

The First-Stage Treatment Algorithm for Deep Infected Total Hip Arthroplasty

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Abstract


Background. Periprosthetic infection after total hip arthroplasty is a relatively common and severe complication. A two-stage revision with the temporary use of a spacer is the gold standard treatment for the deep infected total hip arthroplasty. Some authors report mechanical complications associated with spacers, which can lead to a poor functional outcome. Therefore, the aim of the study was to analyze the effectiveness of the first-stage of treatment of hip PJI with a two-stage method and to develop an spacer application algorithm in order to achieve the optimal functional result. **Materials and Methods.** Between 2015 and 2017, 38 patients with deep periprosthetic infection received an articulation spacer as part of a two-stage protocol in Botkin Moscow City Hospital. The mean age was 60.5 (interquartile range from 52 to 69) years. Five different types of spacers were used in the study, selected individually according to the Paprosky acetabular defects classification. The overall frequency of complications was evaluated. **Results.** The overall periprosthetic infection treatment effectiveness was 92.1%. There was the recurrent infection in 3 patients (7.9%), in 2 (5.26%) cases microbial associations were founded. Mechanical complications occurred in 8 (21%) patients. Spacer dislocation occurred in 4 (10.4%) cases, spacer fracture in another 2 (5.2%). There were also 2 cases of protrusion into the pelvis (5.2%). **Conclusion.** The first stage a two-stage revision hip arthroplasty should be carefully planned. To choose the appropriate spacer we proposed an algorithm based on our data to achieve a better functional result.


Keywords: hip revision hip arthroplasty, prosthetic joint infection, spacer, two-stage revision.

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Background

In connection with the increased number of performed primary hip joint endoprosthetics, the amount of complications and subsequent revisions increases. Today, the most serious complication is periprosthetic infection since it requires special diagnostic methods, and its treatment is associated with developing a technically sophisticated revision treatment plan. When acute pain occurs following hip arthroplasty, it is necessary to exclude a possible infection in the operated region [7, 16, 21].

Often, most surgeons of both community health centres and hospital outpatient units often are unable to diagnose or they choose the wrong strategy for managing periprosthetic infection. This leads to catastrophic consequences not only in the zone around the joint, but also in the patient's body as a whole. According to the literature database, the incidence of deep periprosthetic infection is 0.25–1% over the course of a year following primary hip arthroplasty [11]. It is the periprosthetic infection that is the third most common cause of revision arthroplasty, which ranges from 1 to 3% [12]. With other revisions, the risk of infection varies from 4% to 10%, but with revisions for periprosthetic infection, the incidence rate of complications reaches 27–32.3% [14, 18]. It is also necessary to note the high cost of treatment. For example, in the UK, the price of treating one patient is about 40 000 \$, and in the USA the overall costs increased from 320 million \$ in 2001 to 566 million in 2009. By 2020 they are projected to exceed more than 1.5 billion \$ [9].

Two-stage revision arthroplasty remains the gold standard for treatment of late, deep periprosthetic hip joint infection as classified by M.B. Coventry and D.T. Tsukayama [3].

The objective of the present study is to evaluate the effectiveness of the first stage of a two-stage treatment for deep periprosthetic hip joint infection and to develop an

algorithm for choosing a spacer in order to achieve an optimal functional result.

Materials and Methods

In the Center for Bone and Joint Replacement at the S.P. Botkin Moscow State Clinical Hospital, in the period from 2015 to 2017, 38 patients underwent a two-stage revision hip joint arthroplasty for a deep periprosthetic infection. There were 20 women (52.6%) and 18 men (47.4%). The average age of patients was 60.5 years (interquartile range from 52 to 69).

The median manifestation time, i.e. the time from the primary operation to diagnosing septic instability of the components, was 9 months. The median time to complete the first stage of revision arthroplasty, i.e. the time from the diagnosis of periprosthetic infection to the completion of the first stage of revision, was 3.5 months.

Initially, all patients underwent total hip arthroplasty: for post-traumatic coxarthrosis — 10 (26.5%) patients, degenerative coxarthrosis — 17 (44.7%), dysplastic coxarthrosis — 5 (13.1%), hip fracture — 6 (15.7%). Of the 38 patients, 11 (28.94%) underwent a revision intervention for aseptic instability of the components.

