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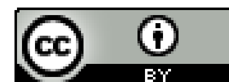

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ABSTRACT

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CLINICAL CHARACTERISTICS OF BONE DEFECTS IN PERIPROSTHETIC INFECTION OF THE HIP JOINT

The purpose of this analysis was to describe and characterize bone defects that were detected in patients of the observation array to unify the diagnostic algorithm, which will allow comparing the effectiveness of two-stage tactics of treating periprosthetic infection in different groups of patients.

Materials and methods: A prospective array was formed, which included 117 patients, who were divided into 2 groups. To the first experimental group, we assigned 53 patients with early (up to 4 weeks) onset of the infectious process after primary hip arthroplasty. To the second group, 42 cases of late manifestation of periprosthetic infection were assigned.

Results: The absence of bone defect or type I was significantly more common among patients with early development of periprosthetic infection, which was detected in 66.0% of patients and in 35.7% of patients with late development of periprosthetic infection. All types of type II defects were more common in patients with late development of periprosthetic infection, which was found in 52.4% of cases, in contrast to patients with early manifestation of periprosthetic infection, where this type was found in 33.9% of cases. Both types of type III bone defects were found only among patients with late periprosthetic infection, which was found in 11.9% of cases and were not found among patients with early manifestation of infectious prosthesis. Absence or type I bone defect was observed in most patients with early periprosthetic infection, which was found in 84.9% of cases and in most patients with late periprosthetic infection in 73.8% of cases. The distribution of type II bone defects of the hip was uniform in the observation groups, which indicates the absence of the influence of time determinants in the development of this type of bone defect. In the early stages of periprosthetic infection development, there are no severe types of bone defects, however, in patients with late manifestation, these defects were detected in 11.9% of cases.

Conclusions: Different types of bone defects are characteristic of different periods of periprosthetic infection. Early manifestations of periprosthetic infection are characterized by either the absence of bone defects or the first type of them. The distribution of type II bone defects of the thigh was uniform in the observation groups, which indicates the absence of the influence of time determinants in the development of this type of bone defect.

Keywords: periprosthetic infection, diagnostics, radiological examination, bone defects, treatment.

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КЛІНІЧНА ХАРАКТЕРИСТИКА КІСТКОВИХ ДЕФЕКТІВ ПРИ ПЕРИПРОТЕЗНІЙ ІНФЕКЦІЇ КУЛЬШОВОГО СУГЛОБУ

Метою цього аналізу було описати та охарактеризувати дефекти кісток, виявлені у пацієнтів масиву спостереження, для уніфікації діагностичного алгоритму, що дозволить порівняти ефективність двоетапної тактики лікування перипротезної інфекції у різних групах пацієнтів.

Матеріали та методи: Було сформовано проспективний масив, до якого увійшли 117 пацієнтів, яких було розділено на 2 групи. До першої експериментальної групи ми віднесли 53 пацієнтів з раннім (до 4 тижнів) початком інфекційного процесу після первинного ендопротезування кульшового суглоба. До другої групи було віднесено 42 випадки пізньої маніфестації перипротезної інфекції.

Результати: Відсутність дефекту кістки або I типу значно частіше зустрічалася серед пацієнтів з раннім розвитком перипротезної інфекції, яка була виявлена у 66,0% пацієнтів та у 35,7% пацієнтів з пізнім розвитком перипротезної інфекції. Усі типи дефектів II типу частіше зустрічалися у пацієнтів з пізнім розвитком перипротезної інфекції, яка була виявлена у 52,4% випадків, на відміну від пацієнтів з ранньою маніфестацією перипротезної інфекції, у яких цей тип був виявлений у 33,9% випадків. Обидва типи дефектів кісток III типу були виявлені лише у пацієнтів з пізньою перипротезною інфекцією, яка була виявлена у 11,9% випадків, та не були виявлені серед пацієнтів з ранньою маніфестацією інфекційного протезу. Відсутність або дефект кістки I типу спостерігався у більшості пацієнтів з ранньою перипротезною інфекцією, яка була виявлена у 84,9% випадків, та у більшості пацієнтів з пізньою перипротезною інфекцією у 73,8% випадків. Розподіл дефектів кісток кульшового суглоба II типу був рівномірним у групах спостереження, що свідчить про відсутність впливу часових детермінант у розвитку цього типу дефекту кістки. На ранніх стадіях розвитку перипротезної інфекції тяжкі типи дефектів кісток відсутні, проте у пацієнтів з пізньою маніфестацією ці дефекти були виявлені в 11,9% випадків.

