Microbiological substantiation of the use of xenografts saturated with silver nanocrystals for the treatment of burn wounds

The aim of the work: to study the antimicrobial efficacy of xenografts saturated by silver nanoparticles, to suggest their application in the treatment of burned wounds.

Materials and Methods. The antimicrobial efficacy of xenografts saturated with silver nanocrystals was investigated in vitro by diffusion into agar, in a liquid nutrient medium and by studying the adhesive activity using test cultures: *Staphylococcus aureus* ATCC 6538, *Escherichia coli* ATCC 25922, *Pseudomonas aeruginosa* ATCC 9027 and *Candida albicans* ATCC 8565-653.

Results and Discussion. The antimicrobial properties of silver, which was saturated the pieces of cryolyophilized xenoskin, were not inferior to the effectiveness of modern dressings, which were used as a positive control (wound dressing applications Mepilex Transfer Ag (Mölnlycke, Sweden) та Atrauman Ag (Heidenheim, Germany)) in studies. Nanosilver had reduced a bioburden in infected wounds and the adhesive potential of microorganisms, which is important to prevent contamination of burn wounds. Thus, the possibility of using xenografts saturated with silver nanocrystals is considered for local treatment of burns in order to prevent purulent-inflammatory complications that may occur.

Key words: burns; xenograft; silver nanocrystals; antimicrobial properties.

Problem statement and analysis of recent research and publications. One of the main factors determining the prognosis of burn injuries severity is microbial contamination of the wound. It is known, at least 50 % of a mortality caused by burns are the result of wound infections, which is inevitable even with perfect compliance with the rules of asepsis and antiseptics. The critical number of microbes that determines the development of the inflammatory purulent process is ≥ 105 microbial cells in 1 g of wound tissue [1]. Invasion and colonization of the wound surface by microorganisms slow down a wound healing, lead to a deepening burn, and may lead to generalization of infection. Therefore, a treatment of local medicines that would prevent microbial contamination of burn wounds or reduce it below the critical level must be provided.

The elaboration of silver-containing antimicrobial applications is one of the modern nanotechnology and medicine fields. First of all, an advantage of silver nanoparticles use is due to the pharmacological effects of this metal: a wide antimicrobial range, lack of development of a resistance of most pathogenic microorganisms to silver containing medicines, their immunomodulatory properties, absence of data of hypersensitivity to them [2, 3]. The mechanisms of antimicrobial action of this metal are not yet studied well. However, it has been known that such action conditioned the interaction of positively charged silver ions with the electrostatic forces of the microbial cell, which have a negative charge; inhibition of transmembrane transport of Ca\(^{2+}\) and Na\(^{+}\); formation of silver complexes with nucleic acids, which leads to disruption of DNA stability, or with a sulfur atom, which leads to the inactivation of proteins containing thiol groups, thereby inhibiting the viability of microorganisms [4, 5, 6]. In another study, it was found that silver ions exhibit bactericidal properties by inhibiting bacterial cell wall synthesis and affecting ribosome protein synthesis at the 30S subunit, or by inhibiting the activity of some transmembrane enzymes, thereby damaging the bacterial cell membrane structure [7, 8]. It is proved that silver, especially in nanocrystalline form, has fungicidal activity. The effect of silver is due to the irreversible binding of this metal to the cysteine residue, which contains a thiol group in the phosphomannose isomerase, interrupts the synthesis of cell walls and, in turn, leads to loss of essential nutrients and death of fungi, for instance *C. albicans* [9].

The antimicrobial properties of silver are significantly enhanced by its transition into nanoparticles [6]. Silver nanoparticles considered as the most promising as they contain remarkable antimicrobial efficacy due to their large surface area to volume ratio [10]. The use of silver as nanoparticles can reduce the concentration of the metal hundreds of times while maintaining all its bactericidal properties. It is proved that the use of silver medicines increases wound healing, in particular, burns due to the reduction of inflammatory processes in the wound, prevention of microbial contamination and modulation of fibrogenic cytokines [6, 11, 12]. Summarizing the current data of medicinal and antimicrobial properties of silver nanoparticles the new wound management standards based on the usage of silver can be suggested as potential therapeutic choice.
The aim of the work: to study the antimicrobial efficacy of xenografts saturated by silver nanoparticles, to suggest their application in the treatment of burned wounds.

