Prosthetic Repair of the Abdominal Wall Using Light and Ultra-Light Synthetic and Titan-Containing Materials in High Bacterial Contamination (Experimental Study)

DOI: 10.17691/stm2015.7.4.08
Received May 13, 2015

© **V.V. Parshikov,** MD, DSc, Professor, Department of Hospital Surgery named after B.A. Korolyov[1];
A.A. Mironov, PhD, Associate Professor, Department of Neurotechnology, Institute of Biology and Biomedicine[2]; Senior Researcher, Experimental Modeling Unit, Central Scientific Research Laboratory; Associate Professor, Department of Normal Physiology named after N.Y. Belenkov[1];
E.A. Anikina, Anesthesiologist[3];
M.I. Zaslavskaya, MD, DSc, Professor, Department of Microbiology and Immunology[1];
A.I. Alyokhin, Deputy Chief Doctor on Scientific Work[4];
A.A. Kazantsev, Researcher, Research and Methodology Department[4]

[1]Nizhny Novgorod State Medical Academy, 10/1 Minin and Pozharsky Square, Nizhny Novgorod, 603005, Russian Federation;
[2]Lobachevsky State University of Nizhni Novgorod, 23 Prospekt Gagarina, Nizhny Novgorod, 603950, Russian Federation;
[3]City Hospital No.35, 47 Respublikanskaya St., Nizhny Novgorod, 603089, Russian Federation;
[4]Central Clinical Hospital of the Russian Academy of Sciences, 10 Fotiyevoy St., Moscow, 119333, Russian Federation

The aim of the investigation was to study the course of the reparative process in the early postoperative period after the abdominal wall prosthetic repair using light and ultra-light materials in bacterial contamination in experiment.

Materials and Methods. Retromuscular abdominal wall repair was modeled on rats using light (ultra-light) endoprostheses contaminated by Staphylococcus aureus and Escherichia coli in the Central Research Laboratory of Nizhny Novgorod State Medical Academy. The course of the early postoperative period has been studied, characteristic features of the inflammatory reaction depending on the microorganism cultures and mesh used have been evaluated with the help of the original rating scale.

Results. Prosthetic repair in bacterial contamination in experiment is accompanied by a marked inflammatory reaction. Changes are statistically more significant after infecting by E. coli culture. The most intensive inflammation is observed on day 3 (S. aureus) and day 5 (E. coli) after the intervention with the regression of the process by day 14. On day 3–7 after the operation in group E. coli the inflammatory reaction was more expressed after TiMesh implantation relative to PP Light application, whereas in group S. aureus it was more significant in case of PP Light application.

Conclusion. Using light and ultra-light mesh in a compromised area of surgical intervention in abdominal wall prosthetic repair is possible by stringent indications taking into account potential usefulness and high risk, possessing adequate experience, and observing a number of conditions. Endoprosthesis should not be placed in contact with the zone of maximum contamination.

Key words: prosthetic repair; mesh; hernia; contamination.

Incisional hernia of the abdominal wall is a common disease. It forms in 11–20% of people undergone laparotomy. Incidence of muscular-aponeurotic layer defects in operated obese patients exceeds 30% [1]. Tension-free technique using mesh endoprostheses is a recognized method of abdominal wall plasty and is the basis of the modern concept of treating this cohort of patients [2]. Its application is recommended and justified both in a planned and emergency surgery [3]. However such operations have their own features, caused by the risk of specific complication development. New technical solutions and methods are being actively worked out for their prevention [3–5].

Implantation of endoprosthesis in bacterial contamination entails the risk of purulent inflammatory complications [6]. Currently, the problems of using meshes in the compromised intervention area are far from being solved [6, 7]. In this connection a group of ultra-light endoprostheses deserves special attention. This is a new category of mesh materials, which has recently become available for clinical practice. Application of these meshes in the condition of bacterial contamination has not been analyzed so far. The course of the early postoperative period in this situation has not been studied. A minimal load of the implantation zone by a synthetic material is very likely to be an optimal solution for plastic repair in a compromised wound. A variety of questions are being actively discussed in the foreign and Russian literature [8–11] but no unified approach has been suggested up till now [5, 12]. Investigations on

For contacts: Parshikov Vladimir Vyacheslavovich, e-mail: pv1610@mail.ru

the experimental contamination of meshes *in vivo* are not presented in the Russian literature. The well-known Russian National Recommendations on the prevention and management of surgical infection do not contain clear instructions on the questions being considered [13, 14].

