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Analysis of knee arthroplasty revision causes

M.V. Girkalo✉, I.N. Shchanitsyn, V.V. Ostrovskij

Research Institute of Traumatology, Orthopaedics and Neurosurgery at the Razumovsky Saratov State Medical University, Saratov, Russian Federation

Corresponding author: Mikhail V. Girkalo, girkalo@mail.ru

Abstract

Introduction Existing discrepancies in knee arthroplasty registries regarding the definition of indications for revision TKA lead to confusion related to the identification of the leading pathology. Many works indicate not only one but several reasons for revision which makes comparison difficult. Therefore, the issue of categorizing indications for revision TKA is a weak point of the available registries and of any large retrospective series. **Purpose** To systematize the etiology of pathological conditions leading to revision knee arthroplasty.

Materials and methods The study included 361 revision knee arthroplasties. A comparative analysis of the etiology of complications of primary arthroplasty was carried out with data from national arthroplasty registries and clinical studies.

Results The main indications for revision knee arthroplasty were infection in 48.2 % of cases (174/361), aseptic implant instability (osteolysis) in 38.2 % (138/361), and instability of the ligamentous apparatus in 4.2 % (15/361). In 98 cases (27.1 %), only one type of complication was identified, and in 263 (85.2 %) more than one. Infection prevailed among early complications (126/234, 54 %) and aseptic loosening (osteolysis) (69/127, 54 %) predominated among late complications.

Discussion In our opinion, the indications for revision arthroplasty can be divided into three main etiological groups: periprosthetic infection (group I); conditions associated with a response to polyethylene wear products (osteolysis) (group 2); and biomechanical disorders, which include spatial malposition, incorrect implant sizes and all types of instability (group 3).

Conclusion Our systematization of revision arthroplasty causes can help in further research and will be useful in creating a national registry of arthroplasties in Russia.

Keywords: knee joint, joint replacement, complications, revision arthroplasty, registry, infection, instability, osteolysis

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INTRODUCTION

Total knee arthroplasty (TKA) is the most common and effective treatment method for patients with advanced knee osteoarthritis (OA). It can relieve pain and improve functional status [1]. However, some patients do not experience improvement due to complications that develop and require repeated surgery on the joint. Revision knee arthroplasty is a complex therapeutic and diagnostic task with an increased risk of complications compared to primary knee arthroplasty [2]. It requires a responsible approach to the indications for revision TKA, which determines the need for a detailed analysis of the reasons for the primary arthroplasty failures. Accurate identification of the leading pathology in the replaced knee joint and targeted elimination of its cause ensures a favorable outcome in the treatment of patients with complications after primary arthroplasty.

A general idea of all the reasons of TKA failures and the absolute indications for revision arthroplasty can be obtained by studying the data from national registries and multicenter studies. However, registry data vary due to the specifics of filling out data forms, analyzing and interpreting the results obtained [3]. Multicenter studies provide a more detailed picture. Nevertheless, their results may also be ambiguous. Dalury et al. stated that the first place among the reasons for revision arthroplasty is implant instability and infection [4], and according to Thiele et al. the leader among the indications for revision is instability of the implant components followed by instability of the ligamentous apparatus while infection takes only the third place [5]. Sharkey et al. reported that polyethylene wear was the most common cause of revision, observed in 19.4 % of all revisions at their institution [6]. However, 10 years later, Sharkey et al. reported that aseptic loosening (39.9 %) surpassed polyethylene wear (3.5 %) [7]. Recently, polyethylene wear has not been considered as an isolated indication for revision arthroplasty since there is an opinion that wear products initiate the development of osteolysis.

The existing discrepancies in knee arthroplasty registries that may determine indications for revision TKA lead to confusion regarding the identification of the leading pathology. Thus, some authors consider pain in the knee joint in the absence of proven presence of other types of complications as a separate indication for revision. However, the cause of this condition may be unspecified infections, instability of the ligamentous apparatus, misalingment of components, or progression of osteoarthritis. Many works indicate not only one but several reasons for revision, what makes comparison difficult. Thus, the issue of categorizing indications for revision TKA is a weak point of the available registries and any large retrospective series.

Purpose of the work was to systematize the etiology of pathological conditions leading to revision knee arthroplasty.