Materials and Methods. The antimicrobial efficacy of xenografts saturated with silver nanoparticles was studied in vitro by diffusion in an agar and in a liquid nutrient medium according to standard laboratory methods [13]. The following ATCC strains of microorganisms were used in the experiments as: Staphylococcus aureus ATCC 6538, Escherichia coli ATCC 25922, Pseudomonas aeruginosa ATCC 9027 and Candida albicans ATCC 885-653. The method of diffusion in an agar was standardized by the ensuring thickness of the Mueller-Hinton nutrient medium (10 mm), the area of xenograft flaps (1 cm²) at a concentration of 0.5 on the McFarland turbidity standard. Xenograft flaps were pre-moistened with sterile sodium chloride saline. In a Petri dish on the surface of nutrient medium a xenograft flap saturated with silver nanoparticles and also samples of Mepilex Transfer Ag (Mölnlycke, Sweden) and Atrauman Ag (Heidenheim, Germany) silver-containing dressings (positive control) and a sterile xenograft flap were placed. The bacterial cultures were incubated at 37 °C during 24 hours. The results were carried out by measuring the diameter of the zone of growth inhibition of microorganisms around the samples. Evaluation of antimicrobial activity, taking into account the size of the flaps, was performed according to the following criteria: an absence of microbial growth inhibition around the flap or presence of a growth inhibition zone up to 16 mm in diameter was assessed test-microorganisms as not susceptible to the sample; the zone of growth inhibition with a diameter of 16–19 mm was evaluated as low susceptibility of a test-strain to the sample; the zone of growth inhibition with a diameter of 19–29 mm was evaluated as sufficient. Antibacterial and antifungal effects on test-strains of microorganisms were also determined using a liquid nutrient medium. Xenograft flaps saturated with and without silver nanoparticles, and flaps of Mepilex Transfer Ag (Mölnlycke, Sweden) and Atrauman Ag (Heidenheim, Germany) dressings sized 10x10 mm were put in test tubes with sterile sugar meat-peptone broth (MPB). Then 0.1 ml of standardized suspension of daily cultured test-strain at a concentration of 0.5 on the McFarland standard was added to each tube. After that test tubes were incubated at 37 °C for 1 hour, 24, 48 and 72 hours. The presence or absence of microbial growth was visually assessed, and the contents of the tubes were inoculated on a sugar meat-peptone agar (MPA) in Petri dishes by a streak method using a 2 mm diameter bacterial loop and the concentration of the microbial cells in each test tube was determined by the Gold method. Each of the experiment was performed 10 times. Statistical analysis of the obtained data was performed using the software package Statistic 10.0 and Microsoft Office Excel.

The adhesive properties of test-strains of microorganisms were studied on formalized human erythrocytes O (I) blood group, Rh (+) according to the Brillis method [14]. To assess the effect of silver nanoparticles on the adhesive activity of test-strains the determination the index of adhesiveness of microorganisms (IAM) was done. Test-microorganisms were considered non-adhesive if IAM <1.75, low-adhesive if IAM=1.76–2.5, medium-adhesive (IAM=2.5–4.0), high-adhesive (IAM>4.0). If a difference between the indexes of adhesiveness in the experiment and control was at 20 % or more the changes of an adhesive potential of bacteria or yeast were considered significant. The experiments were performed three times. The obtained data were displayed as arithmetic means with standard deviation (x ± SD), subjected to statistical processing using Microsoft Excel 2003.

