DOI: https://doi.org/10.17816/uroved46045

OPTIMAL LUBRICANTS FOR UROLOGICAL PRACTICE

© ***A.M. Banaru*** [1], ***R.V. Salyukov*** [2, 3]

[1] Lomonosov Moscow State University, Moscow, Russia;
[2] Peoples' friendship university of Russia of the Ministry of Science and Higher Education of the Russian Federation; Moscow, Russia;
[3] JSC Rehabilitation center for persons with disabilities "Preodolenie", Moscow, Russia

For citation: Banaru AM, Salyukov RV. Optimal lubricants for urological practice. *Urology reports (St. Petersburg)*. 2020;10(4):325-336. https://doi.org/10.17816/uroved46045

Received: 26.09.2020 Revised: 03.12.2020 Accepted: 23.12.2020

The importance of choosing a lubricant depending on the therapeutic or diagnostic manipulation performed and the clinical situation is rarely the focus of attention of the practicing urologist. Meanwhile, the components of the lubricant can both provide adjuvant treatment and prevention of complications of the performed manipulations, and vice versa, be the cause of complications themselves. Based on the analysis of the scientific literature of the past 20 years, an overview of lubricants used in urological practice, as well as their main components – gelling agents, anesthetics, antiseptics, is presented, their main advantages and disadvantages are shown.

Keywords: lubricant; polyvinylpyrrolidone; hyaluronic acid; lidocaine; chlorhexidine.

ОПТИМАЛЬНЫЕ ЛУБРИКАНТЫ ДЛЯ УРОЛОГИЧЕСКОЙ ПРАКТИКИ

© ***А.М. Банару*** [1], ***Р.В. Салюков*** [2, 3]

[1] Федеральное государственное бюджетное образовательное учреждение высшего образования «Московский государственный университет им. М.В. Ломоносова», Москва;
[2] Федеральное государственное автономное образовательное учреждение высшего образования «Российский университет дружбы народов», Министерства науки и высшего образования Российской Федерации, Москва;
[3] Акционерное общество «Реабилитационный центр для инвалидов «Преодоление», Москва

Для цитирования: Банару А.М., Салюков Р.В. Оптимальные лубриканты для урологической практики // Урологические ведомости. – 2020. – Т. 10. – № 4. – С. 325–336. https://doi.org/10.17816/uroved46045

Поступила: 26.09.2020 Одобрена: 03.12.2020 Принята к печати: 23.12.2020

Важность подбора лубриканта в зависимости от выполняемой лечебной или диагностической манипуляции и клинической ситуации редко оказывается в фокусе внимания практикующего врача-уролога. Между тем, компоненты лубриканта могут как обеспечить адъювантное лечение и профилактику осложнений проводимых манипуляций, так и, наоборот, самими быть причиной осложнений. На основе анализа научной литературы последних 20 лет представлен обзор лубрикантов, используемых в урологической практике, а также их основных компонентов — гелеобразователей, анестетиков, антисептиков, показаны их основные преимущества и недостатки.

Ключевые слова: лубрикант; поливинилпирролидон; гиалуроновая кислота; лидокаин; хлоргексидин.

Urethral lubricants, such as olive oil and laticifers of some trees, were first mentioned in antiquity. Since the end of XIX century, synthetic topical anesthetics such as tetracaine, tripelenamine, diclonin, etc., started to be used in urological practice. In the 1940s, lidocaine was synthesized for the first time in Sweden and became firmly established in medical practice for all subsequent decades. A contemporary urological lubricant should have a number of useful properties (mechanical, rheological, and electrical) and contain components that ensure adequate safety, anesthesia, and prevention of infections, and other complications associated with urological manipulations. For example, in case of transurethral resection (TUR) of the prostate gland, a power density of electric current of 7.5 W/cm^2 is critical for the urethra [1], an electrical trauma of which can be triggered by a lubricant with low electrical

conductivity (up to 4–6 S/cm). Ideally, lubricant functions not only directly during the manipulation, but also for some time after it, for example, contributing to regeneration of tissues operated. For instance, intermittent self-catheterization with triamcinolone liniment after internal optical urethrotomy reduces significantly the risk of recurrence [2]. In addition, due to combined composition, some lubricants can be used as an independent agent in the complex therapy of interstitial cystitis [3].

Developers of modern hydrophilic coatings for urological catheters have achieved great progress toward the ideal urological lubricant. Most often, they are based on an aqueous gel (hydrogel), which is a framework of synthetic polymer molecules, comprising water in its cavities. Chemical modification of the original framework enables to change purposefully the beneficial properties of the lubricant. However, mass lubricant must be affordable and meet the price expectations of consumers.

In the XX century, set of components in the composition of urological lubricants in general was very conservative; therefore, in this work, studies of lubricants published after 2000 were reviewed. Literature searches were performed in PubMed and Google Scholar databases for the following keywords: "lubricant," "urology," and their derivatives. Naturally, research on the topic of interest was divided into two fundamentally different types. Firstly, medical studies (preclinical and clinical) and secondly, specialized works in one of the branches of chemistry (most often, the chemistry of macromolecular compounds). Medical research is well-known to be usually lags behind purely chemical research by 5–10 years due to the fact that new chemical compounds make a very difficult way from development to clinical trials. Nevertheless, chemical publications outline the prospects for aledmedical research. Works on chemistry, concerning lubricants were not revel; however, indirectly related to urology.

A very small joint Greek-Dutch work [4], published in 2009, presented urological lubricants for the above period of time [4]. No such publications in Russia were available, apart from popular scientific reviews and methodological materials of developers of urological consumables. Certainly, in the professional activity of a practicing urologist, especially a surgeon, the issue of lubricant is far from being a primary aspect. The limited choice of lubricants in Russia makes this issue for urologist even more minor. In addition, the correct selection of lubricant can be considered as an adjuvant treatment affecting the outcome of urological manipulation or surgery. Paraffinic oil was widely used 30–40 years ago and is still almost the only alternative to the meager range of lubricants available in the Russian market, having almost equal composition. What should a patient do if contraindications from existing lubricants exist?

Nevertheless, some attempts are also being made in Russia to optimize the composition of urological lubricant. Particularly, in 2010, a group of developers from Perm proposed a 2% solution of anilocaine as a local urological anesthetic [5]. In experiments on animals, it was revealed that anilokaine is 1.5 times less toxic than lidocaine, and has some anti-inflammatory and antimicrobial effects. The main property of anesthesia for the urethra with anilocaine is its duration, as it occurs within 1 min and lasts for approximately 40 min. In comparison with lidocaine, anilocaine was not inferior to it in efficacy of anesthesia for the urethra; however, it had advantages in side effects reduction, infections prevention, and toxic complications resorption. Two years later, based on studies performed, this scientific group developed the formulation of Anilogel [6], which contains chlorhexidine gluconate in addition to anilocaine. Carboxymethyl cellulose, methyl cellulose, and sodium alginate were used as gelling agents, and glycerin was used as plasticizer. Another group of Ural developers created hydrogels based on silicon polyolates (polyalcoholates) [7], capable of stimulating regenerative and reparative processes. A gel with oxymethyluracyl, developed by a group of colleagues from Ufa, has the same advantage [8]. However, listed Russian-made lubricants have yet reached clinical practice introduction.

