RESEARCH PAPER

Perioperative Hematologic, Histopathological, Anesthetic, and Surgical Predictors of Major Postoperative Complications Following Gastrointestinal Surgery: A Prospective Observational Study

Muhammad Arslan[1], Muhammad Kaleem Sattar[2], Imam Alam[3], Sarah Azhar[4], Naseeb Mumtaz Abbasi[5], Noreen Atzaz[6], Zhang Pusheng[7], Tariq Mahmood[8]*

[1] Department of General Surgery, Southern Medical University, Guangzhou, China.
[2] Department of Anaesthesiology, Tertiary Care Hospital Nishtar-II, Pakistan.
[3] Department of General Surgery, Mekran Medical College, Turbat, Mekran, Pakistan.
[4] Department of Pathology, Baqai Medical College, Baqai Medical University, Pakistan.
[5] Department of Hematology/Pathology, Klash Social Security Hospital, Millat Town, Faisalabad, Pakistan.
[6] Department of Chemical Pathology, Rawal Institute of Health Sciences, Pakistan.
[7] Department of Breast Surgery, Zhujiang Hospital, Southern Medical University, Guangzhou, China.
[8] Department of Anesthesia, King Khalid Hospital, Hail, Saudi Arabia.
Corresponding Author: Prof. Zhang Pusheng**; Email:** pushion@qq.com

ABSTRACT

Background: Major postoperative complications following gastrointestinal surgery remain an important cause of prolonged hospitalization, reintervention, intensive-care use, and mortality. This study assessed the hematologic, histopathologic, anesthetic, and surgical factors associated with major postoperative morbidity.

Methods: A prospective observational study of 120 adults undergoing gastrointestinal surgery between January 2025 and January 2026 was conducted at the Department of Anaesthesiology in Tertiary Care Hospital Nishtar-II, Pakistan, and in Klash Social Security Hospital, Millat Town, Faisalabad, Pakistan. Major complications were considered to be Clavien–Dindo grade III–V events occurring within 30 days. Multivariable logistic regression was used to assess the candidate predictors.

Results: Major postoperative complications occurred in 34 patients (28.3%). The factors independently associated with major morbidity were hemoglobin <10 g/dL, severe inflammatory or necrotic histopathology, mean arterial pressure (MAP) <65 mmHg for ≥15 minutes, and emergency surgery. Emergency surgery showed the strongest association (adjusted odds ratio [aOR] 2.72, 95% CI 1.17–6.32), followed by prolonged intraoperative hypotension (aOR 2.51, 95% CI 1.07–5.87), severe inflammatory/necrotic histopathology (aOR 2.37, 95% CI 1.03–5.45), hemoglobin <10 g/dL (aOR 2.26, 95% CI 1.01–5.09), and NLR ≥5 (aOR 2.18, 95% CI 1.01–4.72). The integrated model showed good discrimination (AUC 0.81, 95% CI 0.73-0.89).

Conclusion: Major complications after gastrointestinal surgery are associated with interacting hematologic, pathological, anesthetic, and surgical factors. An integrated perioperative assessment can help to more effectively stratify early risk and provide post-operative monitoring. The identification of these easily accessible predictors may help in focused optimization, tight monitoring of hemodynamics, and prompt escalation of care for high-risk gastrointestinal surgical patients.

Keywords: Gastrointestinal surgery; postoperative complications; anemia; neutrophil-to-lymphocyte ratio; histopathology; intraoperative hypotension; perioperative risk.

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.INTRODUCTION

Despite improvements in surgical technique, perioperative anesthesia care, antimicrobial prophylaxis, critical care, and enhanced recovery pathways, major gastrointestinal surgery carries significant postoperative morbidity [1]. Anastomotic leakage, intra-abdominal infection, postoperative bleeding, pulmonary dysfunction, acute renal injury, and cardiovascular events are other complications that may lead to extended hospital stays, reintervention or intensive care, and postoperative mortality. Early identification of patients at increased risk is therefore essential for perioperative optimization, informed clinical decision-making, and appropriate allocation of postoperative monitoring resources [2,3].

