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FORECASTING AND PREVENTION OF SPIKE FORMATION IN ACUTE INTESTINAL OBSTRUCTION

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ABSTRACT: This article is dedicated to studying the mechanisms of adhesion formation in acute intestinal obstruction (AIO) and developing effective methods for their forecasting and prevention. The study involved a comprehensive analysis of clinical data from 300 patients, experimental work using anti-adhesion barrier materials, and molecular-biological research. Key risk factors for adhesion formation were identified, including the duration of surgery lasting more than 90 minutes, the presence of inflammatory diseases of the abdominal cavity, and the

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use of open surgical methods. The analysis of molecular markers such as CRP, IL-6, TGF-β, as well as genetic polymorphisms of COL1A1 and COL3A1, allowed for the identification of risk groups and the proposal of a personalized approach to prevention. The results showed that the use of anti-adhesion barrier materials based on hyaluronic acid reduced the incidence of adhesion formation from 62% to 18%. A comprehensive prevention algorithm was developed, including preoperative testing, minimizing surgical trauma, using modern materials, and implementing early rehabilitation programs. The introduction of this algorithm led to a reduction in the incidence of adhesions to 22%, a decrease in repeated hospitalizations to 10%, and a reduction in the average length of hospitalization from 14 to 9 days. The results confirm the effectiveness of the comprehensive approach and justify the need for its implementation in clinical practice to improve treatment outcomes and enhance the quality of life for patients

Keywords: acute intestinal obstruction, adhesion formation, prevention, anti-adhesion materials, molecular markers, laparoscopy, forecasting, early rehabilitation, genetic screening, inflammatory markers.

INTRODUCTION

Acute intestinal obstruction (AIO) is one of the most dangerous and complex surgical pathologies, requiring urgent intervention. Adhesion formation is the leading etiological factor, occurring in 60-70% of cases of chronic intestinal obstruction and complicating the postoperative period. According to the World Health Organization (WHO), more than 4 million people suffer from adhesive disease annually, and up to 70% of all cases of acute intestinal obstruction recurrence are caused by the adhesive process. In developed countries, the treatment of complications related to adhesions costs about 2 billion dollars annually, which indicates significant economic losses. An analysis of clinical data in Uzbekistan shows that, of more than 15,000 cases of abdominal surgery annually, 40% of patients develop adhesions, leading to chronic pain, impaired bowel function, and repeated hospitalizations. Particularly problematic are cases of AIO in the working population, which exacerbates the socio-economic consequences of the disease. Modern studies emphasize the need for early forecasting of adhesion risk, as this significantly reduces recurrence rates and improves patients' quality of life. The most promising preventive methods include the use of anti-adhesion barriers, minimally invasive surgical techniques, as well as comprehensive drug therapy aimed at reducing inflammatory processes. However, the implementation of these methods in clinical practice requires further scientific substantiation and testing. The relevance of this topic is determined not only by the high frequency of adhesion formation but also by the lack of universal preventive approaches, which creates a need for the development of innovative methods for forecasting and prevention. The aim of this study is to identify key risk factors, improve preventive methods, and implement new technologies aimed at reducing the frequency of adhesion formation in acute intestinal obstruction.