MATERIALS AND METHODS

The study included 361 clinical records in 288 patients who underwent revision arthroplasty between January 2016 and December 2019. The study was conducted at the SSMU Research Institute for TO&N, approved by the local ethics committee (protocol dated 10.04.2018 No. 8), included in the scientific research plan of SSMU (state registration number NIOKTR AAAA-A18-118050890023-7).

As part of the study, we analyzed the etiology of complications that determined the indication for revision TKA, including time after primary TKA; calculated the rates of revision interventions; various demographic data, including age, gender, body mass index (BMI), presence of concomitant pathology; surgical techniques used to perform revision TKA.

We define revision surgery as a new intervention on a previously replaced knee in which one or more components (femoral, tibial, liner, patella) are changed, removed, realigned, or added. Revision surgery may or may not be accompanied by re-implantation of new components during the same surgical session (single-stage revision) or at a later date (multi-stage revision). All procedures of single- and multi-stage treatment due to infection were regarded as one revision. We divided all

revision interventions into first and repeated revisions. A repeated (second) revision was defined as an intervention after the first revision arthroplasty. Procedures in which all components were removed and a cement spacer was placed due to infection were also recorded as a separate revision event. The revisions included surgical procedures with arthrotomy aimed at improving the balance of the soft tissues of the joint (arthrolysis), debridement and irrigation of the joint, sanitation of the joint in case of chronic recurrent hemarthrosis. We also interpreted revisions for failure of unicondylar implants due to progressive arthrosis as a separate revision intervention.

Time to revision was defined as the interval between primary arthroplasty and the first revision, and between the first revision and re-revision. In cases of two-stage revision, we used the date of re-implantation as the end time point of revision. Due to the lack of a consistent and generally accepted categorization of revision periods into early and late in the literature, we adhered to those proposed by Sharkey et al. time intervals: up to two years was early revision, more than two years was late revision [6].

Diagnosis of pathological conditions was carried out as follows. To confirm periprosthetic infection, the criteria of the International Consensus of Joint Infection were used [8]: the presence of a fistula, double detection of the infectious agent during bacteriological examination of punctate synovial fluid of the knee joint and biopsy specimens, leukocytes and neutrophils counts in synovial fluid. X-ray data were used to detect osteolysis in the implant area. To assess the spatial orientation of the components, radiography was taken in a standing position capturing the hip, knee, and ankle joints, and, if necessary, computed tomography (CT) was used. Spatial orientation of the components and failure of the knee joint ligaments was confirmed intra-operatively. Findings were compared with national registries and published studies.

Statistical data processing was carried out using SPSS 21.0. The normality of the distribution of quantitative characteristics was assessed using the Kolmogorov – Smirnov and Shapiro – Wilk methods. Given the non-normal distribution of most quantitative characteristics, nonparametric statistical methods were used. To describe quantitative parameters, median and quartiles were used. Analysis of differences between groups in quantitative characteristics was carried out using the Mann – Whitney U-test. For qualitative characteristics, the Pearson Chi square test was used. Results were considered significant at $p < 0.05$, and two-sided significance was assessed for all criteria.

RESULTS

For the period from 2016 throughout 2019, the SSMU Research Institute for TO&N performed 7,877 knee arthroplasties, of which 7,516 were primary and 361 were revision. Revision interventions accounted for 4.58 % of the total number of arthroplasties. In 175 cases out of 361 (48 %), primary arthroplasty was also performed at SSMU, 186 patients out of 361 (52 %) were referred to our center from other medical institutions. Among all cases of revision knee arthroplasty, the first revision was performed in 64.5 % (233/361). The second revision was completed in 27.7 % (100/361). The third and fourth revisions were performed in 6.4 % (23/361) and 1.4 % (5/361), respectively. According to gender, revision interventions prevailed in women, amounting to 75 % (270/361). Median age was 65 years (59–71; IQR — interquartile range); BMI was 34 (29-37; IQR). In the majority of cases, the indication for primary arthroplasty was osteoarthritis (82 %).

Among the first revisions, 139 operations (59.7 %) occurred after less than two years after the initial implantation. The median was 19 months (IQR: 11–36 months). In 128 cases (35.4 %) two or more revisions were performed on one joint. 74 % (95/128) of all repeated revisions were completed within two years. In terms of age groups, patients aged 65 to 74 years were more likely to undergo revision arthroplasty (43 %), followed by patients aged 55 to 64 years (38 %).