There are an inherent number of factors that put someone at risk for major complications after surgery. Preoperative hematologic abnormalities may be a reflection of both the physiological reserve and the amount of systemic disease burden [4]. Anemia reduces tissue oxygen delivery and wound healing, and inflammatory markers derived from leukocytes,

such as the neutrophil-to-lymphocyte ratio, may reflect systemic inflammation and shift in the immune response. These are laboratory parameters that are routinely available, are inexpensive, can be repeated without difficulty, and can be obtained before surgery, making them attractive for use in a pre-operative risk assessment [5].

Histopathological features might convey another dimension of risk not necessarily included in perioperative prediction models. The presence of extensive tissue inflammation, necrosis, changes associated with perforation, poor tumor differentiation, and lymphovascular or perineural invasion may be indicative of more aggressive or advanced disease, and may correlate with increased operative complexity, tissue fragility, contamination, and systemic inflammatory activation. However, their association with early postoperative morbidity has been less well studied in conjunction with traditional perioperative factors [6,7].

Postoperative risk may also be altered by factors occurring during the anesthetic and surgical intervention. Low blood pressure for an extended period of time, significant blood loss, blood transfusion during surgery, use of vasopressor agents, emergency admission, contaminated surgical field, and length of surgery will all lead to tissue hypoperfusion, inflammatory stress, organ dysfunction, and impaired recovery [8-10]. While each of these factors has been separately linked to poor results, research often assesses these in a siloed approach to health care and fails to examine them in the context of an integrated model that incorporates hematologic, pathological, anesthetic, and surgical characteristics [11].

A multidimensional assessment might then offer a more clinically relevant picture of the risks of gastrointestinal surgery. The purpose of the present prospective observational study was to determine hematologic, histopathological, anesthetic, and surgical factors that may predict major postoperative complications following gastrointestinal surgery. The main goal was to identify 30-day Clavien–Dindo grade III–V complication risk factors alone, and the secondary goal was to assess the discriminatory performance of an integrated perioperative prediction model [12].

MATERIALS AND METHODS

Study Design and Setting:

This prospective observational study was conducted from January 2025 to January 2026 at the Department of Anaesthesiology, Tertiary Care Hospital Nishtar-II, Pakistan, and Klash Social Security Hospital, Millat Town, Faisalabad, Pakistan. Consecutive adult patients who received general anesthesia for major gastrointestinal surgery were prospectively recruited, and postoperative outcome data were collected. The study was performed in line with the principles of the Declaration of Helsinki, and the results are reported following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) recommendations.

Population and Sample Size

One hundred and twenty (120) consecutive patients undergoing elective or emergency gastrointestinal surgery were enrolled. Adults ≥18 years of age who were scheduled for gastrointestinal surgery (major gastric, small-intestinal, colorectal or other intra-abdominal gastrointestinal surgery) under general anesthesia were eligible for enrollment without regard to sex. Patients undergoing minor gastrointestinal surgery, diagnostic endoscopy without major surgery, and patients undergoing surgery for complications of a previous procedure before enrollment were excluded, as were patients with incomplete perioperative records and patients who were unable to have 30-day postoperative follow-up.

Preoperative Assessment

Demographic and clinical data at the time of enrolment were gathered, including age, sex, body mass index, smoking status, diabetes mellitus, hypertension, cardiovascular disease, chronic respiratory disease, renal impairment, diagnosis of primary gastrointestinal disease, malignant or benign disease, and elective or emergency surgical status. The American Society of Anesthesiologists (ASA) physical-status classification was used to rate the preoperative physiological status.

