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Microbiological analysis of wound content in patients with type 2 diabetes mellitus with diabetic foot syndrome

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Abstract. An important component of the comprehensive conservative treatment of diabetic ulcers is antibacterial therapy, as without timely and correct treatment, patients may develop toxic shock syndrome, leading to multiple organ failure. The aim of the study was to examine the species variety of the wound content in diabetic foot ulcers in patients with type 2 diabetes and to determine the susceptibility of the isolated microorganisms to antimicrobial drugs. Given the results of the bacteriological examination of the wound content, the most frequently isolated microorganisms were: *Staphylococcus aureus, Staphylococcus haemolyticus, Klebsiella* spp., *Pseudomonas aeruginosa, Corynebacterium* spp., *Escherichia coli, Proteus* spp., and fungi of the genus *Candida* spp. The study not only investigated the microbial variety in diabetic foot syndrome but also established the effectiveness of applying antibacterial agents to specific isolated pathogens.

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The most effective antibiotics were tigecycline and vancomycin, with the susceptibility of the specified microorganisms ranging from 89.6% to 100.0%, respectively. The susceptibility of *S. aureus* and *S. haemolyticus* to amikacin was 75.9% and 62.1%, respectively. *P. aeruginosa* was susceptible to only 3 out of the 12 antibiotics included in the study, namely: amikacin, vancomycin, and ciprofloxacin. *Klebsiella* spp. showed moderate susceptibility (45.5%) only to doxycycline. *Corynebacterium* spp. was resistant to most of the studied antimicrobial agents, and only to amikacin, tigecycline, vancomycin, and chloramphenicol, the susceptibility level was within 50.0-100.0%. *E. coli* demonstrated high susceptibility (100.0%) to such antimicrobial drugs as ciprofloxacin, ceftazidime, chloramphenicol, amikacin, azithromycin, tigecycline, and ertapenem. *Proteus* spp. was susceptible (100.0%) to chloramphenicol, amikacin, azithromycin, tigecycline, and ertapenem. The identification of the microbial diversity of the wound contents of a diabetic ulcer and a broad antibiotic profile will allow the optimization of antibiotic therapy in accordance with the treatment protocol for this pathology and prevent the development of antibiotic resistance

Keywords: metabolic disease; diabetic foot infection; microorganisms; antibiotics; antibiotic resistance

Introduction

Type 2 diabetes mellitus (T2DM) is considered a complex healthcare problem and ranks among the leading diseases in modern society. Since 2000, due to its high rate of spread and numerous complications, T2DM has raised concerns not only in Ukraine but also internationally [1]. According to the World Health Organization (WHO), about 500 million people suffer from diabetes today. Scientists predict that by 2040, the number of cases will exceed 400 million [2, 3]. In Ukraine, there are 3.5 million people with diabetes, with 1.23 million diagnosed cases (35.0% of all people with diabetes) [1, 2]. Monitoring studies show that the number of people with diabetes in Ukraine is increasing by an average of 5.0-7.0% annually [1].

One of the most common and severe surgical complications of type 2 diabetes is diabetic foot syndrome (DFS), which complicates the course of the disease in nearly 30.0-80.0% of cases and is the leading cause of non-traumatic amputations. According to the global registry and medical statistics in developed European countries, the annual incidence of DFS is 23.0-25.0% among diabetic patients and is the cause of hospitalization for every fourth patient, with one in seven undergoing high limb amputation [4, 5]. According to O. Laktionova *et al.* [2], the recurrence rate can reach 45.0%. DFS is a complex of symptoms that develop pathological changes in the feet, such as purulent-necrotic processes, bone and joint lesions, and ulcers, arising against the background of specific changes in peripheral nerves, blood vessels, skin, and soft tissues [5, 6].

Diabetic foot syndrome is considered a major medical and social problem for both patients and healthcare systems not only in Ukraine but worldwide. The prevalence of chronic wound defects in the soft tissues of the lower extremities ranges from 4.0 to 15.0%. Among all hospitalised individuals with diabetic foot, patients with trophic foot ulcers constitute 6.0-10.0%, and their hospital stay is 60.0% longer compared to patients without skin integrity violations [6, 7].

