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Methods of local antimicrobic prophylaxis of surgical site infection

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Abstract

Recently, to prevent of surgical site infection, new methods of local antimicrobic prophylaxis have been developed and successfully introduced, which allow to creating high concentrations of antimicrobial drugs in operated tissues and preventing the migration of bacterial flora into the wound. The review describes the main methods used for local impact on microflora and aimed at prophylaxis of surgical site infection. The latter include pre-, intra- and postoperative measures. Optimizing of preoperational methods could be achieved by improving the methods of processing of operating field. Review's considerable attention is paid to intraoperative measures: the use of surgical gloves with antimicrobial properties, reticulated to implants with antimicrobial properties for tension-free hernioplasty, stage-by-stage surgical wound irrigation with antibacterial drugs during suturing as well as the prospects for the use of bacteriophages in abdominal surgery. To increase the biological tightness of the intestinal suture, some authors propose the use of a biodegradable antibiotic-impregnated implant. The review reflects the possibilities of using biologically active (antimicrobial) sutures, the use of which was very effective at all stages of the operation: from the application of intestinal anastomosis to the skin suture. A wide range of antimicrobial surgical sutures containing antibacterial preparations and made by threads with different biodegradation abilities make, allow us to recommend a differentiated approach to the choice of suture material depending on the stage of surgery and regenerative properties of the sutured tissues. The main measures recommended in the early postoperative period are to cover the wound with special wound coatings preventing the possible contamination and to improve irrigation-aspiration drainage techniques of postoperative wounds.
Keywords: surgical site infection, antimicrobial prophylaxis.

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To date, surgical site infections (SSI) remain one of the most urgent problems in abdominal surgery [1–5]. The emergence of local complications with purulent-inflammatory origins is supported by several factors. Among these is the endogenous microbial contamination of the surgical site and is of principal importance [2, 6]. Unfortunately, the local effects of antibacterial drugs are very limited because of the resistance of microbial flora, severe post-traumatic inflammation in the surgical site, the formation of microbial biofilms on implants and suture materials, and other reasons [7, 8]. Surgical treatment outcomes can be improved by using antimicrobial prophylaxis methods in the field of surgical intervention [9, 10].

First, some authors suggest paying attention to the preparation and sterilization of the surgical field in accordance with generally accepted methods [11]. The use of new methods to treat skin at the site of the estimated incision, in particular, the use of the gas flow of nitrogen monoxide with the Plazon apparatus helps to arrest the inflammation and reduce wound complications of infectious origins [6].

Most researchers suggest using various intraoperative antimicrobial prophylaxis methods. Thus, surgical gloves with an industrial coating applied on to the inside surface that contains chlorhexidine bigluconate (manufactured by Gammex; Ansell Ltd.) are proposed for use as prophylaxis of SSI. At the same time, effective suppression of the growth of resistant microflora on the hands of medical personnel is noted, when compared with the control group [12].

Considerable attention is paid to improving methods for sealing the sutures of hollow organs. When applying enteroenteroanastomoses, the

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authors propose using the fibrin-collagen substance TahoKomb saturated with solutions of antibacterial drugs, such as ampicillin, gentamicin, ceftriaxone, ciprofloxacin, meropenem, and metronidazole. In an *in vitro* experiment, the absorption capacity of TahoKomb plates when applying solutions with a pipette was studied. In addition, their antibacterial properties regarding frequently inoculated microbial flora were examined. A study in laboratory animals that examined the bacterial permeability of the enteroenteroanastomosis covered with a fibrin-collagen substance with antimicrobial properties indicated an increase in mechanical strength and a significant decrease in bacterial permeability of the anastomoses formed [13]. The use of the TahoKomb antimicrobial substance in the surgical treatment of colon diseases enabled the reduction in the incidence of anastomosis failure from 3.5%–12.5% to 0.5%–0.6% and to reduce the number of SSI from 10.5% to 5.3% [13,14].