Preliminary hematological studies performed before surgery consisted of hemoglobin concentration, total leukocyte count, absolute neutrophil count, absolute lymphocyte count, and platelet count. Neutrophil-to-lymphocyte ratio (NLR) was obtained by dividing absolute neutrophil count by absolute lymphocyte count. For categorical measurements, a hemoglobin level of less than 10g/dL was regarded as marked preoperative anemia, and an NLR of >5 was considered an elevated NLR.

Histopathological Assessment

All the resected gastrointestinal specimens were processed following routine histopathological procedures. Formalin-fixed tissue specimens were paraffin-embedded, cut, stained with hematoxylin and eosin, and then analyzed by an experienced histopathologist. Histopathological variables included the underlying benign or malignant diagnosis, degree of infiltration by inflammatory cells, tissue necrosis, ulceration, pathological changes of perforation, and other pathological variables. Tumor differentiation, lymphovascular and perineural invasion, and resection-margin status were further documented in patients with gastrointestinal malignancy. In the

primary analysis, severe inflammatory or necrotic histopathology was considered to be either extensive transmural inflammatory infiltration, extensive tissue necrosis, suppurative changes, or perforation-associated tissue destruction.

Anesthetic Management and Intraoperative Variables:

General anesthesia was performed in all patients based on the institutional anesthetic practice and clinical needs. Standard intraoperative monitoring was performed, such as electrocardiography, non-invasive or invasive arterial blood pressure monitoring as indicated, pulse oximetry, capnography, temperature monitoring, and urinary output assessment as applicable.

Anesthetic variables recorded prospectively included duration of anesthesia, heart rate and blood pressure during anesthesia, incidence of hypotension, duration of hypotension, requirement for vasopressor, intravenous fluid administered, estimated blood loss and transfusion of packed red cells. Intraoperative hypotension was defined as a mean arterial pressure (MAP) <65 mmHg. Prolonged hypotension (MAP <65 mmHg for >15 minutes) was regarded as clinically significant. Perioperative red-cell transfusion was defined as packed red-cell administration during surgery or within the first 24 hours after surgery.

Surgical Variables

Operative information comprised the anatomical site of surgery, elective or emergency surgery, open or minimally invasive surgery, surgery time, estimated blood loss, bowel resection, anastomosis, stoma creation, perforative surgery, surgery field contamination, and other or multiple visceral surgery, if applicable.

Operative time: time from skin incision to completion of skin closure. In the categorical analysis, prolonged surgery was considered as surgery time ≥180 minutes. Wounds were classified as per standard surgical wound classification, and contaminated and dirty/infected operative wounds were grouped for the main analysis.

Postoperative assessment and outcomes

Patients were followed up prospectively in hospital and for 30 days after surgery. Postoperative complications were noted on a daily basis from clinical, laboratory, imaging, intensive-care, and follow-up records, and from the surgical record. The main outcome was major postoperative complication within 30 days, defined as Clavien–Dindo grade III, IV, or V. Grade III: surgical, endoscopic, or radiological intervention; grade IV: life-threatening events managed in the intensive-care unit; grade V: postoperative death.

Secondary postoperative complications were 30-day mortality, anastomotic leakage, surgical-site infection, intra-abdominal abscess or collection, postoperative hemorrhage, pneumonia or major respiratory complications, acute kidney injury, cardiovascular complications, unplanned intensive-care admission, reoperation, and length of hospital stay.

Data Collection

A structured data-collection form was used to collect the data prospectively. These haemato-oncological results, anaesthetic notes, operative notes, pathological opinions and post-operative results were then combined in one study database. For comparison and prediction, patients were classified as having or not having major postoperative complications.

Statistical Analysis

Data were analysed using a suitable statistical software package. For continuous variables, mean ± standard deviation values were used for normally distributed data or median and interquartile range for the non-normally distributed variables. Categorical data were presented in numbers and percentages. Independent-samples t-test or Mann–Whitney U test was used to compare continuous variables between patients with and without major postoperative complications, as appropriate. A chi-square test or Fisher's exact test was used to compare categorical variables.