Among the indications for revision, infection was the cause in 48.2 % (174/361) of cases, aseptic instability in 38.2 % (138/361), instability of the ligamentous apparatus in 4.2 %, contracture/arthrofibrosis in 3.9 %, problems with the patella in 1.7 %, periprosthetic fracture in 1.4 %, spatial

maialingment in 1.1 %, wear of the implant in 0.6 %, and other reasons (prolonged wound healing, separation hematomas in three cases) in 0.8 %. One type of complication was revealed in 98 patients (27.1 %), 263 (85.2 %) had more than one type of complication.

Early complications within two years were observed in 234 patients (65 %), late complications two years or more after primary arthroplasty were detected in 127 cases (35 %). The structure of early and late complications is presented in Table 1. Among early complications, infection prevailed in 126 (54 %) cases, and among late complications, aseptic loosening predominated in 69 (54 %) cases.

Table 1

Primary TKA complications and time to revision

Revision cause	Total (n = 361)		Revision time, months					
			Me (IQR)	Early, < 2 years (n = 234)		Late, > 2 years (n = 127)		p*
	abs.	%		abs.	%	abs.	%	
Infection	**174**	**48**	15 (7–27)	**126**	**54**	48	38	**0.004**
Aseptic loosening	**138**	**38**	24 (12–43)	69	30	**69**	**54**	**< 0.001**
Contracture	14	3,9	10 (3–16)	**13**	**5.6**	1	0.8	**0.024**
Ligaments instability	15	4,2	14 (6–19)	12	5.1	3	2.4	0.275
Patella problems	6	1,7	17 (9–32)	4	1.7	2	1.6	0.644
Misalingment	4	1,1	16 (13–44)	3	1.3	1	0.8	0.56
Periprosthetic fracture	5	1,4	13 (10–86)	3	1.3	2	1.6	0.576
Implant wear	2	0,6	26 (18–26)	1	0.4	1	0.8	0.58
Others	3	0,8	5 (1–5)	3	1.3	0	0	0.271

* — χ^2 (Exact Fisher test)

In 149 (64 %) cases, first revisions were performed after primary TKA with posterior stabilization. In 70 cases (30 %), they were done after installation of endoprostheses with preservation of the cruciate ligament. Table 2 presents the characteristics of the revision interventions performed.

Table 2

Characteristics of revision surgeries performed

Revision intervention	All revisions (n = 361)		First revision (n = 233)		Re-revision (n = 128)		p*
	abs.	%	abs.	%	abs.	%	
One-stage revision	130	36	88	37.7	42	32.8	0.378
All components changed	99	76	66	28.3	33	25.7	0.392
Femoral components change	4	3	4	1.7	0	0	
Liner change	11	8	9	3.8	2	1.5	
Liner and tibial component change	3	2	2	0.85	1	0.8	
Tibial component change	13	10	7	3	6	4.7	
Change of unicondylar implant	1	0.3	1	0.4	0	0	0.67
Knee cap replacement	5	1.4	3	1.3	2	1.6	0.581
Two-stage revision	193	53.5	132	56.7	61	47.6	0.101
1 stage: spacer installation	31	16	15	6.4	16	12.5	< 0.001
2 stage: change of spacer for implant	156	81	117	50.2	39	30.4	
Spacer change	6	3	0		6	4.6	
Resection arthroplasty	3	0.8	0		3	2.3	0.044
Revision and sanation (debridement, irrigation)	12	3.3	2	0.9	10	7.8	0.001
Arthrodesis	3	0.8	1	0.4	2	1.6	0.287
Arthrotomy, arthrolysis	14	3.9	6	2.5	8	6.3	0.084
Patella ligament plasty (MPFL reconstruction)	1	0.3	1	0.4	0	0	0.645
Osteosynthesis	5	1.4	2	0.9	3	2.3	0.241

Continuator of the Table 2

Characteristics of revision surgeries performed

Parameters	All revisions (n = 361)	First revision (n = 233)	Re-revision (n = 128)	p*
Time of surgery, min	115 (95–135)	115 (95–135)	110 (75–125)	0.592
Blood loss, ml	200 (200–300)	200 (200–300)	200 (200–300)	0.672
Blood loss along the draining system, ml	300 (200–500)	300 (200–500)	300 (200–500)	0.353
Term of hospital stay, days	8 (7–10)	8 (7–10)	9 (8–13)	0.046
Follow-up, months	26 (11–52)	26 (14–55)	24 (11–42)	0.501

* — calculation of the χ^2 test (Fisher's exact test) and the Mann – Whitney U test.