Висновки: Різні типи дефектів кісток характерні для різних періодів перипротезної інфекції. Ранні прояви перипротезної інфекції характеризуються або відсутністю дефектів кісток, або першим їх типом. Розподіл дефектів кісток стегна II типу був рівномірним у групах спостереження, що свідчить про відсутність впливу часових детермінант у розвитку цього типу дефекту кісток.

Ключові слова: перипротезна інфекція, діагностика, рентгенологічне дослідження, дефекти кісток, лікування.

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INTRODUCTION

With the increase in the number of primary hip joint endoprostheses implantation, the probability of infectious complications in patients who have undergone this operation increases. That is why there is a trend towards an increase in cases of periprosthetic infection after primary hip joint endoprosthesis replacement worldwide. However, more and more specialists point to the significant role of early diagnostic measures in the early detection of signs of periprosthetic infection [1]. Diagnostic measures allow at the earliest stages to achieve eradication of infection using treatment algorithms. It is from the adequate, effective and timely diagnostic measures, their completeness and comprehensive interpretation that the choice of tactics and the final result of treatment depend, not least, on the performed adequate, effective and timely diagnostic measures [2].

Early diagnosis of manifestations of periprosthetic infection is a rather laborious process. The diagnostic standards for periprosthetic joint infections have fundamentally changed from a complete reliance on culture to strategies that include the ability to diagnose periprosthetic infection with a negative culture result using multiple criteria. Several authoritative organizations, including the Musculoskeletal Society of Infections (MSIS), the International Consensus Meeting (ICM), the European Society for Bone and Joint Infections, and the Infectious Diseases Society of America (IDSA), have released their own versions of periprosthetic infection scoring systems over the past decade, but many clinicians point to their shortcomings [3]. These include the difficulty of considering multiple criteria and their specificity in defining periprosthetic infection, frequent changes in criteria, and the lack of consensus among experts in defining and using different criteria and their constant indicators. Many reports of poor use of existing criteria or, conversely, the emergence of information about the use of new markers do not allow for the confident use of diagnostic protocols in the detection of periprosthetic infection [4, 5].

During the development of the infectious process in patients after hip arthroplasty, bone tissue deficiency can often be identified. One of the components of the diagnostic search for the development of periprosthetic infection is the clinical and radiological characteristics of both bone components involved in the hip joint. To characterize the state of bone tissue of both the acetabulum and the femoral component, the presence or absence of bone tissue loss is first determined radiographically, which is an obligatory component in the further planning of treatment and rehabilitation of patients with periprosthetic infection.

The purpose of this analysis was to describe and characterize bone defects that were detected in patients of the observation array to unify the diagnostic algorithm, which will allow comparing the effectiveness of two-stage tactics for treating periprosthetic infection in different groups of patients.

MATERIALS AND METHODS

To solve the research tasks dedicated to determining the diagnostic features of the development of periprosthetic infection, a prospective array was formed, which included 117 patients.

The inclusion criteria for the prospective study were:

1. Patient age over 18 years;
2. The presence of verified and diagnosed periprosthetic infection that occurred after primary endoprosthetic surgery according to the Recommendations of the Second International Consensus Conference on Periprosthetic Infection (2019);
3. The term of treatment at the State Institution "National Institute of Traumatology and Orthopedics of the National Academy of Medical Sciences (NAMS) of Ukraine" from 01.01.2021 to 31.12.2023.
4. Absence of confirmed severe oncological pathology that could affect the results of treatment.
5. Informed consent of the patient to participate in the scientific study (f.380u) is obtained.