Univariable analysis was used to assess the potential predictors. Multivariable binary logistic regression was then performed to determine independent predictors of major postoperative complications from the clinically relevant variables and those associated with an association to the primary outcome. Results were reported as aORs and 95% CIs. Due to the number of patients included in the sample (n=120), the final multivariable model included only a selected number of clinically relevant variables to minimize overfitting. Prior to building the model, collinearity between candidate predictors was checked. A receiver operating characteristic curve (ROC) and area under the curve (AUC) were used to evaluate the model discrimination. A two-sided P value <0.05 was considered statistically significant.

Ethical Considerations

The study was approved by the relevant institutional ethics committees prior to its commencement. Written informed consent was obtained from all participants or their legally authorized representatives, where applicable. In all cases, patient confidentiality was respected, and all the information gathered was used only for the research.

RESULTS

A total of 120 patients were included in the study, comprising 61 males (50.8%) and 59 females (49.2%). A total of 34 patients (28.3%) developed a major postoperative complication (Clavien–Dindo grade III–V), while 86 patients (71.7%) had no major complication. Patients with major complications were

significantly older (60.5 ± 14.1 vs 52.7 ± 15.0 years, P=0.010) and had a higher rate of ASA class III–IV (52.9% vs 27.9%, P=0.009). Major postoperative morbidity was also much higher among patients who underwent emergency surgery (61.8% vs 29.1%, P=0.001). There was a nearly equal distribution of male and female patients in both outcome groups, and sex was not significantly associated with postoperative complications (P=0.907). The hematological findings revealed that the hemoglobin level in patients with major complications was significantly lower than that in patients without major complications (10.4 ± 1.9 vs 11.9 ± 2.0 g/dL, P<0.001); moreover, hemoglobin <10 g/dL was present in 38.2% of patients with major complications and in 15.1% of patients without major complications (P=0.005). Similarly, the NLR was significantly higher in patients developing a complication (6.4 vs 4.1, P=0.002); in the group of patients with complications, NLR ≥5 was present in 64.7% of patients compared to 37.2% in the uncomplicated group (P=0.006) (Table 1).

Table 1. Baseline and Hematological Characteristics

Variable	No major complication (n=86)	Major complication (n=34)	P value
Age, years	52.7 ± 15.0	60.5 ± 14.1	0.010
Male	44 (51.2%)	17 (50.0%)	0.907
Female	42 (48.8%)	17 (50.0%)	0.907
ASA III–IV	24 (27.9%)	18 (52.9%)	0.009
Emergency surgery	25 (29.1%)	21 (61.8%)	0.001
Hemoglobin, g/dL	11.9 ± 2.0	10.4 ± 1.9	<0.001
Hemoglobin <10 g/dL	13 (15.1%)	13 (38.2%)	0.005
NLR	4.1	6.4	0.002
NLR ≥5	32 (37.2%)	22 (64.7%)	0.006

Histopathological, anesthetic, and operative characteristics also differed significantly between the two groups. Severe inflammatory or necrotic histopathological changes were present in 50.0% of patients with major complications compared with 23.3% of those without complications (P=0.004). Clinically significant intraoperative hypotension, defined as MAP <65 mmHg for at least 15 minutes, occurred in 47.1% of patients with major morbidity compared with 19.8% of patients without major morbidity (P=0.003). Vasopressor support was required more frequently in the complication group (52.9% vs 30.2%, P=0.020), while perioperative red-cell transfusion was required in 44.1% compared with 19.8% (P=0.006). Prolonged operative duration of at least 180 minutes was also more common among patients developing major complications (58.8% vs 34.9%, P=0.017). Furthermore, contaminated or dirty operative fields (55.9% vs 31.4%, P=0.013) and bowel perforation (35.3% vs 17.4%, P=0.033) were significantly associated with major postoperative morbidity (Table 2).

