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Epidemiological surveillance of surgical site infections in large joint replacement

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Abstract

Joint replacement is a reliable and effective surgery that allows profound pain relief and restores joint function in patients. Despite the progress made and the experience gained in joint replacement, surgical site infection is one of the leading postoperative complications. It can proceed as a periprosthetic joint infection, osteomyelitis, sepsis and lead to disabled or dead outcomes. Systematization of risk factors for infectious complications plays an important role as an element of epidemiological surveillance system optimization. Age, the presence of concomitant diseases (for example, diabetes mellitus, cancer, arthritis and systemic collagenosis), carriage of antimicrobial-resistant microorganisms, infectious and inflammation both outside and in the area of surgery, and external factors (surgery duration, correct antibiotic prophylaxis and surgeon's experience) are the most significant risk factors for periprosthetic joint infection. In world practice, the National Nosocomial Infections Surveillance System surgical site infection risk index is used. This criterion does not consider all potential risk factors. It is important to analyze and rank the identified risk factors according to the impact on the development of infectious complications in organizing an epidemiological surveillance system process in a medical organization. Risk factors analysis will identify the most significant modifiable factors for the development, implementation and execution of organizational, preventive measures and epidemic control. The creation and implementation of a standardized preoperative protocol based on a risk factors assessment will allow predicting the surgery outcome and arguing the strategy and tactic of preventive measures.

Keywords: risk factors, joint replacement, prosthetic joint infection, surgical site infection.

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Background

Large joint replacement improves significantly the physical functions and quality of life of patients with musculoskeletal system pathology. In the past decades, the number of large joint replacements performed worldwide tended to increase [1]. In the Russian Federation, from 1994 to 2017, the number of such surgical interventions increased significantly from 3,000 to 113,220 [2].

According to the estimates by Steven Kurtz et al., the need for primary knee replacement and hip joint replacement will increase by 673% and 174%, respectively, in the USA by 2030 [1]. With the increase in the number of surgical interventions in orthopedic surgery, the incidence of infectious

complications will inevitably increase due to an increase in life expectancy, a change in the state of the macro-organism, and an increase in the resistance of microorganisms to antimicrobial agents [3].

Surgical site infection (SSI) in large joint replacement remains one of the most common complications of the postoperative period. At the International Consensus Meeting on Periprosthetic Joint Infection in Philadelphia (2013), one of its chairmen, Prof. J. Parvizi, said that “...periprosthetic joint infection, with all its disastrous implications, continues to pose a challenge to the orthopedic community” [4]. According to the literature, the incidence of prosthetic joint infection ranged from 0.2% to 3.0% after primary endopros-

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thesis replacement and from 3.2% to 5.6% after revision endoprosthesis replacement [5–9].

The development of SSI in patients with trauma is associated with an increase in the number of bed-days by an average of 14 days, a twofold frequency of repeated hospitalizations, and an increase in direct medical costs by more than 300%. Patients with trauma have greater motor activity disorders than patients of other profiles, which leads to a significant decrease in their quality of life [10].

According to the State Report “On the state of the sanitary and epidemiological well-being of the population in the Russian Federation (RF) in 2019,” in Russia, an average of 0.7–0.8 cases of infection associated with the provision of medical care is registered annually per 1000 hospitalized cases ($n = 25463$) [11]. Since 2016, in the range of infections associated with the provision of medical care, SSIs rank second. On average, they account for 23.2% [12].

The concept of SSI as the major form of post-operative infections associated with the provision of medical care was introduced into practice in 1992 and implied infections of the area of the surgical incision, organ, or cavity that occur during the first 30 days of the postoperative period and within a year from the surgery in the presence of implants [13]. In this definition, for specialists exercising epidemiological surveillance, the follow-up period of patients who underwent surgery within 1 year after the provision of high-tech medical care is important. According to the recommendations of the USA National Health Security System for large joint replacement, the follow-up period for the occurrence of an infectious complication is 90 days [14].

