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Experimental Substantiation of the Possibility of Prosthetic Plastic Surgery by the Method Onlay in Conditions of Infection in Ventral Hernias

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ABSTRACT: This paper presents an experimental justification for the use of a polypropylene mesh endoprosthesis in the onlay position for ventral hernia repair under conditions of infection. The study was conducted on 60 white rats, divided into two groups of 30 animals. The control group used a mesh implant treated with a collagen hemosponge without an antiseptic, while the study group used a mesh implant in combination with miramistin . Infection was simulated by administering a Staphylococcus aureus microbial suspension. aureus and Escherichia coli . The course of the wound healing process and morphological tissue changes were assessed for up to 30 days. It was found that combined treatment was accompanied by a reduction in inflammation, earlier wound healing, and the formation of a connective tissue capsule around the implant. These results indicate the potential for further study of this method for local prevention of infectious complications in allohernioplasty .

The relevance of the problem of treatment of postoperative ventral hernias (PVH), especially large and giant ones, is due to the high rate of recurrence, which occurs in 10-60% [1-4], and according to some authors, in 85% of cases. One of the options for allohernioplasty is the placement of the prosthesis in the subcutaneous tissue the onlay method [4]. The total number of specific complications after onlay plastic surgery in the early postoperative period ranges from 12.5 to 41%. Immediate results of onlay hernia repair have shown that seromas occur in 3.2-37% of patients, infiltrates in 1-6.9%, hematomas in 2-7.2%, and skin and subcutaneous tissue necrosis in 1.1-4% [5-10]. Despite conflicting opinions regarding onlay hernia repair, in some cases it is not possible to isolate the preperitoneal space intraoperatively and then place a mesh implant using the sublay technique. The only possible solution in such cases is the use of supraaponeurotic repair.

The use of synthetic mesh endoprostheses is an integral part of modern herniology and is widely used in the surgical treatment of ventral hernias. Thanks to synthetic materials, the incidence of hernia recurrence has been reduced; however, a new problem has arisen, characteristic of implant surgery: an increase in the incidence of infection in the surgical site [5, 6]. At the same time, it has previously been proven that a polypropylene prosthesis, when implanted in infected conditions, does not contribute to the retention of infection in the wound, does not worsen the conditions for its drainage, and does not significantly affect the course of the wound process, which makes it possible to use it without the risk of complications [4, 7]. Existing methods for the prevention of postoperative wound suppuration, developed for operations in primarily sterile tissues [3, 10], are not effective in the presence of infection, which forms an inflammatory ridge around purulent-inflammatory foci, interfering with systemic antibiotic therapy, which subsequently leads to wound suppuration with rejection of the graft. Currently, in order to prevent postoperative wound complications in conditions of infection, a number of methods have been proposed that involve additional implantation of drugs and materials into the plastic surgery area in one way or another [2, 5], however, all of these methods have not found widespread use.

Modern research confirms that the choice of mesh endoprosthesis position is one of the important factors determining the risk of postoperative complications during reconstruction of the anterior abdominal wall. According to a 2025 systematic review that included 10 studies and 910 patients who underwent onlay hernioplasty, the incidence of surgical site infection was 10.1%, seromas - 11.8%, and hernia recurrence - 5.4%. At the same time, the authors emphasize the need for further research with more rigorous standardization of clinical and surgical parameters [6-11]. These data confirm that, despite the technical accessibility of onlay plastic surgery, the prevention of wound complications remains a pressing issue in modern herniology. The development of methods for local antimicrobial treatment of mesh implants is of particular importance. A systematic review and meta-analysis published in the journal *Hernia* in 2024 analyzed 11 studies involving 2660 patients. Various options for pre-antimicrobial treatment of meshes were studied, including the use of antibiotics and antiseptic solutions. A pooled analysis did not find a statistically significant reduction in the incidence of surgical site infection with the use of pre-treated polypropylene meshes; the effect estimate was characterized by a wide confidence interval and very low certainty of evidence [12]. Therefore, the effectiveness of such technologies should be assessed in relation to a specific material, antiseptic, and treatment method. An important area of modern research is the study of the interaction of microorganisms with the surface of synthetic implants. The formation of bacterial biofilms can complicate the eradication of pathogens and contribute to the persistence of infection in the implantation area. In this regard, combined technologies involving the use of a polymer end prosthesis, a biocompatible carrier, and a local antiseptic are of particular interest. However, the proposed advantage of such a combination must be confirmed by the results of microbiological, morphological, and experimental studies.