The analysis of numerous studies demonstrates that the cause of mild to moderate ulcers is predominantly gram-positive bacteria. At the same time, severe or chronic forms of infection are more often characterised by a polymicrobial nature. Among gram-positive bacteria, staphylococci (*Staphylococcus aureus, Staphylococcus epidermidis*) are most commonly isolated. *Hemolytic streptococci* are verified much less frequently. Gram-negative aerobic bacteria are usually represented by microorganisms from the *Enterobacteriaceae* group and *Pseudomonas* spp. [8, 9].

There is often a problem associated with the ineffectiveness of existing treatment protocols for this pathology. Scientists note that this situation may be due to the presence of Methicillin-resistant *Staphylococcus aureus* (MRSA), which leads to the complication of the purulent process and increased mortality, including among patients with diabetic foot syndrome [10]. Anaerobic bacteria are considered the main pathogens, mostly in patients with ischaemic forms of DFS or gangrene. They account for up to 50.0% of all isolated strains. There are suggestions that *Corynebacterium* spp. may play a pathogenic role around necrotic tissues [8, 11].

S. Shapoval *et al.* [10] have shown that the following microorganisms can also be isolated among the mentioned bacteria in purulent-necrotic processes: *Enterococcus faecalis, Enterococcus faecium, Streptococcus agalactiae*, and *Kocuria kristinae*. In turn, A. Prevar *et al.* [12] show in their work the presence of *Citrobacter freundii*, *Enterobacter cloacae*, *E. aerogenes, S. viridians,* and *S. agalactiae*. Therefore, it is crucial to establish the role of microorganisms in the development and course of such purulent-necrotic processes, as well as the rationality of antibiotic therapy. The purpose of the study was to investigate the species variety of the wound content of diabetic foot ulcers in type 2 diabetes and to determine the susceptibility of the isolated microorganisms to antimicrobial drugs.

Materials and Methods

The study involved 80 patients with T2DM and DFS aged 45 to 75 years who were treated at the Municipal Non-Profit Enterprise "Ternopil City Emergency Hospital" from February to October 2023. The inclusion criteria were: people of both sexes, people aged over 18, verified diagnosis of type 2 diabetes mellitus, diabetic foot syndrome and consent to participate in the study. The exclusion criteria were: chronic diseases in the acute phase as well as in the phase of decompensation, treatment with glucocorticosteroids, pregnancy, mental disorders, cancer and suspected cancer, refusal to

participate in the study. All patients were diagnosed with type 2 diabetes: 93.3% were in the subcompensation stage and 6.7% in the decompensation stage. Patients were admitted with pronounced purulent-necrotic lesions in various areas of the foot, with a mixed form of DFS. All patients signed an informed consent to participate in the study.

All patients included in the study were indicated for surgical intervention due to diabetic foot syndrome complicated by purulent-necrotic lesions. To prescribe rational antibiotic therapy, all patients underwent bacteriological examination of purulent discharge from the wounds with microbiota verification. For this purpose, the collection of biological material (pus, exudate, wound content) from the wound surfaces was carried out under aseptic conditions using sterile swabs before the use of antibacterial drugs (ABD). The skin around the wound edges was pre-treated with 70.0% alcohol. The material for the study was taken from the centre to the periphery of the wound surface using two sterile swabs. The first swab was used to prepare a smear, which was stained using the Gram method. The second swab was used to inoculate clinical material onto the surface of solid nutrient media for bacteriological analysis.

To identify microorganisms, the material was cultured on the following nutrient media: for aerobic bacteria – blood agar, yolk-salt agar, sugar broth, serum agar, Endo medium for enterobacteria (Biolife Italiana S.r.l.); for anaerobic bacteria – Wilson-Blair medium, and thioglycolate broth, using gas-generating box to create anaerobic conditions – GENboxanaer (BioMerieux, France). The cultures were incubated in a thermostat at 37°C for 24-48 hours. For the detection of fungi of the genus *Candida* spp., Sabouraud medium (FARMAKTIV LLC, Kyiv, Ukraine) was used with subsequent incubation in a thermostat at 27-30°C for 5 days. The identification of microorganisms was based on their morphological, tinctorial, and cultural characteristics.