The course of wound inflammation involving microorganisms in the zone of implanted mesh endoprosthesis is regarded now in terms of the biofilm process [15, 16]. Application of antibiotics does not solve all the problems connected with the possible infecting of the implants [17, 18] neither do materials of biological nature [19]. The number of works, devoted to the experimental study of the plastic repair under bacterial contamination, is relatively small.

The aim of the investigation was to study the course of the reparative process in the early postoperative period after the abdominal wall repair using light and ultra-light materials under bacterial contamination in experiment.

Materials and Methods. Mesh repair of the abdominal wall was modeled on rats in the Central Research Laboratory of Nizhny Novgorod State Medical Academy. The work was performed in accordance with ethical principles established by European Convention for the Protection of Vertebrata used for Experimental and other Scientific Purposes (the Convention was passed in Strasburg, March, 18, 1986, adopted in Strasburg, June, 15, 2006) and approved by Ethics Committee of Nizhny Novgorod State Medical Academy and the laws of the Russian Federation ("The rules of humane treatment of laboratory animals", "Deontology of the medicobiological experiment"). It was a double blind controlled study. The object of the experiment was chosen in compliance with the principles of R3 concept, generally accepted in experimental surgery and biology [20].

Operations (n=48) were performed under general anesthesia with 30 mg/kg of nembutal intraperitoneally. By the time of intervention the age of the animals (n=24) was 6 months, weight — 380±35 g. Meshes PP Light (polypropylene, 90 μm, 36 g/m^2) and TiMesh (polypropylene, 65 μm, 16 g/m^2) with titanium evaporated by PACVD technology (plasma-activated chemical vapor deposition) were chosen for the investigation. Both implants are referred to class 1 on the basis of Klinge–Klosterhalfen classification [21], and are knitted meshes according to Zhukovsky classification [22]. TiMesh is classified by Coda as an ultra-lightweight material, while PP Light is a border-line material between light and ultra-lightweight [23].

Prosthetic repair was performed in accordance with the principles of modern herniology, the technique did not contradict the issues approved by the Russian Society of Herniologists [24–27]. The size of endoprostheses implanted to the rats (1×1 cm) was close to those traditionally used [27]. Meshes were fixed in a usual way by atraumatic polypropylene suture thread 4/0.

Surgical intervention was performed in accordance using sublay retromuscular technique (reconstruction according to Timoshin) [2, 24]. First, medial laparotomy was performed. Rectus sheaths were opened. Dissection of the retromuscular space was done. Abdominal cavity and posterior leaves of the rectus sheaths were sutured. Endoprosthesis 1×1 cm in size was placed on the posterior leaves of the rectus sheaths, fixed to the posterior layers in four opposite points around the perimeter by an atraumatic polypropylene thread 4/0. Anterior layers of the rectus sheaths and then the wound were sutured. The stages of implantation are shown on Figures 1, 2.

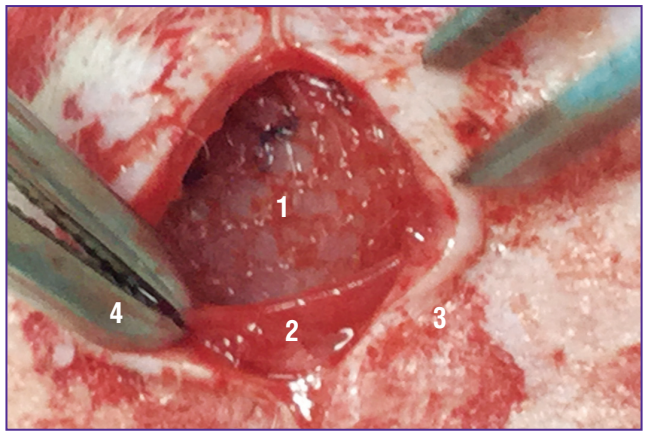

Figure 1. Retromuscular mesh implantation: TiMesh endoprosthesis (*1*); skin (*2*); muscle (*3*); instrument (*4*)