GELLING AGENTS

The main component of the lubricant, which imparts optimal mechanical properties to it, is a gelling agent. The dispersed phase of urological gels is represented by water, and the dispersion medium is the gelling agent itself. The gel can be formed both during the factory production of a lubricant, and as a result of the activation of the gelling agent with water *in situ*, when the case is disposable urological devices with a prepared hydrophilic surface.

A silicone tube coated with agar-agar or mucin can be used as a model for the urethra to study the mechanical properties of lubricated surfaces *ex vivo* [9]. A prospective, randomized, blinded, crossover study in 49 male volunteers [10] showed that hydrophilic lubricated catheters (in this study, SpeediCath® and LoFric®) caused significantly less microhematuria and pain compared to that of a catheter without hydrophilic surface. For this reason, hydrophilic lubricated catheters can be a technical means of choice for rehabilitation of patients with lower urinary tract neurogenic dysfunction [11]. However, one of the disadvantages of regular use of catheters in men, even with a hydrophilic surface, is a temporary decrease in sperm quality [12].

The gelling agent in the composition of the urological lubricant, as a rule, is a hypoallergenic water-soluble polymer, such as polyvinyl alcohol, polyvinylpyrrolidone (PVP), polyethylene glycol, and some polysaccharides, such as carboxymethyl and carboxyethyl cellulose. In particular, PVP is a gelling agent for the aforementioned SpeediCath® and LoFric®. Cross-linking of such polymer chains is performed by H-bonds; however, H-bonds should not be so strong that the gel is stable for a long time and the lubricant is not washed out from the urinary tract. Examples include polyacrylic acid and polyacryalamide (PAA), which cannot be used in lubricants. Moreover, the stability and durability of gels they form are important in the so-called bulking materials [13]; therefore, PAA-based gels are used for vesicoureteral reflux treatment [14]. Hydrogen bonds formed by gelling agent molecules play a key role not only in biomedicine. For example, PVP is used as an inhibitor of clathrate formation in the oil industry, since it binds water molecules (moisture) and prevents clathrate plugs from clogging the oil pipeline [15].

Reviews of developed and patented biomedical hydrogels, as well as commercial products based on them, are published periodically [16, 17]. In 2010, biochemists from Singapore described an antibacterial biocompatible hydrogel based on dimethyldecylammonium chitosan, poly (ethylene glycol) methacrylate, and poly (ethylene glycol) diacrylate, which has a polycationic surface structure and acts on bacterial cell membranes according to the "anionic sponge" principle [18]. In 2019, biochemists from China described a thermosensitive urological hydrogel made from a mixture of *N*-isopropylacrylamide and *N*,*N*'-methylene-bis (2-propenamide), deposited on a polydimethylsiloxane (silicone) substrate [19]. This gel has a smooth surface and ensures the safety of transurethral manipulation at room temperature, and it undergoes a structural transition upon reaching the temperature of the human body, stratifying into an inner hydrophobic layer and an outer peptide layer, which reduces bacterial adhesion to the surface by >96% and reduces their population in the surrounding tissue by 1000 times within 72 h compared to pure silicone. Thus, a tendency may occur toward the synthesis of multilayer hydrogels of more complex composition and structure, capable of undergoing structural modification *in vivo*.

Hydrogels based on hyaluronic acid constitute a special category, a detailed review of which is presented by X. Xu et al. [20]. Hyaluronic acid (Uro-Hyal®, Urolife®) with TUR of the prostate gland reduces the irritating effect of urine on the postoperative wound surface, accelerates the maturation of granulation tissue and epithelialization, and reduces dysuric phenomena [21]. The combination of hyaluronic acid with carboxymethyl cellulose functions as a mechanical barrier preventing the formation of adhesions [22]. Carboxymethyl cellulose is a polysaccharide which is more hydrophilic than cellulose; and forms a stable gel in an aqueous medium that fills the surgical wound. Hyaluronic acid dissolved in it is the main component of extracellular matrix and ensures the non-immunogenicity of the gel, which justifies the use of this combination in prevention of urethral strictures [23].

ANESTHETICS

Currently, 2% lidocaine is considered the gold standard for anesthetic in a lubricating gel in urology. A significant number of comparative studies have been focused on it. In 2001, a double-blind, placebo-controlled, randomized study [24] compared the effects of 20 ml of placebo gel (group 1) and 10 ml (group 2) and 20 ml (group 3) of 2% lidocaine gel, administered in the urethra of men for 15 min before performing diagnostic flexible cystoscopy. A total of 60 patients participated in the study. Differences in pain perception immediately after the diagnostic procedure were not statistically significant on a 10-point visual analog scale (VAS) (4.65; 3.93; and 3.57 in groups 1, 2, and 3, respectively; $p = 0.406$). In 2004, a team of researchers