Results and Discussion. Estimation of antimicrobial activity of xenografts and dressings samples by agar diffusion method is shown in Table 1. According to the data obtained, the xenograft saturated with silver nanoparticles was not inferior to the effectiveness of the Mepilex Transfer dressing, and it was found to be better than Atrauman Ag dressing. According to the obtained zones of growth retardation of test cultures on solid nutrient medium, gram-positive bacteria S. aureus and yeast C. albicans, non-fermenting gram-negative rods of P. aeruginosa showed low sensitivity to silver nanoparticles. Susceptibility to the studied samples of E. coli was assessed as sufficient. As a result of incubation of standardized suspension of pure cultures of test microorganisms (Staphylococcus aureus, Escherichia coli and Pseudomonas aeruginosa and yeasts Candida) in sugar MPB in the presence of given flaps a distinct antimicrobial effect of silver nanoparticles was found (Table 2). After 1 hour of culturing the test-strains in the presence of xenograft flaps saturated with silver nanoparticles, also Mepilex Transfer Ag and Atrauman Ag dressings, no growth of gram-negative bacteria was detected, but very weak growth of Staphylococcus aureus and Candida was observed. Very weak growth was detected in test tubes with xenograft flaps without silver nanoparticles too. The concentration of the microbial suspension in these tubes was decreased, apparently due to the adsorption properties of cryolypophilized xenograft. The most effective influence of silver nanoparticles was found on test-strains of E. coli and C. albicans. Even after 48 hours the MPB in test-tubes remained sterile, and after 72 hours very weak growth of these microorganisms was observed. The growth of single colonies of test-
strains of *S. aureus, P. aeruginosa* was detected after 48 hours of cultivation only. Cryolyophilized xenograft flaps saturated with silver demonstrated antimicrobial properties that were not inferior to the degree of effectiveness of modern dressings, which were used as a positive control (Table 2). Mepilex Transfer Ag dres-

| No. | Microorganism | Time |
|-----|----------------|------|
| 1   | *S. aureus*    | 1 hr |
|     |                | 24 hrs |
|     |                | 48 hrs |
|     |                | 72 hrs |
| 2   | *E. coli*      | 1 hr |
|     |                | 24 hrs |
|     |                | 48 hrs |
|     |                | 72 hrs |
| 3   | *P. aeruginosa*| 1 hr |
|     |                | 24 hrs |
|     |                | 48 hrs |
|     |                | 72 hrs |

Table 2. Determination of antimicrobial properties of cryolyophilized xenograft with silver nanoparticles in liquid nutrient medium

| No. | Microorganism | Time |
|-----|----------------|------|
| 1   | *S. aureus*    | 1 hr |
|     |                | 24 hrs |
|     |                | 48 hrs |
|     |                | 72 hrs |
| 2   | *E. coli*      | 1 hr |
|     |                | 24 hrs |
|     |                | 48 hrs |
|     |                | 72 hrs |
| 3   | *P. aeruginosa*| 1 hr |
|     |                | 24 hrs |
|     |                | 48 hrs |
|     |                | 72 hrs |

Table 1. Determination of antimicrobial activity of cryolyophilized xenograft saturated with silver nanoparticles by agar diffusion method

| No. | Microorganism | Xenograft flap saturated with silver nanoparticles | Control |
|-----|---------------|---------------------------------------------------|---------|
|     |               | zone of microbial growth inhibition, mm | level of susceptibility | zone of microbial growth inhibition, mm | level of susceptibility | zone of microbial growth inhibition, mm | level of susceptibility |
| 1   | *S. aureus*   | 18.1±0.6 | low | 0 | non | 17.3±0.9 | low | 16.3±1.5 | low |
| 2   | *E. coli*     | 21.8±1.8 | sufficient | 0 | non | 20.3±2.2 | sufficient | 18.3±1.1 | low |
| 3   | *P. aeruginosa*| 18.5±1.8 | low | 0 | non | 16.0±0.8 | low | 13.8±2.2 | low |
| 4   | *C. albicans* | 16.7±1.6 | low | 0 | non | 15.5±2.1 | low | 15.1±1.4 | low |
Notes: + – very weak microbial growth (growth of single colonies – up to 10 on a medium in a Petri dish), which is less than 10³ colony-forming units (CFU)/ml;
++ – weak growth (10–25 colonies), which is 10³ – 5x10³ CFU/ml;
+++ – moderate growth (from 50 to 100 colonies), which is 10⁴ – 10⁶ CFU/ml;
++++ – massive growth (impossible to count the number of colonies), amounting to 10⁹ CFU/ml

C. albicans

| 1 | 2        | 3        | 4       | 5       | 6       | 7       | 8       |
|---|----------|----------|---------|---------|---------|---------|---------|
| 4 | C. albicans | 1 hr     | +       | ++      | +       | +       | +++     |
|   |          | 24 hrs   | -       | +++     | -       | -       | +++     |
|   |          | 48 hrs   | -       | ++++     | +       | +       | +++     |
|   |          | 72 hrs   | +       | ++++     | +       | +       | +++     |

