

Etiology of acute periprosthetic joint infection and the results of its surgical treatment

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Introduction Surgical treatment of acute periprosthetic infection is possible with the technique of debridement and replacement of only modular components of the implant, provided that the implant is stable. Positive outcomes by using this technique in the acute infection phase range between 85 and 100 % while in the chronic phase they the success range is only 0–50 %. This is explained by the ability of bacteria to form biofilms on metal and polyethylene implant surfaces. **Material and methods** We conducted the analysis of the treatment results in 35 patients with acute periprosthetic infection of the hip and knee joints. They all had joint debridement with replacement of the modular components of their implants. The implant elements removed were examined for the presence of biofilms and its pathogenic microorganisms. **Results** Laboratory methods of investigation revealed that irreversible biofilm types were found on the surface of the removed components of the implants in all patients if periprosthetic infection was manifested for more than 2 weeks. Arrest of the infectious process was achieved only in 10 patients (66.7 %) with knee pathology and in 11 patients (55 %) with infected hip joint area. **Discussion** The main cause of acute postoperative and hematogenic infection of joints is an isolated gram-positive microflora, which is observed in more than 50 % of cases. Irreversible biofilm types on the surface of the implant components in the patients with the duration of periprosthetic infection for more than 2 weeks explain the high rate of purulent process recurrence which reaches 33.3 % after debridement in infected knees and 45 % after debridement in the hip joints. **Conclusion** It seems worth reviewing the indications for the technique of debridement by which not all the elements of the implant are changed and reduce its use if infection lasts for more than 2 weeks. However, this assumption requires further study.

Keywords: arthroplasty, knee joint, hip joint, periprosthetic infection, biofilm, microflora

INTRODUCTION

The generally accepted classifications of periprosthetic infection differentiate infection by the type of contamination of the surgical wound and the time relapsed after joint replacement. According to them, acute postoperative infection occurs within the first months after joint replacement and acute hematogenous infection happens not earlier than in a year [1, 2, 3, 4]. Treatment of such types of infection is possible with the technique of debridement and replacement of only modular implant components, provided that the implant is stable [5, 6].

Positive outcomes reported by using this technique in the acute phase of infection are within the range of 85–100 % and in the chronic one they range within 0–50 % [2, 5, 6, 11]. This is explained

by the ability of bacteria to form biofilms on the metal and polyethylene surfaces of implant components. It is believed that adhesion is reversible at the initial stages of biofilm formation until the biofilm acquires a three-dimensional structure with the presence of glycocalyx and resistant strains of microorganisms [11, 12, 13, 14]. Unfortunately, up to the present time, there are no reliable literature data on the timing of this process course. This fact does not allow for a substantiated conclusion about the degree of implant contamination and, accordingly, for a clear decision on whether the implant could be further used or needs to be changed.

Our purpose was the analysis of the etiology of acute periprosthetic joint infection and the study of the efficiency of its surgical management.

MATERIAL AND METHODS

The analysis of the treatment results was conducted in 35 patients with the duration of the infectious process from 2 to 4 weeks (an average period

of 3.77 ± 0.49 weeks), which were hospitalized for periprosthetic infection between 2004 and 2016 at the Ilizarov Center. Twenty patients had infected

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hip joints and the knee joint was infected in 15 patients.

Diagnostic measures were performed according to the recommendations of the *Proceedings of the International Consensus Meeting on Periprosthetic Joint Infection*. Infection was classified according to D.T. Tsukayama. It was established that 30 patients (85.7 %) had acute postoperative and 5 patients (14.3 %) were with acute hematogenous infection.

All patients underwent debridement of the joints followed by replacement of modular implant components and a course of etiotropic antibiotic therapy for 6 weeks. During the surgical intervention, the infected periarticular tissues as well as the removed implant components were taken for the study to identify pathogens and the presence of biofilms on the surface of the implants. The intensity of biofilm formation by the strains of bacteria detected was investigated.

The results of treatment of all 35 patients were followed up (range, 1–12 years). The mean follow-up period was 6.5 ± 3.6 years. Statistical processing was carried out using the Microsoft Excel software program.