LITERATURE REVIEW

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In a number of fundamental and clinical studies by foreign scientists (Ellis H., Menzies D., Holmdahl E., diZerega G.S., Kamel R., and others), it has been shown that adhesion formation is a key factor in recurrent acute intestinal obstruction (AIO) in 60-70% of cases [1;2;3]. According to T. Parker et al. (USA), the treatment of adhesive complications costs about 2 billion dollars annually, and adhesions are responsible for 50-65% of repeated hospitalizations [4;5]. Wang et al. (China) note that the risk of adhesion formation is particularly high in patients with immune dysfunction and concomitant inflammatory diseases of the abdominal cavity [6]. In the studies by Menzies D. and Kamel R., the molecular-biological aspects of adhesion formation are highlighted: an increase in the levels of interleukin-6 (IL-6), tumor necrosis factor (TNF-α), and transforming growth factor-beta (TGF-β) contributes to the excessive production of fibroblasts and enhanced collagen formation [7;8]. Holmdahl E. and colleagues have proven that the use of anti-adhesion barrier systems (based on hyaluronic acid, carboxymethylcellulose, etc.) can reduce the frequency of adhesion formation by 30-40% [9;10]. In the works of Ellis H. and diZerega G.S., it is also noted that the preventive approach to adhesion formation, starting from the preoperative stage, is the most promising. According to researchers, comprehensive therapy (antibacterial, anti-inflammatory, immunostimulatory) and minimizing the trauma of the surgical intervention (using laparoscopic technologies) are decisive in preventing adhesion formation [11;12]. Modern foreign research (Parker T., Menzies D., Wang H., Kamel R.) actively implements a multimodal approach: combining early diagnosis (ultrasound, CT, MRI), the use of biomaterials (bio-barrier gels and films), as well as personalized treatment regimens based on the genetic profile of the patient [15;16]. According to their data, this approach reduces recurrent cases of AIO by almost two times and decreases the risk of postoperative complications by 25-35% [17].

In scientific publications by Russian researchers (Ivanov A.I., Petrov V.S., Sidenko N.V., Grigoryev M.P., and others), adhesion formation in acute intestinal obstruction is considered one of the main causes of mortality, which reaches 8-10% in some regions [18;19]. Petrov V.S. and colleagues note that, in patients with postoperative adhesions, the likelihood of reoperation within the first 3-5 years after the primary surgery increases to 40% [20]. Research by Ivanov A.I. indicates the leading role of systemic inflammatory responses (elevated levels of C-reactive protein, IL-1, IL-6) in the formation of dense adhesions, which may lead to severe forms of AIO [21]. Grigoryev M.P. emphasizes the importance of strictly adhering to surgical technique, using minimally invasive methods (laparoscopy), and proper postoperative rehabilitation to reduce recurrence rates [22]. In the works of Ukrainian authors (Kovalenko A.V., Maksymchuk P.A., Doroshenko N.M., and others), it is noted that the main risk factors for adhesion formation are repeated surgical interventions, a history of inflammatory diseases of the abdominal cavity, and delayed medical consultation [23]. According to Doroshenko N.M., the use of modern barrier technologies in planned surgeries reduces the risk of massive adhesion formation by 30% [9;19]. Moreover, new preventive methods are proposed, including carbotherapy, physiotherapeutic procedures, and antibacterial protection, which significantly impact the reduction of postoperative complications. Overall, studies in the CIS countries (Russia, Ukraine, Belarus, etc.) emphasize the need for a comprehensive approach to the prevention of adhesions: combining minimally invasive surgery, the use of anti-adhesion agents, early rehabilitation (fast-track surgery), and taking into account the individual characteristics of the patient allows for a

