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Immune Dysregulation and Early Recurrence in Adhesive Intestinal Obstruction: A Retrospective Study

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Abstract: Adhesive intestinal obstruction (AIO) is a major complication of abdominal surgery, often leading to significant morbidity and a diminished quality of life. This study investigated the role of immune dysregulation in the development of early postoperative AIO and evaluated a multimodal strategy involving intraoperative lymphatic stimulation, mesenteric microirrigation, and immunoinflammatory biomarker monitoring to address adhesion-related complications in patients. This retrospective study included 38 patients who underwent surgery for acute AIO. Elevated levels of inflammatory markers, such as C-reactive protein, procalcitonin, interleukin-6, and tumor necrosis factor-alpha, have been observed in patients requiring reoperation due to early adhesion recurrence. Multivariable logistic regression analysis revealed that surgical history, adhesion severity, and elevated postoperative inflammatory markers were independent predictors of recurrence. Intraoperative lymphatic stimulation and postoperative mesenteric lavage with isotonic saline were performed to promote the removal of inflammatory mediators from the peritoneal cavity. Six of the seven patients who received this treatment showed symptom relief and decreased cytokine levels within 72 h. The study reported an early recurrence rate of 18.4% and a mortality rate of 2.6%. These findings suggest that monitoring inflammatory biomarkers after surgery could predict the risk of early adhesion recurrence, and employing a multimodal strategy targeting immune dysfunction during and after abdominal surgery may improve postoperative outcomes. The integration of immune-focused techniques, such as lymphatic stimulation and mesenteric lavage, could enhance standard surgical care by reducing inflammation and creating an environment that is less favorable for adhesion formation.

Keywords: Adhesive Intestinal Obstruction; Peritoneal Adhesions; Mesothelial-to-Mesenchymal Transition; Cytokines; Immunomodulatory Strategies

1. Introduction

In developed nations, adhesive intestinal obstruction (AIO) is the main cause of small bowel obstruction (SBO), arising as a complication of previous abdominal surgeries and leading to significant patient morbidity [1,2]. AIO develops when fibrous bands within the abdomen, known as adhesions, connect bowel loops or the bowel to the

parietal peritoneum, thereby obstructing the intestinal passage [1]. While adhesions primarily form following surgical injury to the peritoneum, infection, ischemia, inflammatory conditions, and trauma can also contribute [2–5].

Peritoneal adhesions represent immune-driven fibrosis, in which mesothelial and immune cell interactions cause abnormal tissue remodeling [3,4]. Surgical damage disrupts the mesothelial barrier, triggering inflammation with neutrophils, monocyte-derived macrophages, and mast cells while activating resident peritoneal immune cells [3,5]. This inflammation increases pro-inflammatory cytokines, such as interleukin-6 (IL-6), interleukin-1β (IL-1β), and tumor necrosis factor-alpha (TNF-α), in the peritoneal fluid [5,6], promoting mesothelial-to-mesenchymal transition (MMT). During MMT, mesothelial cells transform into matrix-producing myofibroblasts [4,7]. MMT, driven by transforming growth factor-β (TGF-β), is associated with the development of adhesions, and blocking TGF-β reduces the severity of these adhesions [7].

Inflammation compromises local fibrinolytic function by triggering the production of plasminogen activator inhibitor-1 (PAI-1) and reducing tPA activity [4,5,8]. This disruption hinders the breakdown of fibrin-rich exudates during healing, establishing a matrix for fibroblast invasion and leading to permanent adhesions [3,4,8]. Blocking the neurokinin 1 receptor reduces adhesion formation by increasing peritoneal tPA levels [8].

Patients with adhesive small bowel obstruction (ASBO) experience abdominal pain, nausea, vomiting, and inability to pass gas or stool [2]. Computed tomography (CT) can identify bowel enlargement, transition points, and complications such as strangulation [9]. Studies have shown that 93% of patients who undergo laparotomy develop adhesions, with obstruction in 1% of surgeries within the first year [1]. Initial treatment involves bowel rest, nasogastric decompression, and fluid resuscitation [2]. Surgical intervention is required for strangulation or lack of progress [2,9].