The following culture media were used to isolate aerobic and facultative anaerobic bacteria: agar with 5 % blood; yolk-salt agar; Levin's medium; Wednesday Sabouraud medium. The cultures were incubated at 37 °C for 24–48 hours. To determine the degree of seeding, the culture was divided into sectors by the medium plate in the Petri dish. Colonies of each type in the sectors were counted after incubation and the result was expressed in the decimal logarithm of the colony-forming units (CFU / ml).

The generic and species identification of the isolated bacterial cultures was carried out both with the

traditional method (based on the study of their tincorial, cultural and biochemical properties) and with the bacteriological analyzers ATB Expression (BioMerieux, France) and Walk Away 40 Plus (Siemens, USA) using appropriate microtest kits.

To study and to reveal the ability of various strains of conditionally pathogenic microorganisms to form a biofilm, the technique of obtaining biofilms in 96-well plastic plates for enzyme immunoassay was used. The results were read on a photometer at a wavelength of 630 nm (EL 808, BioTek Instruments Inc., USA). The biofilms formed at the bottom of the wells by the microorganisms studied were repeatedly washed with phosphate buffer to remove plankton cells, stained with gentian violet and rinsed again. The dye was extracted with 96 % ethanol. The level of biofilm formation was determined by measuring the optical density of the final spirit solution at a wavelength of 630 nm. It was assumed that the intensity of staining of the contents of the wells corresponded to the degree of biofilm formation. To visualize biofilms, they were grown on the surface of the Petri dish cover slips, followed by fixation and staining. The results were assessed using a light microscope.

All studies were conducted in accordance with the ethical standards of the Helsinki Declaration of the World Medical Association on *Ethical principles of scientific medical research with human participation*, as amended in 2000 and the *Rules of clinical practice in the Russian Federation* approved by Order No. 266 of the Ministry of Health of the Russian Federation from June 19, 2003. Patients signed informed consent for the publication of the study findings without identifying individuals.

RESULTS

After a careful preoperative planning, a surgical approach to the infected joint was performed using standard methods. Modular implant components were carefully removed with the help of revision instruments and were sent for microbiological tests in sterile containers. Next, radical debridement of the purulent and inflammatory focus was carried out with subsequent irrigation of tissues. Implantation of new modular implant components followed. This technique is illustrated by the following clinical cases.

Patient S., 46 years old, was diagnosed with **acute postoperative periprosthetic infection** of

the hip joint (**Fig. 1**). Radiographic study revealed type 1 femoral bone defect and type 1 defect of acetabulum structures according to Paprosky. HHS of his functional state was 59 points. Infection was caused by *Pseudomonas aeruginosa*.

In our clinic, joint debridement was performed with the change of modular components. Infection was arrested (remission 2 years); functional HHS was 85 points.

Another clinical case is patient M., 80 years old, with **acute hematogenous periprosthetic infection** of the knee joint (**Fig. 2**). Bone defect of

the femur was F2B type and of the tibia it was T2B type according to AORI. Functional KSS state was

74 points. Infection was caused by *Streptococcus pneumoniae*.

