

The Mechanism and Prevention Strategies of Postoperative Intestinal Adhesion and Infectious Complications in Patients with Acute Appendicitis

Wendong Luo^{1,2}, Ong Swee Leong¹, Haniif Ahmad Mazian³, Hasmali Mohamad^{1*}, Harmy Mohamef Yusoff¹, Tiejun He²

¹ Faculty of Medicine, Universiti Sultan Zainal Abidin, Terengganu, Malaysia.

² The Third Affiliated Hospital of Jinzhou Medical University, China.

³ KPJ Sri Manjung Specialist Hospital, Perak, Malaysia.

ABSTRACT

Following appendectomy invasive complications such as adhesions and infections persist as crucial medical problems. Examining both the frequency and influencing elements plus patient outcomes of these medical issues creates guidelines for effective management solutions. A follow-up period of one year after surgery was implemented for 125 patients who underwent appendectomy procedures between January and December 2023 within this prospective observational study. Researchers used univariate statistical methods to evaluate the incidence of adhesion formation and influential risk factors such as patient attributes and surgical techniques combined with infection rates. Adhesions formed after surgery impacted 20 patients (16.0%), resulting in adhesive bowel obstruction for 6 patients (4.8%) while another 14 patients (11.2%) had non-specific signs on imaging postoperatively. Research found patients who developed adhesions possessed considerably elevated neutrophil-to-lymphocyte ratios (NLR) while surgical procedures for these patients were more frequently carried out as open surgeries compared to patients without adhesions showing statistical significance ($p < 0.05$). While SSIs showed a rise from 12 at the 30-day mark to 17 cases after 12 months the numbers of intra-abdominal abscesses remained constant at 7 cases and stable at 3 cases for sepsis. Laparoscopic surgery first-line approaches together with inflammatory marker-based risk assessment and enhanced existing postoperative procedures lead to better treatment results by lowering complication rates in appendicitis cases.

Keywords: Appendectomy, Postoperative Adhesions, Surgical Site Infections, Inflammatory Markers, Laparoscopic Surgery.

INTRODUCTION

Acute appendicitis serves as a worldwide emergency condition by affecting 7–8% of people during their lives according to Harriott and Sadava [1]. The affliction emerges when the vermiform appendix becomes inflamed followed by obstruction thus requiring most patients to undergo an appendectomy for treatment. Appendectomy stands as an operation with established safety but intestinal adhesions alongside infectious complications continue to be major operating room concerns that create extensive patient pathology and health system costs [2]. Complications from complicated appendicitis require improved surgical approaches combined with postoperative cares to achieve better patient results. Abdominal surgery frequently results in postoperative intestinal adhesions through the formation of fibrous bands between abdominal organs or tissues. The development of these postoperative tissue bands may cause problems including small bowel obstruction in addition to abnormal pain sensitivity and reproductive difficulties mostly affecting women's health [3]. Evaluation of peritoneal trauma leads to fibrin deposition and fibroblast proliferation as the body suppresses fibrinolysis while inflammatory processes worsen these effects. Planned surgical interventions require scientific instruments to detect which patients face the highest risk of tissue adhesion formation according to recent research findings. A group led by Liu, et al. [4] developed a predictive nomogram from clinical and intraoperative markers to determine whether patients facing adhesion risk in children meet specified criteria for sensitivity and specificity assessment. The validation of these tools throughout different populations presents an ongoing challenge. The

postoperative management of appendicitis requires careful attention to reduce infectious complications which can develop into surgical site infections (SSIs) and intra-abdominal abscesses (IAAs) and sepsis [5]. Observational studies show that the preoperative neutrophil-to-lymphocyte ratio (NLR) can identify patients at risk of postoperative complications by demonstrating an odds ratio of 4.2 among patients with values greater than 11.3 according to Mori, et al. [6]. Gangrenous or perforated appendicitis presents high infection rates of 30% among pediatric patients according to Aravind, et al. [7]. Timely hospital stays combined with intraoperative drainage result in elevated postoperative complication frequencies according to Degrate, et al. [8]. Research demonstrates the requirement for proven strategies which combat complications during health care treatments. For early management, do Vale Fonseca, et al. [9] have demonstrated that late treatment will lead to peritonitis and sepsis between other serious effects. Analysis from de Wijkerslooth, et al. [10] examined traditional extended antibiotic postoperative practices and began championing risk profile-dependent tailored prescriptions instead. Progress has been made in preventing postoperative complications from appendicitis but scientific knowledge still lacks optimal prevention approaches. Research on postoperative complications in appendicitis faces substantial limitations because it examines exclusively paediatric patients or single institutional cohorts without performing independent validations of predictive models [4, 7]. The effectiveness of laparoscopic appendectomy as minimally invasive surgery shows potential results in lowering adhesions alongside infections but needs