THE AIM OF THE STUDY:

Experimental study of the results of endoprosthetics , as well as the development of measures for the implantation prevention of wound suppuration and implant rejection against the background of infection in the experiment.

MATERIAL AND METHODS:

The experimental studies were preceded by an investigation of the presence of dormant infection in patients with postoperative hernias, as well as the nature of the microflora in the presence of wound fistulas in the hernial sac area and the bacterial landscape in the case of suppuration of postoperative wounds after allohernioplasty, hernial fluid in strangulated hernias. For this purpose, old ligatures removed during surgery, excised granulomas and fragments of cicatricially altered edges of the aponeurosis, and hernial fluid were subjected to bacteriological examination. A total of 97 samples were collected. The pathogenic microflora culture was 47-59%. It can be argued that the majority of allohernioplasty operations are performed in conditions of knowingly infected tissues. In the case of suppuration of postoperative wounds, the following infections were indicative of wound suppuration: Staphylococcus aureus (27.2%), Staphylococcus epidermidis (5.4%), Escherichia coli (45.4%) and a small number of other groups of bacteria (Klebsiella pneumonia), in 7.3% of cases there was no growth.

At the first stage, bench tests were carried out to determine the sensitivity of Staphylococcus aureus, Staphylococcus epidermidis, Escherichia coli, that is, clinical strains of bacteria to the antibiotic miramistin 0.01%. The drug has a pronounced bactericidal effect against gram-positive (Staphylococcus spp., Streptococcus spp.), gram-negative (including

Pseudomonas aeruginosa, Escherichia coli, Klebsiella spp.) microorganisms. In the experiment, we used a new domestic drug, Collagen Hemotube, developed at the Research Center for Chemistry and Physics of Polymers of the Academy of Sciences of the Republic of Uzbekistan and the State Institution Republican Specialized Scientific and Practical Center of Surgery named after Academician V.Vakhidov, to coat the polypropylene mesh. An abdominal hernia was modeled in an experiment in vivo in 60 mature outbred white rats weighing 200-250 g under ether anesthesia. The work was carried out in full compliance with the legislation ("Rules for the Humane Treatment of Laboratory Animals", "Deontology of Medical and Biological Experiments") and the ethical principles established by the European Convention for the Protection of Vertebrate Animals used for Experimental and Other Scientific Purposes (adopted in Strasbourg on 18.03.1986 and confirmed in Strasbourg on 15.06.2006). The experimental study was conducted to develop measures to improve the results of allohernioplasty under infected conditions. In the 1st series of experiments, PP mesh covered with hemogel was used for plastic surgery on an infected wound in the onlay position (30 rats). In the 2nd series of experiments, PP mesh treated with hemogel in combination with miramistin was implanted in the onlay position on the infected wound (30 rats). Experimental animals were injected with 1 ml of a mixture of microbial suspension containing 2 billion microbial bodies of Staphylococcus into the surgical wound in order to infect it. aureus and Escherichia coli. The course of the wound healing process was studied based on the duration of its individual phases using standard clinical criteria: the time of elimination of the perifocal reaction, the nature and amount of discharge, the time of wound cleansing and the appearance of granulation, the frequency of wound suppuration with rejection of the polypropylene mesh . The object of the morphological study was blocks of excised muscular- aponeurotic areas of the anterior abdominal wall with a fragment of the polypropylene mesh, according to the study time. Microscopy and microphotography were carried out using an optical system consisting of a Leisa CME light microscope, a DCM-500 digital eyepiece camera, and FUTURE WINJOE software. Statistical data processing was performed using Microsoft software. Office Excel 2016 and Statistica 10.0. Values are presented as the mean and its standard error (M±m). The significance of differences between means was determined using Student's t-test. A result was considered statistically significant at $p<0.05$.