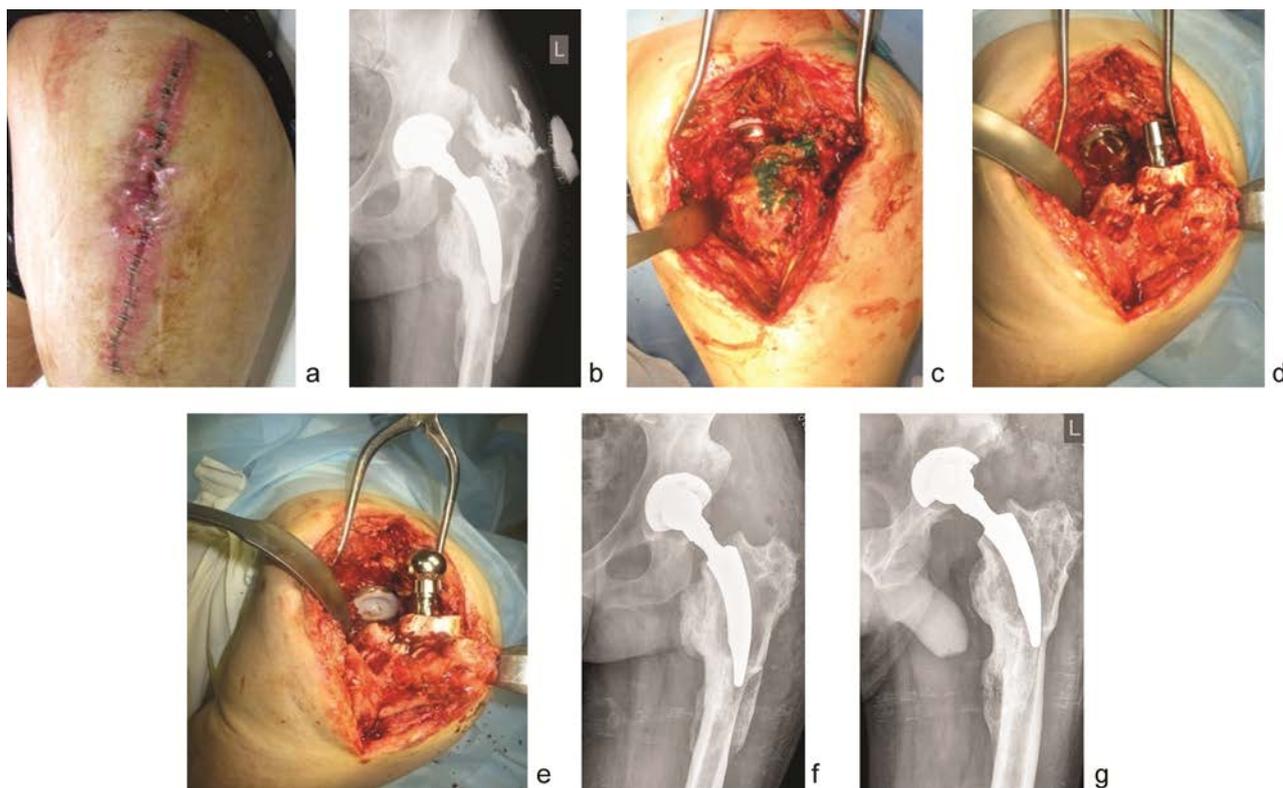


Fig. 1 X-rays of the patient S and stages of the debridement technique: **a** – local status upon admission; **b** – fistulogram of the joint; **c** – condition of the joint tissues before the debridement; **d** – condition of joint tissues after debridement; **e** – reduction of the head; **f, g** – radiographs of the hip joint one year after the operation