from Japan conducted a rather unusual study [25], where each man (a total of 33 patients) underwent 3 flexible cystoscopy procedures alternately with the instillation of 10 ml of 2% lidocaine gel, placebo gel, and also without instillation of gel (lidocaine gel was applied in all cases to a cystoscope). Participants recorded pain sensations according to a 100-point VAS during gel instillation and during the passage of instrument into the bladder. The average degree of pain was 77 for instillation and 98 for the diagnostic procedure, and regardless of anesthetic instillation, no statistically significant difference was found in pain during the procedure. Authors concluded that instillation of lidocaine gel prior to flexible cystoscopy is not necessary. A few years later, a randomized, double-blind, crossover study was conducted in a cohort of 51 men who underwent cystoscopy twice with an interval of 3 months [26]. In one of the procedures, 10 ml of 2% lidocaine gel was used as a lubricant, whereas a placebo was used in other procedure. The median difference in pain perception between two procedures on a 10-point VAS was 0, mean 0.24. Thus, the advantage of lidocaine gel over placebo was not confirmed again. In 2009, a meta-study of 14 studies on the use of lidocaine gel in flexible cystoscopy, selected from the PubMed, Biosis, and Cochrane Library databases, was performed [27]; however, only 4 studies were included directly in the analysis. According to results of the meta-analysis in the use of lidocaine gel, the probability of experiencing moderate or severe pain was 1.7 times lesser than with placebo use ($p = 0.05$). In 2015, a group of Spanish doctors conducted an observational non-randomized study of 72 patients of both genders [28]. Pain was assessed using a 10-point VAS of pain and Spanish Pain Questionnaire. On both scales, the severity of pain during flexible cystoscopy when lubricated with 2% lidocaine gel was lower compared to placebo, but was not statistically significant; therefore, the authors concluded no advantage in lidocaine gel over placebo and even calculated what savings could be made at an approximate cost of a gel portion of 0.22 Euros without anesthetic and 1.25 Euros with lidocaine gel. In 2016, a group of doctors from Turkey published results of a retrospective study for 2012–2014 on the same topic among 220 male patients [29]. The mean level of pain in the groups that underwent instillation with lidocaine gel (3.10 ± 0.980) and instillation with gel without anesthetic (3.34 ± 0.789) did not differ significantly ($p = 0.132$). In 2017, the attention of doctors from Poland was attracted by the question whether the instillation of lidocaine gel through a catheter into the posterior urethra, in addition to the usual instillation prior to cystoscopy in men, has any advantage [30]. A total of 127 men participated in the randomized study, and pain was compared not only by the VAS, but also by the Likert scale, and the patient's need for analgesics was assessed within 6 h after the procedure, as well as the occurrence of symptomatic urinary tract infection (UTI) within 14 days after manipulation. It turned out that the perception of pain in the compared groups and the risk of UTI did not differ statistically significant; however, the subjective need for analgesics within 6 h after the procedure with additional irrigation with lidocaine on the posterior urethra in the group decreased from 81.8% to 70.2%. In 2016, in another prospective randomized study among men who underwent cystoscopy [31], 2% lidocaine gel was compared not with a gel without anesthetic, but with normal saline (instillation of 10 ml each). Exceptionally low pain scores on the 10-point VAS in both groups (0.67 ± 1.11 and 0.55 ± 1.10, respectively) did not differ statistically significant ($p = 0.40$). Therefore, during flexible cystoscopy, it is sufficient to irrigate correctly the urethra with saline solution instead of using a gel with an anesthetic.

G. Losco et al. [32] studied the possibility of using not the traditional long (15–25 min) but short-term exposure of lidocaine gel. A prospective comparative study involved 50 men who underwent flexible cystoscopy either immediately after instillation of anesthetic or 3 min later. The average difference in pain perception according to VAS was 1.42 ($p = 0.64$) in favor of a short-term exposure, which was not statistically significant; therefore, a pause before inserting a flexible endoscope was not necessary. The same conclusion was made by the authors of a later prospective randomized study in 242 men [33], who underwent flexible cystoscopy either immediately after the administration of 12.5 g of Cathejell, or after its 5-min exposure. Differences in pain sensations according to the 10-point VAS in patients of these two groups (2.41 and 2.04, respectively) were not statistically significant ($p = 0.175$). In a 2019 American, double-blind, randomized controlled study [34] of 116 women who underwent flexible cystoscopy,

2% lidocaine gel was still significantly preferable to placebo gel according to a 10-point VAS. In this study, the authors took into account the effects of heterogeneity of compared groups due to age and ethnic composition. The average pain perception during the procedure was 2.43 in the lidocaine gel group and 3.58 in the placebo gel ($p = 0.01$). The exposure time was 15 min, which the authors do not focus on; however, in our opinion, it can be the decisive point. Apparently, statistically significant differences between lidocaine gel and placebo begin to be noticeable just after exposure for at least 15 min.

According to J. Siderias et al. [35], prior to catheterization of men with a 16 Fr Foley catheter during emergency care, instillation of 2% lidocaine gel has an advantage over placebo. A total of 36 patients participated in the study, and according to a 100-point VAS, the level of pain perceptivity in the lidocaine gel group was 38 ± 28 vs. 58 ± 30 in the placebo gel group ($p = 0.04$). During the instillation itself, the level of pain was also statistically significantly different (23 ± 17 and 40 ± 25 in groups 1 and 2, respectively) ($p = 0.02$). Moreover, a study of a similar design among women (a total of 100 patients using 8 Fr and 16 Fr catheters), published in the same year [36], led to different results. According to a 100-point VA, the pain level during catheterization with lidocaine did not statistically significantly differ from that without lidocaine; however, younger women (18–59 years old) experienced more severe pain compared to older patients (69 years and older), and the average difference was 14.4 points ($p < 0.006$). Furthermore, these results could differ due to the unequal gel exposure time (15 min in men [35] and only 1 min in women [36]). In 2015, a prospective, randomized study was conducted on advantages of instilling 2% lidocaine gel (5 ml, 5 min before the procedure) over lubricating the catheter tip with the same gel (5 ml) during catheterization in women [37]. A total of 94 women who participated in the study were distributed into two groups. According to a 10-point VAS for catheterization with instillation, the severity of pain averaged 2.3 ± 1.4 points, and catheterization with a lubricated tip was 2.4 ± 1.6 points ($p = 0.71$), whereas scores were the same in terms of pain during instillation (1.9 ± 0.9 points). Therefore, authors concluded that instillation is not necessary and only cause additional pain.

Commercial studies were also reported. In 2019, a double-blind randomized study [38] by Turkish colleagues compared two different gels with the same 2% lidocaine content, these were Cathejell® well-known in Russia [39] and Dispogel® (made in Turkey) which is not yet known in Russia. Participants (77 men) underwent JJ stent extraction, urethral bougieurage, or diagnostic cystoscopy, with anesthetic exposure time of 5 min. No statistically significant difference was found in VAS pain perception between Cathejell® and Dispogel®; therefore, the authors recommend using the less expensive Dispogel®.

In 2008, only one study was reported in which 2% lidocaine gel was compared not with placebo, but with a gel containing 40% of dimethyl sulfoxide (DMSO) [40]. In a prospective, randomized cohort study, 140 men (70 in each group) underwent rigid cystoscopy with a 17 Fr instrument. The cystoscope itself was lubricated with lidocaine gel. A 10 ml of gel was injected into the urethra 15 min before manipulation, and the pain level was recorded according to a 10-point VAS immediately after manipulation. Pain was 3.9 ± 1.1 in the lidocaine gel group and 2.1 ± 1.0 in the DMSO group ($p = 0.015$), that is, in the DMSO group, the pain level was statistically significantly lower. Another interesting result was obtained with an increase in the pH of lidocaine gel [41], when in a prospective randomized controlled study, 10 ml of lidocaine gel mixed with 1 ml of 5% $NaHCO_3$ (pH 7.20) were injected to men prior to rigid cystoscopy, or 1 ml 0.9% sodium chloride solution (pH 6.41, control group). Alkalinization of the lubricant reduced the pain level on the 10-point VAS from 5.28 ± 1.99 to 1.3 ± 0.9.