RESULTS AND DISCUSSION:

Wound healing in animals of the 1st series of the experiment was accompanied by a progressive increase in tissue contamination with frequent addition of a secondary infection, which clinically manifested itself as the occurrence of a progressive purulent-inflammatory reaction (wound suppuration). In animals of the 2nd series, in which a polypropylene mesh treated with a hemosponge impregnated with miramistin was used for plastic surgery , the wound process proceeded more favorably, with the engraftment of the polypropylene implant. We conducted a comparative analysis of the results of morphological studies of the wound process using only a PP mesh treated with a hemosponge , and a PP mesh treated with a hemosponge in combination with miramistin under infection conditions. In the experiment, to create conditions for microbial contamination, 1 ml of a physiological solution containing 2 billion suspensions of microbial bodies of a daily culture of Staphylococcus was introduced into the postoperative wound of animals. aureus and E. coli . After implantation of the polypropylene mesh, the skin and subcutaneous fat were also tightly sutured. One day after hernioplasty of the experimental hernia under conditions of infection, signs of a progressive inflammatory reaction were detected in the tissues of the surgical wound suture area in the form of increasing edema and the appearance of extensive small-point or confluent hemorrhages. From the second day of the postoperative period, the release of a turbid exudate with an unpleasant odor was noted between the sutures. Signs of purulent inflammation in the area of the sutured wound persisted for 6-7 days, after which a more favorable course of the wound process was observed in 3 rats with the release of serous-purulent effusion, but with healing on the 10th-11th day. In 17 animals, partial wound dehiscence developed, which then gradually cleared of purulent-necrotic contents . By the 14th day, the wounds had practically healed by secondary intention, and no rejection of the polypropylene mesh was observed. In 10 rats, the purulent-inflammatory process progressed on the 6-7th postoperative days, which in 5 animals led to complete wound dehiscence due to total suppuration with partial (fragmentary) wound healing by secondary intention with rough wound edges on the 18-19th day without rejection of the polypropylene mesh. Complete implant rejection occurred in 3 rats. In the 2nd series of experiments, an implant in combination with GemG and Miramistin was used for plastic surgery of an experimental RA hernia. Moderate tissue edema was observed in the sutured wound area in all animals during the first 3-4 days; isolated diapedetic hemorrhages were occasionally observed on the skin. In 4 rats, a scanty serous discharge and partial suppuration of the postoperative wound were recorded through the suture line starting from the 2nd-3rd day after surgery. In 22 animals, inflammatory processes in the postoperative wound area were suppressed

on the 5th-6th day after surgery, and by the 7th-8th day the wounds healed by primary intention. In the remaining 4 animals, the inflammatory reaction in the postoperative wound area persisted during the same time period, which led to partial divergence of its edges. Suppression of the perifocal reaction and wound cleansing from necrotic masses in these animals were recorded by the 10th-11th day of the postoperative period, and healing by secondary intention - on the 13th-14th day. Light microscopy on day 3 of animals treated with HemG -treated polypropylene but without antibiotics (control group) - revealed an acute inflammatory process around the sutures and in the cell loops with necrosis of the base, i.e., the maternal tissue (Fig. 1a). The surrounding tissue, in a state of reactive inflammation, is rich in segmented leukocytes, neutrophils, and histiocytes. Significant sequestration of surrounding tissue debris is occurring. The suture surface contains flattened macrophages and fibrinoid deposits with plasma proteins. Small leukocyte infiltrates are also present.

