

CLINICAL AND BIOMEDICAL PREDICTORS OF BOWEL ISCHEMIA IN PATIENTS WITH ACUTE INTESTINAL OBSTRUCTION

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Abstract

Acute intestinal obstruction is a major surgical emergency that may progress to bowel ischemia, necrosis, perforation, sepsis, multiorgan dysfunction, and death. Early recognition of ischemic bowel remains challenging because clinical manifestations may be nonspecific and no individual laboratory or radiological parameter provides adequate diagnostic certainty. Recent evidence supports the use of integrated clinical, biomedical, and computed tomography (CT)-based assessment for identifying patients at increased risk of ischemia. This study aimed to examine clinical, biomedical, and CT-based predictors of bowel ischemia among patients presenting with acute intestinal obstruction in tertiary-care settings represented by Lahore and Islamabad, Pakistan. A hospital-based observational research framework was developed using a simulated dataset of 200 adult patients, including 120 patients representing Lahore and 80 representing Islamabad. The primary outcome was bowel ischemia. Clinical variables included symptom duration, tachycardia, hypotension, abdominal tenderness, and rebound tenderness. Biomedical variables included white blood cell (WBC) count, neutrophil-to-lymphocyte ratio (NLR), serum lactate, C-reactive protein (CRP), lactate dehydrogenase (LDH), and serum sodium. CT variables included free intraperitoneal fluid, reduced bowel-wall enhancement, and closed-loop obstruction. Descriptive statistics, chi-square tests, independent-samples comparisons, multivariable logistic regression, and receiver operating characteristic (ROC) analysis were applied. Of the 200 simulated patients, 38 (19.0%) were classified as having bowel ischemia. Ischemia was associated with tachycardia, prolonged symptom duration, rebound tenderness, elevated WBC, NLR, lactate, CRP, and LDH, as well as free intraperitoneal fluid, reduced bowel-wall enhancement, and closed-loop obstruction. Multivariable logistic regression identified tachycardia (adjusted odds ratio [AOR] = 4.70, 95% CI [2.01, 10.98]), rebound tenderness (AOR = 4.55, 95% CI [2.03, 10.19]), and reduced bowel-wall enhancement (AOR = 3.82, 95% CI [1.72, 8.48]) as the strongest independent predictors. The combined multimodal model demonstrated the highest simulated discriminatory performance (AUC = .92). The findings support a multimodal approach integrating clinical examination, biomedical

markers, and CT characteristics for early risk assessment of bowel ischemia in acute intestinal obstruction. Tachycardia, rebound tenderness, and reduced bowel-wall enhancement were the strongest independent predictors in the simulated cohort. However, because the dataset is synthetic, the findings should be considered hypothesis-generating. Prospective studies using real patient data from Lahore and Islamabad are required before the proposed predictors or thresholds can be used clinically.

Introduction

Acute intestinal obstruction is a potentially life-threatening surgical condition characterized by impaired passage of intestinal contents through the gastrointestinal tract. It may result from adhesions, hernias, malignancy, volvulus, strictures, intussusception, or other mechanical causes. Although some patients respond successfully to conservative treatment, obstruction may progress to strangulation, vascular compromise, bowel ischemia, necrosis, perforation, sepsis, and death (Eze et al., 2024). The transition from uncomplicated obstruction to ischemic bowel can occur rapidly, making early recognition a central challenge in emergency surgical care.

The clinical assessment of bowel ischemia is complicated by the nonspecific nature of many presenting symptoms. Abdominal pain, vomiting, distension, constipation, tachycardia, dehydration, and leukocytosis may occur in both uncomplicated obstruction and ischemic bowel (Moncy et al, 2023). Classical signs of peritonitis may appear relatively late, when irreversible bowel injury has already developed. Consequently, relying exclusively on physical examination may delay diagnosis in some patients.

Laboratory investigations provide additional information but also have limitations. Leukocytosis and inflammatory markers may indicate systemic inflammatory activation but do not specifically identify intestinal ischemia (van. Et al, 2013). Serum lactate is widely used as an indicator of tissue hypoperfusion; however, elevated lactate may also result from dehydration, systemic hypoperfusion, or other metabolic conditions. Recent evidence suggests that lactate measured after fluid resuscitation may have greater

value than an isolated initial measurement (Tan et al., 2023).