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significant reduction in the recurrence rates of AIO [5;10;13]. In Uzbekistan, the problem of adhesion formation in acute intestinal obstruction is given serious attention by researchers such as Saidov Z.A., Nazarov O.T., Norov B.K., Rakhmonov A.U., and others [1;6;16]. According to Saidov Z.A., more than 15,000 cases of emergency surgeries on abdominal organs are recorded annually in the republic, and in 40-45% of these cases, adhesions later form, leading to repeated patient visits [2;17]. In his work, Nazarov O.T. emphasizes the importance of early diagnosis of adhesions using ultrasound and tomography methods, as well as the use of laparoscopic control, which enables the timely identification and dissection of thin adhesions before the development of severe forms of AIO [7;18]. According to Norov B.K., this approach reduces the risk of repeated hospitalizations by 25-30% [9;20]. Rakhmonov A.U. and colleagues are studying local anti-adhesion drugs based on hyaluronic acid and chitosan, which are undergoing clinical trials at several national centers (Tashkent, Fergana, Jizzakh). Preliminary results indicate that the use of such barrier agents in combination with antibacterial and anti-inflammatory therapy significantly reduces the likelihood of extensive adhesion formation [14;21]. Special attention is given to the work of a group of scientists led by Saidov Z.A., studying genetic predispositions to adhesion formation. Preliminary data suggest increased expression of several genes associated with collagen formation (COL1A1, COL3A1) and inflammation (IL-6, TNF-α) in patients with frequent recurrences of AIO [12;22]. These studies provide the opportunity for the prospective development of a personalized approach to adhesion prevention, where genetic screening can be used to predict the risk of complications and adjust patient management strategies [15;23]. Thus, the analysis of scientific literature shows that the issue of adhesion formation in acute intestinal obstruction remains highly relevant worldwide. Researchers from abroad, the CIS, and Uzbekistan agree that effective prevention of AIO recurrences is impossible without a comprehensive and personalized approach: the use of modern minimally invasive surgical techniques, anti-adhesion barriers, immunomodulators, as well as careful pre- and postoperative management of patients, with mandatory consideration of their individual characteristics. All of this should be based on modern clinical and experimental data obtained through multicenter studies.

METHODOLOGY OF THE STUDY

The methodological approach to researching the problem of predicting and preventing adhesion formation in acute intestinal obstruction (AIO) is based on the comprehensive application of clinical, experimental, and analytical methods. The study was conducted at the specialized surgical department of the Tashkent State Medical Institute from 2020 to 2024, encompassing 300 patients diagnosed with acute intestinal obstruction. The primary focus was on developing an algorithm for predicting and preventing adhesions, based on clinical and laboratory data. The clinical part of the study included an analysis of medical histories of patients who underwent surgical treatment for acute intestinal obstruction (AIO), with a focus on identifying risk factors for adhesion formation, such as the type of surgical intervention, operation duration, presence of concomitant inflammatory diseases, and postoperative period characteristics. Adhesion processes were diagnosed using ultrasound methods, computed tomography, and laparoscopy. In the experimental part, laboratory animals (rats and rabbits) were used to model adhesion formation conditions. The application of various anti-adhesive barrier materials (hyaluronic acid,

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carboxymethylcellulose) allowed for assessing their effectiveness in reducing the risk of adhesion formation. Morphological evaluation of tissue samples included histological analysis of adhesion density and structure, as well as the study of cellular activity. Immunological and biochemical studies included determining levels of inflammation and adhesion formation markers, such as C-reactive protein, interleukin-6 (IL-6), tumor necrosis factor-alpha (TNF-α), and transforming growth factor-beta (TGF-β). The use of polymerase chain reaction (PCR) and enzyme-linked immunosorbent assay (ELISA) enabled molecular analysis of genetic predisposition to adhesions (COL1A1, COL3A1). For adhesion prevention, modern anti-adhesive barrier materials, minimally invasive surgical techniques, anti-inflammatory and antibacterial therapy were applied. Additionally, an early rehabilitation program was developed, including patient mobilization in the postoperative period, physiotherapeutic procedures, and nutritional support. Data analysis was carried out using statistical processing methods, including correlation analysis, multivariate regression analysis, and predictive modeling. This allowed for identifying key risk factors and assessing the effectiveness of the proposed preventive measures. All stages of the study were conducted in compliance with ethical standards approved by the local ethics committee.

RESEARCH RESULTS

As part of the study, a comprehensive analysis of clinical, immunological, biochemical, and experimental data was conducted, allowing for a deeper understanding of the mechanisms of adhesion formation in acute intestinal obstruction (AIO) and the justification of effective preventive measures. A total of 300 patients with a confirmed diagnosis of AIO who underwent surgical treatment in specialized surgical departments were included in the study. The results are grouped according to the main research directions.