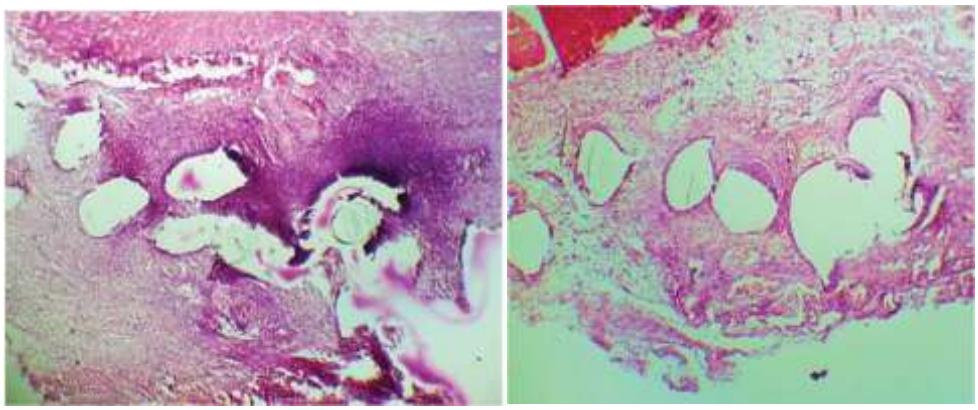


Fig. 1 - Day 3. Control group (without miramistin). Infected endoprosthesis (polypropylene thread, mesh). Fibrinous-leukocyte infiltrate surrounding the threads of the endoprosthesis . Staining with hematoxylin and eosin. Magnification x80 (a). Main group. Infected endoprosthesis (polypropylene thread, mesh, GemG + miramistin). Stained with hematoxylin and eosin. Magnification X80 (b).

On the third day of implantation (Fig. 1-b) of the polypropylene + GemG + Miramistin endoprosthesis (main group), pronounced tissue edema and an inflammatory cellular infiltrate consisting of non-resident cells were observed around the threads. Lymphocytes and neutrophils predominated in the visual field. A large number of phagocytic macrophages were observed in the immediate vicinity of the endoprosthesis threads. On the inner surface of the abdominal wall at the level of the fascia, the endoprosthesis was surrounded by a thin capsule; there were no signs of collagen fiber formation.

Thus, on the third day, the morphological picture observed in the connective tissue is completely consistent with exudation, the severity of which is significantly greater than under sterile conditions. This is confirmed not only by the large area of the infiltrate, but also by the predominance of neutrophils, macrophages, and mast cells in the degranulation stage in the field of view**,** including when using endoprostheses with antibacterial properties. That is, on the third day, the inflammatory and degenerative process is still ongoing in animals of both groups. When examining microscopic preparations using endoprostheses, GemG without miramistin (control group) on the 7th day revealed that the fibrous connective tissue of the dermis was sharply edematous, the blood vessels were full-blooded, and a large number of mast cells in various stages of functional activity were located around them (Fig. 2a). The endoperitoneal surface of the parietal peritoneum was totally destroyed, with the disintegration of the aponeurosis. Diffuse inflammatory infiltration was observed over the entire surface of the microsection. There were signs of angiomatosis without cell proliferation. In the area of mesh fixation, the annular rim was represented by coarse fibrous tissue with uneven vascularization and perifocal Diffuse mononuclear inflammatory infiltration with neutrophil admixture. In the main group (polypropylene + GemG + miramistin), moderate inflammatory cellular infiltration remained around the threads of the polypropylene mesh on the 7th day (Fig. 2-b). However, the mesh prosthesis was surrounded by a capsule; the capsule was thinner compared to later stages, the collagen capsule was poor in proliferating cells, mesenchymal protein content accumulated between the threads, and the mucoid and fibrinoid swelling was loose and reticular. The tissue around the implant acquired a loose cellular structure with myxomatous foci . An accumulation of lymphocytes and histiocytic infiltrates was noted around it, and vascular formations were scant .