To determine the susceptibility of the isolated pathogenic microorganisms to antibacterial drugs, the Kirby-Bauer qualitative method was used with standard discs. Pure bacterial cultures were cultivated on the Mueller-Hinton medium, and fungi on Sabouraud medium. The following antibiotics were tested in the study: ciprofloxacin, ceftazidime, chloramphenicol, amikacin, azithromycin, ceftriaxone, doxycycline, erythromycin, methicillin, tigecycline, vancomycin, and ertapenem. The assessment and analysis of the results were conducted by determining the diameters of growth inhibition zones according to standard table data [13].

Statistical processing of the numerical data was performed using Excel software (Microsoft, USA) tabulating the data and expressing them in per cents. All studies were conducted in compliance with the main bioethical norms and the requirements of the Helsinki Declaration, cited by O. Nawrot [14], as confirmed by the conclusion of the Bioethics Commission of I. Horbachevsky Ternopil National Medical University, Ministry of Health of Ukraine (protocol No. 77 dated April 18, 2024).

Results

Pathological material for determining the species diversity of microorganisms causing and promoting limb suppuration in diabetes was obtained from patients, among whom the share of men was 66.25% and women 33.75% (see Table 1).

Table 1. Age distribution of patients with T2DM and DFS

Age	Women %		Men %	
	n	%	n	%
Until 50 years old	6	22.20	12	22.64
51-60	6	22.20	13	24.52
61-70	10	37.03	13	24.52
After 70	5	18.51	15	28.30
In total	27	33.75	53	66.25

Source: table compiled by the authors

According to the results of the bacteriological study of the wound content, the following microorganisms were identified: *Staphylococcus aureus, Staphylococcus haemolyticus, Klebsiella* spp., *Pseudomonas aeruginosa, Corynebacterium* spp., *Escherichia coli, Proteus* spp., and fungi of the genus *Candida* spp. With high frequency (30.0%), *S. aureus* and *S. haemolyticus* were found (see Fig. 1).

This percentage of identification of the specified microorganisms is due to their properties: the ability to produce proteolytic factors that disrupt the skin barrier. Therefore, staphylococci are the main colonisers of chronic suppurative wounds. Next in prevalence in the microbiome of purulent wounds against the background of diabetes was the gram-negative rod *Klebsiella* spp., with a frequency of isolation among bacteria of 11.0%. Microbiological examination of ulcers in DFS showed the presence of such bacteria in the biomaterial as *Corynebacterium* spp. These organisms are part of the normal microbiota of mucous membranes and healthy skin, especially in areas like the feet, and are considered colonizing rather than pathogenic bacteria. The frequency of detection of corynebacteria was 9.0%.

Results of microbiological research: *Pseudomonas* spp., *E. coli,* and *Proteus* spp. were identified significantly less frequently, with less than 10.0% occurrence: *P. aeruginosa* – 6.0%, *E. coli* – 5.0%, and *Proteus* spp. – 5.0%. Typically, *P. aeruginosa* is rarely verified in purulent-necrotic lesions. In 4.0% of cases, fungi of the genus *Candida* spp. were isolated in addition to the microorganisms described above. Their appearance is possibly related to the immunosuppression associated with T2DM (see Fig. 1).