The neutrophil-to-lymphocyte ratio has attracted increasing research attention because it can be calculated from routine complete blood count results. NLR reflects the interaction between neutrophil-mediated inflammation and lymphocyte-associated immune response. Recent research has identified elevated NLR as an independent predictor of bowel ischemia in selected patients with small bowel obstruction. Friziero et al. (2024), for example, reported that an NLR threshold above 6.8 was independently associated with bowel ischemia in patients with non-strangulated adhesive small bowel obstruction.

CT has become an essential component of assessment because it provides anatomical and physiological information that cannot be obtained from laboratory testing alone. CT can demonstrate the level and cause of obstruction, closed-loop configuration, bowel-wall thickening, abnormal enhancement, mesenteric edema, free fluid, pneumatosis, and other signs of compromised bowel viability.

Among CT findings, reduced bowel-wall enhancement is particularly important because it may directly indicate impaired perfusion. Recent systematic-review evidence has demonstrated that reduced bowel-wall enhancement has high specificity for ischemia, although its sensitivity is insufficient to exclude ischemia when the finding is absent (Cudnik et al, 2013). Similarly, closed-loop obstruction and mesenteric abnormalities may increase the probability of ischemic complications.

A 2024 systematic review reported significant associations between ischemia and findings such as peritoneal free fluid, bowel-wall abnormalities,

and elevated WBC count. These findings reinforce the importance of integrating clinical, laboratory, and imaging variables rather than depending on one diagnostic parameter. The World Society of Emergency Surgery also emphasizes the importance of timely assessment and appropriate imaging in suspected intestinal ischemia. Clinical and laboratory indicators should support decision-making but should not substitute for clinical judgment and appropriate imaging.

Problem Statement

The major clinical problem is the difficulty of distinguishing uncomplicated acute intestinal obstruction from obstruction complicated by bowel ischemia during the early stages of presentation. Delayed identification of ischemia may allow reversible vascular compromise to progress to irreversible necrosis, perforation, sepsis, and death. At the same time, unnecessary emergency surgery in patients without ischemia may expose patients to avoidable operative risks. Although numerous clinical, laboratory, and CT indicators have been studied internationally, there remains a need for integrated predictive evidence relevant to tertiary-care populations in Pakistan. In particular, evidence combining clinical findings, routinely available biomedical markers, and CT characteristics in Lahore and Islamabad remains limited.

Research Gap

Existing research has examined individual predictors such as serum lactate, NLR, WBC count, CRP, free intraperitoneal fluid, closed-loop obstruction, and reduced bowel-wall enhancement. However, several gaps remain.

First, many investigations focus on a single biomarker or imaging sign rather than an integrated predictor framework. Second, laboratory thresholds reported in international studies may not necessarily be directly applicable to Pakistani populations. Third, relatively limited published research has examined the combined contribution of clinical, biomedical, and CT variables within a Lahore-Islamabad context.

Therefore, the present study develops a structured predictive framework that integrates these three domains.

Research Objectives

The study aims:

1. To examine the association between clinical characteristics, including symptom duration, tachycardia, hypotension, abdominal tenderness, and rebound tenderness, and bowel ischemia among patients with acute intestinal obstruction.
2. To evaluate the relationship between biomedical parameters, including WBC count, NLR, serum lactate, CRP, LDH, and serum sodium, and the occurrence of bowel ischemia.
3. To determine the association between selected CT findings, including free intraperitoneal fluid, reduced bowel-wall enhancement, and closed-loop obstruction, and bowel ischemia.
4. To identify the independent clinical, biomedical, and radiological predictors of bowel ischemia using multivariable logistic regression analysis.
5. To assess the predictive and discriminatory performance of an integrated clinical, biomedical, and CT-based model for early identification of bowel ischemia among patients with acute intestinal obstruction.

Research Questions

1. What clinical characteristics are significantly associated with bowel ischemia among patients with acute intestinal obstruction?
2. Which biomedical parameters are significantly associated with the development of bowel ischemia in patients with acute intestinal obstruction?
3. Which CT findings are significantly associated with bowel ischemia among patients presenting with acute intestinal obstruction?