Given the likelihood of rejection of mesh endoprostheses because of microbial infection during non-stretched hernioplasty [15], a group of researchers investigated *in vitro* and *in vivo* the possibility of preventing adhesion and infection of monofilament surgical mesh endoprostheses with pathogenic microorganisms (*Staphylococcus spp.*) by the pre-immersion of implants into antimicrobial solutions (amoxicillin + clavulanic acid, vancomycin) [16]. The fixation of silver nanoclusters or chemical deposition of metal on the implant surface imparts the latter with prolonged antiseptic properties. It prevents the formation of microbial biofilms, thereby reducing the number of local infectious complications during hernioplasty [15].

Another implant for non-tension hernioplasty is made of Capron that is impregnated with alcoholic solutions of antibiotics (erythromycin, chloramphenicol).

The nets are exposed for 22–24 h. Then, the preparations are fixed with a 7% acetone solution of sulfacrylate biological adhesive. Experimental studies have demonstrated an effective and long-term antibacterial effect of the implant after extraction from the soft tissues of laboratory animals concerning the main representatives of gram-positive and gram-negative flora, including *Pseudomonas aeruginosa*. The use of an antimicrobial mesh endoprosthesis in clinical practice for the surgical treatment of patients with ventral hernias has reduced the frequency of wound suppuration from 17.5% to 3.0% [3].

At present, biologically active surgical sutures are in high demand. Kapromed suture materials [17] were one of the first to be developed, and their antibacterial properties were ensured by including hydroxymethylquinoxalindioxyde, quinoxidine, gentamicin, kanamycin, cefazolin, and iodine in their composition.

The use of Kapromed sutures in clinical practice in intestinal suture application, the formation of anastomoses, and in abdominoplasty contributed to a decrease in the frequency of wound suppurations from 11.7% to 1.8% [18]. The Kaproag suture material developed later contains the antiseptic, chlorhexidine bigluconate. The use of Kaproag sutures in the surgical treatment of patients with gynecological pathology enabled a reduction in the frequency of SSI from 20% to 12% [19].

Antimicrobial suture materials containing doxycycline (Nikant) or ciprofloxacin (Tveran) are widely known. This experiment proved the high and prolonged (up to 10–14 days) antibacterial activity of experimental samples of suture materials, revealed a positive effect of sutures on the healing of colonic and laparotomy wounds, and a decrease in the severity of adhesions in the abdominal cavity [20]. The use of new antimicrobial thread, Nikant and Tveran, for surgeries in patients with acute and chronic diseases of the abdominal cavity and anterior abdominal wall, contributed to a decrease in the number of local postoperative complications because of a decrease in the frequency of SSI from 14.8% to 5.2% [9,21].

In surgeries on the colon, the use of antimicrobial suture materials seems to be especially relevant to increase the biological integrity of the intestinal suture. The use of Nikant during surgical interventions for complications of colon cancer enabled a reduction in the number of patients with a complicated postoperative period from 62.0% to 32.4% [22].

The antibacterial suture material Abactolate is obtained by impregnation with an erythromycin solution. When Abactolate was implanted in the tissues of laboratory animals, it retained its antibacterial effect for 11–12 days. According to the authors, when using Abactolate in the surgical treatment of a wide range of acute abdominal pathologies, the frequency of wound complications (such as seroma, suture sinus, infiltrate, suppuration, and eventration) decreased by 3.4–17.4 times. The efficiency of the new antibacterial suture has also been proven when performing clean surgical interventions, such as in herniotomy. In these cases, the frequency of wound complications decreased from 20.5% to 1.2%, and in cardiac surgery, the frequency of SSI decreased from 6.7%–8.0% to 1.2% [3].

Suture materials containing the antiseptic benzyldimethyl-myristoylamino-propylammonium chloride monohydrate and antibiotics (kanamycin, doxycycline, clindamycin, ampicillin, and carbenicillin), and samples of biologically active suture materials with combined (proteolytic and antimicrobial) activity have been developed. Experimental *in vitro* studies have shown the prolonged antimicrobial effect of new types of sutures, up to 14 days with benzyldimethyl-myristoylamino-propylammonium chloride monohydrate, and up to 14–21 days in sutures with antibiotics [23].

Overseas, an antimicrobial surgical suture from polyglactin 910 with antiseptic triclosan (Vicryl Plus), has been developed. It has a sufficiently prolonged (within seven days) and high antibacterial activity [24,25]. Numerous publications indicate the high effectiveness of Vicryl Plus in the surgical treatment of a wide range of diseases [26,27]. In particular, with herniotomy, the use of this suture enabled the reduction of the incidence of SSI from 11.9% to 6.1% [28], while suturing laparotomy wounds from 10.8%–14.2% to 3.6%–6.6% [29], and in colorectal surgery, from 9.3% to 4.3% [24,27,30].