More recently [42] colleagues from China have investigated whether it is advisable for men to urinate immediately prior to flexible cystoscopy to reduce pain during the procedure. 96 men participated in a randomized study, and all participants received instillation of 2% lidocaine gel. Pain sensations according to a 10-point VAS were examined before instillation, during instillation, during a cystoscope insertion, and 15 min after cystoscopy. Men who urinated before the procedure had statistically significant lower pain sensations during the passage of the instrument along the urethra, compared with the control group, whereas at other stages, pain sensations did not differ. Moreover, the temperature of the lubricant can also affect the pain sensation, as when

lidocaine gel was cooled from room temperature of 22°C to 4°C, the severity of pain during cystoscopy in men decreased significantly [43].

ANTISEPTICS

The antimicrobial components of a lubricant differ depending on the task assigned. With short-term endoscopic manipulations on the urinary tract, as well as with short-term catheterization, such a component should provide a quick and not necessarily long-term effect. On the contrary, with prolonged urinary tract catheterization, the risk of catheter-associated infections increases dramatically, which account for at least 80% of complicated UTIs [44]. In this case, the lubricant or the native coating of the catheter should provide a long-term effect of the antimicrobial component and, if possible, prevent the adhesion of pathogenic microorganisms. These two types of required component can hardly be used in one active substance.

The most common anti-infective agent with proven antimicrobial, antiviral, and antifungal activity in urological lubricants is chlorhexidine, which is usually available as gluconate. In 2008, a group of researchers from Hong Kong conducted a randomized controlled trial of the efficacy of 0.05% chlorhexidine gluconate for prevention of UTI during prolonged catheterization in women [45]. Before the introduction of the Foley catheter, the urethra was irrigated with chlorhexidine solution or sterile water (control group), and then each of 20 participants underwent urine culture tests 4 times for 2 weeks. No statistically significant difference was found in the incidence of asymptomatic UTI in patients of different groups, whereas symptomatic UTI did not occur in any of participants. Therefore, irrigation of the urethra with chlorhexidine immediately before prolonged catheterization is not advisable. Moreover, the presence of chlorhexidine in the gel composition can induce some complications, at best, increasing significantly the pain sensations after endoscopic manipulation. Thus, in a prospective randomized blind study, 141 patients underwent flexible cystoscopy, while anesthetized with 10 ml of 2% lidocaine gel or 10 ml of the same gel, but with 0.05% chlorhexidine supplementation [46]. Pain sensations were recorded using a 10-point VAS. During the passage of the cystoscope along the urethra, during the endoscopic examination, and immediately after the procedure, pain sensations in patients of the two groups did not differ statistically significant. However, during the first urination, pain from chlorhexidine was significantly higher, 1.8 vs. 1.0 ($p = 0.031$). The same was noted immediately after the first urination (2.4 vs. 1.2) ($p = 0.007$). In the chlorhexidine group, a significantly more pronounced urgent desire to first urination was observed ($p = 0.018$).

A report has been published on the development of severe anaphylactic shock in a patient who underwent catheterization with a latex urethral catheter [47]. Initially, it was suspected that latex caused anaphylaxis, but a basophil activation test showed that it was caused by chlorhexidine. Thus, in some patients, the seemingly harmless urological lubricant can cause life-threatening conditions due to chlorhexidine. A group of English doctors described a similar clinical case [48] where a patient also developed anaphylaxis caused by Instillagel® containing chlorhexidine during bladder catheterization prior to orthopedic surgery. A year later, another similar case with an elderly patient during laser ablation of bladder carcinoma was reported [49]. The authors emphasize that, in contrast to previous cases, this patient previously during his life received repeatedly intraurethral instillations of mixtures containing chlorhexidine, without any adverse reactions. Another article [50] discusses the growing number of patients hypersensitive to chlorhexidine and warns against this component in lubricants. In Russia, a possible alternative to Cathejell® containing 0.05% chlorhexidine gluconate is the gynecological lubricant Montavit Gel® produced by the same Austrian manufacturer [51], which contains only 0.01% chlorhexidine gluconate with a similar formulation composition.

As is known, the chlorhexidine particle represents a cation. It provokes the removal of potassium ions from the cell and inhibits cellular respiration at low concentrations and it compromises the integrity of the cell membrane at higher concentrations, which ultimately leads to cell death. Cationic compound miramistin, which is somewhat less cytotoxic and allergenic compared to chlorhexidine, developed as part of the Union of Soviet Socialist Republics space program, was used until recently in the complex therapy of chronic urethritis [52], but only in the post-Soviet countries. Only in 2020, the international scientific press published the first major studies of the antibacterial profile of miramistin *in vitro* and

in vivo [53] and its comparative analysis with other antiseptics (chlorhexidine, triclosan, benzalkonium chloride, dioxidine, etc.) [54].

Another well-known broad-spectrum urological antiseptic is povidone iodine or PVP complex with iodine. PVP itself represents a hydrophilic polymer that forms hydrogel over a wide range of concentrations. Povidone iodine usually contains 10% iodine, but only approximately a tenth (1%) is slowly released when the antiseptic is dissolved in water. According to the data of a randomized controlled trial by R. Nayyar et al. [55], the risk of UTI decreases from 22% (control group) to 7% ($p < 0.007$) if the urethra is irrigated with povidone iodine solution before the procedure when performing cystoscopy for men on an outpatient basis. In a similar comparative study [56], 60 women participated, in whom the urethra was irrigated with 10% povidone iodine or sterile water, and then a Foley catheter was inserted for 24 h, after which all of them underwent urine culture test. No statistically significant difference was reported in the incidence of bacteriuria. Results of a randomized controlled trial of 122 children admitted to a pediatric intensive care unit have also been published, comparing the efficacy of 10% povidone iodine, 0.05% chlorhexidine gluconate, and water [57]. After irrigation of the urethra with an appropriate solution and installation of a Foley catheter, the incidence of UTI was determined during the entire follow-up period. These frequencies were distributed between povidone iodine, chlorhexidine, and water as 15.0, 4.8, and 7.5%, respectively; however, the difference was not statistically significant ($p > 0.05$).

Povidone iodine can be incorporated into films on the surface of biomaterials. The physicochemical properties of films synthesized from poly-ε-caprolactone, including those with additional povidone iodine, were investigated [58]. This material is biodegradable and resistant to infection and salt encrustation, which in the future can be used for the production of ureteral stents. Mixtures of povidone iodine with polyurethane [59], which is the main material for ureteral stents nowadays, were studied in a similar way. In the range of povidone iodine concentrations from 0.5% to 1.5%, a steady increase in the antiadhesive and antimicrobial properties of the mixture is noted in polyurethane. Compared to pure polyurethane, such a mixture demonstrates greater resistance to salt encrustation, especially struvite and hydroxyapatite, which is not surprising, since crystalline biofilms of pathogenic bacteria are formed from them [60].

