Prevention of Complications of Incisional Hernia Repair: Current Problem State (Review)

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The review covers the important aspects of complications in incisional hernia repair. The paper specifies the most relevant issues of modern herniology, its social and economical aspects, considers the preventive techniques for preoperative, intraoperative and postoperative complications. When describing the preoperative predictive and preventive methods in complications, the authors analyzed the existent classifications and integral grading scales for patients' state indicators, showed the benefits and drawbacks of current techniques of preoperative preparation.

The part devoted to an intraoperative period presents the main current hernia repair techniques, mesh implants, and their characteristics. Much attention is given to the description of surgical options depending on mesh arrangement in relation to anatomical abdominal wall layers, and the assessment of mesh implant types, their selection for a specific clinical setting. The review considers the principles of component separation as one of the most promising directions of abdominal surgery. When studying the postoperative preventive methods, the emphasis was made on the description of fast-track principles. Currently, a fast-track technique is being widely used in surgery, and gaining popularity in herniology.

Key words: incisional hernia; hernia repair; mesh; herniology; component separation; fast-track.

Introduction

Incisional hernia (IH) of the anterior abdominal wall is one of the most common unwanted consequence of abdominal surgeries. IH occurs in 20% cases, and in high-risk patients (with systemic connective tissue dysplasia, abdominal aortic aneurysms, etc.) even in a favorable postoperative course — in more than 35% cases. About 50% of all hernias develop within the first two years after surgery [1–3]. Hernioplasty for IH is one of the most frequent operations in current abdominal surgery.

All the factors contributing to IH formation can be divided into two groups: patient-dependent and surgical technique-dependent factors. The first group factors include: male sex, smoking, a long-term glucocorticosteroid course, the presence of comorbidities (morbid obesity, abdominal aortic aneurysms, chronic obstructive pulmonary disease, malignant tumors, etc). A biological factor is of primary importance, which means connective tissue metabolic imbalance. Compared to normal patients, those with hernias are found to have collagen I and III ratio reduction in transverse fascia, aponeurosis, and the anterior abdominal wall skin, as well as an increased level of collagen matrix metalloproteinases [4, 5]. The second group factors involve the errors in selecting suture materials and a technique to close laparotomy wounds, as well as surgeon's insufficient experience [6, 7].

The treatment of IH patients worldwide is a socio-economic problem, since it requires time and material expenses. Annually, in the USA, $3.2 billion is spent for the treatment of such patients [8]. In France, an average treatment cost of a patient is about €6.5 thousand [9], in Sweden — €9 thousand, and the national cost value reaches €18 million [10]. In case of mesh implant infection, the expenses for a patient can reach $100 thousand [11]. The data specify the urgency of an issue for IH surgery and stimulate the search and development of new preventive techniques for postoperative complications; the techniques consisting in selecting rational preoperative preparation, the determination of optimal surgery extent, as well as the development of a postoperative algorithm of patient's management due to his somatic status.

Integral scales for hernioplasty risk complication prognosis

The use of scales for risk prognosis holds a prominent place among the preoperative methods for prognosis and prevention of postoperative hernia complications. Integral scales based on patients' condition indicators have acquired great popularity among surgeons [12].

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The scale of American Society of Anesthesiologists (ASA) is the most common and easy to use. It enables to predict any risks of postoperative complications reliably, and it is available for a wide use in clinical practice [13, 14]. To estimate the probability of developing wound infection complications and recurrent hernias, Breuing et al. in 2010 [15] suggested the scale dividing all the patients with ventral hernia into four classes. Patients with a low risk of wound complications, without the episodes of surgical site infection (SSI) in past history are referred to class I. Class II (comorbid) involves the patients with comorbidities (morbid obesity, diabetes mellitus, immunodeficiencies or chronic obstructive pulmonary disease, as well as smokers). Class III includes the patients with SSI in their past history or a functioning colostomy, class IV includes the patients with an infected postoperative wound or an infected implant. Class I patients are recommended to use synthetic mesh implants, while class III and IV patients — biological meshes. However, the classification makes no risk evaluation of wound infection development in each class giving no recommendations for risk reduction, and sizes and position of hernia defects are not considered as well.