Table 2. Histopathological, Anesthetic, and Surgical Characteristics

Variable	No major complication (n=86)	Major complication (n=34)	P value
Severe inflammatory/necrotic histopathology	20 (23.3%)	17 (50.0%)	0.004
MAP <65 mmHg ≥15 min	17 (19.8%)	16 (47.1%)	0.003
Vasopressor requirement	26 (30.2%)	18 (52.9%)	0.020
Red-cell transfusion	17 (19.8%)	15 (44.1%)	0.006
Operative duration ≥180 min	30 (34.9%)	20 (58.8%)	0.017
Contaminated/dirty operative field	27 (31.4%)	19 (55.9%)	0.013
Bowel perforation	15 (17.4%)	12 (35.3%)	0.033

The spectrum of postoperative complications included intra-abdominal infection or abscess in 11 patients (9.2%), pneumonia or major respiratory complications in 10 (8.3%), anastomotic leakage in 9 (7.5%), and acute kidney injury requiring intensive management in 9 (7.5%). Unplanned reoperation was required in 10 patients (8.3%), while 15 patients (12.5%) required unplanned postoperative intensive-care admission. Five patients died within 30 days, giving an overall postoperative mortality rate of 4.2%. These findings demonstrated that infectious, respiratory, renal, and anastomotic complications constituted the major contributors to postoperative morbidity in the study cohort (Table 3).

Table 3. Major Postoperative Outcomes

Outcome	n (%)
Clavien–Dindo grade III–V complication	34 (28.3%)
Anastomotic leakage	9 (7.5%)
Intra-abdominal infection/abscess	11 (9.2%)
Pneumonia/major respiratory complication	10 (8.3%)
Acute kidney injury	9 (7.5%)
Unplanned reoperation	10 (8.3%)

Unplanned ICU admission	15 (12.5%)
30-day mortality	5 (4.2%)

To determine independent predictors of major postoperative complications, multivariable logistic regression was performed. Emergency surgery was the most significant independent risk factor for major morbidity after adjustments for clinically relevant variables (aOR 2.72, 95% CI 1.17–6.32; P=0.020). Extended periods of intraoperative hypotension were associated with about a 2.5-fold increase in the odds of major complications (aOR 2.51, 95% CI 1.07–5.87; P=0.034), and severe inflammatory or necrotic histopathology was associated with more than a 2-fold increase in the odds of major complications (aOR 2.37, 95% CI 1.03–5.45; P=0.042). Preoperative hemoglobin <10 g/dL (aOR 2.26, 95% CI 1.01–5.09; P=0.048) and NLR ≥5 (aOR 2.18, 95% CI 1.01–4.72; P=0.047) also remained significant independent predictors. The combined model incorporating hematological, histopathological, anesthetic, and surgical variables demonstrated good discrimination, with an AUC of 0.81 (95% CI 0.73–0.89) (Table 4).

Table 4. Independent Predictors of Major Postoperative Complications

Predictor	Adjusted OR	95% CI	P value
Hemoglobin <10 g/dL	2.26	1.01 – 5.09	0.048
NLR ≥5	2.18	1.01 – 4.72	0.047
Severe inflammatory/necrotic histopathology	2.37	1.03 – 5.45	0.042
MAP <65 mmHg ≥15 min	2.51	1.07 – 5.87	0.034
Emergency surgery	2.72	1.17 – 6.32	0.020

DISCUSSION

The present prospective observational study identified a combination of hematological, histopathological, anesthetic, and surgical variables associated with major postoperative complications following gastrointestinal surgery [1]. Significant major Clavien–Dindo grade III–V complications were observed in 28.3% of patients, highlighting the high morbidity of major gastrointestinal surgery. Preoperative hemoglobin <10 g/dL, high neutrophil-to-lymphocyte ratio, severe inflammatory or necrotic histopathological changes, prolonged intraoperative hypotension, and emergency surgery were the principal independent predictors. These factors together had a good discriminatory power for postoperative risk with an AUC of 0.81 [2,3].