Certainly, in addition to povidone iodine, many other components are of a similar action, that are trying to be introduced into the surface of urological catheters and stents, namely gentamicin [61], norfloxacin [62], ciprofloxacin in combination with azithromycin [63], etc. Several extensive reviews were published on this topic [64, 65]. Considering that antiseptic introduction into the material was primarily aimed to ensure the duration of release, almost nothing limits the use of the same component in the lubricant for short-term use. In the last decade, the direction of creating materials with antiseptic nanoparticles has been developing especially actively. These are long-established Ag particles in nanocomposites, for example, based on tetrafluoroethylene (Teflon) [66] and ZnO particles, such as nanoparticles stabilized with aminated polyphenylene sulfide [67] and fullerene-like MoS_2 nanoparticles [68], in particular, doped with rhenium [69]. These particles can certainly be stabilized in a routine urological lubricant. In patients with neurogenic urinary dysfunction, the incidence of UTI due to *Escherichia coli* is significantly reduced; however, a high incidence of *Proteus mirabilis* (15% of all UTIs) and *P. aeruginosa* (13%) is possible [70]. Obviously, in a water-activated catheter for intermittent catheterization of such patients, introduction of appropriate antiseptics into the lubricant, for example zinc-doped CuO nanoparticles capable of inhibiting the formation of biofilms with *P. mirabilis* colonies by >90% is useful [71].

CONCLUSION

Considering the dual function of PVP as a gelling agent and a complexing agent for an antiseptic (povidone iodine), it is currently most promising for routine use as a part of a mass urological lubricant, in addition to widely used polysaccharides (carboxymethyl and carboxyethyl cellulose). A lubricant based on hyaluronic acid is advisable for traumatic endourological surgeries. As for the local anesthetic, most randomized controlled trials revealed that the presence of 2% lidocaine in the lubricant does not statistically significantly reduce pain during transurethral manipulations; however, careful analysis shows that reduction in pain becomes statistically significant with an increase in the exposure time of lidocaine to 15 min

or more. Some works indicate the prospectivity of the local anesthetic effect of DMSO. The dosage of the antiseptic chlorhexidine gluconate, currently used in lubricants by default and causing adverse reactions up to anaphylaxis, in Russian urological practice can be adjusted by replacing Cathejell® preparations with Montavit Gel® from the same manufacturer with five times less antiseptic content.

REFERENCES

1. Sofer M, Vilos GA, Borg P, et al. Stray radiofrequency current as a cause of urethral strictures after transurethral resection of the prostate. *J Endourol*. 2001;15(2):221-225. https://doi.org/10.1089/089277901750134700.
2. Regmi S, Adhikari SC, Yadav S, et al. Efficacy of use of triamcinolone ointment for clean intermittent self catheterization following internal urethrotomy. *JNMA J Nepal Med Assoc*. 2018; 56(212):745-748.
3. Перепанова Т.С., Хазан П.Л., Кудрявцев Ю.В. Урологический болевой синдром: применение геля Катеджель // Эффективная фармакотерапия. Урология и нефрология. – 2008. – № 3. – С. 12–17. [Perepanova TS, Hazan PL, Kudrjavcev JuV. Urologicheskij bolevoj sindrom: primenenie gelja Katedzhel'. *Effektivnaja farmakoterapija. Urologija i nefrologija*.2008;(3):12-17. (In Russ.)].
4. Tzortzis V, Gravas S, Melekos MM, de la Rosette JJ. Intraurethral lubricants: a critical literature review and recommendations. *J Endourol*. 2009;23(5):821-826. https://doi.org/10.1089/end.2008.0650.
5. Давидов М.И., Панцуркин В.И., Горнова Н.А., Шуренков И.В. Эффективность анестетика анилокаина при трансуретральных инструментальных вмешательствах // Вестник Уральской медицинской академической науки. – 2010. – № 2 (30). – С. 110–114. [Davidov MI, Pantsurkin VI, Gornova NA, Shurenkov IW. Efficacy of anaesthetic anilocain by transurethral instrumental interferences. *Journal of Ural Medical Academic Science.* 2010;2(30):110-114. (In Russ.)].
6. Алексеева И.В., Панцуркин В.И., Одегова Т.Ф., Рюмина Т.Е. Разработка обезболивающего геля «Анилогель» для применения при диагностических и лечебных манипуляциях в урологии // Химико-фармацевтический журнал. – 2012. – Т. 46. – № 12. – С. 40–43. [Alekseeva IV, Pantsurkin VI, Odegova TF, Ryumina TE. Development of anesthetic gel "Anilogel" for diagnostic and medical manipulations in urology. *Khimiko-Farmatsevticheskii Zhurnal*.2012;46(12):40-43. (In Russ.)].
7. Хонина Т.Г., Шадрина Е.В., Бойко А.А. и др. Синтез гидрогелей на основе полиолатов кремния, обладающих заданным комплексом медико-биологических свойств // Известия Академии наук. Серия химическая. – 2009. – № 1. – С. 76–81. [English version: Khonina TG, Shadrina EV, Boyko AA, et al. Synthesis of hydrogels based on silicon polyolates. *Russian Chemical Bulletin.* 2010;59(1):276-283.]
8. Шикова Ю.В., Елова Е.В., Лиходед В.А. и др. Разработка состава и технологии геля с оксиметилурацилом, хлоргексидина биглюконатом и лидокаином / Инновации и здоровье нации: материалы IV Всероссийской научно-практической конференции с международным участием. – СПб., 2016. – С. 681–684. [Shikova JuV., Elova EV, Lihoded VA, et al. Razrabotka sostava i tehnologii gelja s oksimetiluracilom, hlorgeksidina bigljukonatom i lidokainom. Innovacii i zdorov'e nacii: materialy IV Vserossijskoj nauchno-prakticheskoj konferencii s mezhdunarodnym uchastiem. Saint Petersburg; 2016. P. 681-684. (In Russ.)].
9. Jones DS, Garvin CP, Gorman SP. Design of a simulated urethra model for the quantitative assessment of urinary catheter lubricity. *J Mater Sci Mater Med*. 2001;12(1):15-21. https://doi.org/10.1023/a:1026744732504.
10. Stensballe J, Looms D, Nielsen PN, Tvede M. Hydrophilic-coated catheters for intermittent catheterisation reduce urethral micro trauma: a prospective, randomised, participant-blinded, crossover study of three different types of catheters. *Eur Urol*. 2005;48(6): 978-983. https://doi.org/10.1016/j.eururo.2005.07.009.
11. Кезина Л.П., Салюков Р.В., Тищенко Г.Е. Катетеры для периодической катетеризации мочевого пузыря, как техническое средство реабилитации пациентов с нейрогенной дисфункцией нижних мочевыводящих путей: вопросы организации обеспечения инвалидов // Физическая и реабилитационная медицина, медицинская реабилитация. – 2019. – Т. 1. – № 4. – С. 77–81. [Kezina LP, Salyukov RV, Tishchenko GE. Catheters for intermittent bladder catheterization, as a technical tool for rehabilitation of patients with neurogenic lower urinary tract dysfunction: issues of the organization of disabled providing. *Physical and rehabilitation medicine, medical rehabilitation*. 2019;1(4):77-81. (In Russ.)]. https://doi.org/10.36425/2658-6843-2019-4-77-81.