Identification of Risk Factors for Adhesion Formation. An analysis of the medical histories of 300 patients revealed several factors that significantly increase the risk of adhesion formation. One of the most critical factors was the duration of surgical intervention: among patients whose surgery lasted more than 90 minutes, the incidence of adhesions reached 65%, whereas for shorter procedures, this rate was around 35% ($p < 0.001$). This result may be attributed to increased tissue trauma and a broader inflammatory response zone during prolonged surgeries. It was also established that a history of chronic inflammatory abdominal diseases (e.g., colitis, Crohn's disease, chronic appendicitis) significantly increases the risk of developing dense and extensive adhesions ($p < 0.01$). These conditions are associated with persistent inflammation, leading to elevated levels of pro-inflammatory cytokines and increased fibroblast activity. Another significant risk factor was the use of traditional open surgical techniques: 72% of these patients later developed pronounced adhesions. In contrast, among those operated on using laparoscopic techniques, only 34% developed significant adhesions ($p < 0.001$). This finding highlights the importance of minimizing surgical trauma and underscores the potential of minimally invasive procedures as a key element in adhesion prevention. Additionally, inflammatory markers in the blood, such as C-reactive protein (CRP) and interleukin-6 (IL-6), were of particular interest. Patients with CRP levels above 10 mg/L and IL-6 levels above 15 pg/mL were more likely to develop dense adhesions, complicating the postoperative period.

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Thus, heightened inflammatory activity may serve as a predictor of adverse outcomes, emphasizing the necessity of early diagnosis and targeted anti-inflammatory therapy.

Table 1. Risk Factors for Adhesion Formation

Risk Factor	Frequency (Patients)	p-value
Surgery duration > 90 minutes	65%	< 0,001
Inflammatory abdominal diseases	52%	< 0,01
Open surgery	72%	< 0,001
CRP level > 10 mg/L	67%	< 0,01
IL-6 level > 15 pg/mL	70%	< 0,001

Experimental Evaluation of the Effectiveness of Preventive Measures. Experimental studies were conducted on laboratory animals, simulating conditions similar to surgical practice in acute intestinal obstruction (AIO). The animals were divided into two groups: a control group (without the use of specialized barrier materials) and a main group, where hyaluronic acid-based membranes were applied. In the control group, the incidence of massive adhesion formation reached 62%, which aligns with literature data indicating a high tendency for adhesion formation following peritoneal trauma. In the experimental group, which received anti-adhesive materials, this rate decreased to 18% ($p < 0.001$). Histological analysis of tissue samples showed that the use of barrier films limited fibroblast migration and prevented excessive collagen deposition, significantly reducing the intensity of the adhesion process. Macroscopic evaluation also revealed a more "mild" and localized adhesion formation in animals treated with anti-adhesive films, whereas the control group exhibited multiple dense adhesions that impaired the functional state of intestinal loops. These findings indicate the potential of such materials in clinical practice to reduce the risk of postoperative complications.

Table 2. Effectiveness of Anti-Adhesive Materials

Group	Massive Adhesion Rate (%)	Inflammation Intensity (points)	p-value
Control group (no barrier material)	62%	7 ± 1,2	-
Hyaluronic acid-based membrane	18%	3 ± 0,8	< 0,001

The role of molecular markers in prognosis. One of the key findings of the study was the identification of the significance of molecular and genetic markers in adhesion formation. Polymerase chain reaction (PCR) methods revealed that patients with COL1A1 and COL3A1 gene polymorphisms had a higher predisposition to excessive collagen production and, consequently, the formation of dense adhesions. The presence of such genetic variations in

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structural protein genes indicated a hyperplastic nature of regeneration, leading to persistent tissue adhesion. Additionally, cytokine and growth factor levels were analyzed, with transforming growth factor-beta (TGF-β) being particularly significant. A TGF-β concentration above 50 ng/mL correlated with pronounced collagen formation ($r = 0.68$; $p < 0.001$). Thus, genetic screening combined with biochemical marker assessment may serve as a foundation for determining an individualized risk of adhesion formation. This approach could enable the selection of optimal preventive measures even before surgery.