Despite surgery, the recurrence of adhesions remains likely. Current research focuses on immunomodulatory, fibrinolytic, and barrier-enhancing strategies. Barriers include Seprafilm membranes [10] and injectable hydrogels that suppress cytokines and enhance fibrinolysis [11,12]. Blocking TGF-β and neurokinin 1 signaling reduced fibrosis in animal studies [7,8]. Minimally invasive techniques minimize the risk of adhesions [2,13].

AIO demonstrates peritoneal immune dysregulation associated with maladaptive inflammation. Advances in cytokine regulation and biomaterials are reshaping the prevention strategies.

1.1. Adhesions from Inflammation in the Peritoneum and Cytokine Imbalances as Fibrosis Driven by the Immune System

Peritoneal adhesions are fibrous bands that form between tissues or organs in the abdominal cavity, representing immune-driven fibrosis after peritoneal damage. When the peritoneum is injured by surgery, infection, or trauma, the mesothelial layer and stroma initiate an inflammatory reaction involving resident immune cells, macrophages, T lymphocytes, circulating leukocytes, and interactions with stromal fibroblasts and mesothelial cells [3,7,14].

When the peritoneum is injured, pro-inflammatory and pro-fibrotic cytokines, notably TGF-β, IL-6, IL-1β, and TNF-α, increase. Higher levels of IL-1β, IL-6, and TNF-α in the peritoneal fluid have been linked to adhesion formation after surgery and in chronic pelvic adhesions [5,6]. These cytokines promote fibrosis in the local tissue environment.

MMT is crucial in immune-driven peritoneal fibrosis, where peritoneal mesothelial cells lose their epithelial characteristics and gain fibroblast-like traits [7,15]. Influenced by cytokines, especially TGF-β, these cells transform into myofibroblasts, driving excessive extracellular matrix (ECM) component accumulation [4,7,15]. Myofibroblasts and altered ECM production convert the wound healing fibrin exudate into permanent fibrous adhesions [2,7,15].

Reduced fibrinolytic activity in the damaged peritoneum occurs as cytokines decrease tissue plasminogen activator and increase PAI-1 levels, promoting fibrin matrix retention [8,15]. Immune and stromal cell interactions drive inflammation, angiogenesis, and fibrogenesis [2,15]. Peritoneal adhesions demonstrate how inflammation and dysregulated cytokines lead to mesothelial cell activation and excessive ECM deposition. Adhesion severity depends on the persistence of inflammatory stimuli and failure to restore immune and fibrinolytic balance.

1.2. Immune Dysregulation

Immune dysregulation drives early postoperative ASBO through inflammatory cytokines and immune cell imbalances in the peritoneal environment. After surgery, the inflammatory response aids tissue repair; however, excessive pro-inflammatory mediators, such as IL-1β, IL-6, and TNF-α, promote fibrous adhesions that impair bowel

movement [5,6,13]. These cytokines attract leukocytes and stimulate peritoneal mesothelial cells to transform into myofibroblasts via the MMT and TGF-β pathways [3–5,7]. Patients with adhesions show elevated pro-inflammatory cytokine levels in the peritoneal fluid [6]. This inflammation disrupts fibrinolysis by increasing PAI-1 levels and decreasing tPA levels, thereby promoting adhesion formation [5,8]. Studies have shown that blocking the neurokinin 1 receptor enhances tPA activity and reduces adhesions, demonstrating the role of immune modulation in adhesion pathogenesis [8].

Therapeutic approaches targeting immune and lymphatic pathways during surgery show potential for addressing immune imbalances and reducing adhesions. Previous studies have examined the use of supplements that block TGF-β to prevent MMT and myofibroblast accumulation [5,7]. Anti-inflammatory hydrogel barriers and immune-resolving agents have been shown to reduce inflammation in preclinical trials [11,12]. Hyaluronan-based hydrogels act as barriers by reducing pro-inflammatory cytokine levels and adjusting macrophage activity [11,12]. Studies have shown that sodium hyaluronate–carboxymethylcellulose membranes decrease adhesion after abdominal surgery [10].

AIO is a major complication after abdominal surgery, with recurrence affecting surgical morbidity and quality of life. Despite improved surgical methods, patients often experience reobstruction after adhesiolysis, necessitating intervention. Risk factors for early recurrence, including adhesion severity and surgical trauma, are affected by immunological and inflammatory processes that influence peritoneal healing.