The observation array was divided into 2 groups. We included 53 patients with early (up to 4 weeks) onset of infectious process after primary hip joint replacement in the first study group. There were 34 males (64.1%), and 19 females (35.9%). The age of the patients ranged from 25 to 79 years and was 62.2±7.2 years on average. The second group included 42 cases of late manifestation of periprosthetic infection, which constituted (35.9%) of the total array. There were 27 males (64.3%), and 15 females (35.7%). The age of the patients ranged from 27 to 80 years and averaged 61.0±7.4 years. The obtained data were subjected to statistical processing on a personal computer using the Microsoft Excel 2013 software package (USA), using built-in statistical

processing functions. Considering the number of signs analyzed and the need to ensure uniformity of the resulting indicators, for a correct comparison we chose the method of calculating the coefficient of the polychoric correlation coefficient proposed by K. Pearson. The calculated values of the Pearson probability criterion were compared with its critical values in the Chi-square tables using an error margin of 5% and a degree of freedom (K - 1), which is due to the influence of the law of disjunction. Statistically significant changes were considered to be at a level of confidence of $p<0.05$.

RESULTS

During the development of the infectious process in patients after hip arthroplasty, bone tissue deficiency can often be identified. One of the components of the diagnostic search for the development of periprosthetic infection is the clinical and radiological characteristics of both bone components involved in the hip joint. To characterize the state of the bone tissue of both the acetabulum and the femoral component, the presence or absence of bone tissue loss is first determined radiographically, which is an obligatory component in the further planning of treatment and rehabilitation of patients with periprosthetic infection. The main goal of this analysis was to describe and characterize bone defects that were detected in patients of the observation array for the unification of the diagnostic algorithm, which will allow comparing the effectiveness of the two-stage tactics of treating periprosthetic infection in different groups of patients. For the clinical and radiological characteristics of bone tissue defects in our study, we used the classification of W. Paprosky, which was published in 1994. The choice of this classification is due, firstly, to its clear correspondence to the anatomical landmarks of the hip joint, to its correspondence in terms of the degree of loss and its localization in the bone structures, and secondly, to its greatest popularity among orthopedists and the scientific literature.

Classification of acetabular socket defects

The system assesses the integrity of the rim, walls and columns of the socket:

1. Type I: Minimal defects. The spherical shape is preserved, the rims and columns are intact. There is no displacement of the component.
2. Type II: Moderate defects, the walls are damaged, but the columns are stable. Displacement < 2 cm:
   - IIA: Upper cavitation, displacement of the center of the joint strictly upwards (dome intact).
   - IIB: Defect of the upper rim, displacement upwards and outwards (superolateral).
   - IIC: Destruction of the medial wall (Kohler's line), displacement medially.
3. Type III: Significant destruction of supporting structures (>50%), displacement > 2–3 cm:
   - IIIA ("Up and out"): Defect from 10 o'clock to 2 o'clock. Displacement up and out. Kohler's line intact.
   - IIIB ("Up and in"): Most severe type. Defect from 9 o'clock to 5 o'clock (>60% bone). Displacement up and in (superomedial). Possible pelvic discontinuity.

Classification of Femoral Component Defects

1. Type I: Minimal loss of metaphyseal cancellous bone; diaphysis intact.
2. Type II: Significant metaphyseal destruction, but diaphysis preserved (secure fixation possible in diaphysis).
3. Type III: Significant metaphyseal and proximal diaphyseal bone loss:
   - IIIA: Diaphyseal damage, but > 4 cm of intact bone remains for fixation.
   - IIIB: < 4 cm of intact diaphysis remains.
4. Type IV: Complete destruction of the meta-diaphyseal zone, wide stovepipe canal, fixation with standard legs not possible.

The results of the analysis of acetabular defects in patients of the observation array are given in Table 1.