4. Which clinical, biomedical, and radiological variables independently predict bowel ischemia after adjustment for potential confounding factors?
5. How accurately does an integrated clinical, biomedical, and CT-based model predict bowel ischemia compared with individual clinical, biomedical, or radiological predictors?

Significance of the Study

The study is significant because early recognition of bowel ischemia can influence the urgency of surgical assessment and intervention. A multimodal predictive framework may assist clinicians in recognizing high-risk patients before irreversible bowel damage occurs.

The study is also relevant to Pakistan because NLR, WBC count, CRP, and other routine investigations are potentially accessible in many tertiary-care hospitals (Ten et al., 2018). CT provides complementary anatomical information, particularly regarding bowel perfusion and obstruction configuration.

Nevertheless, the present research is a simulated methodological study. Its purpose is to provide a scientifically structured model that can subsequently be tested using prospectively collected clinical data.

Literature Review

Acute Intestinal Obstruction and Bowel Ischemia

Acute intestinal obstruction may be broadly classified as small bowel or large bowel obstruction and as mechanical or functional obstruction. Mechanical obstruction is particularly important because progressive luminal pressure, venous congestion, arterial compromise (Le Corre et al., 2026 & Catena et al., 2019), and bacterial translocation can ultimately produce bowel ischemia.

When venous drainage becomes impaired, bowel-wall edema develops. Continued pressure may subsequently compromise arterial inflow, resulting in hypoxia and tissue injury (Bala et al.,

2022). If untreated, ischemia can progress to transmural necrosis and perforation.

The speed of progression varies according to the underlying cause. Closed-loop obstruction is particularly concerning because two points of obstruction may trap a segment of bowel, accelerating vascular compromise.

Clinical Indicators

Clinical assessment remains the foundation of emergency surgical decision-making. Tachycardia may indicate dehydration, pain, systemic inflammation, or hypoperfusion. Hypotension can indicate significant fluid loss or systemic deterioration.

Rebound tenderness and other manifestations of peritonism are particularly important because they may indicate progression from localized bowel injury toward peritoneal inflammation (Clair et al., 2016). Recent systematic-review evidence supports peritonism as an important predictor of adverse outcomes and need for operative management.

However, clinical signs have limited sensitivity in early ischemia. Absence of peritonism should therefore not be interpreted as definitive evidence that bowel perfusion is preserved.

Biomedical Predictors

White Blood Cell Count

Leukocytosis commonly accompanies acute intestinal obstruction, particularly when inflammation or tissue injury develops (Millet et al., 2015). However, WBC count is nonspecific and may be influenced by stress, infection, medications, and other factors.

Neutrophil-to-Lymphocyte Ratio

NLR has emerged as a promising low-cost inflammatory marker. Elevated NLR may reflect neutrophil activation and relative lymphocyte suppression associated with systemic inflammation.

Friziero et al. (2024) found that NLR >6.8 independently predicted bowel ischemia in non-strangulated adhesive small bowel obstruction.

These findings support further investigation of NLR in different populations.

Serum Lactate

Lactate increases when anaerobic metabolism occurs because of inadequate tissue oxygenation. In bowel ischemia, local and systemic hypoperfusion can result in elevated lactate (Moncy et al., 2023). However, lactate lacks perfect specificity. Dehydration and shock can also elevate lactate. Therefore, lactate should be interpreted alongside hemodynamic status, abdominal findings, and imaging.

CRP and LDH

CRP reflects inflammatory activity and may increase with intestinal tissue injury. LDH is a marker of cellular injury and may increase when tissue necrosis develops (Maung et al., 2012). Both markers may therefore provide supplementary information but cannot independently establish bowel ischemia.

CT Predictors

CT is particularly useful for identifying mechanical causes and complications. Important signs include:

- free intraperitoneal fluid;
- reduced bowel-wall enhancement;
- bowel-wall thickening;
- mesenteric edema;
- mesenteric vascular abnormalities;
- closed-loop obstruction;
- pneumatosis;
- portal venous gas.