In 2012 Kanters et al. [16] suggested a modified classification by Breuing et al. The patients with SSI in their past histories were referred to class II, while those with a functioning colostomy — to class IV. The risk of developing infectious complications in class I patients was 14%, class II patients — 27%. Class III patients were decided to be subdivided into three subgroups according to wound infection extent: subgroup A means conditionally infected wound (SSI risk is 6–9% cases), subgroup B is infected wound (13–20% cases), subgroup C — dirty wound (40% cases).

In 2015 Petro et al. [17] divided all IH patients into three groups based on hernia crosswise size and a wound infection level due to the classification of Center for Disease Control (USA). Group 1 includes the patients with a defect less than 10 cm wide and a clean wound, group 2 — those with 10–20-cm wide hernias and a clean wound, or with the defect less than 10 cm wide and an infected wound, group 3 — with hernias over 20 cm in width and a clean wound, or any infected wound if hernia width is over 10 cm. The risks of developing SSI and recurrent hernias for group 1 patients is 10%, for group 2 patients — 20 and 15%, respectively, and for group 3 — 42 and 26% cases, respectively. The classification is easy to use and enables to predict a treatment scenario before a surgery.

To predict the risk of seromas based on multiple correlation analysis, there has been developed a scoring scale to assess the complication risks [18]. Each factor was empirically assigned scores from 1 to 3, according to: hernia duration, hernia defect width, mesh implant type and area, hernioplasty type, resorptive activity coefficient of a hernia repair technique (the ratio of general wound surface and exposed muscular area). As a result, the values up to 10 scores are suggested to be rendered as a low-risk interval; from 11 to 14 scores — a moderate risk interval; from 15 to 18 scores — a high-risk interval. According to the authors, the technique enables to assess properly the seroma risk degree and has an intentional effect on controlled risk factors. European Hernia Society (EHS) has recommended the classification suggested by Morales-Conde to evaluate and describe developed postoperative seromas [19, 20].

Along with integral scales to predict postoperative complications and the selection of optimal hernia repair technique, instrumental methods are also being used. There have been described the techniques based on preoperative computed tomography findings [21, 22]. Blair et al. [22] have revealed that the increase in hernia width and area, as well as the thickness of some abdominal wall components, are associated with the higher risk of wound infection after hernia repair. Franklin et al. [21] have shown the width and area of the hernia defect, and the hernia size/anterior abdominal wall surface index percent to correlate with the frequency of intraoperative events, when it is impossible to perform rectus abdominis approximation after separation hernia repair.

Clavien–Dindo classification was suggested to assess postoperative complications, it evaluating the severity of complications according to the treatment required [23]. The study by Kokotovic et al. [24] has revealed the correlation between the complication severity (Clavien–Dindo) and the 30 days readmission rate.

Perioperative prevention of hernia complications

The most common and dangerous complication in hernia surgery is SSI. The main SSI preventive technique is the preoperative administration of systemic antibiotics. Nevertheless, abstract database lacks the studies devoted to the technique efficiency assessment in patients with ventral IH. However, a great number of researches in inguinal hernia surgery haven't shown significant positive results when using antibacterial therapy [25, 26]. Moreover, systemic use of antibiotics is known to result in side effects, as well as contribute to the selection of resistant strains of microorganisms [27]. The experimental data [26] suggest the formation of biofilms on a wound, biofilms being a universal contamination mechanism. The mechanism can be realized on mesh implants as well. The key stage of surface infection is adhesion of microorganisms, which has nonspecific and specific phases and is highly sensitive to external factors. In this case, one of the alternatives of systemic antibiotic prevention in hernia repair can be local use of biocides by brief dipping of an implant in antibiotic or antiseptic solution before implant placing that will prevent both bacterial contamination of the implant and of the surrounding tissues [28, 29].

Preoperative mechanical preparation of the colon enjoys a high rate of enormous popularity among

practicing surgeons, the preparation is widely used in abdominal surgery including herniology. Proponents suppose its advantage to consist in colon decompression and infection risk reduction in case of colon wall damage in adhesiolysis [30]. However, currently, there is no reliable data on the method efficiency. In addition, the studies based on logistic regression of the treatment results in 3709 patients with anterior abdominal wall hernias have revealed the patients with preoperative mechanical preparation of the colon to be likely to develop wound infection within 30 days after surgery [31].