additional research to determine its effect on high-risk patients with perforated appendicitis [2].

Objectives

After appendectomy patients continue to face substantial postoperative complications which include the formation of scar tissue and infectious complications. The objective of this research is to analyse postoperative complexities after appendectomy and their contributing variables alongside outcome assessment to develop specialized care plans.

Methods

Study Design

This single-centre, prospective observational cohort study was designed to enrol patients treated for acute appendicitis over a 12-month period (January 2023 to December 2023). Patients were followed for one year postoperatively, with scheduled follow-up visits at 30 days, 90 days, 6 months, and 12 months (from January 2024 to December 2024) to capture both early and late postoperative outcomes, particularly focusing on intestinal adhesions and infectious complications.

Setting and Population

Setting

This study was conducted in the General Surgery Department of China Southwest Medical University, a tertiary care referral centre. The enrolment period lasted from January 1, 2023, to December 31, 2023, during which patients with acute appendicitis were prospectively observed and managed according to standard clinical protocols.

Patient Enrolment

A total of 125 patients who presented with acute appendicitis were recruited consecutively. Acute appendicitis was primarily diagnosed using a combination of clinical evaluation, the Alvarado score (or Modified Alvarado Score) as an established diagnostic scale, and imaging findings (ultrasound or CT scan). All participants underwent surgical intervention (laparoscopic or open appendectomy) within the aforementioned timeframe.

Inclusion Criteria

1. Age ≥ 18 years
2. Diagnosis of Acute Appendicitis
 - Alvarado score ≥ 7
 - Confirmatory imaging (ultrasound or CT) demonstrating an inflamed appendix.
3. ASA (American Society of Anaesthesiologists) Physical Status Classification I–III
4. Provision of Written Informed Consent

Exclusion Criteria

1. Patients who received conservative treatment (e.g., antibiotics alone) for appendicitis were excluded to maintain a uniform surgical cohort.
2. Individuals with a history of major abdominal procedures (apart from minimally invasive interventions) were excluded to minimize confounding factors affecting adhesion formation.

3. Severe Comorbidities (ASA IV or Higher) of patients with life-threatening systemic disease or those deemed too high-risk for standard surgery were not included.

4. Those who could not complete the required postoperative follow-up schedule (30 days, 90 days, 6 months, 12 months) or whose records were insufficient for analysis were excluded.

5. Cases with concurrent inflammatory bowel disease, pregnancy, or immunocompromised status (e.g., advanced HIV, post-transplant) were excluded to maintain a more homogenous study population.

Ethical Considerations

This study was approved by the Institutional Review Board (IRB) of China Southwest Medical University (No. APP-CYN-981). Written informed consent was obtained from all participants. Patient privacy and confidentiality were maintained in accordance with local data protection regulations, with all data anonymised for analysis and publication purposes.

Data Collection

Data were collected prospectively to ensure consistency and reliability. Preoperatively, basic demographic information such as age, sex, and body mass index (BMI) was recorded in each patient's chart. Clinical presentation details, including the duration of symptoms, past medical history of comorbid conditions, and vital signs upon admission, were also obtained. Laboratory investigations comprised a complete blood count (CBC), from which the neutrophil-to-lymphocyte ratio was calculated, and additional inflammatory markers such as C-reactive protein (CRP).