Table 3. The adhesiveness of test-strains under the action of silver nanoparticles

| Microorganism | xenograft flap saturated with silver nanoparticles | flap of Mepilex Transfer Ag dressing | flap of Atrauman Ag dressing | xenograft flap without silver nanoparticles | without flap |
|--------------|--------------------------------------------------|-------------------------------------|-----------------------------|---------------------------------------------|-------------|
| S. aureus    | 2.56 ± 0.24*                                     | 2.81 ± 0.23*                          | 2.94 ± 0.41*                | 4.61 ± 0.27                                 | 5.52 ± 0.41 |
| E. coli      | 1.86 ± 0.63*                                     | 1.89 ± 0.52*                          | 2.25 ± 0.48*                | 3.9 ± 0.73                                  | 3.93 ± 0.28 |
| P. aeruginosa| 2.21 ± 0.59*                                     | 1.94 ± 0.34*                          | 2.47 ± 0.80                 | 3.84 ± 0.36                                 | 3.88 ± 0.81 |
| C. albicans  | 1.78 ± 0.32                                      | 2.16 ± 0.37                           | 2.35 ± 0.54                 | 2.70 ± 0.93                                 | 2.85 ± 0.43 |

Notes: * – the presence of reliability at a significance level of p <0.05 relative to control (test-strain in the MPB);
- transition of strain to a category with lower adhesiveness.

S. aureus was determined as high adhesive. However, a cultivation of these test-strains in the presence of silver nanoparticles led to the staphylococcal adhesive activity reduction to the average level (IAM=2.56±0.24). The adhesiveness of gram-negative bacteria E. coli and P. aeruginosa was decreased under the influence of silver nanoparticles from medium-adhesive to low-adhesive (IAM became (1.86±0.63) and (2.21±0.59), respectively). The C. albicans test-strains demonstrated a medium adhesive potential. The presence of silver nanoparticles during yeast cultivation caused a decrease of the index of microbial adhesiveness to low level. Obtained data has shown the indexes of the adhesiveness of microorganisms under the influence of silver nanoparticles were changed significantly, as the difference between the indexes of adhesiveness of microorganisms in the experiment and control was more than 20 %.

Silver nanoparticles can be easily incorporated in dressings and have significantly decreased wound-healing time and increased bacterial clearance from infected wounds [16]. Our studies have shown that cryolophehized xenografts saturated with silver nanoparticles can be effectively used to prevent the
development of purulent-inflammatory complications in the treatment of burns, as this metal exhibits antimicrobial properties. It is proved that there is a difference in the efficiency of silver nanoparticles against gram-positive and gram-negative flora. The difference in the degree of a gram-negative and gram-positive microflora sensitivity to silver nanoparticles, apparently, is due to the peculiarities of the structure of the cell membrane, which is confirmed by other studies [3, 17, 18].

The results showed that silver nanoparticles which were saturated xenographs and dressings, caused the transition of test-strains of S. aureus from the category of high-adhesive to the category of medium-adhesive, and test-strains of E. coli, P. aeruginosa, C. albicans – from the category of medium-adhesive to the category of low-adhesive. The decrease in the adhesive

siveness of gram-positive microorganisms is probably due to the blockade of silver nanoparticles of the surface structures of microbial cells required for binding to erythrocyte fibrocnitin. The decrease in the adhesive activity of gram-negative bacteria is due to the destructive action of metal nanoparticles against the fimbrial structures of bacteria that provide adhesion. Reducing the adhesive potential of test-microorganisms is a pathogenetically approach to prevent purulent-inflammatory complications of burn wounds.

Conclusions. The obtained data allows considering the possibility of using xenographs saturated with silver nanoparticles for the local treatment of burns in order to prevent purulent-inflammatory complications that may occur. It shows promising results in healing of contaminated wounds too.

LITERATURE

1. Чернякова Г. М. Застосування сорбційних технологій для лікування інфікованих опікових ран в експерименті / Г. М. Чернякова // Запорізький медичний журнал. – 2017. – Т. 19, № 6. – С. 793–797. URL: http://nbuv.gov.ua/URN/ Zmzh_2017_19_6_20.