Preoperative high doses of glucocorticosteroids are considered to be another method to prevent postoperative infections [32]. The experiment showed glucocorticosteroids to reduce the activity of proinflammatory cytokines, such as IL-6, IL-1, and TNF-α [33], as well as have an antipyretic effect, increase glucose concentration and white blood cells. Beneficial effects of glucocorticosteroids were demonstrated in cardiosurgery, in open and laparoscopic abdominal operations, as well as in orthopedics [34–37]. Jensen et al. [38] were the first to prove high doses of glucocorticosteroids in anterior abdominal wall hernia repair as a part of fast-track protocol to reduce significantly hospitalization time, postoperative pain, nausea and vomiting intensity.

Currently, the technology based on botulinum toxin type A injected in lateral abdominal muscles is gaining widespread appreciation. The injections have a paralytic effect on abdominal wall muscles increasing the abdominal cavity volume that further enables to eliminate hernia defect tension-free and avoid developing intraabdominal hypertension [39]. The technique has become relevant in patients with large hernias and loss of domain (loss of domain is abdominal cavity volume loss due to the fact that the organs are constantly in hernia sac is determined when a hernia sac occupies over 25% abdominal cavity) [40]. Hernia repair in such patients is accompanied by postoperative intraabdominal hypertension and mortality in 5% cases [41]. Clinical studies [42, 43] when using botulinum toxin type A show a significant decrease in hernia transverse size that finally enables intraoperatively bring together hernia edges more closely reducing the tension of lateral abdominal muscles retaining their integrity. The major drawback of the technique is its high cost. Taking into account there are not so many reports for a large-scale implementation of the method into clinical practice, further studies are necessary.

One of the most dangerous IH complications is a venous thromboembolic event. According to Kim et al. and Pannucci et al. [44, 45], deep venous thrombosis rate in this patient group is 0.20–0.59% cases, while pulmonary embolism — 0.2–0.43% cases. According to Andriyashkin et al. [46], postoperative venous thromboembolic rate in IH patients, who underwent thromboembolic complication prevention according to Russian clinical guidelines [47], was 4.2% cases. This fact suggests that an essential condition of efficiency and safety of IH surgery is to perform the whole package of preventive measures, and the widespread use of postoperative ultrasound angioscanning of lower extremity vessels is an essential condition.

Mesh implants in hernia repair

Hernia repair using mesh implants is the standard for up-to-date IH surgery [48, 49]. Their wide implementation enabled to reduce hernia recurrence rate up to 2.7% and increase the postoperative life quality [50]. Currently, over 200 mesh implants are available, their quantity being growing every year. They are produced from various biomaterials (polypropylene, polyethylene terephthalate, polytetrafluoroethylene, polyvinylidene fluoride and others) finally creating a variety of their mechanical and rheological properties [51].

There are several implant classifications. Amid [52] distinguished 4 types based on biomaterial porosity: type I — macroporous (pore size is >75 μm); type II — microporous (pore size is <10 μm); type III — macroporous with multifilament or microporous components; type IV — biomaterials with submicrometer-size pores. In 2012 Klinge et al. [53] upgraded the presented classification: type I — macroporous implants (textile porosity is >60% implant area); type II — fine-porous (<60% implant area); type III — implants with specific properties (e.g., intrabdominal meshes with anti-adhesive covering); type IV— implants with films (porosity-free, with submicrometer pores or secondary cutout holes); type V— 3D meshes; type VI — biological prostheses.

Implant mesh size, as well as the amount of material needed for production directly related to its density (implant unit weight in grams per 1 m^2): heavy implants (unit weight — 90 g/m^2), medium density (50–90 g/m^2), light (35–50 g/m^2), and ultralight (less than 35 g/m^2) [51, 54].

Despite the advantages of mesh implants, their application in IH surgery has its disadvantages. SSI risk increases (SSI rate occasionally reaches 21.5% cases). Seromas, cellulitis, serous and purulent fistulas rank first, to a greater extent it depend on a mesh location [55].