Imaging studies included ultrasound and, where necessary, computed tomography (CT) scans that specifically assessed for signs of an inflamed appendix, peri-appendiceal fluid collections, or other features indicative of acute appendicitis. During the intraoperative phase, data collection focused on the surgical technique used—whether the appendix was removed via an open or laparoscopic approach—as well as operative findings such as the presence of perforation, localized or generalized abscess formation, and the degree of peritoneal contamination. The operative duration was recorded from the first surgical incision to the final skin closure. If any anti-adhesion barrier or specific forms of peritoneal irrigation were applied, these were documented alongside the utilization of abdominal drains and the choice of antibiotic regimens administered intraoperatively.

Postoperatively, the primary measures included the length of each patient's hospital stay, details of antibiotic use (type, dose, and duration), and analgesic requirements. All complications were systematically tracked and classified into infectious complications—such as surgical site infections (SSIs), intra-abdominal abscesses, and sepsis—or non-infectious events, including paralytic ileus or stump appendicitis. Follow-up visits occurred at 30 days, 90 days, 6 months, and 12 months, during which patients underwent physical examinations and, when clinically indicated, repeat ultrasound or CT scans to evaluate for abscesses, adhesions, or other abnormalities. Patient-reported outcomes on pain levels and gastrointestinal symptoms were noted, and any readmissions or additional surgeries, particularly for adhesion-related bowel obstruction, were recorded to capture the full spectrum of postoperative events.

MEASURES AND OUTCOMES

The primary outcomes were the incidences of postoperative adhesions assessed over a 12-month period, as well as the incidence of postoperative infectious complications, including surgical site infections (SSIs) and abscesses, monitored within 30 days postoperatively and extending up to 12 months. These measures allowed for both early detection of acute infectious events and long-term evaluation of adhesions that could develop several months after surgery.

Secondary outcomes focused on identifying specific risk factors—such as an elevated neutrophil-to-lymphocyte ratio, the operative technique employed, and prolonged operative duration—that were associated with adhesive or infectious complications. Researchers documented the hospital discharge timeframe together with readmission frequencies and patient deaths observed during both 30-day and 90-day periods after surgery to evaluate complete patient recovery patterns. Postoperative wellness assessments based upon

health-related quality of life and patient satisfaction were archived when relevant to provide extensive information about recovery.

Statistical Analysis

Statistical computations were conducted through R version 4.4.2 (Posit Software, USA). Descriptive statistics included means ($\pm$ SD) or medians (IQR) for continuous variables, alongside frequency distributions for categorical variables. Inferences were made through univariate tests, Chi-square for categorical outcomes, and *t*-test for continuous data, a *p*-value < 0.05 was considered statistically significant.

Results

The mean age of the cohort was 38.5 ± 14.2 years, with a nearly balanced distribution of males (56.0%) and females (44.0%). The majority underwent laparoscopic appendectomy (68.0%), and imaging was primarily conducted using CT (48.0%), ultrasound (44.0%), or both (8.0%). Further baseline demographic and clinical characteristics are detailed in Table 1.

Table 1: Baseline Demographic and Clinical Characteristics

Variable	Value
Age (years)	38.5 ± 14.2
Sex, n (%)	Male: 70 (56.0), Female: 55 (44.0)
Body Mass Index (kg/m ²)	24.6 ± 3.9
Duration of Symptoms (hours)	31.8 ± 10.9
Comorbidities, n (%)	Hypertension: 20 (16.0), Diabetes: 8 (6.4)
White Blood Cell Count ($\times 10^9/L$)	11.4 ± 3.1
C-Reactive Protein (mg/L)	39.2 ± 23.5
Neutrophil-to-Lymphocyte Ratio (NLR)	7.1 ± 4.0
Alvarado Score	8.2 ± 1.7
Imaging Modality, n (%)	Ultrasound Only: 55 (44.0); CT Only: 60 (48.0) Both: 10 (8.0)
ASA Classification (I–III), n (%)	I: 55 (44.0), II: 50 (40.0), III: 20 (16.0)
Surgical Approach, n (%)	Laparoscopic: 85 (68.0), Open: 40 (32.0)

Note: Values presented as mean $\pm$ SD or n (%). ASA = American Society of Anaesthesiologists.