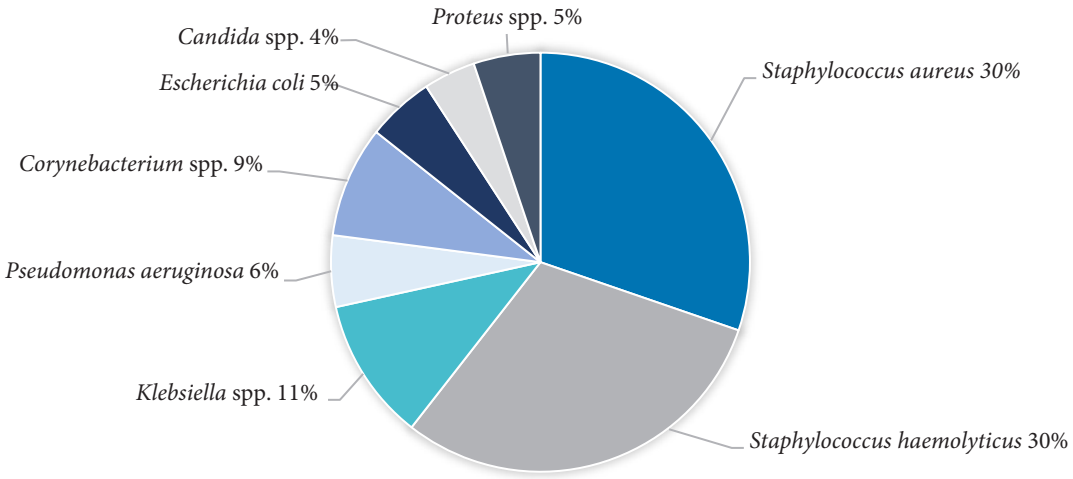

Figure 1. Species diversity of wound content obtained from patients with T2DM with purulent-necrotic complications
Source: compiled by the authors

Research has been conducted not only on the microbial diversity in diabetic foot ulcers, but also on the effectiveness of using specific antibiotics against the identified pathogens. The susceptibility of the isolated bacteria was quite variable. Clinical isolates of *S. aureus* and *S. haemolyticus* showed varying degrees of susceptibility to all studied antibiotics. The most effective antibiotics were tigecycline and vancomycin, used for treating various purulent-septic infections caused by gram-positive bacteria. The susceptibility of these microorganisms to these antibiotics was 89.6% and 100.0%, respectively (see Table 2).

Table 2. Antibiotic susceptibility of microorganisms isolated from purulent-necrotic ulcers in patients with diabetic foot syndrome against the background of type 2 diabetes mellitus

Bacteria / Antibiotic	*Klebsiella* spp.	*S. aureus*	*S. haemolyticus*	*P. aeruginosa*	*Corynebacterium* spp.	*E. coli*	*Proteus* spp.
Ciprofloxacin	R	51.7%	41.4%	100.0%	R	100.0%	R
Ceftazidime	R	37.9%	27.6%	R	R	100.0%	R
Levomycetin	R	62.1%	62.1%	R	50.0%	100.0%	100.0%
Amikacin	27.3%	75.9%	62.1%	100.0%	100.0%	100.0%	100.0%
Azithromycin	R	27.6%	27.6%	R	R	100.0%	100.0%
Ceftriaxone	R	51.7%	41.4%	R	R	R	R
Doxycycline	45.5%	75.9%	62.1%	R	R	R	R
Erythromycin	R	27.6%	34.5%	R	R	R	R
Methicillin	R	51.7%	34.5%	R	R	R	R
Tigecycline	27.3%	89.6%	100.0%	R	100.0%	100.0%	100.0%
Vancomycin	27.3%	89.6%	100.0%	100.0%	100.0%	R	R
Ertapenem	27.3%	51.7%	R	R	R	100.0%	100.0%

Notes: R – resistant
Source: compiled by the authors

In the context of antibiotic therapy, cephalosporins are prescribed, which are chemically and pharmacologically similar to penicillin. The antibiotic ceftriaxone, which is widely used today to treat most bacterial infections and is considered the most successful of the third-generation cephalosporins, showed significantly lower effectiveness: 51.7% for *S. aureus* and 41.4% for *S. haemolyticus*. Similar data were obtained from testing the antibiotic ciprofloxacin. A relatively high susceptibility of *S. aureus* and *S. haemolyticus* (75.9% and 62.1%, respectively) was observed to amikacin, a semisynthetic antibiotic from the third-generation aminoglycosides group, as well as doxycycline, a semisynthetic antibiotic from the broad-spectrum tetracyclines group. The effectiveness of other studied antibiotics ranged from 27.6% to 51.7%. *Klebsiella* spp. was found to be resistant to most antibiotics involved in the study, with only doxycycline showing moderate effectiveness at 45.5% (see Table 2).