Currently, world literature has no adequate definitions of a mesh implant location in anatomical layers of the anterior abdominal wall. EHS working group has proposed for consideration a uniform terminology and distinguished the following mesh positions: onlay, inlay, retromuscular, preperitoneal, intraperitoneal (intraperitoneal onlay mesh — IPOM) [56]. Onlay implies that a mesh implant is located in the subcutaneous fat, above the previously sutured hernia. The meta-analysis of the treatment results of 1948 IH patients showed the wound infection incidence after this method is significantly higher than after retromuscular repair [57]. It is due to a wide dissection of subcutaneous tissue

from aponeurosis that results in a long-term exudation due to impaired blood supply, venous and lymphatic outflow. Russian Society of Surgeons recommends using the technique, when it is impossible to perform retromuscular repair, as well as in difficulties in differentiating anatomical structures of the abdominal wall. In retromuscular repair an implant is located in the space between the sutured posterior leaves of the abdominal rectus muscle sheaths and the hernia orifice edges. The technique is reasonably to be used for lateral hernias, when a mesh is between the abdominal rectus muscle. Recurrences after this hernia repair type occur in 23% cases [57]. Russian Society of Surgeons recommends this technique as a basic approach in IH surgical treatment.

Inlay implies that an implant is beneath the hernia orifice edges, though the orifices are not sutured above the implant. The definition is appropriate for a term "bridge". Some studies [49, 58] have associated inlay with more risks of SSI and recurrent hernias than an onlay technique and retromuscular repair. IPOM is placed behind all abdominal wall layers including the parietal peritoneum.

Since the time when LeBlanc et al. described laparoscopic hernia repair [59, 60] there has been published a great number of randomized controlled studies, which revealed a significant decrease in wound complication and recurrence rate after laparoscopic techniques [61–64]. Goodney et al. in their meta-analysis [65] revealed wound infection rate in IPOM group to be equal to 14% cases, while in a group of open operations it equaled 27% cases. A mean hospitalization period in IPOM patients also was twice as little. Meta-analysis by Sauerland et al. [66] showed similar results. However, no significant difference in hernia recurrence rate was found in both groups [67]. All the studies represented above included both: primary hernias, and IH. In 2015 Awaiz et al. [2] based on the conducted meta-analysis concluded laparoscopic and open approaches in IH to be fully compatible, except intraoperative colon damage rate, which was significantly higher in laparoscopic technique.

Component separation technique

Currently, novel abdominal repair techniques are being introduced in practical herniology, the techniques being based on the separation of anatomical components. Anterior and posterior techniques are distinguished [68]. In 1990 Ramirez et al. [69] described a unique method of the anterior separation hernia repair, when the anterior abdominal wall muscles undergo mobilization and medialization to repair a hernia defect and restore the abdominal raphe. It enables to displace abdominal rectus muscle medially, placing them in their physiological position. On average, the recurrence rate after this surgery is 10–22% [70]. The main drawback of the anterior separation hernia repair is the necessity to separate large dermal-fat grafts that contributes to increase an infection risk in the surgical area up to 26–63% [71].

In order to reduce SSI incidence there have been suggested a mini-invasive modified technique, which was called periumbilical perforator sparing (PUPS). Though the recurrence rates after classical approaches of anterior separation and PUPS were not different, there was found a significant decrease of SSI risk. For example, in the study by Clarke [72] the incidence of skin necroses using classical approaches and PUPS was 25 and 0%, respectively. Similarly, Saulis and Dumanian et al. [73] represented the study findings showing that only 2% operated patients were found to have clinical manifestations of SSI. The long-term recurrence rate after PUPS was 13.8% [74]. Rives–Stoppa–Wantz approach is an anterior separation hernia repair technique, when the space between the abdominal rectus muscle and the posterior sheath wall is separated for 6–8 cm to place a mesh implant [75–78]. Considering brilliant results, in 2004, Americas Hernia Society recognized the technique to be a gold standard for open surgery of ventral hernias [79, 80]. However, despite all the advantages, the approach prohibits tissue dissection beyond the lateral border of the abdominal rectus muscle sheath that makes it inapplicable in surgeries of large hernia defects [76, 80].