Postoperative adhesions were observed in 20 out of 125 patients (16.0%), with adhesive bowel obstruction occurring in 6 patients

(4.8%). Additionally, incidental findings of adhesions on imaging were reported in 14 patients (11.2%).

Table 2: Univariate Analysis for Risk Factors Associated with Adhesions

Variable	Adhesions (n=20) M $\pm$ SD	No Adhesions (n=105) M $\pm$ SD	T / χ^2 (Df)	95% CI	P-value	Effect Size
Age (years)	39.6 ± 15.1	38.2 ± 14.1	$t = 0.40$ (df=123)	−4.6 to 7.4	0.690	$d = 0.10$
BMI (kg/m ²)	25.7 ± 3.5	24.3 ± 3.9	$t = 1.66$ (df=123)	−0.2 to 3.0	0.100	$d = 0.37$
NLR	9.1 ± 4.2	6.7 ± 3.6	$t = 2.53$ (df=123)	0.5 to 4.3	0.013*	$d = 0.58$
Alvarado Score	8.4 ± 1.9	8.2 ± 1.6	$t = 0.47$ (df=123)	−0.5 to 0.9	0.640	$d = 0.11$
Open Surgery, n (%)	12 (60.0)	28 (26.7)	$\chi^2 = 8.20$ (df=1)	—	0.004*	$\phi = 0.26$
ASA Class III, n (%)	5 (25.0)	15 (14.3)	$\chi^2 = 1.67$ (df=1)	—	0.196	$\phi = 0.12$

Note: *Significant at $p < 0.05$. Effect Sizes: Cohen's *d* for Continuous Variables, Phi (ϕ) for Categorical Variables.

Patients with adhesions had significantly higher neutrophil-to-lymphocyte ratios (NLR; 9.1 ± 4.2 vs. 6.7 ± 3.6 , $p = 0.013$, $d = 0.58$) and were more likely to undergo open surgery (60.0% vs. 26.7%, $p = 0.004$, $\phi = 0.26$). Other variables, including age, BMI, Alvarado score,

and ASA Class III status, showed no statistically significant differences between groups.

Detailed results are presented in Table 2, while visual comparisons are provided in Figures 1, 2, and 3.

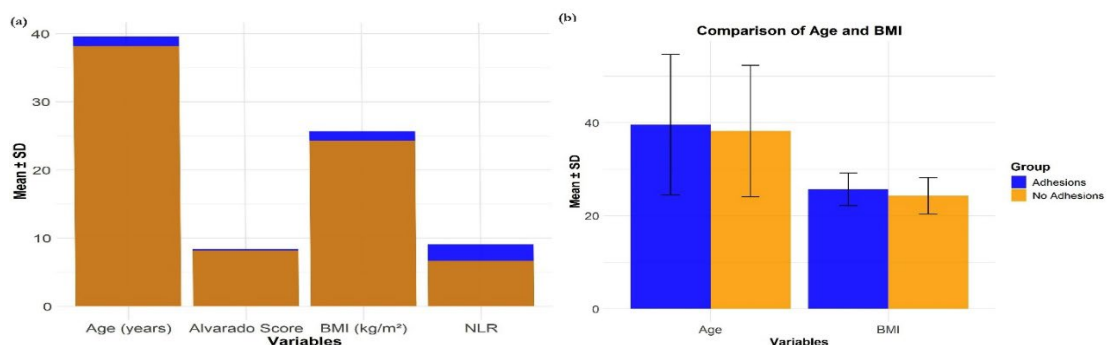


Figure 1: (a) Comparison of Mean Age, Alvarado Score, BMI, and NLR between Patients with and Without Adhesions; (b) Mean Age and BMI With Error Bars Representing Standard Deviation Stratified by Adhesion Status.