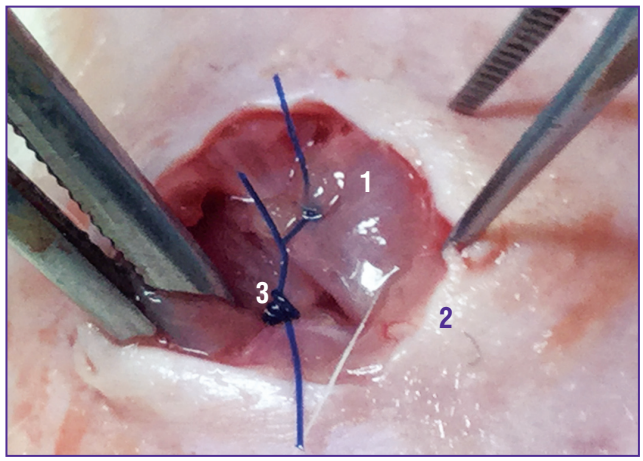

Figure 2. Suture of the rectus sheath: anterior layer of the rectus sheath (*1*); skin (*2*); sutures (*3*)

Table 1

Distribution of implantations by the groups

Group	PP Light	TiMesh	Total
Staphylococcus aureus	8	10	18
Escherichia coli	8	6	14
Control	8	8	16
Total	24	24	48

All animals were divided into three groups. The quantity of implanted endoprostheses in the groups was comparable (Table 1). Microorganisms Staphylococcus aureus and Escherichia coli, which occupy the leading positions in the etiologic structure of septic complications after abdominal operations, were used in the investigation [28]. Besides, these pathogens were estimated by the experts of the World Society of Emergency Surgery to be the most common in infecting endoprostheses both in planned (S. aureus) and emergency surgery (E. coli) [6].

In group 1 (n=18) the zone of mesh implantation was contaminated by S. aureus culture (10^9 CFU/ml, strain 8614), in group 2 (n=14) by E. coli (10^9 CFU/ml, strain 775-3). The stages of contamination are shown on Figures 3, 4. In group 3 (control, n=16) the operative area remained sterile.

Animals were observed for a month (on days 3, 5, 7, 14), examined, weighed, the data were fixed and the operative zone photographed. The results were assessed by six signs using original rating scale, the total score being from 0 to 5 points (Table 2). It was done in the following way. Sign 1 was assigned 0, 1 or 2 points. Signs 2 and 3 were given 0 or 1 point. Points of signs 1, 2 and 3 were summed up, if signs 4, 5 and 6 were absent.