It is believed that the presence of *P. aeruginosa* in wound content complicates the purulent-necrotic process

in DFS patients. Bacteriological studies have shown that this pathogen is highly resistant to most studied antibiotics. Only 3 of the 12 antibiotics included in the study were effective: amikacin, vancomycin, and ciprofloxacin, a representative of the second-generation fluoroquinolones. The susceptibility of *P. aeruginosa* to these antibiotics was 100.0% (see Table 2).

Other microorganisms isolated during bacteriological examination showed a varied level of susceptibility to the studied antibiotics. For example, *Corynebacterium* spp., which is usually a commensal species of the skin, was found to be resistant to most antimicrobial agents, with only 4 of them (amikacin, tigecycline, vancomycin, and levomycetin) showing a positive result. The susceptibility to these drugs ranged from 50.0-100.0%. Due to the significant variability in resistance of this pathogen to antimicrobial agents, there is a need for continuous monitoring of the susceptibility of non-diphtheria corynebacteria isolates. The increasing number of studies demonstrates the relevance of researching the resistance of non-diphtherial corynebacteria, as they participate in biofilm formation, which enhances the development of resistance and the recurrence of various infectious diseases. *E. coli* demonstrated a high level of susceptibility (100.0%) to such antimicrobial drugs as ciprofloxacin, ceftazidime, levomycetin, amikacin, azithromycin, tigecycline, and ertapenem (see Table 2).

Among gram-negative microorganisms, *Proteus* spp. is moderately isolated, which belongs to the *Enterobacteriaceae* family. The presence of this pathogen in the biomaterial taken from patients with DM and DFS indicates a serious complication of this infectious process. According to the results of the antibiogram, *Proteus* spp. was resistant to most of the selected antibiotics, with only levomycetin, amikacin, azithromycin, tigecycline, and ertapenem showing high effectiveness (100.0%). However, the results obtained during the study also demonstrated the resistance of *Proteus* spp. to certain antimicrobial drugs (see Table 2). It can be assumed that during the use of antibiotics in the treatment of purulent-necrotic infections, this microorganism acquired resistance to such medicinal products.

Discussion

S. Shahrokh *et al.* [8] as well as A. Atlaw *et al.* [9], in their studies, showed that purulent-necrotic lesions of the foot in type 2 diabetes mellitus are characterised by a significant microbial load. The cause of mild and moderate ulcerations is gram-positive bacteria. At the same time, severe or chronic forms of infection are more often characterised by a polymicrobial nature. The polymicrobial aetiology of DFS was also identified in this study, especially in chronic conditions.

The species variety of microorganisms causing purulent infections is variable and diverse. Quite often, hospital-acquired strains, characterised by a high level of virulence and antibiotic resistance, are observed to be involved. Numerous microbiological studies indicate that the skin in diabetes is characterised by high colonization of such commensal microorganisms as *S. aureus*, *S. epidermidis*, and S. *haemolyticus*. They are the most common agents of purulent ulcers in type 2 diabetes. However, O. Laktionova *et al.* [2], in their studies, showed that representatives of *Pseudomonas* spp. and the *Enterobacteriaceae* family are also quite common. The frequency of detecting these microorganisms ranges from 28.0 to 40.0% [8, 11, 15], which correlates with these findings.