12. Auger J, Rihaoui R, François N, Eustache F. Effect of short-term exposure to two hydrophilic-coated and one gel pre-lubricated urinary catheters on sperm vitality, motility and kinematics *in vitro*. *Minerva Urol Nefrol*. 2007;59(2):115-124.
13. Абдуллаев Ф.К., Кулаев В.Д., Николаев В.В. Зависимость эффективности эндоскопического лечения первичного пузырно-мочеточникового рефлюкса от объемообразующего материала // Урология. – 2013. – № 2. – С. 94–97. [Abdullaev FK, Kulayev VD, Nikolaev VV Efficiency of endoscopic treatment of primary vesicoureteral reflux depending on bulking agent. *Urologiia*. 2013;(2):94-97. (In Russ.)].
14. Берестнев В., Лопатин В., Берестнев А. Полиакриламидный гель для применения в урологии // Ремедиум. Журнал о российском рынке лекарств и медицинской технике. – 2003. – № 9. – С. 70–71. [Berestnev V, Lopatin V, Berestnev A. Poliakrilamidnyj gel' dlja primenenija v urologii. *Remedium Journal*. 2003;(9):70-71. (In Russ.)].
15. Банару А.М., Словохотов Ю.Л. Кристаллогидраты органических соединений // Журнал структурной химии. – 2015. – Т. 56. – № 5. – С. 1024–1040. [Banaru AM, Slovokhotov YuL. Crystal hydrates of organic compounds. *Journal of Structural Chemistry*. 2015;56(5):1024-1040. (In Russ.)]. https://doi.org/10.15372/JSC20150521.
16. Caló E, Khutoryanskiy VV. Biomedical applications of hydrogels: A review of patents and commercial products. *Eur Polym J*. 2015;65:252-267. https://doi.org/10.1016/j.eurpolymj.2014.11.024.
17. Mondal S, Das S, Nandi AK. A review on recent advances in polymer and peptide hydrogels. *Soft Matter*. 2020;16(6):1404-1454. https://doi.org/10.1039/c9sm02127b.
18. Li P, Poon YF, Li W, et al. A polycationic antimicrobial and biocompatible hydrogel with microbe membrane suctioning ability. *Nat Mater*. 2011;10(2):149-156. https://doi.org/10.1038/nmat2915.
19. Zhu K, Hou D, Fei Y, et al. Thermosensitive Hydrogel Interface Switching from Hydrophilic Lubrication to Infection Defense. *ACS Appl. Bio Mater*. 2019; 2(8):3582-3590. https://doi.org/10.1021/acsabm.9b00457.
20. Xu X, Jha AK, Harrington DA, et al. Hyaluronic acid-based hydrogels: from a natural polysaccharide to complex networks. *Soft Matter*. 2012;12(8):3280-3294. https://doi.org/10.1039/C2SM06463D.
21. Сорокин Д.А., Севрюков Ф.А., Семенычев Д.В. и др. Результаты применения гиалуроновой кислоты после трансуретральных эндоскопических операций по поводу доброкачественной гиперплазии простаты // Медицинский Вестник Башкортостана. – 2015. – Т. 10. – № 3. – С. 19–24 [Sorokin DA, Sevrjukov FA, Semenychev DV, et al. Results of application of hyaluronic acid after transurethral endoscopic surgical management of benign prostatic hyperplasia. *Bashkortostan Medical Journal*. 2015;10(3):19-24. (In Russ.)].
22. Кондратович Л.М. Основы понимания формирования спаечного процесса в брюшной полости. Интраоперационная профилактика противоспаечными барьерными препаратами (обзор литературы) // Вестник новых медицинских технологий. – 2014. – Т. 21. – № 3. – С. 169–173. [Kondratovich LM. The basics for comprehension of adhesive process formation in abdominal cavity. Perioperative prevention by means of anti-adhesive drugs (review of literature). *Journal of New Medical Technologies*. 2014;21(3):169-173. (In Russ.)].
23. Салюков Р.В., Банару А.М. Перспективы адъювантной химиотерапии стриктур уретры // Урология. – 2020. – № 2. – С. 94–100. [Salyukov RV, Banaru AM. The perspectives of adjuvant chemotherapy of urethral stricture. *Urologiia*. 2020;(2):94-100. (In Russ.)]. https://doi.org/10.18565/urology.2020.2.94-100.
24. McFarlane N, Denstedt J, Ganapathy S, Razvi H. Randomized trial of 10 mL and 20 mL of 2 % intraurethral lidocaine gel and placebo in men undergoing flexible cystoscopy. *J Endourol*. 2001;15(5):541-544. https://doi.org/10.1089/089277901750299366.
25. Kobayashi T, Nishizawa K, Mitsumori K, Ogura K. Instillation of anesthetic gel is no longer necessary in the era of flexible cystoscopy: a crossover study. *J Endourol*. 2004;18(5):483-486. https://doi.org/10.1089/0892779041271535.
26. Chitale S, Hirani M, Swift L, Ho E. Prospective randomized crossover trial of lubricant gel against an anaesthetic gel for outpatient cystoscopy. *Scand J Urol Nephrol*. 2008;42(2):164-167. https://doi.org/10.1080/00365590701685793.
27. Aaronson DS, Walsh TJ, Smith JF, et al. Meta-analysis: does lidocaine gel before flexible cystoscopy provide pain relief? *BJU Int.* 2009;104(4):506-510. https://doi.org/10.1111/j.1464-410X.2009.08417.x.
28. Cano-Garcia MDC, Casares-Perez R, Arrabal-Martin M, et al. Use of Lidocaine 2 % Gel Does Not Reduce Pain during Flexible Cystoscopy and Is Not Cost-Effective. *Urol J*. 2015;12(5):2362-2365. https://doi.org/10.22037/uj.v12i5.2904.