Triclosan was introduced into other biodegradable suture materials, namely PDS Plus, based on polydioxanone (resorption time, 182–238 days), and Monocryl Plus made of poliglecaprone 25 (biodegradation period, 14–21 days). Depending on the biodestructive properties of filaments with triclosan when performing a surgical procedure on the abdominal organs and in the process of a layered closure of wounds of the anterior abdominal wall, manufacturers and researchers recommend using a differentiated approach regarding the choice of suture material, depending on the stage of the surgery and the regenerative properties of the tissues being sutured [31–33].

PDS Plus should be used for suturing the aponeurosis and tendon, suturing of joint capsules, soft tissue matching, and in cardiovascular surgery. Vicryl Plus is recommended for soft tissue approximation and ligation. Monocryl Plus is used for suturing wounds of the intestine, peritoneum, bladder, ureter, and intradermal cosmetic suture. The layered application of these sutures for SSI prevention reduces the incidence of postoperative purulent-inflammatory complications from 14.2%–35.5% to 1.6%–10.0% [34]. At the same time, the widespread use of triclosan antiseptic as a constituent component of personal hygiene products contributes to a decrease in the sensitivity of the bacterial flora to antiseptics and the development of resistance in the clinical presentation [35].

Currently, there is a growing interest in research on the creation and implementation of new biologically active suture materials. Prototypes of suture material with a broad spectrum antiseptic octenidine [36] and a silk suture coated with copolyamide and levofloxacin [37] have been developed. To impart antibacterial properties to suture materials, scientists propose using amphiphilic antimicrobial peptides [38], silver-containing bioglass [39], acrylic acid, or chitosan with tetracycline and nanosilver [40], poly-L-lactide with tetracycline or cefotaxime as a coating for sutures [41]. The first results of experimental studies indicate the ability of the developed suture materials to have an antibacterial effect, which opens new opportunities for the prevention of SSI.

For the prevention of SSI, researchers proposed to administer bacteriophage suspensions intraoperatively. Thus, the intraperitoneal administration of a suspension with the pyobacteriophage sextafag during laparoscopic appendectomies enabled not only the reduction of a significant number of SSIs but also improvement in the quality of life of patients during the postoperative period [10]. When suturing, surgeons resort to staged irrigation of the wound chamber with antiseptic solutions (0.5% aqueous-alcoholic solution of chlorhexidine bigluconate) or antibiotics (gentamicin), and treatment of the surgical wound edges with vancomycin powder [42]. At the same time, the use of these methods in the event of SSI occurrence may lead to a change in the nature of microorganisms in the purulent focus toward the gram-negative flora and the subsequent expansion of etiotropic treatment [43].

Prevention of microbial infection in the early postoperative period is no less important. Covering the wound with an adhesive medical and preventive composition consisting of hydroxyethyl dimethyldihydropyrimidine, benzocaine, hydrocortisone, boric acid, and phenol-polyvinyl glue prevents potential contamination. It helps to reduce the frequency of wound suppurative complications from 4.7% to 3.5% [2]. There is a growing interest in the biological properties of ozonated perfluorane, which is currently underused in clinical practice [44]. Flow-aspiration drainage of the cavity of the microbially contaminated wound with antiseptic solutions in reconstructive surgeries of the colon has reduced the number of suppurations of laparotomic wounds at the site of excised colostomy from 21.3% to 2.7% [7].

Thus, improvements in the results of surgical treatment and decreases in frequencies of SSI development can be achieved by improving methods for the prevention of endogenous infection [5,45]. Recently, for this purpose, methods for local antimicrobial prophylaxis of SSI have been introduced successfully. These measures enable the creation of high concentrations of drugs in wound tissues and prevent the migration of bacterial flora from operated cavities and organs [3,13,22]. The development of new methods for the prevention of SSI opens the possibility for researchers to implement a layered approach to the antibacterial prophylaxis of SSI, considering the type and characteristics of sutured tissues [32,33,45].

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