Analysis of the data in Table 1 indicated a significant difference in the distribution of clinical and radiological characteristics of the observation array. Thus, in the general array, patients with type I bone defects of the acetabulum were most often found, which was found in 34.7% of cases and occupied the first rank in the distribution. In the first group, this type of bone defects also occupied the leading positions and was found in 41.5% of cases. Similarly, similar patients in the second group also occupied the first rank, but they were found much less often and were found in 26.2% of cases. The difference between the groups was 1.6 times in favor of the first group, which is explained by the early development of the infectious process in patients of the first group. In 18.9% of patients in the general array, type IIA bone defect of the acetabulum was found, which placed them in the second rank. Among patients of the first group, type IIA defects occurred in 17.0% of cases, ranking third. In the second group, this type of defect occurred somewhat more frequently and was detected in 21.4% of patients, which determined the second rank for them. The third rank in the general array was occupied by patients without bone defects, which was detected in 17.9% of cases. In the first group, patients without bone defects occurred in 24.5% of cases, ranking second. Among patients of the second group, the absence of bone defects occurred in 9.5% of cases, which is more than 2.5 times less often than in

the first group. The ranking distribution determined the fifth rank for them in the second group. In 12.6% of patients of the general array, bone defects of the acetabulum were detected, corresponding to type IIV according to the classification of W. Paprosky (1994).

Table 1 – **Analysis of the distribution of the observation array by the presence of a bone defect of the acetabular cavity according to W. Paprosky (1994)**

Defect type	Number of patients								
	1nd group			2nd group			Total array		
	abs.	%	Ri	abs.	%	Ri	abs.	%	Ri
I	22	41,5	1	11	26,2	1	33	34,7	1
IIA	9	17,0	3	9	21,4	2	18	18,9	2
IIB	5	9,4	4	7	16,7	3	12	12,6	4
IIC	4	7,5	5	6	14,3	4	10	10,5	5
IIIA	0	-	-	3	7,1	6	3	3,2	6
IIIB	0	-	-	2	4,8	7	2	2,1	7
No defect	13	24,5	2	4	9,5	5	17	17,9	3
Total	53	100,0	-	42	100,0	-	95	100,0	-

These patients ranked fourth in the general array. In the observation groups, the distribution was inverse to the previous category. Thus, in the first group, type IIB bone defects occurred in 9.4% of cases and ranked fourth, and in the second group – in 16.7% of cases, ranking third. A similar trend was observed in patients with type IIS bone defects, which were found in 10.5% of patients in the general array and ranked fifth. Among the patients in the first group, this type of bone defect was observed in 7.5% of cases, ranking fifth, and in the second group – this type of defect occurred in 14.3% of cases, ranking fourth. It is worth noting that the difference between the groups was almost twice as large. The sixth place in the general array was occupied by patients with type IIIA defects, which were found in 3.2% of cases. In the first group, patients with such bone defects were not found at all, and in the second group, on the contrary, such patients were found in 7.1% of cases, also occupying the sixth rank. The least common in the general array were patients with bone defects of type IIIB, which were found in 2.1% of cases, occupying the last seventh rank. As in the previous position, in the first group, such patients were not found, and in the second group, these patients were also found in 4.8% of cases, which determined the last seventh rank for them. To determine the reliability of the above indicators, we conducted a polychoric analysis using the Pearson method. The analysis data are presented in Table 2.

Table 2 – **Calculated values of the probability of the indicators of connection**

Indicator	Value of the indicator	Probability
Reciprocal connection indicator φ^2	0,75	+
Polychoric indicator of connection C	0,65	+
Pearson probability criterion χ^2	71,25	+

As indicated by the analysis of the data presented in Table 2, there is a direct positive strong relationship between the sign of the presence of bone defects of the acetabulum and the course of the infectious process in the resulting groups, and the indicated positions are within the probability field ($\chi2$ 71.25 $\geq$ $\chi2st$ 16.8) ($p \leq 0.01$).

The distribution of the observation array according to the classification of femoral component defects according to W. Paprosky (1994) is shown in Table 3.