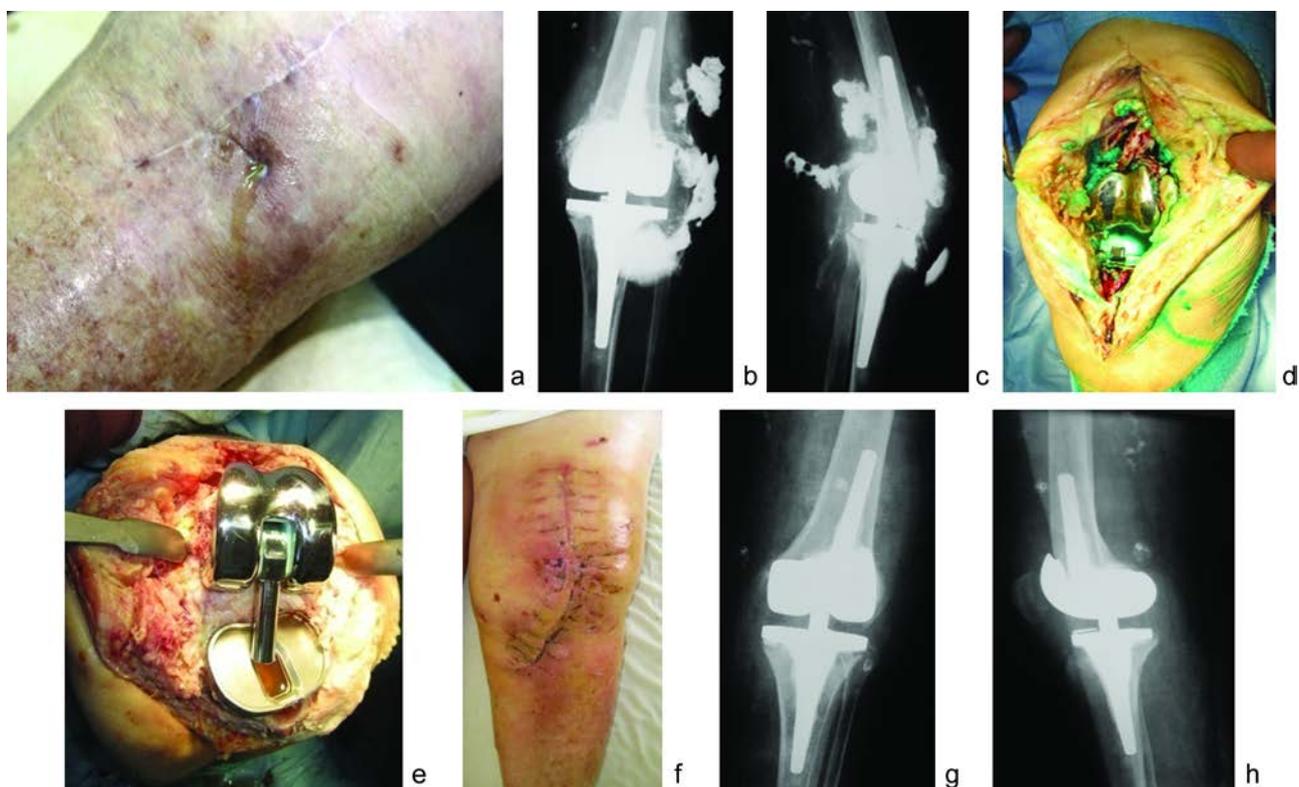


Fig. 2 X-rays of the patient M and stages of the joint debridement technique: **a** – local status at admission; **b, c** – fistulograms of the joint; **d** – condition of joint tissues prior to debridement; **e** – joint tissue condition after debridement; **f** – local status after surgery; **g, h** – X-rays of the knee after operation

The joint was debrided and the polyethylene liner changed. The purulent process was eliminated without removing the implant (remission for 5 years). The functional KSS state is 76 points.

Microbiological study of the biomaterial harvested from 35 patients was conducted according to clinical indications. Thirty three of them showed bacterial growth and bacterial growth was not detected in two patients with periprosthetic knee joint infection (**Fig. 3**).

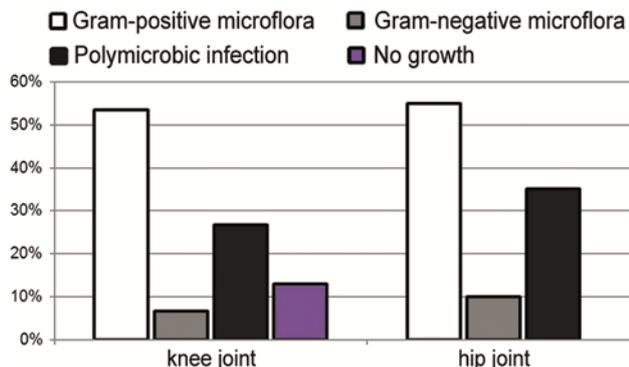


Fig. 3 Microbiological intraoperative findings in patients with acute periprosthetic infection

The diagram data show that the main cause of acute postoperative and hematogenous joint infection is an isolated gram-positive microflora which was detected in more than 50 % of cases. Also, there were significant levels of polymicrobial infection (26.7 % in the knee joint, and 35 % in the hip joint).

Laboratory methods of the study found that irreversible biofilm types were found on the surface of the removed components of the endoprotheses in all the patients with the timing of periprosthetic infection manifestations of more than two weeks. Thereby, all the isolated strains of microorganisms were able to form biofilms of varying degrees of intensity (**Table 1**).

P. aeruginosa strains possessed the greatest pathogenic potential among gram-negative bacteria while *S. epidermidis* was the most pathogenic among strains of gram-positive bacteria.

All of the above had a negative effect on the the purulent process suppression success. Treatment results of patients with periprosthetic infection were assessed according to the international multi-profile Delphi criteria. The results of treatment are presented in **Table 2**.