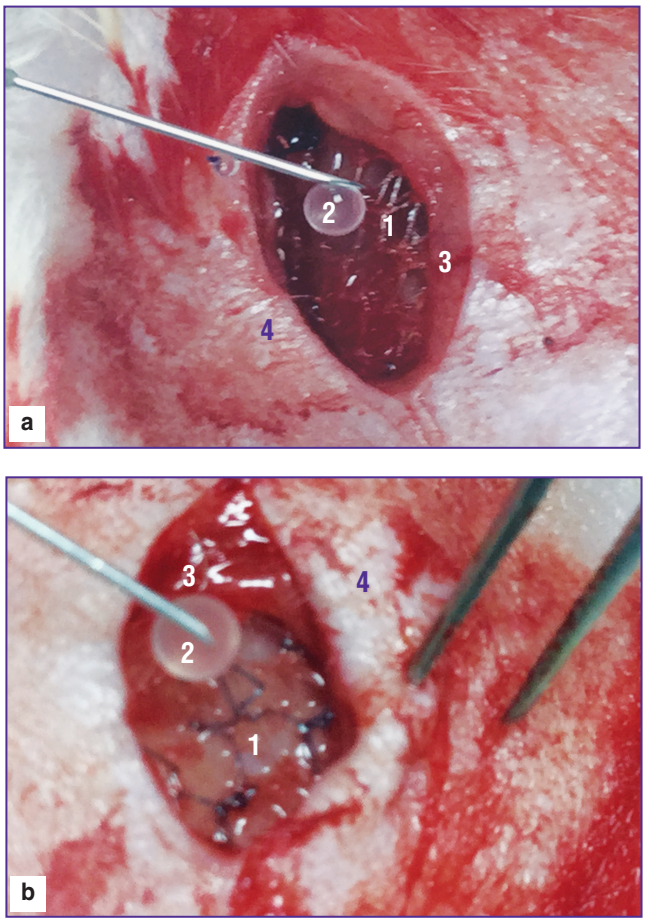

Figure 3. Stages of operative zone contamination: (a) TiMesh endoprosthesis; (b) PP Light endoprosthesis; endoprosthesis (*1*); contamination medium (*2*); muscle (*3*); skin (*4*)

Table 2

Inflammatory process rating scale

No.	Sign	Score (points)
1	Hyperemia	0–2
2	Edema	0–1
3	Exudate	0–1
4	Wound edge diastasis	3
5	Infiltrate	4
6	Suppuration	5

Note. Sign 1 was assigned 0, 1 or 2 points. Signs 2 and 3 were given 0 or 1 point. Points of signs 1, 2 and 3 were summed up, if signs 4, 5 and 6 were absent. If sign 4 was present, whereas there were no signs 5 and 6, the degree of inflammation was assessed as having 3 points at any values of signs 1, 2, 3. If there existed sign 5 but sign 6 was absent, inflammation degree was given 4 points at any values of signs 1, 2, 3, 4. Presence of sign 6 corresponded to 5 points.

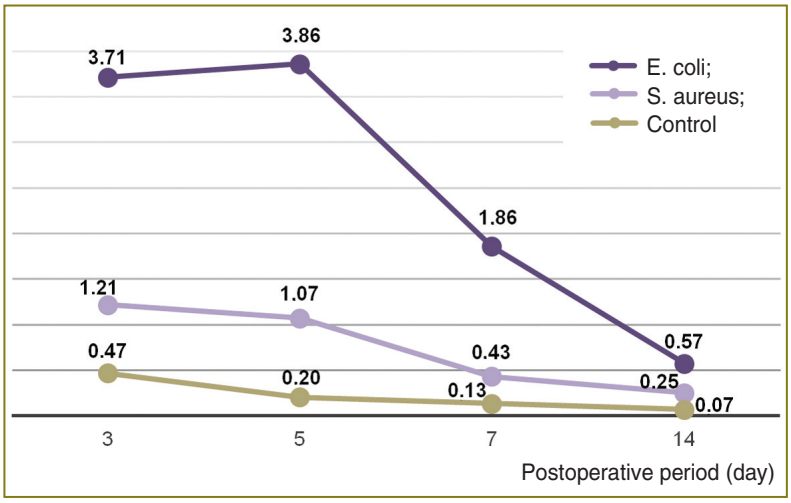

Figure 4. General dynamics of the inflammatory reaction after prosthetic repair (score)

If sign 4 was present, whereas there were no signs 5 and 6, the degree of inflammation was assessed as having 3 points at any values of signs 1, 2, 3. If there existed sign 5 but sign 6 was absent, inflammation degree was given 4 points at any values of signs 1, 2, 3, 4. Presence of sign 6 corresponded to 5 points.

Value distribution was studied by Kolmogorov–Smirnov, Shapiro–Wilk and Lilliefors tests. Statistical analysis of nonparametric sequences was performed by means of Mann–Witney test using Origin Pro 8 software package. Differences were significant at $p<0.05$.

Results. A weak inflammatory reaction was noted in the control group, in contamination groups intensive inflammation was observed with its signs being most marked on days 3–5 (See Figure 4). Differences of the examined groups from the control were statistically significant on days 3, 5 and 7. Postoperative period in the experimental groups had also a number of significant differences. Dynamics of the local inflammatory reaction was most pronounced in group E. coli in all periods of observation; statistically significant differences from group S. aureus were registered on day 3 ($p=0.0005$), day 5 ($p=0.0002$) and day 7 ($p=0.0006$). Peak of changes was noted on day 3 in S. aureus contamination, while this maximum in group E. coli occurred on day 5 of the postoperative period. Measurement of the inflammatory reaction in contamination groups with various prostheses showed that in group E. coli inflammatory changes observed on days 3, 5 and 7 were greater with TiMesh; on day 14 the changes were more marked with PP Light (Figure 5). Meanwhile in group S. aureus inflammation with PP light implantation gained greater score on days 3, 5 and 7; on day 14 maximal changes were noted after implantation of TiMesh. However statistical analysis demonstrated that these differences were not significant. For example, inflammatory reaction in group E. coli on day 3 was more intensive with TiMesh implant (4.17 points) than with PP Light (3.38), though $p=0.13$.