Table 3. Molecular and Genetic Markers

Marker	Mean Level in Patients with Adhesions	Mean Level in Patients without Adhesions	p-value
CRP (мг/л)	15,2 ± 3,1	8,5 ± 2,2	< 0,01
IL-6 (пг/мл)	18,7 ± 4,0	10,3 ± 2,5	< 0,001
TGF-β (нг/мл)	55,4 ± 6,8	35,2 ± 5,4	< 0,001
COL1A1, COL3A1*	Polymorphisms in 28%	Polymorphisms in 11%	< 0,01

Development of a Prognostic and Preventive Algorithm. Based on the obtained data, an algorithm was proposed that includes several key steps: preoperative testing (measurement of CRP, IL-6, TNF-α, TGF-β levels and analysis for the presence of COL1A1 and COL3A1 polymorphisms), optimization of surgical tactics with a priority on laparoscopy, the use of anti-adhesive barrier materials, and an early rehabilitation program (patient activation, physiotherapy, rational antibiotic and immune correction therapy, and nutritional support). This approach allows for the individualization of therapeutic measures and ensures the timely identification of high-risk patients who require more intensive prevention.

Clinical Outcomes of Implementation. In a group of 150 patients who underwent the proposed algorithm, a significant reduction in adhesion formation was observed: the incidence of adhesions decreased from 48% to 22% ($p < 0.001$), the rate of recurrent hospitalizations due to recurrent acute intestinal obstruction (AIO) dropped from 34% to 10% ($p < 0.001$), and the average length of hospital stay was reduced from 14 ± 3 days to 9 ± 2 days ($p < 0.01$). Additionally, a follow-up was conducted for 6–12 months after discharge, during which no severe postoperative complications related to adhesion formation were recorded. According to the SF-36 scale, patients showed faster recovery of physical activity and a reduction in pain syndrome.

Table 4. Clinical Outcomes of Algorithm Implementation

Indicator	Before Implementation (n=150)	After Implementation (n=150)	p-value

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Adhesion formation rate (%)	48%	22%	< 0,001
Recurrent hospitalizations (AIO recurrence) (%)	34%	10%	< 0,001
Average length of hospital stay (days)	14 ± 3	9 ± 2	< 0,01
Severe complications (peritonitis, abscess) (%)	7%	3%	< 0,05

Socio-economic significance. Reducing the number of recurrences of acute intestinal obstruction (AIO) and shortening the duration of hospitalization have a direct impact on the economic efficiency of medical care. According to calculations based on a comparative cost analysis, the savings per patient amounted to approximately 25%. Overall, this leads to the optimization of material resource allocation and more rational use of hospital beds. Moreover, the reduction in repeat surgical interventions and the improvement of rehabilitation outcomes positively affect the overall socio-economic situation by increasing patient productivity and reducing the financial burden on the healthcare system.

Table 5. Costs and Economic Efficiency

Indicator	Before Algorithm Implementation	After Algorithm Implementation	Savings (%)
Average treatment cost per patient (USD)	3000	2250	25%
Repeat surgeries (% of total)	20%	8%	-
Total costs for a group of 150 patients (USD)	450 000	337 500	25%

DISCUSSION OF RESULTS

The results of the conducted study confirm the high significance of a comprehensive approach to predicting and preventing adhesions in acute intestinal obstruction (AIO). Compared to previously published works by foreign researchers (Ellis H., Menzies D., Kamel R.) and domestic scientists (Saidov Z.A., Nazarov O.T., Norov B.K.), the obtained data demonstrate new opportunities for a personalized approach to adhesion risk management. Risk Factor Analysis: The identified key risk factors, such as the duration of surgical intervention, the presence of inflammatory processes in the abdominal cavity, and the use of open surgical methods, are consistent with the findings of Holmdahl E. and Wang H. [1;2]. However, our study focused on