A pressing issue today is the emergence and increase in the number of infections caused by multidrug-resistant bacteria *Klebsiella* spp. This microorganism is known to be the cause of numerous upper respiratory tract infections and is one of the main factors in the development of gastrointestinal diseases. However, in microbial associations, *Klebsiella* spp. is capable of causing purulent-necrotic processes in diabetic foot and is characterised by resistance to antibacterial drugs [15-17]. X. Li *et al.* [16], as well as A.K.P.H. Putra & S. Sundari [17], showed in their studies that this microbe was the cause of necrotic foot lesions in 7.0-11.9% of cases. The same was found by the authors of this study.

Recently, the role of colonizing microorganisms in the development of purulent infections has been increasing, among which *Corynebacterium* spp. plays a leading role [19, 20]. A.N. Khayyat *et al.* [21] identified in their study pathogens with significant tropism for bones and joints, among which *Corynebacterium striatum* is the most common. Some species are associated with urinary tract infections, respiratory infections, surgical wound infections, and endocarditis. However, when *Corynebacterium* spp. are verified in severe infections, including osteomyelitis, they can exhibit pathogenic properties. In such cases, their presence contributes to the development of a pathogenic biofilm. This phenomenon is particularly characteristic of chronic wounds in individuals with diabetes, who have weakened immune responses. Currently, corynebacteria are considered a new pathogen in deep infections of the diabetic foot, with a detection frequency of 4.0-10.0% [11, 18, 21]. The same was found by the authors of this study.

Despite the fact that the majority of skin purulent infections are caused by the presence of staphylococci, the severity of these infections also depends on the presence of other microorganisms, including *Pseudomonas* spp., *E. coli,* and *Proteus* spp. [22]. In conformity with the literature, the following frequencies of these bacteria have been reported: *E. coli* – 17.19% [8]; 7.1% [18]. *Pseudomonas* spp. – 7.54% [8]; 11.9% [18]. *Proteus* spp. – 4.32% [8]; 7.1% [18].

Usually, *P. aeruginosa* is verified quite rarely in diabetic foot ulcers. M.D.M. Bermejo Olano *et al.* [18] as well as W. Sun *et al.* [20] have shown that in patients with DFS on the background of type 2 diabetes, the frequency of *P. aeruginosa* isolation is 7.0 %. The same was found by the authors of this study.This pathogen often causes severe tissue damage in diabetic foot ulcers, leading to sepsis and amputation. The pathogenicity of these bacteria is based on their ability to produce various toxins, proteases, and resist phagocytosis. Clinical isolates of *P. aeruginosa* obtained from chronic wounds are typically resistant to many drugs,

which complicates antibiotic therapy. *Pseudomonas aeruginosa* is considered an opportunistic pathogen known for its metabolic flexibility, exceptional ability to colonise diverse environments, form biofilms, and intrinsic resistance to a wide range of antimicrobial agents due to specific genetic determinants. A.H. Jaber & S.A.F. Almiyah [22] as well as L. Zhuravlyova & O. Keleberda [23] consider that this fact has enabled horizontal gene transfer of resistance genes and allowed P. aeruginosa to overcome the human immune defence.

As the obtained research results and literature data show, numerous purulent-ulcerative lesions of the skin in patients with T2D are usually polymicrobial. Bacteria can exist in the wound as multilayered microbial associations, known as biofilms, surrounded by self-produced extracellular polymeric substances. This structure protects microbial cells from antibacterial agents and the body's immune system, allowing bacteria to proliferate and interfere with wound healing, making such infections difficult to treat.

One of the most important components of comprehensive conservative treatment of a diabetic ulcer is antibacterial therapy, as without correct and timely treatment, patients may develop toxic shock syndrome, leading to multiple organ failure. Today, the resistance of pathogens to antibiotics is considered a significant problem in patients with purulent-necrotic lesions.

According to the recommendations of the Infectious Diseases Society of America (ISDA) regarding antibiotic therapy for moderate and severe cases of diabetic foot syndrome, the main drugs are second and third-generation cephalosporins, combination of β-lactam antibiotics with β-lactamase inhibitors, and carbapenems. Broad-spectrum antibiotics such as ertapenem, ampicillin/sulbactam, imipenem/cilastatin, and piperacillin/tazobactam may also be used. The use of all antibiotics should be based on the bacterial profile of the wound process [19]. Today, there is a decrease in the effectiveness of cephalosporins against staphylococci. For example, S. Shahrokh *et al.* [8] showed resistance of *S. aureus* to ceftriaxone in only 48.0% of cases, which is consistent with these findings.