Under present-day conditions, SSI prevention is one of the global problems given its wide distribution and the decrease in the quality of life of patients; thus, the identification of risk factors for SSI is an important task of epidemiological surveillance. For the organization of epidemiological surveillance, standard definitions of SSI cases should be developed and adapted for each medical organization. They consist of a combination of clinical manifestations and capabilities of a diagnostic service to decide whether a patient has or does not have an infectious complication.

The issues of forecasting the development of periprosthetic infection based on risk factors are relevant. According to the definition of Cherkassky, under the influence of risk factors, epidemiological hazards develop into epidemiological risk, which may (probability) complicate the epidemiological situation at a certain time (risk time), in a certain territory (risk territory), and in a certain population group (risk group) [15]. The systematization of

Table 1. Calculation of the NNIS index

Evaluation criteria	Score	
	0	1
Wound class Clean or clean-contaminated Contaminated or dirty	X	X
ASA score 1–2 3–5	X	X
Surgery duration <T ≥T	X	X

Note: NNIS, National Nosocomial Infection Surveillance System; ASA, American Society of Anesthesiology.

risk factors and identification of specific factors for a trauma hospital will enable the prediction of the result of the influence of risk factors and the development of personalized measures for the prevention of endoprosthesis infection.

The idea of stratification of SSI frequency indicators according to the degree of microbial contamination of the wound was found successful [16]. The definition of contamination according to the Altemeier classification meets the requirements of general surgery, but this needs to be clarified for orthopedic practice. Even with a slightly contaminated wound, the risk of SSI increases considerably in the presence of endoprosthesis implantation. The division of wound cleanliness into classes III and IV becomes conditional, and class II wounds become potentially hazardous in terms of the development of SSI. However, this method does not sufficiently consider the risk of infections associated with the action of endogenous risk factors [17].

In global practice, the calculation of the risk index for the development of infectious complications in the surgical site is used, namely, the National Nosocomial Infection Surveillance System (NNIS index). The latter takes into account three criteria:

1) Criterion of the American Society of Anesthesiology (ASA) in determining the class of the patient’s physical condition.

2) Surgery duration (T-75%)

3) Altemeier wound class.

The assessment was performed by the summation of the scores obtained (Table 1). The values of NNIS risk index can range from 0 to 3 points, and it predicts the probability of SSI. The estimated incidence of infectious complications is as follows: < 1%, 0 points; 1%–5%, 1 point; 15%, 2 points; and up to 25%, 3 points [18–20].

In the RF, the calculation of the NNIS index is regulated by the Federal Clinical Guidelines “Principles for Organizing Perioperative Antibiotic Prophylaxis in Healthcare Institutions” (2014) and is

used to select the approach of preoperative antibiotic prophylaxis (ABP) [21].

Prognostically significant risk factors of SSI in large joint replacement can be divided into two groups, namely, modifiable and non-modifiable risk factors.

Modifiable risk factors

Body mass index (BMI). A clear relationship was establishment between BMI and the incidence of periprosthetic infection [odds ratio (OR) 1.12; $p = 0.009$] [22]. According to Jämsen et al., the infection rate increased from 0.37% (95% confidence interval (CI) 0.15–0.96) in patients with normal BMI to 4.66% (95% CI 2.47–8.62) in patients with morbid obesity (adjusted OR 6.4; 95% CI 1.7–24.6) [23]. BMI >25 is a significant risk factor [5, 6, 20].

In grade II obesity, the incidence of infectious complications was 2.3% ($p \leq 0.01$). Patients with grade III obesity experienced deep infection more often than patients with normal BMI (OR 2.00, 95% CI 0.01–4.44) [24, 25]. In grade III obesity, the incidence of infectious complications reached 64.9% ($p \leq 0.01$). Thus, BMI >40 kg/m² may be a contraindication to surgery [4]. The correction of BMI is crucial for the preoperative preparation of patients during elective surgical interventions on large joints.