The data in Table 3 indicated that in the general array, patients with type I bone defects in the femoral component were most often found, which was found in 54.7 % of cases. In the first group, these patients occupied the first rank and were found in 52.8 % of cases. Similarly, in the second group, patients with type I bone defects also occupied the leading positions, and were found in 57.1 % of cases. In the second rank in the general array, patients with the absence of bone defects in the femur, which was observed in 25.3 % of cases. A slightly different picture was revealed in the observation groups. Thus, in the first group, patients with the absence of bone defects in the thigh were 32.1 %, which determined the second rank for them in the distribution. In the second group, such patients also occupied the second rank in the distribution, but were found almost twice as often, in 16.7 % of cases. The third rank in the general array was occupied by patients with type II bone defects, which were found in 14.7 % of cases. The even distribution of patients with

type II bone defects in the observation groups is striking. Thus, in the first group, such patients are found in 15.1 % of cases, and in the second group – in 14.3 % of cases and occupied the third rank in their groups. In the fourth rank in the general array, patients with more severe type IIIA bone defects.

Table 3 – **Analysis of the distribution of the observation array by the sign of the presence of a bone defect of the femoral component according to W. Paprosky (1994)**

Defect type	Number of patients								
	1nd group			2nd group			Total array		
	abs.	%	Ri	abs.	%	Ri	abs.	%	Ri
I	28	52,8	1	24	57,1	1	52	54,7	1
II	8	15,1	3	6	14,3	3	14	14,7	3
IIIA	0	-	-	3	7,1	4	3	3,2	4
IIIB	0	-	-	1	2,4	5	1	1,1	5
IV	0	-	-	1	2,4	5	1	1,1	5
No defect	17	32,1	2	7	16,7	2	24	25,3	2
Total	53	100,0	-	42	100,0	-	95	100,0	-

This type was found in 3.2 % of patients in the general array. In the first group, similar patients with IIIA bone defects were not found, and in the second group, such patients were found with a frequency of 7.1 % of cases. The last fifth place in the general array was occupied by patients with severe bone defects of the hip, characterized as type IIIB and IV according to the classification by W. Paprosky (1994). In both cases, these patients were found in 1.1 % of the general array. Similarly, a similar picture was found in the observation groups, when in the first group such patients were not found, and in the second group they were recorded in 2.4 % of cases. To determine the reliability of the above indicators, we conducted a polychoric analysis using the Pearson method. The analysis data are presented in Table 4.

Table 4 – **Calculated values of the probability of the indicators of connection**

Indicator	Value of the indicator	Probability
Reciprocal connection indicator φ^2	0,93	+
Polychoric indicator of connection C	0,69	+
Pearson probability criterion χ^2	88,35	+

As indicated by the analysis of the data presented in Table 4, there is a direct positive strong relationship between the sign of the presence of bone defects of the femur and the course of the infectious process in the resulting groups, and the indicated positions are within the probability field ($\chi2$ 88.35 $\geq$ $\chi2st$ 15.1) ($p \leq 0.01$).

DISCUSSION

Successful treatment of periprosthetic infection includes a combination of adequate surgical tactics and etiotropic antimicrobial therapy active against the pathogens of this infectious process. The most common causes of persistent and recurrent infection are the choice of incorrect surgical tactics and/or irrational use of antibiotics [6]. If the periprosthetic infection is acute with an unformed biofilm, it is possible to save the installed implant by performing debridement (DAIR D=Debridment, debridement, removal of all non-viable tissues, A=Antibiotics, antibiotic therapy, IR=Implant Retension, preservation of endoprosthesis components). Debridement is a remedial operation with the preservation of stable endoprosthesis components, but, with this approach, mandatory replacement of the friction pair is necessary [7]. The choice of treatment for periprosthetic infection usually depends on a number of factors, including local factors related to the condition of the bone and soft tissues, fixation and stability of the components, the chronic nature of the infection, the type of organism and the general condition of the patient [8]. There is disagreement among surgeons about which type of fixation of endoprostheses is best to use after the first stage of treatment (eradication of infection). Some publications contain information about the successful implantation of cement endoprostheses impregnated with antibiotics, others demonstrate 100% control over infection after the use of cementless (press-fit) prostheses [4, 9]. Still others argue that the method of fixation of the endoprosthesis components should be based on the intraoperative vision of the surgeon, since cementless or cemented types of fixation do not correlate with the risk of infection recurrence and weakening of the implant stability [10]. There are publications that indicate the