Klebsiella spp. is characterised by a high degree of resistance. The susceptibility of this pathogen to tigecycline, vancomycin, ertapenem, and amikacin was less than 30.0%, although X. Li *et al.* [16] note a high susceptibility (100.0%) of this microorganism to these antimicrobial agents. The reason for the discrepancy between the obtained results and the literature data is likely the fact that *Klebsiella* spp. is increasingly isolated from purulent lesions in patients with type 2 diabetes as a nosocomial species. As known, such species are characterised by multidrug resistance, the level of which increases every year due to the active use of antibiotics.

Another pathogen with a high level of resistance is *P. aeruginosa.* Only some antibiotics show effectiveness against this pathogen. For example, X. Li *et al.* [16] found 100.0% susceptibility of *P. aeruginosa* to amikacin and ciprofloxacin [14]. The obtained results are consistent with the literature data. The high resistance of this pathogen is likely associated with its ability to form biofilms. Therefore, the WHO has included carbapenem-resistant *P. aeruginosa* in the list of bacteria for which there is a critical need to develop new antibiotics for the treatment of infections caused by this pathogen [23].

Among the microorganisms isolated from the wound content of patients with type 2 diabetes, the role of *Corynebacterium* spp. is increasing. This microbe is characterised by a fairly variable susceptibility to antibiotics. For example, W. Sun *et al.* [20] showed high effectiveness (100.0%) of vancomycin and low activity of erythromycin (resistance level was 91.0-100.0%), ciprofloxacin – 93.3%, doxycycline and tigecycline – 77.8% [24], which is consistent with these findings.

E. coli is susceptible to most antibiotics. According to literature data, antibiotics such as ciprofloxacin, ceftazidime, chloramphenicol, amikacin, azithromycin, tigecycline, and ertapenem are highly effective. For example, the sensitivity of *E. coli* to ertapenem was 96.6 %, and to amikacin – 93.3% [18], to ciprofloxacin – 100.0% [20]. Resistance of *E. coli* to third-generation cephalosporins, specifically to ceftriaxone, has been identified. Such resistance of *E. coli* isolates may be associated with the widespread distribution of beta-lactamases among enterobacteria [8]. The same was found by the authors of this study.

The presence of *Proteus* spp. in purulent-necrotic ulcers, complicates the course of such infection. As known, this microorganism participates in the formation of biofilms, which in turn complicates antibiotic therapy, especially in the case of a diabetic ulcer [19, 23, 24]. Literature data indicate ambiguous and variable susceptibility of this pathogen to antibiotics. For example, A. Atlaw *et al.* [9], as well as X. Li *et al.* [16], noted the high effectiveness of ceftazidime and ceftriaxone (84.6-100.0% and 92.3%, respectively). However, in this study, the authors found resistance of *Proteus* spp. to these antibiotics.

Conclusions

The complex therapy of type 2 diabetes with the complication in the form of purulent-necrotic lesions should be based on microbiological examination of wound content, taking into account the antibiotic susceptibility of the isolated strains. Bacteriological analysis showed that diabetic ulcers usually arise due to the presence of not one, but several types of microorganisms, among which *S. aureus* and *S. haemolyticus* are most commonly encountered (their isolation frequency is 30.0%). The frequency of isolation of other bacteria (*Klebsiella* spp., *Pseudomonas aeruginosa, Corynebacterium* spp., *Escherichia coli, Proteus* spp., and *Candida* spp. fungi), which complement the bacterial diversity of purulent-necrotic ulcers, varies within 4.0-11.0%.

The antibiotic ceftriaxone, which is actively used in the majority of infections caused by microbes, was effective in 51.7% against *S. aureus,* 41.4% against *S. haemolyticus*, and the other identified species showed 100.0% resistance.