A significant risk of infectious complications after endoprosthesis replacement was also noted in patients with insufficient body weight (BMI < 18.5 kg/m²; OR 6.0; 95% CI 1.2–30.9; $p = 0.033$) [26].

Rheumatoid arthritis, systemic collagenoses, etc. Categories of patients with inflammatory arthropathies are at a high risk of infectious complications [27]. According to the Department of Rheumoorthopedics of the V.A. Nasonova Research Institute of Rheumatology, the incidence rates of hip and knee joint replacements in patients with rheumatic diseases were 2.95% and 3.63%, respectively [28]. The incidence of periprosthetic infection is associated with disease activity; infectious complications without active rheumatoid process were diagnosed in 0.7% of patients, whereas with grade II, they were diagnosed in 16% ($p \leq 0.01$) [4]. Therapy with glucocorticoids, cytotoxic immunosuppressants, and tumor necrosis factor- α inhibitors also increases the probability of infectious complications [5, 29].

Carriers of *Staphylococcus aureus* and epidermal-resistant *S. aureus* had an increased risk of periprosthetic infection of the hip joint by 29.4% [30, 31]. When the presence of *S. aureus* is combined with one or more endogenous factors, the risk of infectious complications increases to 85% [32]. A multilevel microbial biofilm can form on the

endoprosthesis surface because of the adhesion of the staphylococcus and the deposition of extracellular matrix proteins (fibronectin and fibrinogen). The existence of pathogens in the composition of biofilms complicates significantly the diagnostics of periprosthetic infection and reduces significantly the efficiency of antibiotic therapy [33].

A scientific study presented a classification of periprosthetic infection according to the degree of biofilm maturity [9]. If a periprosthetic infection occurs within 7–90 days, it is considered an infection associated with an “immature” biofilm, and it is possible to preserve the prosthesis during sanitizing interventions. Infections beyond the above period are associated with a “mature” biofilm, and in this case, implant preservation is controversial [34]. Possible consequences of biofilm formation can be septic loosening of the prosthesis, osteolysis, pseudarthrosis, osteitis, or osteomyelitis. In the case of biofilm formation in SSI, diagnostics and treatment are limited because, in most cases, microbiological examination can have negative results [9, 34].

Patients carrying *S. aureus* in combination with one or more endogenous risk factors have an increased risk of infectious complications by 85% [25].

Diabetes mellitus. Patients with diabetes mellitus have an increased risk of periprosthetic infection (adjusted OR 5.47; 95% CI 1.77–16.97; $p = 0.003$) [5, 6, 20]. An excessive glucose level becomes a substrate for bacterial biofilm formation. The type of diabetes mellitus and severity of the disease are important, as complications developed in 7.4% of patients with type 2 diabetes and 42.8% with type 1 diabetes ($p \leq 0.01$). A grade III disease is associated with a high incidence of infectious complications after endoprosthesis replacement (66.7%; $p \leq 0.01$) [4]. Diabetes mellitus more than doubles the risk of prosthetic joint infection regardless of obesity (adjusted OR 2.3; 95% CI 1.1–4.7) [23]. Type 1 diabetes mellitus and a severe course of type 2 diabetes mellitus should be considered contraindications to joint replacement; the patient preparation requires correction of carbohydrate metabolism with an appropriate diet and anti-diabetic agents [4].

Alcohol abuse. Wu et al. (People’s Republic of China) provides evidence that alcohol abuse is also associated with an increased risk of periprosthetic infection (OR 2.95; 95% CI 1.06–8.23; $p = 0.039$) [6].

Inadequate ABP. ABP is indicated for all orthopedic surgeries. According to Gostishchev, rational ABP reduced the incidence of postoperative complications from 20%–40% to 5%–15% [35]. The timing of antibiotic administration should be also considered, as administration earlier than an hour before surgery is ineffective in reducing the

incidence of complications, and the later ABP is performed after the start of the surgery, the higher the probability of infection [36]. The best option when planning ABP is the selection of a drug or a combination thereof that covers the entire spectrum of possible pathogens [21]. The determination of etiologically significant pathogens of periprosthetic infection is possible because of microbiological monitoring.