A detailed examination of patients analyzing the clinical findings and medical history, X-rays of the pelvis, hip joint in two projections, lumbar spine and CT scan of the pelvis was carried out. In all patients, the pain severity, joint function and quality of life were assessed using the Harris Hip Score, WOMAC and VAS. The assessment was carried out just prior to the first stage, before the second stage and 6 months after the second stage.

If a patient was suspected of having a periprosthetic infection, a comprehensive survey of such patient was performed three times with one month intervals, including:

- 1) blood test for ESR and C-reactive protein;
- 2) arthrocentesis of the hip joint with ultrasound guidance;

3) rapid test for leukocyte esterase;

4) cytological and bacteriological examination of punctate with the determination of sensitivity to antibacterial drugs.

The main criterion of the diagnosis was the microflora isolation during bacteriological examination. The 'culture-negative' patients were the most problematic, i.e. those in which the bacterial culture extracted from the joint would not grow. In such cases, we focused on the physical, radiographic and laboratory findings of an infectious process in the joint area.

All patients diagnosed with a septic instability of endoprosthesis components underwent a two-stage revision arthroplasty.

At the first stage, we performed:

1) complete removal of all implanted components, regardless of their stability, along with any associated cement, if present;

2) at least four biopsy samples from the removed components for microbiological examination;

3) processing of the removed components of the endoprosthesis in the ultrasound chamber, followed by taking another bacterial sample;

4) the initiation of intravenous combined antibacterial therapy intraoperatively according to the findings on microflora sensitivity obtained during the examination; in 'culture-negative' cases, an empirical antibiotic therapy with anti-biofilm activity was initiated;

5) thorough debridement and pulsatile lavage;

6) placement of a spacer and its necessary additional fixation to the proximal femur with bone cement;

7) wound closure, including using a Collatamp sponge.

In all patients, after the removal of endoprosthesis components, we installed articulating spacers:

– officinal preformed spacers (Tecres medical) – 11 (28.9%);

– spacers assembled from standard components of the endoprosthesis 15 (39.5%);

– spacers fabricated in the operating theatre with the use of standard moulds – 4 (10.4%);

– complex modified spacers in the absence of acetabular shell support ability – 6 (15.9%) (Patent RU No 2675551);

– individual 3D-printed spacers – 2 (5.2%) (Fig. 1).

The officinal preformed spacers are fabricated in the factory from gentamicin-loaded bone cement. Their advantages are standard sizes, reduced time for preoperative planning and operational guidance, increased mechanical strength, and a longer effect of local release of the antibiotic. Disadvantages: narrow size range, excessive formation of scar tissue in the acetabulum, high risk of dislocation or protrusion when there are large defects of the acetabulum.

Spacers assembled from standard components of the endoprosthesis are often used in our work. Their main advantages are low cost, simplicity and speed of production, the possibility of using with defects of the acetabulum according to the Paprosky classification up to type IIC. However, they have a rather low mechanical strength. In the second stage, there is a risk of an increase in the defect of the acetabulum during the debridement of the cement mantle.

When choosing spacers fabricated in the operating theatre with the use of standard moulds, it is possible to fill the thigh and acetabulum with a large amount of cement, which allows to achieve a fairly high concentration of antibiotic in the surrounding region. In addition, it is a quite inexpensive and affordable method. This type of spacer can be used only with acetabular defects up to type IIB according to the Paprosky classification. The disadvantage of this type of spacer is its brittleness, despite its reinforcement with an iron curved pin, and the restriction in use for massive bone defects of the acetabulum and thigh.

