015, the experience gained in EJA performance, more than 200 performed operations, enabled to significantly reduce the revision rate due to early loosening to 3.5 %.

Table 5

Ratio of early revisions performed for aseptic instability to the total number of primary EJA at different time periods

Time period (years)	Number of primary EJA	Number of early revisions performed for aseptic instability	Rate of early revisions performed for aseptic instability to the total number of primary EJA (%).
1997–2002	36	7	19.4
2003–2008	68	6	8.8
2009–2014	170	25	14.7
2015–2019	254	9	3.5

DISCUSSION

The present study included 177 patients who underwent primary EJA between the ages of 18 and 40. In regard to the survival rate of modern implants, it can be assumed that the majority of patients of this age group might have to undergo from 2 to 5 revisions. Accordingly, each subsequent revision surgery increases the loss of bone tissue. A pronounced defect in the distal humerus extending above the level of the epicondyle needs bone grafting [5]. The present state of experience in using grafting in EJA does not allow making reliable conclusions about their long-term effectiveness. In the foreign literature, the samples of patients with bone defects managed in the area of EJA are about 10–20 observations. P. Mansat's study included 13 patients with severe defects of the humerus and ulna who underwent revision EJA and filling the defects with tubular allografts. On average, after 42 months, 7 patients required revision for PPI (n = 4) and aseptic instability (n = 3) [6]. R. Amirfeyz et al. evaluated the results of using similar grafts in 10 patients (11 elbow joints) at an average follow-up of 75 months (range, 25 to 213). Only one patient required revision due to the developed infection. However, signs of initial or moderately pronounced peri-implant bone resorption were observed in 6 cases [7]. The largest sample is presented in the study by B.F. Morrey: 25 patients with a mean follow-up of 3.4 years (range, 2 to 7.7 years). Despite good indicators of EJ function recovery and satisfaction, 6 patients had serious complications: 3 cases of PPI and 3 periprosthetic fractures [8]. Thus, prevalence of young patients in the structure of primary and revision EJA is likely to lead to an increase in the number of patients with severe bone defects in the long term.

We divided the revisions included into our study into 2 groups: first-performed and repeated ones. Moreover, in both groups, the largest number of revisions was performed for aseptic loosening of the components. According to the world literature, the incidence of this complication in the long-term period ranges from 7 to 15 % [9–11]. Our previous study investigated possible risk factors for early loosening of components, and among them the defects in the technique of performing the operation played the greatest role, and namely, inadequate cementing and inaccurate positioning of components [12]. In this regard, the experience of the surgical team plays an important role in EJA. The data of our study demonstrate a significant decrease in the number of revisions over the past 5 years performed for early loosening, despite the general increase in the number of primary EJAs.

Revision for aseptic instability in some situations is accompanied by the need to fill in pronounced diaphyseal cavity defects. Thanks to the experience extrapolated from hip joint revision surgery, the method of impact bone grafting has now been gaining popularity abroad [13]. N.A. Ramaniraka et al. conducted practical experiments on the stability of cemented implants of the hip joint and found that the micromobility of the femoral stem is minimal when the thickness of the cement mantle is from 3 to 4 mm. With an increase in its thickness, the component instability also increases [14]. Accordingly, in managing extensive cavitary defects with compacted bone chips, we provided a thinner cement coating of the implant to reduce the likelihood of loosening. In our clinic, impaction bone grafting was used in 13 cases for cavitary defects of the humerus in revision EJA. At present, the assessment of the effectiveness of this method has been reported in a few series of observations, which, nevertheless, demonstrate acceptable results in the medium term. Thus, Y.G. Rhee et al. included 16 cases of revision EJA with impacted bone grafting of defects at an average follow-up of 7.4 years (range, 4.1 to 11.2 years). Excellent and good results were recorded in 15 cases. Revision with replacement of components was required in one patient due to a periprosthetic humerus fracture after 8 months [11]. M.I. Loebenberg et al. evaluated the results of 12 interventions with a minimum follow-up period of 2 years (up to 10 years). Re-revision with replacement of components was required in 4 patients for aseptic loosening (n = 2), PPI and fracture of the ulnar component [15]. Alternative methods for cavitary defects, including the use of structural allografts and customized constructs, have not been widely used, since they are accompanied by a significantly higher number of poor outcomes [16–18].

It should be noted that until now there is no unified classification of bone defects in the distal humerus which would enable to determine the optimal method in each specific case. The classification of B.F. Morrey is based on the loss of anatomical structures. Grade 1, there is no block and/or head of the humerus; grade 2, the defect extends to the coronary fossa; grade 3 and 4 correspond to the loss of one or both epicondyles, respectively [19]. This classification does not take into account the severity of the

cavitary defect, the amount of loss in the diaphysis of the humerus, the degree of retraction of the shoulder muscles. The development of a working classification based on long-term clinical and radiological results, in our opinion, would solve the problem of choosing the optimal method for management of bone defects, as well as the need to perform impacted bone grafting in revision EJA.