Duration of surgery. Infection development depends to a large extent on the duration of the joint replacement surgery; the longer the surgery, the higher the risk of postoperative pyoinflammatory complications. Surgery duration ≥ 90 min increases the risk of infectious complications by three times ($p \leq 0.01$) [4]. The risk of periprosthetic infection ($p < 0.0001$) is significantly increased with surgery duration ≥ 210 min compared with surgery < 120 min (adjusted hazard ratio 1.59) [22, 28–30, 37–40].

Composition of bone cement. The use of antibiotic-loaded bone cement reduced the risk of deep SSI (relative risk 0.41; 95% CI, 0.17–0.97; $p = 0.04$) and did not affect the incidence of superficial infection (relative risk 1.47; 95% CI, 1.13–1.91, $p = 0.004$) [40].

Experience of an endoprosthetics surgeon. Undoubtedly, the surgical approach to endoprosthesis replacement should be carefully developed, and the intervention technology must include all possible measures to prevent infectious complications. Thus, in surgeons performing up to 10 surgeries annually, purulent inflammatory complications developed in 20.8% of cases ($p \leq 0.01$) [4].

Non-modifiable risk factors

Age. The average age of patients requiring lower limb joint replacement is 70 years [41]. In the elderly population, the risk of postoperative infectious complications increases because of slowing reparative and recovery processes, decrease in the body's resistance to infections, and presence of concomitant diseases. According to Slobodsky et al., purulent inflammatory complications after endoprosthesis replacement of large joints in patients aged > 70 years developed in 2.4% of cases ($p \leq 0.01$). Wu et al. also indicated that the age of 65–75 years is associated with an increased risk of periprosthetic infection (OR 3.36; 95% CI 1.30–8.69; $p = 0.013$) [6].

A history of purulent-septic processes beyond the surgical intervention site (such as purulent diseases of the lungs, abscesses, pleurisy, peritonitis, severe purulent lesions of soft tissues, extensive and deep burns, etc.) increase the incidence of periprosthetic infection to 13.7% ($p \leq 0.01$) [4].

A history of infectious and inflammatory diseases in the surgical area (such as purulent arthritis,

osteomyelitis, and periprosthetic infection after endoprosthesis replacement) [25] was the cause of infectious complications in the majority of patients (87.1%; $p \leq 0.01$) [4].

Oncological diseases. Associated malignancy (OR 3.1; 95% CI 1.3–7.2; $p < 0.01$) is a risk factor in predicting the development of periprosthetic infection [6, 19, 38]. In patients with cancer, the incidence of deep infection after endoprosthesis replacement ranges from 3.6% to 44.6% [42].

Repeated surgical interventions on the joint and revision endoprosthesis replacement are significant risk factors predisposing patients to periprosthetic infection [5, 19]. In the study of Borisova, in 11.8% (4 cases) of the total number of periprosthetic infections of the hip joint, the anamnesis included previous surgical interventions using hardware in the area of planned prosthetics [31]. If joint replacement was performed for the first time, purulent inflammatory complications developed in 0.6%–0.9% of cases, reaching 33.4% with ≥ 5 surgical interventions on the same joint ($p \leq 0.01$) [4].

Conclusion

1. Literature data show that SSI after endoprosthesis replacement of large joints is the study focus of many authors because of the significant risk of postoperative complications.

2. The main risk factors for the development of postoperative periprosthetic infection are age, concomitant diseases (e.g., diabetes mellitus, oncological diseases, arthritis, and systemic collagenoses), presence of microorganisms resistant to antimicrobial drugs, presence of an infectious and inflammatory process both beyond and in the surgical area, and external factors (such as the duration of surgery, proper ABP, and experience of the surgeon performing the surgery).

3. Development and implementation of a comprehensive standardized preoperative protocol based on the assessment of risk factors are necessary. The possibility of predicting the result of the influence of risk factors enables the realization of the strategy and preventive measures.

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