2. Current development of silver nanoparticle preparation, investigation, and application in the field of medicine / M. Murphy, Kang Ting, Xunli Zhang [et al.] // Journal of Nanomaterials. – Vol. – 2015. – Article ID696918, 12 p.

3. Eid K. A. Sustained broad-spectrum antibacterial effects of nanoliposomes loaded with silver nanoparticles / K. A. Eid, H. M. Azzazy // Nanomedicine (Lond.). – 2015. – Vol. 9 (9). Р. 1301–1310.

4. Interaction of silver nanoparticles with serum proteins affects their antimicrobial activity in vivo / D. P. Gnanaadhas, M. Ben Thomas, R. Thomas [et al.] // Antimicrobial Agents and Chemothery. – 2013. – Vol. 57 (10). – P. 4945–4955.

5. Ramalingam B. Antibacterial effects of biosynthesized silver nanoparticles on surface ultrastructure and nanomechanical properties of gram-negative bacteria viz. escherichia coli and pseudomonas aeruginosa / B. Ramalingam, T. Parandhaman, S. K. Das // ACS Appl Mater Interfaces. – 2016. – Vol. 8 (7). – P. 4963–4976.

6. Silver nanoparticles are broad-spectrum bactericidal and virucidal compounds / H. H. Lara, E. N. Garza-Treviño, L. Ixtepan-Turrent, D. K. Singh // J. Nanobiotechnology. – 2011. – Vol. 9 (30). – Access mode: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3199605/.

7. Bactericidal effect of silver nanoparticles against multdrug-resistant bacteria / H. H. Lara, N. V. Ayalu-Núñez, L. Ixtepan-Turrent, C. Rodriguez-Padilla // World Journal of Microbiology and Biotechnology. –2010. – Vol. 26. – P. 615–621.

8. Ravishankar Rai V. Nanoparticles and their potential application as antimicrobials / V. Ravishankar Rai, A. Jamuna Bai // FORMATEX. – 2011. – P. 197–209.

9. Наночастики срібла: антибактеріальні та антивірусні властивості / О. М. Заморозкина, О. Н. Бобрюнова, О. В. Гавриш, Г. А. Лобань // Фармація та лікарська токсикологія. – 2014. – Т. 38, № 2. – С. 3–11.

10. Наносеребро: технології отримання, фармакологічні властивості, показники до примінення / Н. С. Чернякова, Б. А. Мовчан, М. И. Загородный [и др.] // Препарати і технології. – 2008. – № 5 (51). – С. 33-34.

11. Synthesis, characterization, antibacterial and wound healing efficacy of silver nanoparticles / G. Chinnasamy, S. Chandrasekharan, T. W. Koh, S. Bhatnagar // Azadirachta Indica. Frontiers in Microbiology. – 2021. – No. 12. – P. 611560.

12. Thirumurugan Gunasekaran. Silver nanoparticles as real topical bullets for wound healing / Thirumurugan Gunasekaran, Tadele Nigusse, Magharla Dasaratha Dhanaraju // Journal of the American College of Clinical Wound Specialists. – 2011. – Vol. 3 (4). – P. 82–96.

13. Державна Фармакопея України. – 2 від. Харків: Державне підприємство "Український науковий фармакопейний центр якості лікарських засобів", 2015. – Т. 1. – 1128 с.

14. Брилліс В. І. Методика ізучення адгезивного процеса мікроорганізмів / В. І. Брилліс, Т. А. Бриленко, Х. П. Ленцнер // Лабораторне діло. – 1986. – № 4. – С. 210–212.

15. A review on plants extract mediated synthesis of silver nanoparticles for antimicrobial applications: A green expertise / Shakeel Ahmed, Mudasir Ahmad, Babu Lal Swami, Saiqa Ikram // Journal of Advanced Research. – 2016. – No. 7 (1). – P. 17–28.

16. Microbial glycopolyprotein-capped silver nanoparticles as emerging antibacterial agents / Geeta Gahlawat, Sristy Shikha, Baldev Singh Chaddha [et al.] // Microb. Cell Fact. – 2016. – No. 15. – P. 1–14.