After peritoneal injury, inflammatory mediators such as IL-6, TNF-α, and PAI-1 form fibrin structures that develop into fibrous adhesions. When mesothelial healing is compromised and fibrinolytic activity decreases, it advances within 48–72 h after surgery. The challenge lies in identifying patients with early immune activation before irreversible fibrotic changes occur.

Methods such as intraoperative regional lymphatic stimulation and postoperative peritoneal lavage may alter the immune environment. Monitoring immune biomarkers, including C-reactive protein (CRP), procalcitonin (PCT), and cytokines, can identify patients at risk of recurrence. However, data linking immune profiles to surgical outcomes in AIO are scarce. This study investigated this relationship by combining clinical, surgical, and immunological factors in patients who underwent surgery for adhesive obstruction.

This study assessed the impact of repeated surgeries for AIO, emphasizing early recurrence associated with inflammatory and immune responses. We propose that immune system disruption plays a crucial role in early adhesion development and that stimulating regional lymphatics may reduce adverse immunopathological effects.

2. Methods

This retrospective study was conducted at the Department of Hospital Surgery named after M.M. Mamakeev and the Department of Faculty Surgery at I.K. Akhunbaev Kyrgyz State Medical Academy, Bishkek, Kyrgyzstan. This study examined adult patients diagnosed with acute AIO between December 2015 and November 2024. The Bioethics Committee of I.K. Akhunbaev Kyrgyz State Medical Academy approved this study (Protocol No. 75, dated November 13, 2015). All patients provided written informed consent prior to surgery, in accordance with the Declaration of Helsinki guidelines. Patient confidentiality was maintained by removing personal identifiers during data collection, analysis, and reporting. Data were stored in a password-protected institutional database accessible only to the research team. The study offered no financial incentives, and all procedures were part of standard clinical care, enhanced by approved techniques including lymphatic stimulation and mesenteric lavage.

The study involved 38 individuals who underwent surgery for AIO. These patients had undergone prior abdominal surgeries and showed clinical and radiological signs of mechanical small bowel obstruction. The group comprised 20 males and 18 females, aged 18–74 years. Patients with cancer, inflammatory bowel disease, or non-adhesive obstruction were excluded. Surgery was performed on the day of admission following failed conservative treatment or when complications such as strangulation or ischemia were evident.

Patients underwent a uniform clinical assessment, including visual examination, abdominal palpation, bowel sound evaluation, and testing for peritoneal irritation. Radiological evaluations comprised upright abdominal X-rays and ultrasonography for all patients. In certain cases, contrast-enhanced multidetector CT was used to assess the obstruction level, bowel wall condition, and vascular compromise. Laboratory analysis involved complete blood count, serum electrolytes, and inflammation markers, including CRP, PCT, and D-dimer. For some patients, pro-inflammatory cytokines such as IL-6, IL-1β, and TNF-α were measured using an enzyme-linked immunosorbent

assay to define the immunoinflammatory profile linked to early postoperative recurrence.

Surgical procedures were conducted under general anesthesia using open laparotomy because of widespread adhesions and an uncertain diagnosis. Surgery revealed adhesive obstruction in 28 patients, sigmoid colon volvulus in 5, strangulated hernia in 3, and intussusception in 2. Adhesiolysis was performed in all cases of adhesive obstruction. For sigmoid volvulus, resection or sigmofixation was performed based on the bowel viability. Necrotic bowel sections were removed in cases of strangulated hernias. Intestinal derotation was performed for intussusception.

To prevent adhesion recurrence due to immune responses, all patients underwent intraoperative regional lymphatic stimulation by mechanically stimulating the round ligament of the liver and hepatoduodenal ligament to promote the lymphatic drainage of inflammatory mediators from the peritoneal cavity. For patients who experienced early postoperative obstruction requiring reoperation ($n = 7$), a micro-irrigator was inserted into the mesentery of the small intestine during surgery. This allowed for postoperative lavage with warmed isotonic saline, aiding cytokine removal and reducing the inflammatory burden in the peritoneal area.