Discussion. The course of the early postoperative period after experimental prosthetic repair in heavy bacterial contamination is accompanied by a marked inflammatory reaction. This observation complies with clinical data and reflects a high rate of infectious complications in urgent surgery [6, 29]. The intensity of inflammation and its dynamics depend mainly on a specific strain.

No doubt, individual patterns of inflammatory reaction, found in the present work and reflecting the interaction of contaminating flora and specific mesh endoprosthesis do exist. It has been previously shown in the study [30].

Formation of biofilm on the implant surface is supposed to be a morphological substrate for the given process [31, 32]. Gross contamination of the endoprosthesis surface creates the most favorable conditions for its rapid formation. It has been clearly demonstrated *in vitro* in numerous works [30–33]. And differences in bacterial load of the mesh surfaces depending on the material and strain species have been reliably confirmed [30–33]. The phenomenon of biofilm existence on synthetic endoprostheses *in vivo* has also been proved [16]. On the other hand, an organism possesses effective mechanisms of bacterial biofilm destruction [34, 35]. Therefore, inflammatory changes in the early postoperative period do not always entail chronicity of the infectious process. According to the data of this investigation, macroscopic signs of inflammation in the majority of animals have regressed by day 14.

It has been previously shown [31], that the extent of bacteriological load is in reverse proportion to the diameter of endoprosthesis fiber. In experiments *in vitro* the area of biofilm, covering the light mesh, was the least. This fact is likely to explain the reason why those differences between the examined meshes appeared to be relatively small.

The specific features of the course of early postoperative period after implantation of light and ultra-light endoprostheses under heavy bacterial

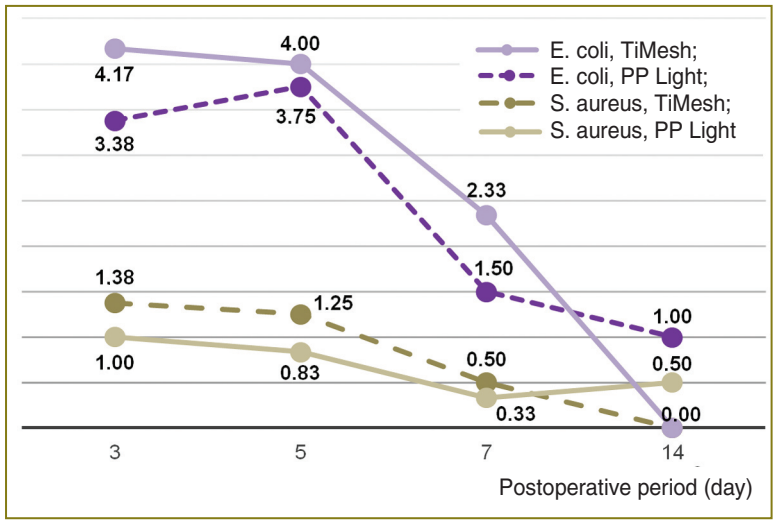

Figure 5. Dynamics of inflammatory reaction in the examined groups depending on endoprosthesis material and microorganism species (score)

contamination, revealed by our work, do not contradict clinical data and the findings of the previous investigations, and are in agreement with the modern concept of the inflammatory process course in the zone of surgical intervention. These features should be taken into consideration when mesh endoprostheses are used in case of infection. The development of special meshes to be used in such situations is a vital and challenging problem [36].