17. Gunasekaran T. Silver nanoparticles as real topical bullets for wound healing / T. Gunasekaran, T. Nigusse, M. D. Dhanaraju // The Journal of the American College of Clinical Wound Specialists. – 2012. – No. 3 (4). – P. 82–96.

18. Marek Konop. Certain aspects of silver and silver nanoparticles in wound care: A mini review / Marek Konop, Tatsiana Damps, Aleksandra Misicka, Lidia Rudnicka // Journal of Nanomaterials. – 2016. – Vol. 47. – Access mode: https://www.semanticscholar.org/paper/Certain-aspects-of-silver-and-silver-nanoparticles-Konop-Damps/7472126b587e267d143dd5f584cbec4b7f8e4ca (date of access 11.01.2016). – Title from screen.
REFERENCES

1. Chernyakova, H.M. (2017). Zastosuvannia sorbtsiinykh tekh­

nolohii dlia likuvannia infikovanykh opikovykh ran v eksperymeny [Use of sorbent technologies to treat infection burn wounds in the experiment]. Zaporizhzhia Medical Journal, 19, 6 (105), 793-797 [in Ukrainian].

2. Murphy, M., Kang Ting, Xinli Zhang, Chia Soo, Zhong Zheng (2015). Current development of silver nanoparticle preparation, investigation, and application in the field of medicine. Journal of Nanomaterials, 12. Retrieved from: https://doi.org/10.1155/2015/696918

3. Eid, K.A., & Azzazy, H.M. (2015). Sustained broad-spectrum antibacterial effects of nanoliposomes loaded with silver nanoparticles. Nanomedicine (Lond), 9 (9), 1301-1310. DOI:10.2217/nnm.13.89.

4. P. Gnanadhas, Ben Thomas, M., & Thomas, R. (2013). Inter­

action of silver nanoparticles with serum proteins affects their antimicrobial activity in vivo. Antimicrobial Agents and Chemotherapy, 57 (10), 4945-4955.

5. Ramalingam, B., Parandhaman, T., & Das, S.K. (2016). Antibi­

tial effects of biosynthesized silver nanoparticles on surface ultrastructure and nanomechanical properties of gram-negative bacteria viz. Escherichia coli and Pseudomonas aeruginosa. ACS Appl. Mater Interfaces, 8 (7), 4963-4976. DOI: 10.1021/acsami.6b00161.

6. Lara, H.H., Garza-Treviño, E.N., Ixtepan-Turrent, L., & Singh, D.K. (2011). Silver nanoparticles are broad-spectrum bactericidal and virucidal compounds. J. Nanobiotechnology, 9, 30. Retrieved from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3199605/ DOI:10.1186/1477-3155-9-30

7. Lara H.H., Ayala-Nuñez, N.V., Ixtepan-Turrent, L., & Rodri­

guez-Padilla, C. (2010). Bactericidal effect of silver nanoparticles against multidrug-resistant bacteria. World Journal of Microbiology and Biotechnology, 26, 615-621.

8. Ravishankar Rai, V., & Jamuna Bai, A. (2011). Nanoparticles and their potential application as antimicrobials. FORMATEX, 197-209.

9. Vazhnycha, O.M., Bobrova, N.O., Hancho, O.V., & Loban, H.A. (2014). Nanochastynky sribla: antybakterialni ta antyfun­

halni vlastyvosti (Silver nanoparticles: antibacterial and anti­

funglal properties). Farmakologohiia ta liksarska toksykolohiia – Pharmacology and Doctor’s Toxicology, 2 (38) [in Ukrainian]. Retrieved from: http://ru.ift.org.ua/node/224

10. Chekman, I.S., Movchan, B.A., Zagorodnyy, M.I., Gapo­

nov, Yu.V., Kurapov, Yu.A., Krushinskaya, L.A., & Kardash, M.V. (2008). Nanoserebro: tehnologii polucheniya, farmako­

logicheskii svoystva, pokazaniya k primeneniyu [Nanosilver: obtaining technologies, pharmacological properties for use]. Preparati i tehnologii – Drugs and Technologies, 5 (51). Retrieved from: https://www.health-medix.com/articles/mistezt­

vo/2008-06-15/32-34.pdf

11. Chinnasamy, G., Chandrasekharan, S., Koh, T.W., & Bhat­

nagar, S. (2021). Synthesis, characterization, antibacterial and wound healing efficacy of silver nanoparticles. Azadirachta Indica. Frontiers in Microbiology, 12, 611560. Retrieved from: https://doi.org/10.3389/fmicb.2021.611560

12. Thirumurugan Gunasekaran, Tadele Nigusse, Magharla Dasaratha Dhanaraju (2011). Silver Nanoparticles as Real Topical Bullets for Wound Healing. Journal of the American College of Clinical Wound Specialists, 3 (4), 82-96. Retrieved from: https://doi.org/10.1016/j.jcws.2012.05.001.