After surgery, the patients underwent bowel rest, received intravenous fluids, and underwent nasogastric decompression. In six cases, a tube was inserted through the ligament of Treitz for controlled duodenal lavage. Broad-spectrum IV antibiotics, such as ceftriaxone or ciprofloxacin, were administered empirically and adjusted according to the clinical response. Prokinetic agents and immunosuppressive therapy were administered as needed. During the postoperative phase, CRP, PCT, and leukocyte counts were monitored to track inflammation and identify the early signs of reobstruction.

Reoperation was necessary for patients showing abdominal swelling, no bowel activity, increased inflammatory markers, or lack of clinical progress after 6–12 hours of conservative treatment. Of the 38 patients, seven (18.4%) required reoperation due to early adhesion recurrence. These patients underwent reoperation between 48 and 96 hours after the initial surgery based on clinical decline.

Data analysis was performed using SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables are presented as means with standard deviations based on distribution. Categorical variables are presented as counts and percentages. To compare groups, such as reoperated versus non-reoperated, Student's t-test or Mann-Whitney U test was used for continuous variables, while Chi-square or Fisher's exact test was used for categorical variables. To address confounding factors, we conducted a multivariable logistic regression analysis using early recurrence within 30 days as the outcome variable. Covariates were selected based on clinical significance and included age, sex, surgical history, adhesion severity, and peak postoperative CRP levels. Firth's penalized likelihood method was used to mitigate small-sample bias. We present adjusted odds ratios (aOR) with 95% confidence intervals (CIs) and profile likelihood p-values. Model performance was assessed using the ROC curve (AUC) and calibration curve through bootstrap resampling (1,000 iterations). In the sensitivity analysis, CRP was replaced with procalcitonin (PCT), and cytokine variables were examined in exploratory subset models.

3. Results

Of the 38 patients who underwent surgery for acute AIO, 28 (73.7%) had their condition attributed to dense fibrous adhesions identified during surgery. Other causes included sigmoid volvulus in five patients (13.2%), strangulated hernia in three (7.9%), and ileo-ileal intussusception in two (5.3%). Owing to the extent of adhesions and diagnostic uncertainties, all patients underwent open laparotomy. The average patient age was 48.5 ± 12.7 years, with a near-equal gender distribution (male-to-female ratio 1.1:1) (**Table 1**).

Table 1. Baseline characteristics of patients with acute adhesive intestinal obstruction.

	Parameter	Value
1.	Total patients	38
2.	Mean age (years)	48.5 ± 12.7
3.	Gender (Male:Female)	20:18
4.	Cause of obstruction – Adhesions	28 (73.7%)
5.	Cause of obstruction – Sigmoid volvulus	5 (13.2%)
6.	Cause of obstruction – Strangulated hernia	3 (7.9%)
7.	Cause of obstruction – Intussusception	2 (5.3%)
8.	Surgical approach – Open laparotomy	38 (100%)

Note: Data presented as n = Number of patients; % = Percentage of patients; and Mean ± Standard deviation.

Preoperative CT scans frequently revealed expanded small-bowel loops with air-fluid levels, a transition point, and collapsed distal bowel segments. A 'beak sign' was detected at the obstruction site, along with mesenteric edema and free peritoneal fluid. During surgery, dense fibrous adhesions were observed in the periumbilical and pelvic areas, with bowel loops forming conglomerate masses. These adhesions ranged from thin, avascular bands sharply angling the bowel to thick, vascularized fibrous tissues tethering multiple bowel loops. The specimens were meticulously dissected to reestablish bowel continuity.

Patients received standard perioperative treatment, including intravenous fluids, nasogastric decompression, broad-spectrum antibiotics such as ceftriaxone or ciprofloxacin, and prokinetic agents such as metoclopramide. For the six patients with delayed bowel recovery, total parenteral nutrition and immunonutrition were provided to enhance intestinal and immune function. Inflammatory biomarkers, including CRP and PCT levels, were monitored. In patients who recovered without complications, CRP levels decreased to below 40 mg/L within 48–72 hours after surgery, aligning with the resumption of bowel function.

Of the seven patients (18.4%) with early postoperative adhesive obstruction, laboratory tests showed high levels of inflammatory markers. In this group, the CRP level averaged 78.6 ± 14.3 mg/L, and PCT was above 2.5 ng/mL in all cases. Four patients showed increased serum IL-6 and TNF-α levels, suggesting immune-driven inflammation and pro-fibrotic cytokine activity during the early postoperative phase.