The first and repeated revisions did not differ significantly when comparing the frequency of one-stage and two-stage interventions. Resection arthroplasty and arthrodesis were performed mainly in re-revision. There was an insignificant increase in the median time between stages of surgical treatment with a two-stage approach in the group of repeated interventions (p = 0.523). Operative time, intraoperative and postoperative blood loss did not differ between the first and second revision groups. The median length of hospital stay for the revision procedure was 8 days (7–10 days); arthrotomy procedures were associated with the longest stay of 12 days (10–14 days) and revision of the patellar component associated with the shortest stay of 3 days (3–5 days).

DISCUSSION

According to national registries and databases, there is an annual increase in the number of revision knee arthroplasties along with an increase in the number of primary knee replacements [9, 10, 11]. In the United States, the number of revision TKAs is predicted to increase by 78–182 % over the next 10 years [10]. Complications after knee arthroplasty are not frequent; however, according to the main arthroplasty registries, they range from 2.0 to 11 %. The Australian registry states the revision rate at the average of 8.6 % over the last 20 years [12]. The English registry reports an average of 6.2 % [13], the North American registry of 8.5 % [14]. The same is observed in Russia. According to the register of Vreden NMRC for TO, an increase in the number of revision arthroplasties was 204 % from 2011 to 2019, while the ratio of primary and revision arthroplasties remained unchanged [15]. At SSMU, the annual revision rate increased slightly from 4.8 % in 2016 to 5.9 % in 2019. The average annual revision rate among all knee arthroplasties for 2016–2019 amounted to 4.6 %.

In our study, the median time between the first operation and revision arthroplasty was 17 months (9–34, IQR). The interval is lower than the data of foreign authors. According to a study by Postler et al., which included 402 observations, the time between primary arthroplasty and the first revision averaged 8.1 years [16]; Sharkey et al. reported a 7-year interval until the first revision [7]; Thiele et al. showed an average time to first revision of 7.9 years in a series of 358 patients [5]. In our opinion, this may be due to the predominance of patients with early complications in our study. Within two years, the first revision was performed in 234 cases, which was 65 %. Our colleagues had early revisions in 76 cases out of 402, which is only 19 % [16].

The structure and correlation of indications for revision arthroplasty in most foreign studies is ambiguous. Thus, according to Sharkey et al., the main reason for revision was polyethylene wear (19.4 %) [6], but 12 years later the data changed, and the leading reason for revision knee arthroplasty was osteolysis (39.9 %) [7]. Thiele et al. identified the following leading indications for revision: osteolysis (21.8 %), ligament instability (21.8 %) and malposition of implant components (20.7 %) [5]. In the Italian and Australian arthroplasty registries, osteolysis as the main indication for revision, accounting for 33 % and 27 %, respectively. The second place as an indication for re-intervention is taken by infection, which accounts for 27 and 23 % of cases,

respectively [17, 12]. Similar results were obtained from the Swiss registry: aseptic loosening and osteolysis were detected in 21.8 % of cases, infection in 14 % [18]. According to the US database, aseptic loosening was also prevalent in the period from 2009 throughout 2013 [19], but in the subsequent US registry (2012–2021), infection was the main reason for revision (28 %) [14].

The structure of complications of primary knee arthroplasty that result in re-intervention, obtained during our study, is presented in Table 1. Among early complications (up to two years after primary knee arthroplasty), infection predominated (54 %), and among late complications, it was aseptic loosening (54 %). The results are similar to other studies. Thus, within a period of up to two years, the most common indications for revision arthroplasty reported are infection and instability of the ligamentous apparatus [5, 7, 16]. The results of studies in which infection is in the first place among the indications for revision demonstrate the prevalence of patients with an increased BMI [20, 21]. Likewise, in our study, among all revisions, interventions in obese patients predominated; the median BMI was 34 kg/m2 (29–37, IQR).

Two-years after primary arthroplasty, the most common indications for revision are osteolysis with instability of implant components and wear of polyethylene [6, 22]. In our study, among the reasons for early revisions following infection are aseptic loosening and osteolysis (30 %), limitation of the range of motion (contracture/arthrofibrosis) (5.6 %), instability of the ligamentous apparatus (5.1 %), problems with the patella (1 .7 %), periprosthetic fractures (1.3 %), malposition of endoprosthetic components (1.3 %) and implant wear (0.4 %). Aseptic loosening and osteolysis, as indications for early revision, were revealed in 30 %.