The antibiotic amikacin was variably susceptible to all investigated microorganisms: *S. aureus* – 75.9%, *S. haemolyticus* – 62.1%, *Klebsiella* spp. – 27.3%, *Pseudomonas aeruginosa*, *Corynebacterium* spp., *Escherichia coli, Proteus* spp. – 100.0%. In the case of *Klebsiella* spp., it is more advisable to use doxycycline, as compared to other tested drugs, its effectiveness was the highest at 45.5%.

The high effectiveness against most of the isolated strains was observed with tigecycline and vancomycin. The susceptibility of *S. haemolyticus, Pseudomonas aeruginosa,* and *Corynebacterium* spp. to the latter was 100.0%; *S. aureus* was susceptible in 89.6% of cases, but *E. coli* and *Proteus* spp. were resistant. Only *P. aeruginosa* was resistant to tigecycline. Thus, the treatment of type 2 diabetes with complicated foot ulcers should be comprehensive, using rational antibiotic therapy based on microbiological examination. Prospects for further research: to study the rate of development of resistance to modern antibiotics in clinical strains of bacteria that cause purulent inflammatory processes in the DFS.

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None.

Conflict of Interest

The authors declare no conflict of interest.

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Мікробіологічний аналіз вмісту ран у пацієнтів з цукровим діабетом 2 типу з синдромом діабетичної стопи

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Анотація. Важливим компонентом комплексного консервативного лікування діабетичної виразки є антибактеріальна терапія, адже без коректного своєчасного лікування у пацієнтів можливий розвиток синдрому токсичного шоку, що призводить до поліорганної недостатності. Метою дослідження було вивчення видового складу ранового вмісту виразки діабетичної стопи при цукровому діабеті-2 та визначення чутливості виділених мікроорганізмів до антимікробних препаратів. За результатами бактеріологічного дослідження ранового вмісту найчастіше виділяли такі мікроорганізми як: *Staphylococcus aureus*, *Staphylococcus haemolyticus*, *Klebsiella* spp., *Pseudomonas aeruginosa*, *Corynebacterium* spp., *Escherichia coli*, *Proteus* spp. та гриби роду *Candida* spp. Проведено дослідження не лише мікробного різноманіття при синдромі діабетичної стопи, а й встановлена ефективність застосування антибактеріального засобу до конкретного виділеного збудника. Найбільш ефективними виявилися антибіотики тігециклін та ванкоміцин, де чутливість вказаних мікроорганізмів становила від 89,6 % до 100 % відповідно. Чутливість *S. aureus* та *S. haemolyticus* до амікацину становила 75,9 % і 62,1 % відповідно. *P. aeruginosa* була чутливою лише до 3 з 12 залучених в дослідження антибіотиків, а саме: амікацин, ванкоміцин та ципрофлоксацин. *Klebsiella* spp. відзначався помірною чутливістю (45,5 %) лише до доксицикліну. *Corynebacterium* spp. виявилися резистентною до більшості досліджуваних антимікробних препаратів і лише до амікацину, тігецикліну, ванкоміцину та левоміцетину рівень чутливості був в межах 50-100 %. *E. coli* продемонструвала високий рівень чутливості (100 %) до таких антимікробних препаратів, як: ципрофлоксацину, цефтазидину, левоміцетину, амікацину, азитроміцину, тігецикліну та ертапенему. *Proteus* spp. були чутливим (100 %) до левоміцетину, амікацину, азитроміцину, тігецикліну та ертапенему. Встановлення мікробного різноманіття ранового вмісту діабетичної виразки та широка антибітикограма дозволить оптимізувати антибіотикотерапію відповідно до протоколу лікування даної патології та запобігти розвитку антибіотикорезистентності, адже саме мікробіом рани визначає розвиток, протікання та ступінь ускладнення гнійно-некротичного процесу

Ключові слова: метаболічне захворювання; інфекція діабетичної стопи; мікроорганізми; антибіотики; антибіотикорезистентність