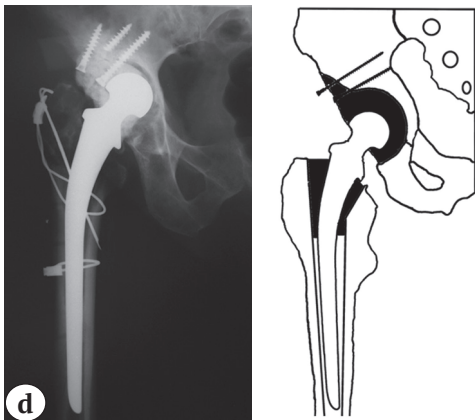
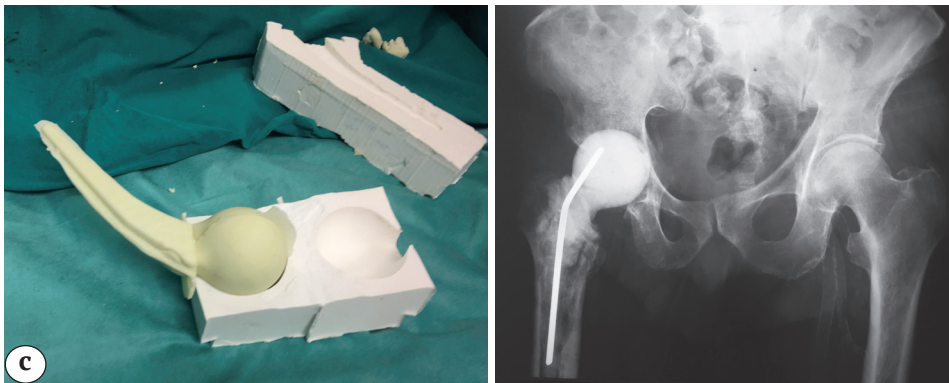
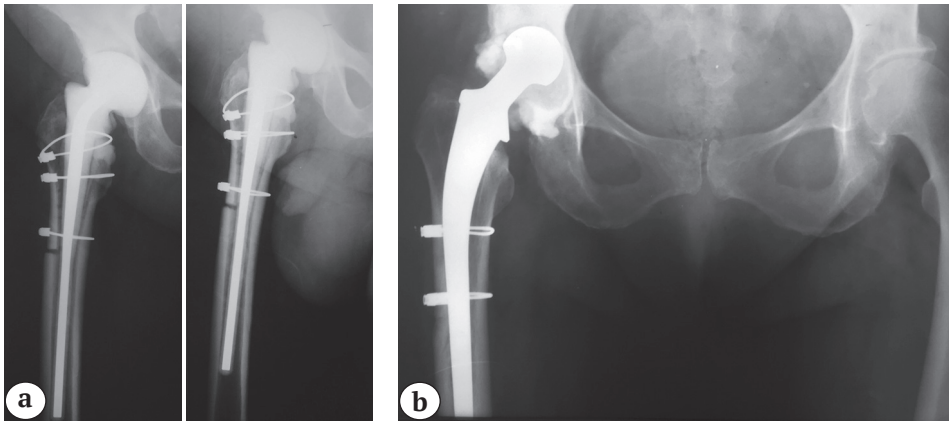
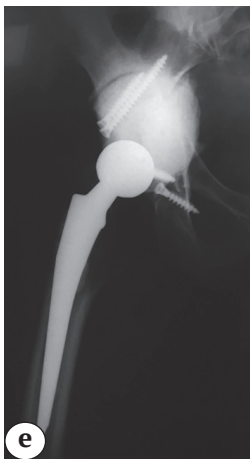


Fig. 1. Types of articulation spacers application in patients:
 a – official preformed spacer (Tecres);
 b – spacer made from standard endoprosthesis component;
 c – spacer made in the operating room using a prepared sample form;
 d – spacer in the absence of support of the acetabular ring (patent RU No. 2675551);
 e – individual 3D spacer



With massive defects of the acetabulum in the absence of support ability of the acetabular shell, the spacer can be used due to screws fixed in the acetabulum roof. These reinforce the cement mass and do not allow it to migrate. Its main advantage is ease of manufacture and low cost, and the disadvantage is brittleness.

Individual 3D-printed spacers are modern types of spacers that can be used for any bone defects in the hip joint. They are easy to install and allow you to immediately achieve the support ability of the limb. The disadvantages of this spacer are its expense, as well as a long period of preparation and fabrication.

We used polymethyl methacrylate-based bone cement, which is laden with an antibiotic dictated by the obtained microbiological data from cultures. This antibiotic possesses a certain thermal stability and water solubility [2, 5].