Among the complications that arose two years or more after primary arthroplasty, the first places were aseptic loosening (54 %) and infection (38 %), followed by instability of the ligamentous apparatus (2.4 %), problems with the patella (1.6 %) and periprosthetic fractures (1.6 %), malposition of endoprosthetic components (0.8 %) and implant wear (0.8 %). These data do not show any discrepancy with the results of previous studies.

It should be noted that continued studies of the etiology of revision knee arthroplasty may be a step towards improving outcomes and reducing the need for repeated revisions in the future. The data we obtained on the rates of revision arthroplasty indicate that the predictions of our foreign colleagues are coming true [23]. We noted an increase in the rate of revision arthroplasties in the structure of operations on the knee joint from 3.1 % in 2017 to 5.9 % in 2019; in absolute terms, there was also an increase up to 116 operations. In our opinion, this is due to the fact that knee replacement surgery is one of the most common in orthopedics and is performed everywhere. At the same time, a significant number of orthopedic surgeons perform less than 50 arthroplasties per year, and the regularity of this procedure performed by the surgeon has an impact on the incidence of complications [24]. In our opinion, this hypothesis requires testing in future studies and it will likely be necessary to determine the minimum threshold of surgical activity of the orthopedic surgeon to successfully complete the learning curve.

Comparing the time interval between primary and revision arthroplasty, we noted a significant difference between our data and the data of foreign studies. Just one and a half years versus seven years reported by Sharkey et al. [7]. This is explained by the significant proportion of early complications in patients in our study. Complications that developed within a period of up to two years were noted in 234 patients (64.8 %), among whom there were predominantly patients with periprosthetic infection (126; 54 %).

Our data coincide with the data of Postler et al. [16]; infection, as the leading indication for revision, was noted by them in 36.3 %, osteolysis in 21.6 % (our data, 48.2 % and 38.2 %, respectively). However, the situation in the national registries of Germany, Norway and New Zealand is

somewhat different, and osteolysis dominates there as the main reason for revision [25, 26, 27]. This may be explained by differences in patient recruitment for studying. Thus, registers take into account all cases of revisions on the territory of the entire state, and these data can be considered quite objective and correct. In the case of studies conducted at large orthopedic centers, the patient population is somewhat different. Due to the high resource intensity [16, 20, 21] and the requirements for the qualifications of medical personnel necessary for the successful treatment of infectious complications, patients with periprosthetic infection from other medical institutions are concentrated in large federal centers. This fact changes the statistics. This is exactly what can be observed in our study and in the study by Postler et al. [16]. It is worth noting that the trend of the North American Health System Registry indicates an increase in infectious complications in the structure of indications for revision arthroplasty, especially with early revision (within the first three months after primary arthroplasty). The comparison of different reasons for revisions revealed an increase in the infection rate from 18.2 % in 2012 [19] to 28.4 % in 2021 [14]. This fact that the North American registry differs from the European and New Zealand national registries suggests that this trend may soon become widespread. In our opinion, this may be due to the worsening somatic status of patients undergoing primary arthroplasty. The results of the studies in which infection takes the first place among the indications for revision demonstrate the dominance of patients with an increased BMI [21]. Likewise, in our study, among all revisions, operations performed on obese patients prevailed. The median BMI was 34 kg/m^2 (29–37, IQR).

Noteworthy is the fact that we found malposition of the implant components in the majority of patients with contractures of the knee joint, signs of instability of the ligamentous apparatus and pain without confirmed osteolysis and infection,. Component misalignment was identified intra-operatively as oversizing or rotational deviations of the femoral and tibial components. These deviations of the endoprosthesis components in most cases manifested themselves clinically in the form of pain and limited range of motion that arose immediately after primary arthroplasty.