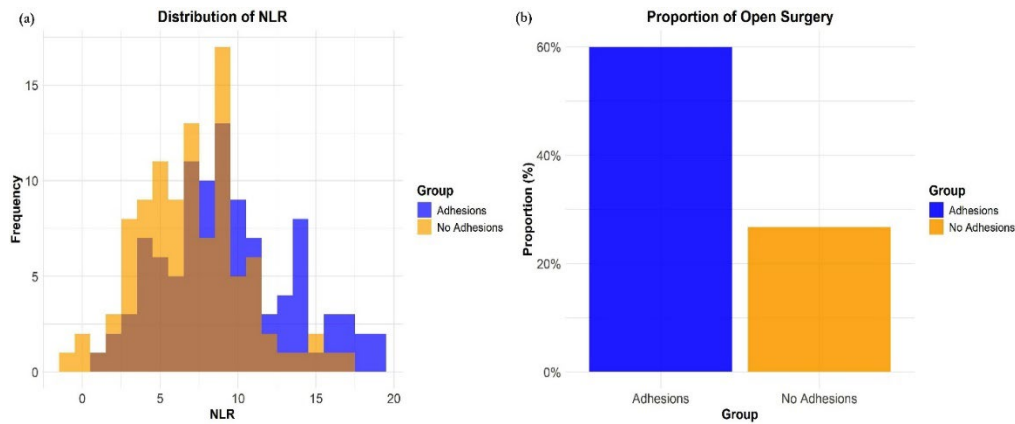


FIGURE 2: (A) Distribution of Neutrophil-To-Lymphocyte Ratio (NLR) Among Patients with and Without Adhesions; (B) Proportion of Patients Undergoing Open Surgery Stratified by Adhesion Status.

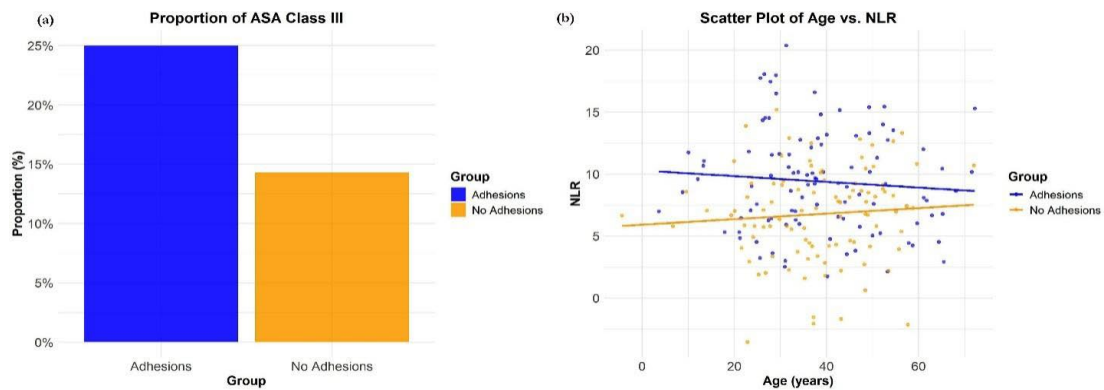


FIGURE 3: (A) Proportion of ASA Class III Patients Stratified by Adhesion Status; (B) Scatter Plot Showing the Relationship Between Age And NLR, With Separate Regression Lines for Patients with and Without Adhesions.

TABLE 3: Univariate Analysis of SSIs at 30 Days, 90 Days, 6 Months, and 12 Months

Variable	SSIs 30 Days (n=17 vs. 108)	SSIs 90 Days (n=12 vs. 113)	SSIs 6 Months (n=9 vs. 116)	SSIs 12 Months (n=7 vs. 118)
Nlr (M ± Sd)	10.3 ± 4.3 vs. 7.2 ± 3.8	10.2 ± 4.2 vs. 7.1 ± 3.8	10.1 ± 4.2 vs. 7.0 ± 3.7	9.8 ± 4.0 vs. 6.8 ± 3.8
T (Df)	t = 3.24 (df=123), p = 0.001*, d = 0.76	t = 3.14 (df=123), p = 0.002*, d = 0.74	t = 3.04 (df=123), p = 0.003*, d = 0.72	t = 2.70 (df=123), p = 0.008*, d = 0.65
Perforation, N (%)	11 (64.7) vs. 22 (20.4)	10 (62.5) vs. 23 (21.1)	10 (66.7) vs. 23 (20.9)	8 (66.7) vs. 25 (22.1)
X ² (Df)	χ ² = 14.27 (df=1), p < 0.001*, φ = 0.34	χ ² = 13.14 (df=1), p < 0.001*, φ = 0.32	χ ² = 15.41 (df=1), p < 0.001*, φ = 0.35	χ ² = 13.27 (df=1), p < 0.001*, φ = 0.33
Drain Placement, N (%)	9 (52.9) vs. 12 (11.1)	9 (56.3) vs. 12 (11.0)	9 (60.0) vs. 12 (10.9)	7 (58.3) vs. 14 (12.4)
X ² (Df)	χ ² = 17.83 (df=1), p < 0.001*, φ = 0.38	χ ² = 19.07 (df=1), p < 0.001*, φ = 0.39	χ ² = 22.11 (df=1), p < 0.001*, φ = 0.42	χ ² = 17.63 (df=1), p < 0.001*, φ = 0.38