Postoperative treatment included intravenous and intramuscular administration of antibiotics (including antibiotics with anti-biofilm activity) while the patient was in the hospital – an average of 12 days post-operation. In the culture-negative group

of patients, we started empirical antibiotic therapy awaiting the results of a microbiological examination of biopsy specimens collected intraoperatively. After discharge from the hospital, patients continued to take oral forms of antibiotics for 6–8 weeks following the operation. Two–three weeks after antibiotic therapy ended, a comprehensive examination was conducted with another biopsy of the joint. Upon negative examination results, patients were directed to the second stage of revision arthroplasty.

We divided all patients into three groups. The first group consisted of 27 patients (71%), in which periprosthetic infection was successfully treated and who had no mechanical complications [maybe: complications in hip biomechanics]. The second group comprised 8 patients (21.1%), in which we also succeeded in eradicating the infection, but these patients had mechanical complications associated with the spacer. The third group consisted of 3 patients (7.9%), in which the infection was not eradicated (Table 1). The study of ESR and C-reactive protein levels was performed just prior to the first stage and 8 weeks following surgery (Table 2).

Patient profiles in three studied groups

Table 1

Indicators	First group <i>n</i> = 27	Second group <i>n</i> = 8	Third group <i>n</i> = 3	Total <i>n</i> = 38	<i>p</i>
Median age (years)	63 (58–68)	59 (50–74)	50 (42–58)	60.5 (52–69)	0.38
Time of manifestation of infection (months)	9 (6–30)	10.5 (5–36)	7 (1–12)	9 (5–27)	0.88
Period prior to the first stage (months)	4 (3–4)	3 (2.5–3.5)	3 (2–8)	3.5 (3–4)	0.12

Data are presented in median format (interquartile range).

ESR and CRP levels prior to the first stage and 8 weeks postoperatively

Table 2

Variables	First group <i>n</i> = 27		Second group <i>n</i> = 8		Third group <i>n</i> = 3		Total <i>n</i> = 38		<i>p</i>	
	before	after	before	after	before	after	before	after	before	после
ESR, mm/h	42 (35–47)	21 (16–30)	54 (40–62)	40 (23–44)	37 (37–37)	38 (35–41)	44.5 (37–57)	25.2 (11.9–42.8)	0.21	0,21
CRP, g/l	11.6 (8.9–12.4)	5.8 (3/7–8.4)	42.8 (25.2–82.8)	5.5 (2.1–11.2)	31 (31–31)	37.2 (18.7–37.2)	26 (16–42)	6.8 (3.7–16)	0.03	0,06

Data are presented in median format (interquartile range).

The median manifestation time, i.e. the time from the primary operation to the diagnosed septic instability of the components was 9 months with no significant differences between groups. The median waiting time of the first stage, i.e. the time from the diagnosed periprosthetic infection to the first stage of revision arthroplasty was 3.5 months, also without significant differences between the groups.

In all groups the mean ESR level before treatment was an average of 44.5 mm/h without a statistically significant difference between the groups. In the first group, C-reactive protein prior to the first stage was 11.6 g/l, which statistically is significantly lower than in the second and third groups (42.8 g/l and 31 g/l, respectively).

In the first and second groups, spacer placement was followed by a significant reduction of pre-treatment ESR and C-reactive protein levels, and in the third group, these indicators did not significantly change.

Statistical analysis

Statistical processing of the obtained data was performed with software package STATISTICA 10 for Windows. We applied the following comparative nonparametric methods of descriptive statistics: Mann — Whitney, Kraskel — Wallis, Wilcoxon. Differences of $p < 0.05$ were considered statistically significant.

Results

All patients came to our clinic a minimum of 3 months postoperatively. According to the Coventry & Tsukayama classification (1996), type II infection was detected in 19 patients (50%), type III — in 19 patients (50%).

In the microbiological examination of the punctate, bacterial flora was obtained only in 29 patients (76.4%):

Staphylococcus aureus — 4, of which 2 are MRSA [methicillin-resistant *Staphylococcus*

aureus]; *Staphylococcus epidermidis* — 9, of which 4 are MRSE [methicillin-resistant *Staphylococcus epidermidis*]; *Staphylococcus xylosum* — 1; *Staphylococcus hominis* — 2; *Staphylococcus capitis* — 1; *Staphylococcus haemolyticus* — 1; *Escherichia coli* — 2; *Enterobacter cloacae* — 1; *Enterococcus faecalis* — 3; *Proteus mirabilis* — 1. In 4 cases, microbial associations were obtained: *Staphylococcus aureus* (MRSA) + *Proteus Mirabilis*, *Staphylococcus ligdunensis* + *Staphylococcus haemolyticus*, *Staphylococcus epidermidis* + *Enterococcus faecalis* in 2 patients.