effectiveness of a two-stage treatment option for affected joints even in patients with significant bone defects. In such a situation, it becomes necessary to use massive bone allografts, which, from the point of view of infection recurrence, according to some, are absolutely safe, and, according to others, are a high risk even with aseptic revisions. Analysis of the results of treatment using the two-stage revision technique gives encouraging results of infection eradication from 75 to 100% with high functional results [11]. According to Ji B., et al. (2022), in the diagnosis of periprosthetic infection of the hip joint, one of the key values is the radiological assessment of the presence of bone defects. The authors emphasize not so much their diagnostic value as their influence on the planning of treatment tactics. The use of clear visualization of bone defects allows determining the presence and size of bone allografts that will be used to close them during revision surgery [12]. Flaten D., et al. (2023) in their work recommend using the classification of bone defects according to W. Paprosky (1994) as this has a direct impact on the choice of revision implant, as well as the use of antiprotrusion devices or metal cages. It is believed that the presence of rapidly progressive osteodefects in patients of both the acetabulum and the femur against the background of high ESR and biomarkers of inflammation clearly indicates the presence of periprosthetic infection and not aseptic loosening of the total endoprosthesis [13]. Protsiuk VV, et al. (2020) conducted a differential diagnosis of septic and aseptic bone defects in revision hip arthroplasty. The paper notes that in aseptic loosening, clearly localized areas of bone defects are determined, while in periprosthetic infection, bone defects have unclear contours and may extend beyond the load zones in the hip joint. Another factor that should alert specialists is the appearance of a periosteal reaction on the thigh. The authors consider this to be an indisputable manifestation of periprosthetic infection [14]. Sancho I, et al. (2022) indicate that the detection of significant type III bone defects on the acetabulum and type III-IV on the thigh is a serious contraindication to the implementation of a one-stage tactic for the treatment of periprosthetic infection. In such cases, the authors consider a two-stage tactic for the treatment of periprosthetic infection to be the gold standard, which allows controlling anatomical stability in the joint at all stages of treatment [15].

CONCLUSIONS

1. Absence of bone defect or type I was significantly more common among patients with early development of periprosthetic infection, which was found in 66.0% of patients and in 35.7% of patients with late development of periprosthetic infection. All types of type II defects were more common in patients with late development of periprosthetic infection, which was found in 52.4% of cases, in contrast to patients with early manifestation of periprosthetic infection, where this type was found in 33.9% of cases. Both types of type III bone defects were found only among patients with late periprosthetic infection, which was found in 11.9% of cases and were not found among patients with early manifestation of infected prosthesis.

2. Absence or type I bone defect was observed in most patients with early periprosthetic infection, which was found in 84.9% of cases and in most patients with late periprosthetic infection in 73.8% of cases. The distribution of type II bone defects of the thigh was uniform in the observation groups, which indicates the absence of the influence of time determinants in the development of this type of bone defect. In the early stages of periprosthetic infection, severe types of bone defects are absent, however, in patients with late manifestation, these defects were found in 11.9% of cases.

PROSPECTS FOR FUTURE RESEARCH

In the future, it is planned to determine the correlation between the occurrence of a bone defect and the previously performed treatment tactics for periprosthetic hip joint infection.

AUTHOR CONTRIBUTIONS

Pavlo Tanasiienko (Computeration, methodology and review of literature)
Genadiy Kolov (Manuscript writing, editing and drafting)
Roman Kozak (Statistics analysis and references arrangement).

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CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

ARTIFICIAL INTELLIGENCE DISCLOSURE

Artificial Intelligence (AI) was used only for grammar revision.

ETHICAL CONSIDERATIONS

All study participants provided informed written consent prior to study enrollment.

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