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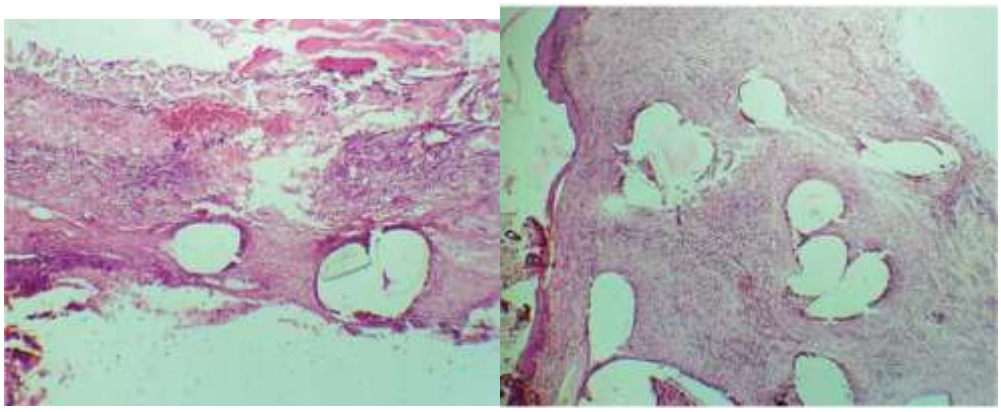


Fig. 2 - Day 7. Control group. Infected endoprosthesis (polypropylene thread, mesh). Fragment of the anterior abdominal wall with fragments of mesh explant. Stained with hematoxylin and eosin. Magnification x80 (a). Main group. Infected Endoprosthesis (PP thread, mesh + GemG + Miramistin). Stained with hematoxylin and eosin. Magnification x50 (b).

Thus, on the seventh day, animals in the main group exhibited a moderate inflammatory reaction, with areas of lymphocytic and histiocytic infiltrates, neutrophilic granulocytes, macrophages, lymphocytes, and plasma cells. Control animal sections retained signs of acute inflammation and alteration. Acute necrosis with destruction of surrounding tissue, an intensely hyperchromic membrane around the filaments, and uneven edema of the interstitial tissue with serous exudate were present.

On the 14th day, with the use of the PP + GemG endoprosthesis (control group, without miramistin), the formation of a connective tissue capsule is observed. Numerous active fibroblasts are present on the prosthesis threads. In the field of vision, small-sized giant multinucleated cells are present; the number of dark basophilic nuclei in them varies from 4 to 6; they are located along the periphery of the cells. The endoprosthesis capsule is free of fibrous formations and is partially anesthetized; at the edges, there is capsule disintegration due to infiltration by segmented leukocytes (Fig. 3a) . On the 14th day, the severity of inflammatory changes around the PP threads with GemG and miramistin (main group) (Fig. 3b) significantly decreased. The endoprosthesis was surrounded by a connective tissue capsule consisting of thin collagen fibers. Inflammatory cellular infiltration persisted in the immediate vicinity of the threads. In some places, the beginnings of thin collagen fibers are visible. Subsequently, the implant threads are surrounded by thin-fibered connective tissue rich in cellular elements. Flattened fibroblasts are adjacent to the surface of the threads. Macrophages are present in the spaces between the threads.