A posterior separation approach combined with retromuscular repair was suggested by Carbonell et al. in 2008 [81]. The authors recommend a vertical dissection of the posterior leaf of the abdominal rectus muscle sheath followed by lateral tissue preparation between the transverse and internal oblique abdominal muscle. Further, the specified separation plane is used to place a large synthetic implant, which will be in a medial segment of the abdominal wall dorsal to the abdominal rectus muscle, and in a lateral segment — to the internal oblique abdominal muscles. The mesh edges are fixed to tissues using transaponeurotic sutures [68]. To prevent hernia recurrence, the anterior leaves of the rectus abdominis muscle sheath are sutures using a one-row continuous locking stitch. Subcutaneous tissue and skin are also sutures by continuous stitches of synthetic suture material in accordance with the existing concept of complex SSI prevention [82, 83].

In 2012 Novitsky et al. described posterior separation hernioplasty — TAR (transversus abdominis muscle release) [80]. Firstly, the technique enables to dissect tissues in a non-vascular area beneath the transversus abdominis that creates an ideal skin-outlying place for mesh implant location maintaining blood supply and innervations of the anterior abdominal wall. Secondly, the release of transversus abdominis makes the medialization of rectus abdominis possible to provide a complete reconstruction of the abdominal raphe and recover the anterior abdominal wall framework [74]. The recurrence rate for this method is less than 10%. Moreover, though SSI incidence is no different from that when using anterior separation repair, the severity

of postoperative complications after TAR is significantly lower [70, 80, 84–86].

Egiev et al. [87] assessed the life quality of patients after TAR. Using the questionnaires MOS SF-36 and EHS Quality of Life Score they revealed a significant increase of physical indices by 19.3% after 3 months, and by 19.8% after a year. According to the scales "Overall health" and "Social functionality", 3 months after repair there was observed a significant increase of the indices by 24.1 and 24.6%. No significant differences were found according to the indices "Emotional functioning" and "Psychological health". Ultimately, the life quality in a postoperative period was higher than before surgery, most changes being found within the period from 3 months to a year. The presence of severe comorbidities had no significant effect on indices dynamics in a long-term period.

Currently, in Russia, there are various expert opinions in relation to separation hernia repair techniques. It is due, firstly, to the lack of reliable multicentre studies with high argumentativeness, secondly, to the differences in operative techniques of separation hernia repair, a wide range of mesh implants used, different approaches to patients' management in a postoperative period.

Intraoperative techniques to prevent complication of postoperative hernias

Among intraoperative techniques to prevent postoperative seromas, the methods based on the use of tissue sealants in the form of fibrin glue, thrombin, platelet glue are noteworthy. These agents activate the last stage of a coagulation cascade, in particular, the transformation of fibrinogen into fibrin in the presence of calcium ions and thrombin. Fibrin sealants comprise human fibrinogen, as well as bovine or human thrombin derivative combined with physiological saline [88]. The major drawback of the method is a high cost of components. In addition, when using fibrin glue in a form of spray, pulmonary embolism can occur [89].

To prevent skin and subcutaneous tissue necrosis, it is necessary to identify and maintain the anterior abdominal wall vessels during the operation. It is of importance in patients with large hernias and obesity requiring wide tissue dissection, panniculectomy or separation hernioplasty resulting in an increased risk of wound infection complications [90].

To improve treatment results, there has been developed a technique for objective evaluation of tissue perfusion using intraoperative fluorescent angiography, which enables to reliably reveal tissue areas with decreased blood perfusion and predict dermal-fat graft necrosis in experiment [91]. Patel et al. [92] were the first to demonstrate the efficiency of the technique in patients after anterior abdominal wall reconstruction, and also compile a first manual for practical application. Colavita et al. [91] assessed fluorescent angiography sensitivity (about 100%) and specificity (90.9%) when making prognoses of postoperative complications in IH patients. Similar results were found when investigating skin flap necrosis after mastectomy in breast reconstructive surgeries [93]. The findings are promising. However, for large-scale implementation into surgical practice further researches in this field are needed.