Note: *Significant at p < 0.05. NLR = Neutrophil-to-Lymphocyte Ratio.

Patients with SSIs at all time points had significantly higher neutrophil-to-lymphocyte ratios (NLR) and were more likely to have undergone perforation or drain placement to those without SSIs. Detailed statistical comparisons, including effect sizes and significance levels, are presented in Table 3. The incidence of surgical

site infections (SSIs) increased steadily from 30 days (n=12) to 12 months (n=17), while intra-abdominal abscesses remained stable after 90 days (n=7). Similarly, the incidence of sepsis remained consistently low beyond 30 days (n=3). Trends and proportions across time points are illustrated in Figure 4.

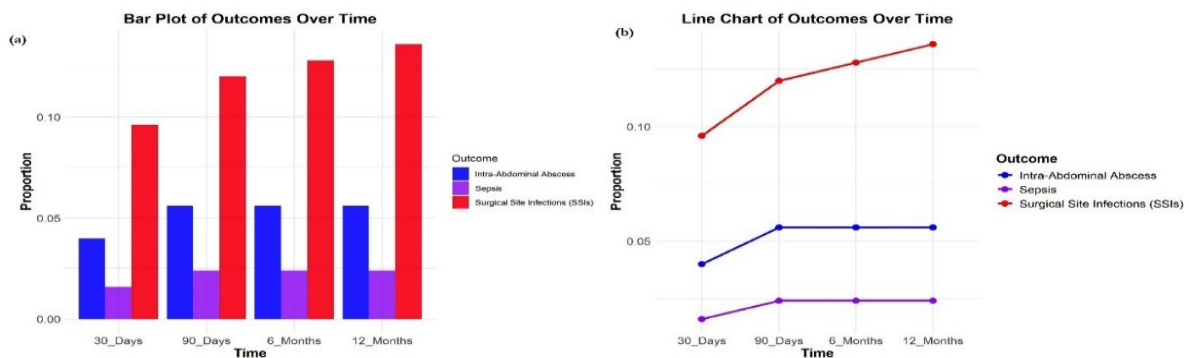




Figure 4: (A) Bar Plot Showing Proportions of Surgical Site Infections (Ssis), Intra-Abdominal Abscesses, And Sepsis Over Time; (B) Line Chart Illustrating Trends in These Outcomes Over 30 Days, 90 Days, 6 Months, and 12 Months; (C) Pie Chart Representing the Distribution of Ssis Across the Four Time Points.

Table 4: Analysis of Secondary Outcomes

Outcome	M ± SD	30 Days	90 Days	6 Months	12 Months	Test Statistic (df)	95% CI / Range	P-Value
Length of Hospital Stay (days)	5.1 ± 2.1	—	—	—	—	t = 1.42 (df=123)	−0.4 to 1.4	0.158
Readmissions, n (%)	—	4 (3.2)	10 (8.0)	12 (9.6)	14 (11.2)	—	—	—
Mortality, n (%)	—	1 (0.8)	1 (0.8)	2 (1.6)	2 (1.6)	—	—	—
Adhesion-Related Reoperations, n (%)	4 (3.2) at 12 months	—	—	—	4 (3.2)	—	—	—
Patient Satisfaction Score†	8.2 ± 1.5	—	8.1 ± 1.3	—	8.3 ± 1.4	t = 0.97 (df=120)	−0.5 to 1.3	0.335

Notes: †Measured on a 10-point Likert scale. Mortality rates are shown cumulatively.