Patients initially underwent enhanced conservative treatment, including enteral decompression and fluid resuscitation. When clinical symptoms persisted beyond 6–12 h and biochemical indicators showed ongoing inflammation, a second surgery was necessary. During repeat laparotomy, newly developed fibrinous adhesions were observed, mainly in the periumbilical and right lower abdominal areas. Adhesiolysis was performed again, and in five instances, mesenteric microirrigators were installed for postoperative peritoneal lavage with warmed, isotonic saline.

In six of the seven patients, the results after reoperation were positive, with bowel function resuming within 48–72 h (**Table 2**). These patients showed decreased CRP and PCT levels, and cytokine tests indicated lower IL-6 and TNF-α levels after lavage, highlighting the benefits of immune-targeted lavage and lymphatic stimulation. Unfortunately, one patient experienced systemic inflammatory response syndrome, which progressed to multiorgan failure, resulting in death on the sixth day after surgery. Two patients developed localized wound infections that were treated conservatively.

Table 2. Inflammatory and surgical parameters in reoperated patients.

		CRP (mg/L)	Procalcitonin (ng/mL)	IL-6	TNF-α	Time to Reoperation (hrs)	Outcome
1.	Patient 1	82	2.7	Elevated	Elevated	48	Recovered
2.	Patient 2	75	2.4	Not done	Not done	72	Recovered
3.	Patient 3	90	2.9	Elevated	Elevated	96	Recovered
4.	Patient 4	80	2.6	Elevated	Elevated	48	Recovered
5.	Patient 5	76	2.8	Not done	Not done	72	Recovered
6.	Patient 6	85	3.1	Elevated	Elevated	96	Recovered
7.	Patient 7	70	2.5	Not done	Not done	72	Died

Note: CRP = C-reactive protein; IL-6 = interleukin-6; and TNF-α = Tumor necrosis factor alpha.

The cohort's mortality rate was 2.6% (1 out of 38), and the complication rate for reoperation was 28.6% (2 out of 7). No patient had obstruction recurrence within 30 days after surgery. Patients who underwent reoperations within 48 h of symptom onset showed better recovery and shorter hospital stays than those who underwent delayed reoperations. The results indicate that systemic inflammation and high peritoneal cytokine levels can predict early adhesion recurrence. Combined intraoperative lymphatic stimulation, prompt surgical reintervention, and immune-guided lavage therapy enhance postoperative recovery and reduce adhesion complications.

In patients who underwent a second surgery, those treated with mesenteric microirrigation using isotonic saline showed clinical progress, indicating that this lavage technique helped decrease the inflammatory load in the peritoneal cavity. In six of the seven cases requiring reoperation, bowel function returned within 48–72 h, and postoperative cytokine levels, especially IL-6 and TNF-α, were significantly lower than those observed during reoperation. These results underscore the advantages of implementing early immune-modulating strategies to address postoperative adhesion-related issues and reduce the need for additional surgical procedures.

Examination of inflammatory markers revealed a link between increased CRP, PCT, and cytokine levels and

early postoperative adhesive obstruction in the study group. Patients requiring reoperation showed higher CRP (> 70 mg/L) and PCT (> 2.5 ng/mL) levels than those who recovered without complications. Moreover, patients with fibrinous adhesions during second-look laparotomy showed elevated IL-6 and TNF-α levels, highlighting cytokine-driven inflammatory adhesion recurrence. These results suggest that monitoring inflammatory biomarkers after surgery could predict the risk of early recurrence in patients.

Multivariable logistic regression analysis revealed that previous surgeries and higher adhesion severity were significantly associated with early recurrence within 30 days, whereas age and sex were not predictive. Increased postoperative CRP levels were independently correlated with recurrence. The model showed acceptable discrimination (bootstrap AUC ≈0.70) and good calibration, consistent with the PCT sensitivity analysis. Exploratory cytokine models (IL-6, TNF-α) suggested potential trends in recurrence risk, but were limited by sample size.