The second place in terms of the number of revisions performed is taken by the PPI (23 % in both groups). According to the literature, the incidence of infection after primary and revision EJA ranges from 1 to 12.5 % [20–23]. There are several options for surgical treatment of PPI in revision EJA: debridement with retention of the implant, one-stage revision, resection arthroplasty, and two-stage revision. Revision with retention of the implant can only be used in the treatment of acute PPI; otherwise the risk of infection recurrence sharply increases [24]. According to Achermann et al., this intervention is indicated only if the following four conditions are met:

• short period of infection onset (no later than 3 months);

• timely revision performance (no more than 21 days from the onset of symptoms);

• preservation of para-articular soft tissues;

• sensitivity of microorganisms to antibiotics, which are active even against biofilms (rifampicin for staphylococci, quinolones for gram-negative bacteria).

One-stage revision, according to the author, is possible only if soft tissues are intact and if microorganisms that cause intractable inflammation are not detected, which include rifampicin-resistant staphylococci, enterococci, as well as quinolone-resistant bacilli and fungi [25]. The Materials of the II International Consensus Conference on Musculoskeletal Infection state that until now there are no clear indications for a one-stage replacement of EJ implant components in deep infection. However, it is preferable to resort to two-stage revision in the presence of sinuses, compromised para-articular soft tissues or systemic sepsis, [26]. The performance of resection arthroplasty is often accompanied by unsatisfactory results due to the loss of EJ stability (especially in a defect extending to the level of the humeral epicondyle); therefore, it can be considered only for elderly patients with a low level of activity, as well as in a high surgical or anesthetic risk [27].

Therefore, to date, two-stage revision is the only method of treating chronic PPI, which is able to stop the infectious process with a high probability and restore EJ function [28, 29]. According to our study, out of 29 patients, only 2 (6.7 %) had infection recurrence after the second stage of revision. At the same time, rather contradictory information about the effectiveness of this intervention was presented in the literature. W.B.J. Rudge et al. showed 19 patients who underwent two-stage revision with recurrence of infection in three cases (16 %) [30]. D.A. DeBernardis et al. retrospectively studied 14 cases of PPI. The recurrence rate of infection after the second stage of revision was 35.7 % (5:14) [31]. C.A. Peach et al. reported a series of 33 observations of chronic PPI. The efficiency of two-stage revision was 89 % [32].

Summarizing the above, it should be noted that the choice of the optimal method of surgical treatment for PPI should be based on the time of the onset of symptoms, the nature of the pathogen, the sensitivity of the microorganism to antibiotics, the state of soft tissues, as well as the surgical and anesthetic risks.

CONCLUSION

The age from 51 to 60 years among the patients prevailed significantly. However, the total proportion of patients under 40 years of age in the group of primary AP was 33.5 % while in the revision group it was 32.4 %, what makes us think about the prospects of reoperations.

In the groups of the first and repeated revisions, the most common causes were aseptic loosening of components (47 % and 50 %, respectively) and periprosthetic infection (23 % in both groups). A significantly smaller number of revisions were performed for dissociation, fatigue fracture of components, heterotopic ossification, periprosthetic fracture, and soft tissue complications.

Most revisions due to infection (83.4 %) were performed within the first three years after the previous intervention. With regard to the timing of aseptic instability, the early and late periods were identified. After 2015, the experience in arthroplasty, which is more than 200 surgeries, enabled us to significantly reduce the rate of early revisions to 3.5 % in relation to the total number of primary arthroplasty. However, in the more long-term period, the expected increase in the number of patients with severe bone defects and recurrent infections actualizes the search for new surgical solutions in revision arthroplasty of the elbow joint.

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Information about the authors:

1. Alimurad G. Aliev – M.D., mur23mur@yandex.ru;
2. Andrey V. Ambrosenkov – Candidate of Medical Sciences, ortopedus09@gmail.com;
3. Andrey A. Boyarov – M.D., boyarovaa@mail.ru;
4. Georgy I. Zhabin – Doctor of Medical Sciences, Professor, gijavj@rambler.ru;
5. Svetlana Yu. Fedyunina – Candidate of Medical Sciences, fedyuninasyu@mail.ru;
6. Rashid M. Tikhilov – Doctor of Medical Sciences, Professor, info@rniito.org;
7. Igor I. Shubnyakov – Doctor of Medical Sciences, info@rniito.org.