In 9 so-called 'culture —negative' patients (23.6%), there was no growth of flora from diagnostic punctures. However, considering that the clinical findings and the evaluation of all other criteria indicated periprosthetic infection, these patients were still directed to a two-stage revision arthroplasty. Tissue specimens collected for microbiological examination intraoperatively did indicate periprosthetic infection: *Staphylococcus aureus* — 5 (MRSA 3) and *Staphylococcus epidermidis* — 4 cases (MRSE 2).

Despite the treatment, two months following spacer placement, 3 (7.9%) patients developed a reinfection which manifested itself in a fistulous form. It is worth noting that 2 patients (5.26%) had microbial associations. These patients underwent a re-debridement and replacement of spacer.

Prior to the first stage, an overall average Harris Hip Score was 31.5, which corresponds to an unsatisfactory function. Prior to the second stage, it averaged 54 scores, which reflects a statistically significant improvement of hip biomechanics. On the VAS score, the pain severity prior to the first stage averaged 8 scores; prior to the second stage — 3 scores. On the WOMAC score, prior to the first stage, the index averaged 74 scores; after the first stage was completed — an average of 38 scores (Table 3).

Table 3

Outcome assessments of the first stage of treatment, scores

Rating scales	Before spacer placement	After spacer placement	<i>p</i>
Visual Analogue Scale (VAS)	8 (6–9)	3 (2–5)	<0.001
Harris Hip Score	31.5 (26–36)	54 (42–64)	<0.001
WOMAC	74 (50–78)	38 (25–61)	0.001

Data are presented in median format (interquartile range).

In the postoperative period, complications such as dislocated spacer were observed in 4 patients (10.4%); fracture of reinforcing screws of the acetabulum, and their migration together with the spacer in 1 patient (2.6%); fracture of the spacer fabricated in the operating theatre in standard moulds in 1 patient (2.6%); spacer migration into the pelvic cavity in 2 patients (5.2%) (Fig. 2).

We noted that, using officinal preformed spacers for acetabular defects IIC, IIB and in 2 cases of IIIA according to the Paprosky classification, dislocations of the spacer were observed. In two patients with IIC defects, spacers migrated into the pelvic cavity. The fracture of the spacer, which was fabricated in the operating theatre in standard moulds, occurred in one patient with IIB defect. In one patient with IIIB defect, the fracture of reinforcing screws of the acetabulum, and their migration together with the spacer occurred as a result of trauma (a fall on the side).

Prior to performing the second stage, we analyzed separately the data of 8 patients

(21%) with inadequate spacer function on functional scales: the VAS Score was 6.12; Harris Hip Score — 41.6; WOMAC — 65.8 scores. Together this was regarded as an unsatisfactory result. The above mechanical complications caused additional difficulties in performing the second stage.

Discussion

There are a great number of guidelines and methods for treating a deep periprosthetic hip joint infection, considering various factors. However, preference is given to a two-stage technique, which is regarded as the gold standard [7, 10, 16, 19].

According to various authors' data, the percentage of success with this method of treatment ranges from 60 to 95% [1, 19, 15]. D. Toms et al. reported 38% of reinfection [13], K. Uchiyama et al. reported 32.3% of relapses [14, 21]. M. Gomez et al. succeeded in 80% of cases [6], S. Lim et al. exhibited a 78% success rate [10]. In our study, the effectiveness of a two-stage exchange for periprosthetic infection was 92.1%. Additionally, the effective-



Рис. 2. Mechanical complications in the postoperative period:

a — spacer dislocation; b — spacer breakdown; c — spacer protrusion to the pelvic cavity

ness of a method to eradicate the infection does not depend on selected type of spacer.