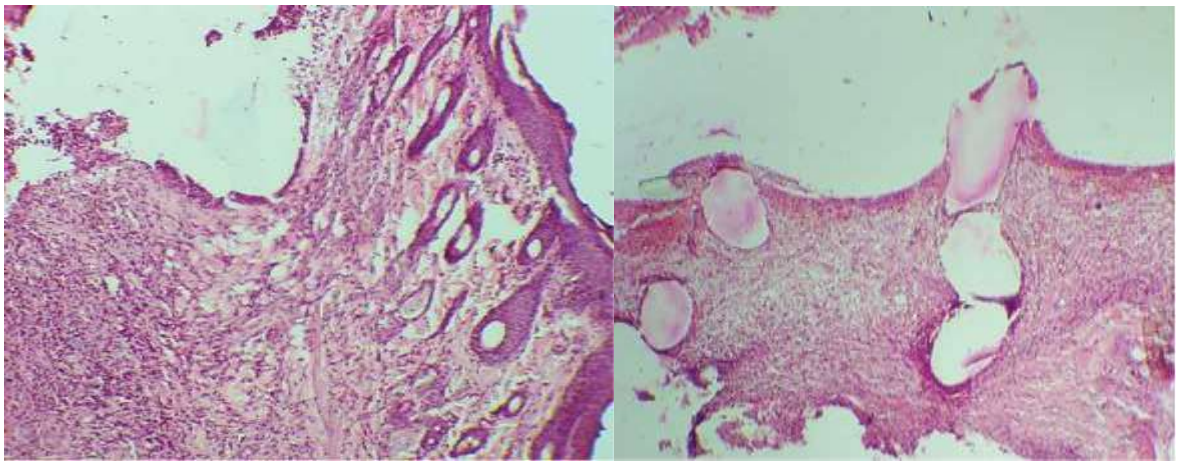


Fig. 3 - Day 14. Control group without miramistin . Infected endoprosthesis (PP thread, mesh + HemG). Stained with hematoxylin and eosin. Magnification x80 (a). Main group. Infected Endoprosthesis (PP thread, mesh + GemG + Miramistin). Stained with hematoxylin and eosin. Magnification x100 (b).

Thus, by day 14, a well-formed connective tissue capsule was detected in specimens using an implant treated with HemG and miramistin, although minor microbial contamination still persisted. In the control group, the endoprosthesis capsule was free of fibrous formations and partially anesthetized. Capsule disintegration at the edges was observed due to infiltration by segmented leukocytes, infiltration, and edema. On day 21 (control group), the threads were surrounded by a thin layer of loose connective tissue, which merged smoothly with the surrounding tissue. Collagen fibers were located in the deeper layers, acquiring an ordered direction (Fig. 4a). On the surface of the threads, cells were more closely arranged, forming concentric layers. Diffuse mononuclear inflammatory infiltration penetrated the intermuscular spaces, causing necrosis and destruction of muscle fibers. The endoprosthesis threads are surrounded by loose, fine-fibrous connective tissue, rich in cellular elements, containing macrophages, multinucleated giant cells of foreign bodies and young fibroblasts.

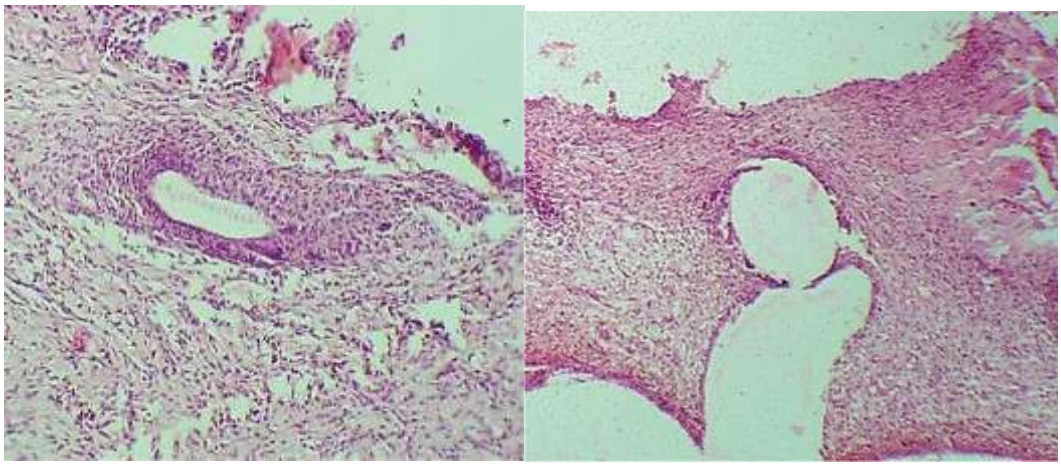


Fig. 4 - Day 21. Control group. Micrograph of tissue surrounding the PP endoprosthesis + GemG without miramistin under microbial contamination conditions. Hematoxylin and eosin staining. Magnification x100 (a). Main group. PP mesh + GemG + miramistin (b). Hematoxylin and eosin staining.