Table 1

Strains of microorganisms detected in patients with acute periprosthetic infection after the hip and knee joint arthroplasty

Family	Genus and species	Absolute number	% to the total
<i>Staphylococcaceae</i>	<i>MRSA, MRSE, MRSH, MRSC</i>	10	61
	<i>S. aureus</i>	8	
	<i>S. epidermidis</i>	5	
	<i>S. saprophyticus</i>	3	
	<i>S. hominis</i>	1	
	<i>S. haemolyticus</i>	1	
<i>Enterococcaceae</i>	<i>Enterococcus faecalis</i>	7	15
<i>Streptococcaceae</i>		1	2
<i>Corynebacteriaceae</i>		2	4
<i>Enterobacteriaceae</i>	<i>Enterobacter cloacae</i>	2	12
	<i>Proteus mirabilis ESBL</i>	1	
	<i>Enterobacter cloacae ESBL</i>	2	
<i>Pseudomonadaceae</i>	<i>Pseudomonas aeruginosa</i>	2	4
<i>Moraxellaceae</i>	<i>Acinetobacter baumannii</i>	1	2
TOTAL		46	100

Table 2

Results of treatment of patients with periprosthetic infection after hip and knee joint arthroplasties

Infection location	Number of patients	Infection recurrence	Infection arrest
Knee joint	15	5 (33.3 %)	10 (66.7 %)
Hip joint	20	9 (45 %)	11 (55 %)
TOTAL	35	14 (40 %)	21 (60 %)

Infectious process was arrested in 10 out of 15 patients with knee joint pathology. Two patients with a relapse of the purulent process underwent a repeated debridement. Another two patients had a two-stage revision arthroplasty and one patient had knee arthrodesis with the use of the Ilizarov technology.

Acute periprosthetic infection was stopped in 11 out of 20 patients with the hip joint pathology. Two-stage revision was used in five cases of recurrence. Two patients repeated the debridement and one underwent resection arthroplasty. One more patient rejected to change the implant.

DISCUSSION

Success in fighting acute periprosthetic infection by the method of joint debridement and replacement of modular implant components, according to various authors, varies from 33.3 to 77 %. The literature data are presented in **Table 3**.

The table shows a sufficiently high level of unsatisfactory results by using the above-mentioned method of infection management, including infection recurrence which ranges between 23 and 66.7 %. This is caused by a long course of the infection process, presence of polymicrobial infection and the ability of bacteria to form biofilms on the surface of implants [15].

It is well known that the irreversible biofilm type increases the resistance of microorganisms that compose it to the effects of antimicrobial and

antiseptic drugs. The three-dimensional structure of the irreversible biofilm includes exopolysaccharides, the synthesis of which is provided by bacteria. In the case of polymicrobial associations in the biofilm, the exometabolites of one microorganism support the growth and development of the other microorganism. This results in the biofilm stability to the influence of external factors [16, 17].

The patients studied by us had quite long periods of the infectious process (3.77 ± 0.49 weeks), an irreversible biofilm type on the removed implants and a significant level of polymicrobial infection (26.7 % and 35 % in the knee and hip joints, respectively). In our opinion, these factors caused the recurrence of the purulent process which was observed in 40 % of cases.

Table 3

Summary data on the effectiveness of using the debridement technique in the treatment of acute periprosthetic joint infection

Author	Number of cases	Follow-up	Infection recurrence	Infection arrest
Chiu F.Y., 2007 [7]	20	3 years	40 %	60 %
Choong P.F., 2007 [8]	147	1.5 years	24 %	76 %
Gardner J., 2011 [5]	44	5 years	43 %	57 %
Siddiqui M.M., 2012 [9]	12	2 years	66.7 %	33.3 %
Westberg M., 2012 [10]	38	4 years	29 %	71 %
Sukeik M., 2012	26	6.6 years	23 %	77 %
Ilizarov Center	35	6.5 years	40 %	60 %

CONCLUSION

The main cause of acute postoperative and hematogenous joint infection is an isolated gram-positive microflora which is observed in more than 50 % of cases. Simultaneously, there is a significant level of polymicrobial infection (26.7 % in the knee joint, 35 % in the hip joint). The laboratory methods of investigation established the presence of an irreversible biofilm type on the surface of the removed implant elements in all the patients with the duration of

periprosthetic infection manifestations of more than 2 weeks. It explains the high rate of recurrence of the purulent process which reaches 33.3 % after knee and 45 % after hip joint debridement. It seems worth reviewing the indications for the technique of debridement by which not all the elements of the implant are changed and reduce its use for cases in which infection is manifested for more than 2 weeks. However, this assumption requires further study.

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