An interesting position was taken by M. Gomez et al., who drew attention to the high heterogeneity of data about the effectiveness of two-stage exchange. They analyzed 178 patients with periprosthetic hip joint infection and found that, after the first stage, only 77% of patients underwent the second stage. In the remaining cases, due to various complications, reimplantation was not performed, and alternative techniques were used [6].

Our use of the diagnostic and treatment algorithm allowed for detecting the infection in 76.4% of cases. In the remaining 23.6% of patients ('culture-negative'), the microflora was obtained intraoperatively, enabling immediate administration of a targeted antibiotic therapy.

It should be understood that the purpose of the spacer is not only as a substrate when treating infection, but also to ensure the function of the joint. All our patients were equipped with articulating spacers, since they do not impose functional limitations and do not reduce the quality of life [1, 19].

A distinctive feature of our work was the study and evaluation of non-infectious complications, such as spacer dislocations, metal

implant fractures with their subsequent migration, spacer fractures and their protrusion into the acetabulum, since a small number of studies highlight this problem. The total of mechanical complications was 21%, of which dislocation of the spacer was 10.4%; fracture of reinforcing screws of the acetabulum and their migration together with the spacer — 2.6%; fracture of the spacer fabricated in the operating theatre in standard moulds — 2.6%; protrusion of the acetabulum and migration of the spacer into the pelvic cavity — 5.2%.

J. Jung et al. reported the frequency of mechanical complications in 40.8% of cases (17% of dislocations, 10.2% of spacer fractures, 13.6% of hip fractures) [8]. M. Faschingbauer et al. analyzed 138 patients to which spacers were placed, and identified 19.6% of mechanical complications, including 8.7% of spacer fractures, 8.7% of dislocations, 0.7% of hip fractures, 0.7% of protrusions into the pelvis, 0.7% of fractures and dislocations of the spacer [4].

To prevent non-infectious complications, it is necessary to carefully plan the first stage of revision intervention. To this end, we propose an algorithm for choosing a spacer in patients with various defects of the acetabulum according to the Paprosky classification (Table 4).

Table 4

Algorithm for choosing a spacer in patients with variable acetabular defects according to the Paprosky-Perona –Lawrence classification

Type of defect	A	B	C
I	1. Preformed official spacers 2. Spacers assembled from standard components of the endoprosthesis	–	–
II	1. Preformed official spacers 2. Spacers assembled from standard components of the endoprosthesis 3. Spacers fabricated in the operating theatre in standard moulds	1. Spacers fabricated in the operating room in standard moulds 2. Spacers assembled from standard components of the endoprosthesis 3. Preformed official spacers (excessive internal rotation)	1. Complex modified spacers in the absence of support of the acetabular shell 2. Individual 3D-printed spacers
III	1. Individual 3D-printed spacers 2. Complex modified spacers in the absence of support of the acetabular shell	1. Individual 3D-printed spacers 2. Complex modified spacers in the absence of support of the acetabular shell	–

Before proceeding to the second stage, the functional result in 8 patients (21%) with mechanical complications of the spacer was separately analyzed according to the selected scales, and the result was unsatisfactory. Also, mechanical complications caused additional difficulties in accomplishing the second stage.

Assessment of the patient's quality of life and functional outcome after the second stage, depending on the use of different spacers at the first stage of revision arthroplasty, may be the subject of further research.

Conclusion

In two-stage revision hip joint arthroplasty, it is necessary to carefully plan the first stage and select the appropriate type of articulating spacer. A properly selected spacer is the basis of a good functional result and technically simplifies the second stage implementation.

In our study, we could achieve success in eradicating periprosthetic infection in 92.1% of the cases with articulating spacers implanted. Among the cases of reinfection, it is worth noting that a greater number of relapses were observed in 2 patients (5.62%) with microbial associations.

In 8 cases (21.05%), mechanical complications associated with the spacer occurred, significantly worsening the patient's quality of life and complicating the technical implementation of the second stage, but with no impact on eradication of the infection.

A two-stage revision arthroplasty should also be aimed at improving the patient's quality of life. To minimize the above complications and improve the functional result achieved in the first stage of treatment, an algorithm to choose an articulating spacer based on the defect of the acetabulum according to the Paprosky classification is presented. Thus, the proper implementation of the first stage naturally enhances the effectiveness of treatment of a deep periprosthetic hip joint infection overall.

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