As Fig. 4-b shows, on the 21st day, animals in the main group develop a proliferative reaction with a large number of fibroblasts located between sparse collagen fibers, arranged in a disordered manner. They are thin, with a high content of amorphous intercellular substance. Abundant formation of a vascular network is also noted in the zone of proliferation of young connective tissue. The endoprosthesis thread is surrounded by a forming annular connective tissue. A tissue capsule containing lymphohistiocytes, macrophages, and multinucleated foreign body giant cells. On the surface of the threads, the cells are flattened, forming a continuous layer. Cells with a random distribution of nuclei are encountered, but sometimes the nuclei are larger and fewer in number.

Thus, on the 21st day in the main group, the mesh threads The endoprosthesis was surrounded by a fibrous connective tissue capsule. Minor inflammatory changes were present only in the immediate vicinity of the endoprosthesis. The endoprosthesis thread was surrounded by a forming annular capsule of lymphohistiocytes, macrophages, and foreign body multinucleated giant cells. On the surface of the threads, the cells were flattened and formed a continuous layer. In the control group, the endoprosthesis threads were surrounded by loose, fine-fibrous connective tissue rich in infiltrates and inflammatory cellular elements, containing young fibroblasts, macrophages, and foreign body multinucleated giant cells. On the 30th day, in the control group (Fig. 5a) (polypropylene + without miramistin), an accumulation of cellular and tissue reactions was noted around the prosthesis. The process of formation of a mature connective tissue capsule with proliferation, transformation, and differentiation of cells was mainly underway. However, inflammatory phenomena persist, namely, weakly expressed lymphoplasmacytic infiltrates with an admixture of macrophages.

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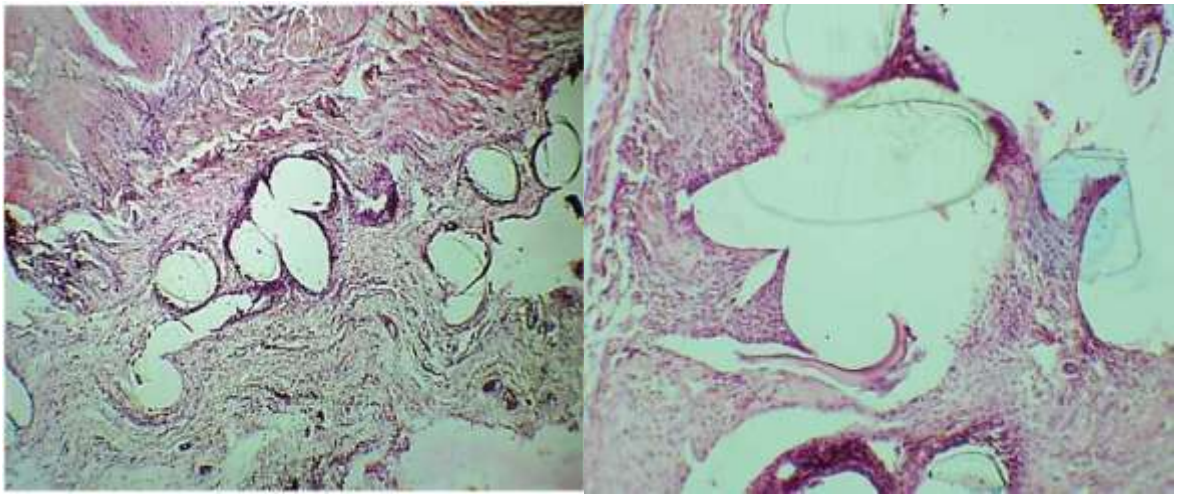


Fig. 5 - Day 30. Control group. Polypropylene mesh + HemG . Mild lymphoplasmacytic infiltrates with macrophages. Hematoxylin and eosin staining. Magnification x80 (a). Main group. Polypropylene mesh + miramistin + HemG . Hematoxylin and eosin staining. Magnification x150 (b).