The fact is that the main reasons for patient dissatisfaction, which reduces the quality of life, are pain, limited range of motion and joint instability [28]. However, these symptoms can be a manifestation of various conditions and pathological processes. In our study there were eight of these (from infection and aseptic instability to misorientation and pain of unknown etiology). Many conditions have a common nature. Thus, problems with the patella such as instability or pain, as well as contracture or arthrofibrosis, can be a consequence of spatial misorientation of the components of the endoprosthesis [29, 30]. In our opinion, the entire set of indications for revision (complications of primary arthroplasty) can be divided into three main etiological groups: group I of periprosthetic infection; group II are conditions associated with a response to polyethylene wear products (osteolysis); group III are biomechanical disorders, which include spatial malposition, improper size of the endoprosthesis and all types of instability. According to this categorization, we can offer an explanation of the causes of these complications. Thus, the risk of infectious complications is influenced by the patient's condition (obesity, concomitant pathology and immunodeficiency); in the development of osteolysis, an important risk factor is the quality of the materials from which the implant is made. In particular, high molecular weight polyethylene without cross-linked molecules is significantly inferior in wear resistance to polyethylene made using crosslink technology or impregnated with vitamin E. The complications in the group of biomechanical disorders is caused by errors in the surgical technique of performing the operation and depends on the skill of the surgeon and his equipment with high-precision instruments such as computer navigation or personal resector units. All of the above involves carrying out a set of measures to stratify and manage the risks of developing these complications (Table 3).

Table 3

Characteristics of TKA complication groups

Parameters	I group INFECTION	II group OSTEOLYSIS	III group BIOMECHANICAL DISORDERS
Nosological form	Periprosthetic infection	Aseptic instability Osteolysis Implant migration	Contracture Ligamentous instability Patella problems Disbalance of intervals Displacement Malpositioning
Etiology	Agent + patient's condition	Polyethylene product wear	Errors in TKA performance
Risk factors	Concomitant pathology (obesity, immune deficiency, etc)	Implant material quality and design	Surgeon's learning curve, not accurate instrumentation
Prevention measures	Selection and preparation of patients to surgery	Improvement of TKA implant technical characteristics	Increase the accuracy of TKA through the use of "digital assistants" (CT planning, navigation, personal blocks)

Our study has certain limitations. More than half (51 %) of the patients were referred to our center from other medical institutions located in the same or another territorial subject of the Russian Federation. This may distort the structure of complications due to the fact that treatment of periprosthetic infection, as a very resource-intensive section in traumatology and orthopedics, may not be performed in every clinic. This leads to an influx of patients with infectious complications to our center and changes the distribution of complications towards an increase in the infectious ones. Again, patients who had previously been observed in other clinics were not always able to objectively assess their condition, which led to difficulties in establishing the exact timing of the onset of complications after primary arthroplasty. Diagnostic categories for assessing reasons for revisions vary across databases and registries. The issue of categorizing reasons for revision arthroplasty is a weak point in any large retrospective series, and in our study some reasons may have been misclassified into one group or another. In some cases, several indications for revision were seen simultaneously, and it was not possible to establish the root cause of the complication. Therefore, we used a hierarchy of revision reasons to rank cases with more than one cause, which was the majority of patients (85 %). Given the short follow-up period in our study (2-5 years) compared to some other registry data, complications that often occur soon after surgery (infection) are more common than late complications (aseptic loosening). Despite these limitations, we were able to illustrate data on the etiology of revision arthroplasty in a large group of patients. Future research should include examination of risk factors for revision. To ensure the validity and power of such studies, it is necessary to implement a national registry that will allow the assessment of results in a large cohort of patients.

CONCLUSION

The pathological conditions resulting in revision knee artroplaty can be grouped into 1) periprosthetic infection; 2) conditions associated with a response to polyethylene wear products (osteolysis); and 3) biomechanical disorders that include spatial malposition or improper implant size and all types of instability. Our systematization of the causes of revision arthroplasty may help in further research and will be useful in creating a national arthroplasty registry in Russia.

Conflict of interest *None*

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Ethical statement *The study was approved by the local ethics committee of the Federal State Budgetary Educational Institution of Higher Education Razumovsky Saratov State Medical University of the Ministry of Health of Russia (protocol No. 8 of April 10, 2018) and was carried out in accordance with ethical standards developed in accordance with the Declaration of Helsinki of the World Medical Association.*

Informed consent *All study participants signed an informed consent form.*

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Information about the authors:

Mikhail V. Girkalo — Candidate of Medical Sciences, traumatologist-orthopedist, girkalo@mail.ru, https://orcid.org/0000-0001-5847-1153, SPIN-code: 6151-4375;

Ivan N. Shchanitsyn — Candidate of Medical Sciences, senior researcher, dr.green@list.ru, https://orcid.org/0000-0003-0565-5172, SPIN-code: 3653-9302;

Vladimir V. Ostrovskij — Doctor of Medical Sciences, neurosurgeon, sarniito@yandex.ru, https://orcid.org/0000-0002-8602-2715, SPIN-code: 7078-8019.