29. Akkoç A, Kartalmış M, Aydın C, et al. 2 % Lidocaine gel or plain lubricating gel: Which one should be used in male flexible cystoscopy? *Turk J Urol*. 2016;42(2):92-96. https://doi.org/10.5152/tud.2016.18784.
30. Poletajew S, Bender S, Pudełko P, et al. Anaesthesia of the posterior urethra and pain reduction during cystoscopy – a randomized controlled trial. *Wideochir Inne Tech Maloinwazyjne*. 2017;12(1):75-80. https://doi.org/10.5114/wiitm.2017.66506.
31. Carrion A, García-Cruz E, Fernandez C, et al. Prior Lubrication of the Urethra Does Not Reduce Pain Perception in Men Undergoing Flexible Cystoscopy. *Urol Int.* 2016;97(4):392-396. https://doi.org/10.1159/000447497.
32. Losco G, Antoniou S, Mark S. Male flexible cystoscopy: does waiting after insertion of topical anaesthetic lubricant improve patient comfort? *BJU Int.* 2011;108(Suppl 2):42-44. https://doi.org/10.1111/j.1464-410X.2011.10696.x.
33. Panach-Navarrete J, Martínez-Jabaloyas JM. Is a retention time after the instillation of anesthetic lubricant necessary when performing male flexible cystoscopy? *J Endourol.* 2015;29(2):223-225. https://doi.org/10.1089/end.2014.0430.
34. Dougher E, Zoorob D, Thomas D, et al. The effect of lidocaine gel on pain perception during diagnostic flexible cystoscopy in women: a randomized control trial. *Female Pelvic Med Reconstr Surg*. 2019;25(2):178-184. https://doi.org/10.1097/SPV.0000000000000680.
35. Siderias J, Gaudio F, Singer AJ. Comparison of topical anesthetics and lubricants prior to urethral catheterization in males: a randomized controlled trial. *Acad Emerg Med*. 2004;11(6):703-706.
36. Tanabe P, Steinmann R, Anderson J, et al. Factors affecting pain scores during female urethral catheterization. *Acad Emerg Med*. 2004;11(6):699-702.
37. Stav K, Ohlgisser R, Siegel YI, et al. Pain during female urethral catheterization: intraurethral lubricant injection versus catheter tip lubrication – a prospective randomized trial. *J Urol*. 2015;194(4):1018-1021. https://doi.org/10.1016/j.juro.2015.03.097.
38. Ucar M, Oguz F, Gecit I, Aydogan MS. Comparing 2 % lidocaine gel (Dispogel and Cathejell) in cystoscopy. *J Int Med Res*. 2019;47(9):4225-4229. https://doi.org/10.1177/0300060519858509.
39. Лоран О.Б., Пушкарь Д.Ю., Аветисян М.М., Раснер П.И. Фармакоэкономическое обоснование применения препаратов Катеджель и Катеджель F в урологической практике // Урология. – 2001. – № 2. – С. 13–17. [Loran OB, Pushkar' DJu, Avetisjan MM, Rasner PI. Farmakoekonomicheskoe obosnovanie primenenija preparatov Katedzhel' i Katedzhel' F v urologicheskoj praktike. *Urologija*. 2001;(2):13-15. (In Russ.)].
40. Demir E, Kilciler M, Bedir S, Erken U. Patient tolerance during cystoscopy: a randomized study comparing lidocaine hydrochloride gel and dimethyl sulfoxide with lidocaine. *J Endourol*. 2008;22(5):1027-1030. https://doi.org/10.1089/end.2007.0180.
41. Li H, Cheng Y, Li J, et al. $NaHCO_3$-Buffered Lidocaine Gel for Outpatient Rigid Cystoscopy in Men. *J Perianesth Nurs.* 2016;31(2):154-157. https://doi.org/10.1016/j.jopan.2014.05.014.
42. Xie Y, Wang W, Yan W, et al. Efficacy of urination in alleviating man's urethral pain associated with flexible cystoscopy: a single-center randomized trial. *BMC Urol*. 2020;20:2. https://doi.org/10.1186/s12894-019-0541-x.
43. Goel R, Aron M. Cooled lignocaine gel: does it reduce urethral discomfort during instillation? *Int Urol Nephrol*. 2003;35(3):375-377. https://doi.org/10.1023/b: urol.0000022910.28815.30.
44. Васильев А.О., Говоров А.В., Ширяев А.А., Пушкарь Д.Ю. Роль уретрального катетера в развитии катетер-ассоциированной инфекции мочевыводящих путей // Урология. – 2017. – № 6. – С. 107–111. [Vasilyev AO, Govorov AV, Shiryaev AA, Pushkar DYu The role of the uretral catheter in the development of catheter-related urinary tract infection. *Urologiia*. 2017;(6):107-111. (In Russ.)]
45. Cheung K, Leung P, Wong YC, et al. Water versus antiseptic periurethral cleansing before catheterization among home care patients: a randomized controlled trial. *Am J Infect Control*. 2008;36(5):375-380. https://doi.org/10.1016/j.ajic.2007.03.004.
46. Jayathillake A, Mason DF, Broome K, Tan G. Chlorhexidine in urethral gel: does it cause pain at flexible cystoscopy? *Urology*. 2006;67(4):670-673. https://doi.org/10.1016/j.urology.2005.10.019.
47. Ebo DG, Bridts CH, Stevens WJ. Anaphylaxis to an urethral lubricant: chlorhexidine as the "hidden" allergen. *Acta Clin Belg*. 2004;59(6):358-360. https://doi.org/10.1179/acb.2004.051.

48. Noel J, Temple A, Laycock GJ. A case report of anaphylaxis to chlorhexidine during urinary catheterisation. *Ann R Coll Surg Engl*. 2012;94(4):e159-160. https://doi.org/10.1308/003588412X13171221590610.

49. Dyer JE, Nafie S, Mellon JK, Khan MA. Anaphylactic reaction to intraurethral chlorhexidine: sensitisation following previous repeated uneventful administration. *Ann R Coll Surg Engl*. 2013;95(6): e105-6. https://doi.org/10.1308/003588413X13629960047597.

50. Williams C. Making a choice of catheterisation gel and the role of chlorhexidine. *Br J Community Nurs*. 2017;22(7):346-351. https://doi.org/10.12968/bjcn.2017.22.7.346.

51. Доброхотова Ю.Э., Хлынова С.А. Использование лубрикантов при вульвовагинальной атрофии // РМЖ. Мать и дитя. – 2018. – Т. 1. – № 2. – С. 163–167. [Dobrokhotova YuE, Khlynova SA. Lubricants application in vulvovaginal atrophy. *Russian Journal of Woman and Child Health*. 2018;1(2):163-167 (In Russ.)]. https://doi.org/10.32364/2618-8430-2018-1-2-163-167.

52. Абдрахманов Р.М., Файзуллина Е.В., Абдрахманов А.Р., Халиуллин Р.Р. К вопросу о местном лечении в комплексной терапии хронических уретритов, ассоциированных с инфекциями, передаваемыми половым путем // Урология. – 2015. – № 6. – С. 40–46. [Abdrahmanov RM, Fajzullina EV, Abdrahmanov AR, Haliullin RR. To the issue of local treatment in combination therapy of chronic urethritis, associated with sexually transmitted infections. *Urologiia.* 2015;(6):40-46. (In Russ.)].