13. (2011). Derzhavna farmakopeya Ukrainy [State Pharmacopeia of Ukraine]. Derzh. sluzhba lik., zasob. zasob. Ukra. nauk. farm. tsentr yakosti likar. zasobiv. Kharkiv [in Ukrainian].

14. Brillis, V., Brilene, T., Lentsner, H.P., & Lentsner, A.A. (1986). Metodika izucheniya adgezivnogo protsessa mikroorganiz­

mov [Method of studying the adhesive process of microorganisms]. Laboratornoe deło – Laboratory Business, 4, 210-212 [in Russian].

15. Shakeel Ahmed, Mudasir Ahmad, Babu Lal Swami, & Saiqa Ikrar (2016). A review on plants extract mediated synthesis of silver nanoparticles for antimicrobial applications: A green expert­

ise. Journal of Advanced Research, 7 (1), 17-28.

16. G. Gahlawat, Sristy Shikha, Baldev Singh Chaddha (2016). Microbial glycolipoprotein-capped silver nanoparticles as emerging antibacterial agents. Microb. Cell Fact, 15, 1-14.

17. Gunasekaran, T., Nigusse, T., & Dhanaraju, M.D. (2012). Silver nanoparticles as real topical bullets for wound healing. The journal of the American College of Clinical Wound Special­

ists, 3 (4), 82-96. Retrieved from: https://doi.org/10.1016/j. jcwls.2012.05.001

18. Marek Konop, Tatsiana Damps, Aleksandra Misicka, & Lidia Rudnicka (2016). Certain aspects of silver and silver nanoparti­

cles in wound care: A minireview. Journal of Nanomaterials, 10. Retrieved from: https://doi.org/10.1155/2016/7614753. Article ID 7614753

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МІКРОБІОЛОГІЧНЕ ОБГРУНТУВАННЯ ВИКОРИСТАННЯ КСЕНОТР АНСПЛАНТАНТІВ, НАСИЧЕНИХ НАНОКРИСТАЛАМИ СРІБЛА, ДЛЯ ЛІКУВАННЯ ОПІКОВИХ РАН

Мета роботи: вивчити антимікробну ефективність насичених нанокристалами срібла ксенотрансплантантів, які використовуватимуться у лікуванні опікових ран.

Матеріали і методи. Протимікробну ефективність ксенотрансплантантів, насичених нанокристалами срібла, досліджували in vitro методом дифузії в агар і в рідкому поживному середовищі, а також вивчаючи вплив нанокристалів срібла на адгезивну активність тест-культур: Staphylococcus aureus ATCC 6538, Escherichia coli ATCC 25922, Pseudomonas aeruginosa ATCC 9027 та Candida albicans ATCC 885-653.

Результати досліджень та їх обговорення. Протимікробні властивості срібла, якими були насичені клапті кріоліофілізованої ксеношкіри, не поступалися за ступенем ефективності сучасним перев’язувальним матеріалам, які використовували як позитивний контроль (абсорбуючі стерильні пов’язки Mepilex Transfer Ag (Mölnlycke, Sweden) та Atrauman Ag (Heidenheim, Germany)) у дослідженнях. Наносрібло виконує роль антимікробного бар’єру в рані та знижує показники адгезивного потенціалу мікроорганізмів, що важливо для запобігання контамінації опікових ран.

Отримані результати дають змогу розглядати можливість використання ксенотрансплантантів, насичених нанокристалами срібла, для місцевого лікування опікових ран з метою профілактики гнійно-запальних ускладнень, що можуть виникати.

Ключові слова: опікові рані; ксенотрансплантант; нанокристали срібла; антимікробні властивості.