Thus, prosthetic repair in bacterial contamination in experiment is accompanied by a marked inflammatory reaction in the implantation zone, which has statistically significant differences from the control group in the period from 3 to 7 days. These changes are significantly more expressed after infecting by E. coli culture. The most intensive inflammation is observed on day 3 (S. aureus) and day 5 (E. coli) after the intervention, the process regressing by day 14. On day 3–7 after the operation the inflammatory reaction in group E. coli was more marked with TiMesh endoprosthesis than with PP Light; in group S. aureus the inflammatory reaction was more intensive when PP Light was used but these differences are not statistically significant.

Conclusion. Application of mesh endoprostheses in a compromised area of surgical intervention in abdominal wall prosthetic repair is possible by stringent indications taking into account potential usefulness and high risk, possessing adequate experience, and observing a number of conditions. Endoprosthesis should not be placed in contact with the zone of maximum contamination.

Study Funding. The work was supported by the Ministery of Education and Science of the Russian Federation on the topic “Development of ultra-light mesh materials on the basis of titan fibers, improving tissue regeneration”. Agreement No.14.607.21.0085 of 5 November 2014.

Conflicts of Interest. The authors have no conflicts of interest related to the present study.

References

1. Nieuwenhuizen J., Eker H.H., Timmermans L., Hop W.C.J., Kleinrensink G.-J., Jeekel J., Lange J.F.; PRIMA Trialist Group. A double blind randomized controlled trial comparing primary suture closure with mesh augmented closure to reduce incisional hernia incidence. *BMC Surg* 2013; 13: 48, http://dx.doi.org/10.1186/1471-2482-13-48.

2. Iurasov A.V., Shestakov A.L., Kurashvili D.N., Abovian L.A. The modern concept of surgical treatment of patients with postoperative hernias of the anterior abdominal wall. *Vestnik eksperimental'noy i klinicheskoy khirurgii* 2014; 4: 405–413.

3. Narezkin D.V., Sergeev E.V. Problemy primeneniya setchatykh endoprotezov pri gryzhesechenii ushchemlennykh posleoperatsionnykh ventral'nykh gryzh. V kn.: *Materialy X nauchnoy konferentsii “Aktual'nye voprosy gerniologii”* [Problems of using mesh endoprostheses in herniotomy of strangulated postoperative ventral hernias. In: Proceedings of X scientific conference “Actual problems of hernitology”]. Moscow; 2013; p. 102–104.

4. Kukosh M.V., Vlasov A.V., Gomozov G.I. Prevention of early postoperative complications at endoprosthesis of ventral hernias. *Novosti khirurgii* 2012; 20(5): 32–37.

5. Vlasov A.V., Kukosh M.V. The problem of wound complications in abdominal wall endoprosthesis replacement in ventral hernias. *Sovremennye tehnologii v medicine* 2013; 2: 116–124.

6. Sartelli M., Coccolini F., van Ramshorst G.H., Campanelli G., Mandalà V., Ansaloni L., Moore E.E., Peitzman A., Velmahos G., Moore F.A., Leppaniemi A., Burlew C.C., Biffl W., Koike K., Kluger Y., Fraga G.P., Ordonez C.A., Di Saverio S., Agresta F., Sakakushev B., Gerych I., Wani I., Kelly M.D., Gomes C.A., Faro M.P. Jr., Taviloglu K., Demetrashvili Z., Lee J.G., Vettoretto N., Guercioni G., Traná C., Cui Y., Kok K.Y., Ghnnam W.M., Abbas Ael-S., Sato N., Marwah S., Rangarajan M., Ben-Ishay O., Adesunkanmi A.R., Segovia Lohse H.A., Kenig J., Mandalà S., Patrizi A., Scibé R., Catena F. WSES guidelines for emergency repair of complicated abdominal wall hernias. *World J Emerg Surg* 2013; 8(1): 50, http://dx.doi.org/10.1186/1749-7922-8-50.

7. Zafar H., Zaidi M., Qadir I., Memon A.A. Emergency incisional hernia repair: a difficult problem waiting for a solution. *Ann Surg Innov Res* 2012; 6(1): 1, http://dx.doi.org/10.1186/1750-1164-6-1.