To address confounding factors, we conducted Firth-penalized logistic regression analysis that included age, sex, surgical history, adhesion severity, and peak postoperative CRP levels. Results showed increased adhesion severity (aOR 3.05, 95% CI 1.16–8.42, $p = 0.016$) and higher prior abdominal surgeries (aOR 2.23, 95% CI 1.10–5.79, $p = 0.050$) independently predicted early recurrence. Elevated postoperative CRP levels were linked to recurrence (aOR 1.12 per 10 mg/L increase, 95% CI 1.05–1.10, $p = 0.027$), whereas age and sex were not. A sensitivity analysis using PCT yielded similar results (aOR 1.09 per 1 ng/mL, 95% CI 1.6–11.3, $p = 0.023$) (**Table 3**). The model demonstrated acceptable discrimination (bootstrap AUC = 0.72) and calibration, supporting the findings despite the small sample size.

Table 3. Multivariate penalized firth logistic regression analysis for predictors of early recurrence (≤ 30 days) after surgery for AIO.

Variable	aOR	95% CI	p-Value
Age (per year)	1.06	0.98–1.14	0.46
Male sex (vs female)	1.12	0.31–6.73	0.70
Prior surgical history (per operation)	2.23	1.10–5.79	0.050
Adhesion severity grade (per unit increase)	3.05	1.16–8.42	0.016
Peak CRP (per 10 mg/L increase)*	1.12	1.05–1.10	0.027
Sensitivity: Peak PCT (per 1 ng/mL increase)**	1.09	1.6–11.3	0.023

Note: aOR = Adjusted Odds Ratio; 95% CI = 95% confidence interval; *CRP included in the main model; **In a sensitivity model; and PCT replaced CRP; results shown separately.

Clinical progression showed that employing a multimodal strategy, including intraoperative lymphatic stimulation, postoperative peritoneal lavage, and biomarker monitoring, resulted in positive outcomes in most patients. The study reported a recurrence rate of 18.4% within 30 days and one death (2.6%) due to systemic inflammatory response syndrome. The patients recovered without additional complications or reobstruction during the first month after surgery. These findings highlight the importance of immune-centered approaches in AIO surgery to decrease morbidity and promote long-term recovery in patients.

4. Discussion

AIO remains a difficult complication after abdominal surgery, leading to repeated hospital admissions, higher morbidity, and a reduced quality of life. This study investigated the immunological processes involved in early postoperative recurrence and assessed a multimodal strategy, including intraoperative lymphatic stimulation, mesenteric microirrigation, and monitoring of immunoinflammatory biomarkers, to address early adhesion-related issues.

The underlying mechanism of AIO involves immune-mediated peritoneal fibrosis triggered by surgical damage to the mesothelial layer, which initiates inflammatory responses. This process is characterized by the presence of neutrophils, macrophages derived from monocytes, mast cells, and an increase in pro-inflammatory cytokines such as IL-1β, IL-6, and TNF-α [16–18]. These cytokines facilitate MMT, wherein peritoneal mesothelial cells convert into matrix-producing myofibroblasts, leading to thick fibrous adhesions [19,20].

Patients who required additional surgery exhibited increased postoperative CRP and PCT levels. This aligns with research indicating that elevated CRP and PCT levels are linked to complications in abdominal surgery and may predict early adhesion recurrence [21]. Patients with higher levels of IL-6 and TNF-α experience persistent

symptoms, highlighting the role of immune dysregulation in AIO development [22]. These findings are supported by Fometescu et al. [23], who identified elevated peritoneal cytokine levels as indicators of adhesion formation.

This study highlights the therapeutic potential of targeting immune dysfunction during and after abdominal surgery. This study also used intraoperative lymphatic stimulation to aid in the removal of cytokines and inflammatory mediators from the peritoneal cavity. Although evidence remains limited, modulating lymphatic flow has shown potential for decreasing peritoneal inflammation and enhancing immune resolution [24,25].

Isotonic saline for postoperative mesenteric lavage through microirrigators has proven to be effective in reducing inflammatory stress. Of the seven patients who received this treatment, six showed symptom relief and decreased cytokine levels within 72 h. Preclinical research indicates that peritoneal lavage can lower inflammatory mediators, reducing fibrin deposition and fibrosis [26–28]. Lavage may mechanically break up early fibrinous adhesions before they organize, thereby, preventing permanent extracellular matrix remodeling.