Currently, tension-free hernioplasty is being frequently used in IH surgery, as it does not lead to postoperative intraabdominal pressure build-up, higher than the initial level. However, any hernia repair eliminates a hernia sac acting as an additional volume of the abdominal cavity. As a result, regardless of hernia repair technique, intraabdominal pressure consistently grows, as well as the risk of developing the following intraabdominal hypertension [94]. The case fatality in this syndrome is 42–68%, and if not treated — 100%. In this regard, needless to say, that the monitoring of intraabdominal pressure in IH patients is required [95].

Postoperative techniques to prevent postoperative hernia complications

Among the postoperative techniques to prevent IH complications, wearing an abdominal bandage is gaining popularity. However, reliable data on it efficiency are limited [96, 97]. Some authors subjectively believe that wearing a bandage does benefit just to relieve a postoperative pain providing comfort and improving breathing capacity. There was just a single study [98], which revealed that elastic bandage wearing improves postoperative lung capacity, and another study showed that bandage wearing reliably contributes to early activization after laparotomy [99]. We have found none studies assessing the method efficiency in relation to the effect it has on IH incidence and recurrence rate.

To standardize nursing and speed up a postoperative recovery, fast-track surgery is gaining popularity in various surgery fields enhancing recovery after surgery. It aims at easing metabolic, neuroendocrine and inflammatory stress responses of the body to an operative injury, and minimizing the risk of developing postoperative complications and hospital stay duration, as well as financial expenses. The key principles are optimal prevention and postoperative pain treatment, enhancement of intestine function recovery.

Currently, the information on using fast-track principles in IH surgery is represented in several articles only. The study by Majumder et al. [100] describes the following algorithm. Preoperatively, patients with obese are recommended to reduce body mass, and those with diabetes mellitus — to reduce glycosylated hemoglobin up to a value less than 8%. In addition, a patient should give up smoking at least a month before surgery. An obligatory step of preoperative preparation is the screening for obstructive sleep apnea and a carrier state of methicillin-resistent *S. aureus* (MRSA). Moreover, all patients have been prescribed energy beverages with arginine and omega 3 fatty acids. To prevent lower

extremity vein thrombosis, patients are administered 5000 units of unfractionated heparin subcutaneously every 8 h. Along with that, there has been used an intermittent pneumatic compression of lower limbs. Standard antibacterial prevention is started immediately before the first incision is made, and stopped 24 h after the surgery. MRSA carriers are additionally given a single dose of first-generation cephalosporin and vancomycin. Moreover, all patients are administered Alvimopan and gabapentin preoperatively. Intraoperatively, in order to reduce a postoperative pain syndrome after TAR, patients are given anesthesia of liposomal bupivacaine diluted to 200 ml (100 ml for each side) for transversus abdominis blockage. A routine nasointestinal intubation of the small intestine is not performed. Postoperative fluid intake is allowed from the first day, the volume being not more than 250 ml within 8 h, and from the second day — fluid volume is not limited. Meals can be started from the third postoperative day.

The use of the algorithm has demonstrated a reliable reduction of colon function recovery, hospital stay and the number of readmissions within 90 days after surgery [100]. Similar results were shown by Jensen et al. [38]. Moreover, the authors proved significant decrease of postoperative pain intensity, nausea, and fatigue based on visual scales. They demonstrated the tendency for postoperative complication rate and readmission rate increase. However, considering that the meta-analyses [36, 101] have shown reliable decrease in recurrence rate and no effect on readmission, the tendency can be considered as a mere coincidence.

Fast-track protocol principles are the next stage in general duty nursing evolution and can be an integral part of a complex nursing for patients after major abdominal wall surgeries.

Conclusion

The analysis of modern Russian and foreign literature data indicates that despite a variety of techniques and agents, currently, the search for an ideal method for prognosis and perioperative prevention of complications in incisional ventral hernia is being continued. The development and improvement of integral scales and classifications based on patient's state indices are proceeding. The efficiency of some preventive and treatment techniques in their variety is questionable, while no unified approaches to prevent complications have been developed. There is the necessity for further studies and development of novel types of mesh implants, the techniques to fix implants in the anterior abdominal wall tissue, as well as the improvement and development of new prognosis, preventive, diagnostic and treatment techniques for postoperative complications followed by developing a unified protocol to manage patients with incisional ventral hernias.

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