8. Golovin R.V., Nikitin N.A., Prokopiev A.A. Prognosis of development of complications of injuries after combined allohernia plastic interventions for postoperative ventral hernias of median localisation. *Sovremennye problemy nauki i obrazovaniya* 2014; 2. URL: www.science-education.ru/116-12914.

9. Sonis A.G., Grachev B.D., Stolyarov E.A., Ishutov I.V. Prevention and treatment of infection wound complications at prosthetic hernia repair. *Rany i ranevye infektsii* 2014; 2(1): 16–23.

10. Bahar M.M., Nooghabi A.J., Nooghabi M.J., Jangjoo A. The role of prophylactic cefazolin in the prevention of infection after various types of abdominal wall hernia repair with mesh. *Asian J Surg* 2015, 38(3): 139–144, http://dx.doi.org/10.1016/j.asjsur.2015.01.006.

11. Cobb W.S., Warren J.A., Ewing J.A., Burnikel A., Merchant M., Carbonell A.M. Open retromuscular mesh repair of complex incisional hernia: predictors of wound events and recurrence. *J Am Coll Surg* 2015; 220(4): 606–613, http://dx.doi.org/10.1016/j.jamcollsurg.2014.12.055.

12. Petter-Pucher A.H., Fortelny R.H. The heart of darkness. *Hernia* 2015; 19(2): 195–196, http://dx.doi.org/10.1007/s10029-014-1336-3.

13. *Abdominal'naya khirurgicheskaya infektsiya. Rossiyskie natsional'nye rekomendatsii* [Abdominal surgical infection. Russian national recommendations]. Otv. red. Savel'ev V.S., Gel'fand B.R. [Savel'ev V.S., Gel'fand B.R. (editors)]. Moscow; 2011.

14. *Strategiya i taktika primeneniya antimikrobnykh sredstv v lechebnykh uchrezhdeniyakh Rossii. Rossiyskie natsional'nye rekomendatsii* [Strategy and tactics of applying antimicrobial means in the health care settings in Russia. Russian national recommendations]. Pod red. Savel'eva V.S., Gel'fanda B.R., Yakovleva S.V. [Savel'ev V.S., Gel'fand B.R., Yakovlev S.V. (editors)]. Moscow; 2012.

15. Hoiby N., Ciofu O., Johansen H.K., Song Z.J., Moser C., Jensen P.Ø., Molin S., Givskov M., Tolker-Nielsen T.,

Bjarnsholt T. The clinical impact of bacterial biofilms. *Int J Oral Sci* 2011; 3(2): 55–65, http://dx.doi.org/10.4248/IJOS11026.

16. Kathju S., Nistico L., Melton-Kreft R., Lasko L.A., Stoodley P. Direct demonstration of bacterial biofilms on prosthetic mesh after ventral herniorrhaphy. *Surg Infect (Larchmt)* 2015; 16(1): 45–53, http://dx.doi.org/10.1089/sur.2014.026.

17. Cargill J.S., Upton M. Low concentrations of vancomycin stimulates biofilm formation in some clinical isolates of Staphylococcus epidermidis. *J Clin Pathol* 2009; 62(12): 1112–1116, http://dx.doi.org/10.1136/jcp.2009.069021.

18. Chebotar I.V., Mayansky A.N., Konchakova E.D., Lazareva A.V., Chistyakova V.P. Antimicrobial resistance of bacteria in biofilms. *Klinicheskaya mikrobiologiya i antimikrobnaya antibiotikoterapiya* 2012; 1(14): 51–58.

19. Primus F.E., Harris H.W. A critical review of biologic mesh use in ventral hernia repairs under contaminated conditions. *Hernia* 2013; 17(1): 21–30, http://dx.doi.org/10.1007/s10029-012-1037-8.

20. *Rukovodstvo po laboratornym zhivotnym i al'ternativnym modelyam v biomeditsinskikh tekhnologiyakh* [Guidelines on laboratory animals and alternative models in biomedical technologies]. Pod red. Karkishchenko N.N., Gracheva S.V. [Karkishchenko N.N., Gracheva S.V. (editors)]. Moscow; 2010.

21. Klinge U., Klosterhalfen B. Modified classification of surgical meshes for hernia repair based on the analyses of 1,000 explanted meshes. *Hernia* 2012; 16(3): 251–258, http://dx.doi.org/10.1007/s10029-012-0913-6.