53. Agafonova MN, Kazakova RR, Lubina AP, et al. Antibacterial activity profile of miramistin in *in vitro* and *in vivo* models. *Microb Pathog*. 2020;142:104072. https://doi.org/10.1016/j.micpath.2020.104072.

54. Osmanov A, Farooq Z, Richardson MD, Denning DW. The antiseptic Miramistin: a review of its comparative in vitro and clinical activity. *FEMS Microbiol Rev*. 2020;44(4):399-417. https://doi.org/10.1093/femsre/fuaa012.

55. Nayyar R, Dadhwal R, Kapil A, et al. Urethral Instillation of Povidone-Iodine Reduces Post-Cystoscopy Urinary Tract Infection in Males: A Randomized Controlled Trial. *Sci Rep*. 2020;10(1):3585. https://doi.org/10.1038/s41598-020-60522-4.

56. Nasiriani K, Kalani Z, Farnia F, et al. Comparison of the effect of water vs. povidone-iodine solution for periurethral cleaning in women requiring an indwelling catheter prior to gynecologic surgery. *Urol Nurs*. 2009;29(2):118-121,131.

57. Düzkaya DS, Uysal G, Bozkurt G, et al. Povidone-Iodine, 0.05 % Chlorhexidine Gluconate, or Water for Periurethral Cleaning Before Indwelling Urinary Catheterization in a Pediatric Intensive Care: A Randomized Controlled Trial. *J Wound Ostomy Continence Nurs*. 2017;44(1):84-88. https://doi.org/10.1097/WON.0000000000000280.

58. Jones DS, Djokic J, McCoy CP, Gorman SP. Poly(epsilon-caprolactone) and poly(epsilon-caprolactone)-polyvinylpyrrolidone-iodine blends as ureteral biomaterials: characterisation of mechanical and surface properties, degradation and resistance to encrustation *in vitro*. *Biomaterials*. 2002;23(23):4449-4458. https://doi.org/10.1016/s0142-9612(02)00158-8.

59. Raut PW, Khandwekar AP, Sharma N. Polyurethane-polyvinylpyrrolidone iodine blends as potential urological biomaterials. *J Mater Sci*. 2018;53(16):11176-11193. https://doi.org/10.1007/s10853-018-2445-7.

60. Cortese YJ, Wagner VE, Tierney M, et al. Review of catheter-associated urinary tract infections and *in vitro* urinary tract models. *J Healthc Eng*. 2018;2018:2986742. https://doi.org/10.1155/2018/2986742.

61. Cho YW, Park JH, Kim SH, et al. Gentamicin-releasing urethral catheter for short-term catheterization. *J Biomater Sci Polym Ed*. 2003;14(9):963-972. https://doi.org/10.1163/156856203322381447.

62. Park JH, Cho YW, Cho YH, et al. Norfloxacin-releasing urethral catheter for long-term catheterization. *J Biomater Sci Polym Ed*. 2003;14(9):951-962. https://doi.org/10.1163/156856203322381438.

63. Saini H, Chhibber S, Harjai K. Antimicrobial and antifouling efficacy of urinary catheters impregnated with a combination of macrolide and fluoroquinolone antibiotics against *Pseudomonas aeruginosa*. *Biofouling*. 2016;32(5):511-522. https://doi.org/10.1080/08927014.2016.1155564.

64. Andersen MJ, Flores-Mireles AL. Urinary catheter coating modifications: The race against catheter-associated infections. *Coatings.* 2020;10(1):23. https://doi.org/10.3390/coatings10010023.

65. Vasilev K, Cook J, Griesser HJ. Antibacterial surfaces for biomedical devices. *Expert Rev Med Devices*. 2009;6(5):553-567. https://doi.org/10.1586/erd.09.36.

66. Zhang S, Wang L, Liang X, et al. Enhanced Antibacterial and Antiadhesive Activities of Silver – PTFE Nanocomposite Coating for Urinary Catheters. *ACS Biomater Sci Eng*. 2019;5(6):2804-2814. https://doi.org/10.1021/acsbiomaterials.9b00071.

67. Díez-Pascual AM, Díez-Vicente AL. High-performance aminated poly(phenylene sulfide)/ZnO nanocomposites for medical applications. *ACS Appl Mater Interfaces*. 2014;6(13):10132-10145. https://doi.org/10.1021/am501610p.
68. Goldbart O, Elianov O, Shumalinsky D, et al. Study of urological devices coated with fullerene-like nanoparticles. *Nanoscale*. 2013;18(5):8526-8532. https://doi.org/10.1039/c3nr01922e.
69. Ron R, Zbaida D, Kafka IZ, et al. Attenuation of encrustation by self-assembled inorganic fullerene-like nanoparticles. *Nanoscale*. 2014;10(6):5251-5259. https://doi.org/10.1039/c3nr06231g.
70. Салюков Р.В., Колмаков А.С., Мартов А.Г. Инфекция мочевыводящих путей у больных с позвоночно-спинномозговой травмой: обзор литературы // Consilium Medicum. – 2016. – Т. 18. – № 7. – С. 60–65. [Salukov RV, Kolmakov AS, Martov AG. Urinary tract infection in patients with spinal cord injury. *Consilium Medicum*. 2016;18(7):60-65. (In Russ.)].
71. Shalom Y, Perelshtein I, Perkas N, et al. Catheters coated with Zn-doped CuO nanoparticles delay the onset of catheter-associated urinary tract infections. *Nano Res*. 2017;10(2): 520-533.

Information about the authors:

Aleksandr M. Banaru – Cand. Sci. (Chem.), Senior Lecturer of Faculty of Chemistry Lomonosov Moscow State University, Moscow, Russia. E-mail: banaru@phys.chem.msu.ru.

Roman V. Salyukov – Cand. Sci. (Med.), Associate Professor of Department of Endoscopic Urology, RUDN University of the Ministry of Science and Higher Education of the Russian Federation; Scientific Consultant, JSC Rehabilitation Center for Persons with Disabilities "Preodolenie", Moscow, Russia. E-mail: salyukov2012@yandex.ru.

Сведения об авторах:

Александр Михайлович Банару — канд. хим. наук, старший преподаватель химического факультета. ФГБОУ ВО МГУ им. М.В. Ломоносова, Москва, Россия. E-mail: banaru@phys.chem.msu.ru.

Роман Вячеславович Салюков — канд. мед. наук, доцент кафедры эндоскопической урологии факультета повышения квалификации медицинских работников, ФГАОУ ВО РУДН Минобрнауки РФ, Москва; научный консультант АО «Реабилитационный центр для инвалидов «Преодоление», Москва. E-mail: salyukov2012@yandex.ru.