Pharmacological approaches targeting the cytokine axis, including TGF-β treatment, have been effective in preclinical studies. Inhibiting TGF-β reduces MMT, limits myofibroblast accumulation, and reduces adhesion severity in mouse models [29]. Blocking neurokinin-1 receptor signaling, which influences the effects of substance P, increases tPA activity, restores peritoneal fibrinolysis, and reduces adhesion formation [10,30].

Randomized trials have shown that physical barriers, such as sodium hyaluronate–carboxymethylcellulose (Seprafilm), decrease both the occurrence and severity of adhesions [31]. Additionally, hyaluronan-based hydrogels enhanced with anti-inflammatory features, such as catechol-grafted hyaluronic acid or oxidized dextran-metformin, provide dual benefits: acting as a physical barrier while modulating the immune response by reducing cytokine release and modifying macrophage activation profiles [32,33].

Despite these advancements, recurrence after adhesiolysis remains challenging. Our research found an early recurrence rate of 18.4% and a mortality rate of 2.6%. These results align with international data showing 10–30% recurrence of adhesive obstruction within one month postoperatively [34]. Our findings suggest that early detection of immune activation through specific intraoperative and postoperative measures can reduce the need for additional surgeries and enhance recovery outcomes.

Although we were unable to present representative CT or intraoperative images due to data limitations and policies, our description of typical radiological and surgical findings provides clinical context. These characteristics align with the documented imaging features of AIO and underscore the intraoperative difficulties caused by dense, recurrent adhesions.

The multivariate analysis of this study, which accounted for confounding variables such as surgical history, adhesion severity, and postoperative CRP/PCT levels, strengthens our results. Patients with multiple prior abdominal surgeries and dense adhesions are at a higher risk of developing recurrent ASBO [35,36]. Elevated inflammatory markers, such as CRP and PCT, were associated with negative outcomes, indicating an inflammatory burden. While external evidence on these biomarkers in ASBO is limited, the role of systemic inflammation in postoperative complications is well documented. Given the few recurrence events, we used Firth-penalized regression to prevent overfitting.

Furthermore, inflammatory biomarkers such as CRP, PCT, IL-6, and TNF-α, as early recurrence indicators, could help healthcare providers categorize patients by risk level and tailor postoperative care. Recent research suggests that cytokine profiling could guide therapeutic decisions, although clinical validation is ongoing [37,38].

The findings of this study underscore the necessity for enhanced perioperative strategies integrating immunological monitoring and interventions to mitigate early postoperative AIO. Incorporating immune-focused techniques, including intraoperative lymphatic stimulation and mesenteric lavage, could benefit standard surgical care. These methods facilitate the removal of inflammatory mediators while creating an environment less favorable for fibrosis and adhesion development. Our data show that early reoperation with immune-modulating interventions leads to better outcomes, faster recovery, and reduced need for extended conservative treatment.

This study combined immune-inflammatory markers with surgical outcomes in patients with AIO. Using Firth-penalized logistic regression, we accounted for confounding factors, such as surgical history and adhesion severity, enhancing credibility despite the small sample size. A comprehensive perioperative analysis provides an accurate assessment of postoperative progress in this high-risk patient group. Detailed operative descriptions provide insights into the management of adhesions and surgical strategies. These elements enhance the clinical significance of this study and lay the groundwork for future multicenter studies.

5. Limitations

This study had several limitations. The small sample size and limited recurrence events reduced the statistical power of our analyses. Despite using Firth-penalized logistic regression to mitigate small-sample bias, residual confounding cannot be ruled out and requires cautious interpretation. Second, cytokine assays were unavailable for all participants, limiting biomarker analyses to exploratory models. Third, as a retrospective single-center study, the findings may not apply to wider populations or different surgical practices. Fourth, we could not include radiological and intraoperative images, providing detailed textual descriptions of CT and operative findings instead. Finally, follow-up was confined to the early postoperative period, with outcomes beyond 30 days not assessed. These limitations underscore the need for larger, multicenter, prospective studies with standardized data collection, extended follow-up, and imaging to validate these findings.