22. Zhukovsky V.A. *Polimernye endoprotezy dlya gernioplastiki* [Polymer implants for hernia repair]. Saint Petersburg: Eskulap; 2011.

23. Coda A., Lamberti R., Martorana S. Classification of prosthetics used in hernia repair based on weight and biomaterial. *Hernia* 2012; 16(1): 9–20, http://dx.doi.org/10.1007/s10029-011-0868-z.

24. *Rezolyutsiya X nauchnoy konferentsii "Aktual'nye voprosy gerniologii"* [Resolution of X scientific conference "Urgent problems of herniology"]. Moscow; 2013. URL: http://herniaweb.ru/index.php?cat_id=30.

25. Pushkin S.Yu., Belokonev V.I. Treatment of medial ventral hernias with the use of synthetic endoprosthesis. *Khirurgiia* 2010; 6: 43–45.

26. Vorovskii O.O. Interaction of composite mesh implanted with peritoneum abdominoplasty. *Rossiyskiy mediko-biologicheskiy vestnik im. akademika I.P. Pavlova* 2013; 3: 118–123.

27. Protasov A.V., Krivtsov G.A., Mikhaleva L.M., Tabuika A.V., Shukhtin N.Yu. Effects of inguinal hernioplasty mesh implant on reproductive function. *Khirurgiia* 2010; 8: 28–32.

28. Kochetkov A.V., Gudilov M.S. Clinical and laboratory diagnosis and monitoring of septic complications after abdominal operations. *Novosti khirurgii* 2015; 23(1): 105–111.

29. Bondarev V.A., Kchibekov E.A., Topchiev M.A. Otsenka techeniya ranevogo protsessa pri ushchemlennykh gryzhakh peredney bryushnoy stenki. V kn.: *Materialy X nauchnoy konferentsii "Aktual'nye voprosy gerniologii"* [Assessment of the wound healing process in strangulated ventral hernias. In: Proceedings of X scientific conference "Actual problems of hernitology"]. Moscow; 2013; p. 28–30. URL: http://herniaweb.ru/index.php?cat_id=63.

30. Sanders D., Lambie J., Bond P., Moate R., Steer J.A. An in vitro study assessing the effect of mesh morphology and suture fixation on bacterial adherence. *Hernia* 2013; 17(6): 779–789, http://dx.doi.org/10.1007/s10029-013-1124-5.

31. Parshikov V.V., Chebotar I.V., Khodak V.A., Samsonov A.A. In vitro studies of biofilms on the surface of synthetic macroporous endoprostheses for abdominal wall plasty. *Sovremennye tehnologii v medicine* 2012; 1: 15–20.

32. Reslinski A., Dabrowiecki S., Glowacka K. The impact of diclofenac and ibuprofen on biofilm formation on the surface of polypropylene mesh. *Hernia* 2015; 19(2): 179–185, http://dx.doi.org/10.1007/s10029-013-1200-x.

33. Pérez-Köhler B., Sotomayor S., Rodríguez M., Gegúndez M.I., Pascual G., Bellon J.M. Bacterial adhesion to biological versus polymer prosthetic materials used in abdominal wall defect repair: do these meshes show any differences in vitro? *Hernia* 2015, http://dx.doi.org/10.007/s10029-015-1378-1 [Epub ahead of print].

34. Mayansky A.N., Chebotar I.V. Staphylococcal biofilms: structure, regulation, rejection. *Zh Mikrobiol Epidemiol Immunobiol* 2011; 1: 101–108.

35. Chebotar I.V., Konchakova E.D., Evteeva N.I. Neutrophil dependent breakdown of biofilms formed by Staphylococcus aureus. *Zh Mikrobiol Epidemiol Immunobiol* 2012; 1: 10–15.

36. Kuznetsov A.V., Shestakov V.V., Smarzh T.M. Results of herniotomies at infected tissues at different ways antibiotic prophylaxis. *Meditsina i obrazovanie v Sibiri* 2014; 3. URL: http://ngmu.ru/cozo/mos/article/pdf.php?id=1404.