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molecular-biological markers, such as TGF-β levels and genetic predispositions (COL1A1, COL3A1), which expand predictive capabilities and open up prospects for the implementation of genetic screening in clinical practice. Effectiveness of Anti-Adhesion Materials Experimental data confirm the results of studies by diZerega G.S. and Holmdahl E., which also demonstrated a reduction in adhesion formation rates with the use of barrier materials [3;4]. However, our study additionally revealed a correlation between the effectiveness of these materials and the levels of inflammatory markers (CRP, IL-6), highlighting the necessity of comprehensive preoperative preparation to optimize outcomes. The inclusion of an early rehabilitation program (fast-track surgery) has proven effective in reducing recurrence rates and shortening hospitalization duration. These findings align with studies conducted by Parker T. et al. However, our study additionally confirmed the importance of integrating nutritional support and physiotherapy in the postoperative period [5;6]. The implementation of the proposed algorithm has significant economic importance, as evidenced by a 25% reduction in patient treatment costs. This finding aligns with studies conducted in CIS countries (Ivanov A.I., Petrov V.S.). However, the proposed approach incorporates additional measures, such as the use of molecular-biological markers and treatment individualization, which enhance its effectiveness [7;8]. Comparison with International Experience: Scientific data on the use of anti-adhesion barriers and minimally invasive techniques are widely represented in international literature. However, in the context of Uzbekistan, the developed algorithm has been adapted for the first time to local clinical and socio-economic conditions. This makes our study particularly relevant for resource-limited countries, where the rational use of new technologies is of key importance. Study Limitations: Despite the significant results obtained, our study has certain limitations. First, a longer observation period is required to assess long-term outcomes. Second, multicenter studies are needed to confirm the universality of the proposed algorithm. Third, the economic evaluation of the algorithm's implementation requires further analysis to account for long-term effects.

CONCLUSION

The conducted study has provided important scientific and practical data on the mechanisms of adhesion formation in acute intestinal obstruction (AIO) and has led to the development of effective approaches for their prediction and prevention. It was established that the key risk factors include surgical procedures lasting more than 90 minutes, chronic inflammatory processes in the abdominal cavity, and the use of traditional open surgical methods. Patients with elevated levels of C-reactive protein (CRP > 10 mg/L) and interleukin-6 (IL-6 > 15 pg/mL) were found to have a significantly higher risk of developing extensive adhesions. Experimental studies confirmed the high efficacy of anti-adhesion barrier materials. The use of hyaluronic acid and carboxymethylcellulose-based membranes reduced the incidence of extensive adhesions from 62% to 18%. These materials limit fibroblast migration, reduce inflammation intensity, and prevent excessive collagen deposition, demonstrating their strong preventive value. The analysis of molecular and genetic markers such as COL1A1, COL3A1, and TGF-β highlighted their significance in predicting adhesion risk. Genetic screening, combined with inflammatory marker assessment, allows for the identification of high-risk groups and the development of individualized prevention strategies. Based on the obtained data, a comprehensive prevention algorithm was developed and implemented. This algorithm includes preoperative testing,

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minimizing surgical trauma with a preference for minimally invasive methods, the use of anti-adhesion materials, and an early rehabilitation program. Its implementation reduced adhesion rates from 48% to 22% and hospital readmissions due to recurrent AIO from 34% to 10%. The average length of hospitalization decreased from 14 ± 3 days to 9 ± 2 days, indicating improved treatment and rehabilitation outcomes. The study results also demonstrate the significant socio-economic impact of the proposed approaches. A reduction in recurrence rates and shorter hospital stays led to a 25% decrease in treatment costs per patient, proving the economic feasibility of these measures. The integration of the developed algorithm not only improves patients' quality of life but also optimizes healthcare resource utilization. Thus, the study confirms the high effectiveness of a comprehensive approach to adhesion prediction and prevention in AIO. The application of modern anti-adhesion materials, molecular-biological markers, personalized strategies, and optimized rehabilitation programs significantly improves clinical outcomes, reduces the burden on the healthcare system, and enhances patients' quality of life. Further multicenter studies are recommended to confirm the long-term efficacy of these methods and adapt them for broader clinical application.

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