The mean hospital stay was 5.1 ± 2.1 days, with readmissions increasing from 4 cases at 30 days to 14 cases at 12 months. Mortality was low, with 2 cumulative deaths by 12 months, and adhesion-related reoperations were observed in 4 cases (3.2%) at 12 months. Further details, including statistical analyses, are provided in Table 4.

Discussion

Our study highlights the burden of postoperative adhesions and infectious complications following appendectomy, emphasizing the need for targeted strategies to improve patient outcomes. Adhesions were particularly associated with higher neutrophil-to-lymphocyte ratios (NLR) and open surgery, while surgical site infections (SSIs) showed a decreasing trend over time. Our research data validates previous research that shows open surgery operations lead to higher complication rates. The results from Khan, et al. [11] indicated laparoscopic appendectomy (LA) produced lower wound infection rates than open appendectomy (OA), which matches the higher rates of adhesions and SSIs we found during open procedures. Moreira, et al. [12] documented elevated complication rates in open surgical procedures thereby validating our study findings. The reliable evidence confirms that laparoscopic procedures should remain the default operative choice because they minimize postoperative complications. Research links high NLR levels to postoperative adhesions because they show similar relationships mentioned in studies about inflammatory indicators used for complication prediction. Kohga, et al. [13] showed preoperative CT images together with systemic inflammation levels can efficiently identify intra-abdominal abscesses, while our research showed similar findings for adhesions. Research demonstrates how NLR presents opportunities to identify risk through non-invasive assessment which allows pre-emptive intervention adjustments. Our study contributes new knowledge about SSIs and abscess development during appendicitis attacks. Gupta, et al. [14] and Romano, et al. [15] demonstrated that gangrenous appendicitis poses a major risk for infectious complications such that severe cases lead to increased SSIs and intra-abdominal abscesses. The risks of postoperative infections emphasize the critical need for both early and precise diagnosis since these identifying patients during imaging and clinical evaluation.

Postoperative care approaches have been challenged by Fuad, et al. [16] and Strohäker, et al. [17] who reveal restricted relationships between intraoperative swab culture findings and actual infection progression. Our study supports this scepticism, as empirical antibiotic regimens effectively managed infections, and routine swabbing may not add significant clinical value in uncomplicated cases. The stability of intra-abdominal abscess and sepsis rates over time aligns with findings from Petukhov, et al. [18], who noted that infection rates remain consistent postoperatively, particularly in uncomplicated appendicitis. This suggests that most complications are front-loaded within the first few weeks, emphasizing the need for vigilant early postoperative monitoring to improve outcomes. Dietary and demographic factors also remain critical considerations. While our study did not focus on dietary patterns, prior work by Imanieh, et al. [19] links poor dietary habits and constipation to appendicitis risk. Preventive strategies should include holding surgical procedures along with lifestyle-changing dietary modifications to prevent complications from occurring in the beginning rather than later. Our results provide valuable input to current discussions regarding antibiotic prophylaxis practices. Alternative research by Coakley, et al. [20] and Fuad, et al. [16] demonstrated that extended antibiotic treatments provide limited value during non-perforating cases while increasing overall patient morbidity. Our research validates individualized post-operative antibiotic management protocols instead of universal standard treatment protocols for preventing complications better resources while they remain in use. Our study increases clinical practice knowledge about postoperative complication risk factors and intervention strategies by delivering essential medical practice insights. Research outcomes demonstrate the necessity of individualized care which includes the combination of operative improvements with patient-specific inflammatory measurements throughout post-surgical monitoring procedures to optimize appendicitis treatment results.

Conclusion

Our research shows that patients with elevated neutrophil-to-lymphocyte ratios and who undergo open procedures experience

substantial postoperative adhesions and infections while receiving appendicitis treatment. The research shows that laparoscopic interventions require imminent risk stratification through inflammatory markers while performing personalized care

postoperatively to minimize patient complications. This study identifies practical predictors which advance present knowledge to deliver vital information that enhances appendicitis treatment outcomes for patients.

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