There are multinucleated giant cells of foreign bodies around the threads of the polypropylene endoprosthesis , it is noted Formation of a powerful connective tissue capsule 2.6 mm thick, from which ingrowth of young connective tissue fibers into the endoprosthesis cells is noted . The capsule is represented by 5-10 layers of coarse collagen fibers, the inner layers of the capsule are concentrically oriented around the mesh implants , and on the outside they smoothly transition into bundles of collagen fibers of the connective tissue. On the 30th day, the endoprosthesis threads (Fig. 5b) in animals of the main group were surrounded by a connective tissue capsule consisting of orderly arranged and oriented collagen fibers along the endoprosthesis , that is, a smooth connective tissue capsule is formed around the mesh thread. Proliferation and transformation of cells around the explant. The formation of macrophages, labrocytes , giant cells, fibroblasts and fibrocytes, and single lymphocytes is noted.

The obtained results should be considered in the context of modern studies of antimicrobial modification of mesh endoprostheses. In an experimental study [13], coatings of surgical meshes based on gentamicin palmitate and chlorhexidine compounds were studied , where the antimicrobial properties of the coatings, the possibility of suppressing the formation of biofilms and the compatibility of modified materials with the requirements for medical implants were assessed [13-15]. This work confirms the relevance of the development of local antimicrobial technologies for the prevention of infection of mesh endoprostheses. An important aspect of the interpretation of this study is the need to distinguish between clinical signs of improvement of the wound process, morphological signs of tissue integration and directly proven antimicrobial effect. A decrease in inflammatory infiltration and the formation of a connective tissue capsule around polypropylene threads indicate the development of reparative processes, but in themselves do not confirm the full Eradication of microorganisms. To objectively confirm the antimicrobial effect of the combination of Hemoglobka and Miramistin, quantitative microbiological studies are necessary, including dynamic determination of the bacterial load in tissues and on the implant surface.

It should also be noted that the current evidence base for local antimicrobial treatment of mesh implants is still limited. According to a systematic review by Bontekoning et al. [12], existing clinical data do not allow for the reduction in infection rates with pre-treatment of polypropylene meshes to be considered universally proven. Therefore, the results of the present experiment should be considered as a basis for further study of the specific combination of implant material, collagen carrier, and antiseptic, rather than as definitive confirmation of its clinical efficacy.

Thus, the implantation of polypropylene with HemG In all cases, implantation of a prosthesis into known infected tissue leads to wound suppuration, but without implant rejection, even in the presence of a purulent-inflammatory process that lasts up to 14 days or more. Implantation of a polypropylene implant with HemG in combination with Miramistin in infected conditions suppresses the purulent-inflammatory process in the wound within 7-14 days and ensures implant engraftment.

CONCLUSIONS:

The development of postoperative purulent complications in 47-59% of patients with postoperative ventral abdominal hernias after implantation of a synthetic prosthesis is caused by unresected ligature fistulas and inflammatory infiltrates arising from previous surgeries, which lead to wound suppuration and implant rejection. Under experimental conditions, implantation of a polypropylene mesh prosthesis treated with a hemosponge without an antiseptic in the onlay position into known infected tissues in all cases leads to wound suppuration, and in some cases, to implant rejection. In infected conditions, implantation of a polypropylene mesh prosthesis treated with a hemosponge in combination with the antiseptic Miramistin in the onlay position ensures suppression of the purulent-inflammatory process on days 7-14 and implant engraftment. The developed method for local prevention of purulent wound complications in allohernioplasty under conditions of infection, using a polypropylene mesh treated with a hemosponge and miramistin , ensures suppression of infection and the inflammatory reaction in wounds and allows to reduce the frequency of early purulent-inflammatory - complications, therefore this method can be recommended for clinical use.

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