Anemia before surgery was independently predictive of a major postoperative morbidity. Hypothemoglobin reduces the degree of tissue oxygenation during periods of increased metabolic demand, operative blood loss, and/or hemodynamic instability [4]. Gastrointestinal surgical patients may also have anemia due to chronic blood loss, malignancy, malnutrition or systemic inflammation. Low hemoglobin thus may be a marker for reduced physiologic reserve and increased disease burden. The results indicate that special care should be taken in the pre-operative evaluation and correction of clinically significant anaemia, where surgical urgency allows [5,6].

There was also an independent association between complications and an elevated NLR (hazard ratio: 1.23). NLR is an easy-to-access measure of overall inflammatory activity, which depends on the balance of inflammation caused by neutrophils and immune response mediated by lymphocytes [7]. Patients with high NLRs therefore might be taken to surgery with a higher inflammatory state and lower immunological reserve, which can lead to susceptibility to postoperative organ dysfunction, impaired healing, and infection. Since it is available from routine blood counts, NLR is especially appealing for the assessment of perioperative risk [8,9].

An interesting observation was the correlation between severe postoperative complications and inflammatory or necrotic histopathology. However, extensive inflammation and necrosis associated with perforation may represent higher local disease burden, poor tissue quality, higher bacterial burden, and systemic inflammatory activation. Such data indicate that histopathology features may contain clinically relevant prognostic data in addition to their traditional diagnostic and staging functions [10-13].

Of anesthetic factors, long duration of intraoperative hypotension was significantly and independently associated with postoperative morbidity. Chronic decrease in mean arterial pressure (MAP) can lead to decreased perfusion of the kidneys, heart, brain, and gut, especially in individuals with low functional reserve. This finding is clinically important because intraoperative blood pressure is potentially modifiable through appropriate fluid management, vasopressor use, blood-loss control, and individualized hemodynamic targets [14,15].

The most significant surgical risk factor was emergency surgery. Patients who need urgent gastrointestinal operations often have perforation,

gastrointestinal obstruction, gastrointestinal bleeding, gastrointestinal ischemia, or sepsis, and usually have little time to optimize their physiology before surgery. These procedures also tend to have a higher incidence of contamination, tissue edema, technical difficulty, and higher intra-operative instability. This could be due to these factors and may account for the significantly increased complication rate seen in emergency cases [16,17].

In the unadjusted analysis, other factors (e.g., use of vasopressors, perioperative transfusion, contaminated operative field, bowel perforation, and longer duration of operation) were all associated with complications. While these variables were not included in the final parsimonious model, they are still clinically relevant measures of (physiological) stress and complexity of the surgery. Given the relatively small number of primary outcome events, it was important to limit the multivariable model to prevent overfitting [18,19].

The study has a number of strengths, such as being prospective, having included both elective and emergency gastrointestinal procedures, and having assessed both predictors from multiple perioperative domains [20]. But some drawbacks need to be taken into account. The sample size is relatively small, and the number of major complications meant that the number of variables that could be included in the adjusted model was small. The heterogeneous gastrointestinal diagnosis and surgical procedure might also be a limitation for procedure-specific interpretation. Moreover, the study design is observational, and an external validation of the prediction model is needed before applying it in routine clinical practice [5,20].

CONCLUSION

Preoperative anemia, elevated NLR, severe inflammatory or necrotic histopathology, prolonged intraoperative hypotension, and surgical urgency were associated with major postoperative complications after gastrointestinal surgery. These results suggest that the risk of complications after surgery is not related to one single variable at the perioperative time, but rather to a combination of biological, pathological, anaesthetic and surgical variables. The combination of easily accessible hematological parameters and histopathological and intraoperative data could be helpful to further optimize the early risk stratification and identify patients who may benefit from more aggressive perioperative optimization and postoperative monitoring.

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