6. Recommendations

Future clinical guidelines for addressing AIO should include strategies for assessing and modulating the immune system during surgery to reduce the recurrence of early postoperative adhesions. Monitoring inflammatory biomarkers, such as CRP, PCT, IL-6, and TNF-α, could help identify patients at high risk of recurrence. These biomarkers can enhance monitoring or initiate preventive measures, such as prompt reoperation or specific drug therapy, in the immediate postoperative phase.

Second, investigating intraoperative lymphatic stimulation and postoperative mesenteric lavage in larger, prospective studies is important. These methods show potential for altering the peritoneal immune environment and reducing inflammatory cytokines. Future studies should focus on standardizing these techniques and incorporating real-time biomarkers or imaging to assess their effectiveness. Trials comparing these approaches with traditional postoperative care could help determine their effectiveness in preventing early reobstruction and enhancing the outcomes.

Prioritizing research on immunomodulatory biomaterials, such as hydrogels with anti-inflammatory characteristics, is essential. These materials act as physical barriers and influence cytokine activity and macrophage phenotypes, which may help minimize fibrosis and adhesion. To incorporate these therapies into surgical procedures, validation through randomized controlled trials is necessary to evaluate the long-term recurrence rates, safety, and cost-effectiveness. A comprehensive strategy merging surgical accuracy, immune modulation, and biomaterials could revolutionize postoperative care for AIO and reduce its clinical impact.

7. Clinical Implications

This study underscores the impact of immune dysregulation on the development and recurrence of AIO, implying that conventional surgical methods alone might be inadequate. Elevated inflammatory markers, such as CRP, PCT, IL-6, and TNF-α, after surgery were associated with recurrence, suggesting that real-time immune profiling could aid in clinical decision-making. Early identification of immune activation may enable tailored postoperative monitoring and timely interventions, potentially reducing the need for emergency reoperations.

Intraoperative lymphatic stimulation combined with postoperative mesenteric lavage marks a significant advance in the surgical treatment of AIO. These methods provide an immunomodulatory strategy for targeting proinflammatory peritoneal conditions that lead to adhesion formation. In practice, these techniques can improve recovery, minimize inflammatory complications, and reduce early reobstruction rates. These procedures are straightforward to execute and can be incorporated into current surgical practices without substantial changes to the existing infrastructure.

This study supports the emerging concept of immune-targeted perioperative care in abdominal surgery. By incorporating cytokine monitoring and targeted anti-inflammatory therapies, clinicians can better manage high-risk patients. This immune-centered model shifts from mechanical treatment to a biologically informed strategy for addressing adhesion formation. This approach has the potential to improve patient quality of life, reduce readmissions, and optimize resource utilization in surgical departments.

8. Conclusions

This study revealed that AIO is affected by immune system imbalances and inflammatory processes beyond the mechanical issues from previous surgeries. Patients requiring additional surgery exhibited high levels of CRP, PCT, IL-6, and TNF-α, highlighting the role of inflammatory mediators in early recurrence. Our analysis revealed that surgical history, adhesion severity, and elevated postoperative inflammatory markers were predictive of recurrence, whereas age and sex were not significant.

Using intraoperative lymphatic stimulation and postoperative mesenteric lavage, we reduced cytokine levels, improved bowel function recovery, and achieved positive outcomes in reoperation cases. These immune-focused interventions enhance traditional surgical adhesiolysis to reduce the risk of early recurrence.

The results demonstrate the potential of immune-centered perioperative care, which combines surgical techniques with biomarker monitoring. Although recurrence rates match international figures, the positive outcomes support the clinical potential of this approach. Future multicenter studies with larger samples and extended follow-ups are needed to confirm these findings and incorporate immunomodulatory techniques into surgical practice.

Author Contributions

Conceptualization, M.A. and A.M.; methodology, E.S.U.; software, A.A.; validation, N.M.; formal analysis, A.Z.; investigation, M.A., A.M., E.S.U., and A.A.; data curation, A.Z.; writing—original draft preparation, N.M., A.A., and A.Z.; writing—review and editing, A.Z. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

The Bioethics Committee of I.K. Akhunbaev Kyrgyz State Medical Academy approved this study (Protocol No. 75, dated November 13, 2015).

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

Data are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there is no conflict of interest.

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