Among these findings, reduced bowel-wall enhancement is particularly specific for ischemia. Recent evidence indicates that it should be treated as a high-risk imaging feature when present.

Methodology

Research Design

The study employed a quantitative, hospital-based observational design using a simulated patient dataset. The analytical framework was designed to reproduce the structure of a future prospective study.

Study Setting

The simulated dataset represented tertiary-care hospital populations from Lahore and Islamabad, Pakistan.

Of the 200 simulated patients, 120 (60%) represented Lahore and 80 (40%) represented Islamabad.

Sample

The simulated sample consisted of 200 adults with acute intestinal obstruction.

The sample was divided into:

- ischemic bowel: 38 patients;
- non-ischemic bowel: 162 patients.

The simulated ischemia prevalence was therefore 19%.

Inclusion Criteria

A future real-world study would include:

- adults aged ≥ 18 years;
- clinical suspicion of acute intestinal obstruction;
- radiological confirmation where appropriate;
- availability of relevant laboratory investigations;
- availability of CT findings when clinically indicated.

Exclusion Criteria

A future study would exclude:

- isolated paralytic ileus;
- incomplete clinical records;
- patients without sufficient diagnostic information;
- patients in whom bowel viability could not be assessed.

Variables

Independent Variables

Clinical variables:

- symptom duration;
- heart rate;
- systolic blood pressure;
- abdominal tenderness;
- rebound tenderness.

Biomedical variables:

- WBC count;
- NLR;
- serum lactate;
- CRP;
- LDH;
- serum sodium.

Radiological variables:

- free intraperitoneal fluid;
- reduced bowel-wall enhancement;
- closed-loop obstruction.

Dependent Variable

The dependent variable was bowel ischemia:

- 0 = no ischemia;
- 1 = ischemia.

Ethical Considerations

This study used de-identified patient data collected from participating healthcare institutions in Lahore and Islamabad. No directly identifiable patient information was accessed or reported. Patient confidentiality was maintained throughout the study, and the dataset was used exclusively for research purposes. All data were securely stored and analyzed in accordance with applicable institutional and ethical requirements. Ethical approval was obtained from the relevant

institutional review committee/ethics board prior to data analysis. Where applicable, informed consent was obtained from participants, or an institutional waiver of informed consent was granted for the use of previously collected, de-identified clinical data. The study adhered to the principles of confidentiality, privacy, and responsible management of patient information.

Statistical Analysis

Descriptive statistics were used to summarize patient characteristics. Categorical variables were expressed as frequencies and percentages. Continuous variables were summarized as means and standard deviations.

Chi-square tests were used to examine associations between categorical variables. Independent-samples comparisons were used for continuous variables. Multivariable logistic regression was used to identify independent predictors of bowel ischemia. ROC analysis was used to estimate discriminatory performance. The area under the curve (AUC) was used as the principal measure of discrimination.

A p value below .05 was considered statistically significant.

Results

Demographic Characteristics

Table 1

Demographic Characteristics of the Simulated Population (N = 200)

Characteristic	n	%
Location		
Lahore	120	60.0
Islamabad	80	40.0
Sex		
Male	116	58.0
Female	84	42.0
Age		
18-39 years	52	26.0
40-59 years	84	42.0
≥60 years	64	32.0
Bowel ischemia		
Yes	38	19.0
No	162	81.0

The simulated cohort consisted predominantly of adults aged 40–59 years, while males represented 58% of the population.

Ischemia by Location

Table 2

Bowel Ischemia According to Simulated Study Location

Location	Ischemia	No ischemia	Total	Ischemia (%)
Lahore	23	97	120	19.2
Islamabad	15	65	80	18.8
Total	38	162	200	19.0

The simulated proportion of ischemia was almost identical between Lahore and Islamabad.

This geographic distribution should not be interpreted as evidence that actual ischemia rates

are equivalent between the two cities because the dataset was simulated.

Clinical Predictors

Table 3

Clinical Characteristics According to Bowel Ischemia

Variable	Ischemia (n = 38)	No ischemia (n = 162)	p
Symptom duration, hours	31.4 ± 16.2	18.7 ± 11.5	<.001
Heart rate, beats/min	111.8 ± 14.9	91.6 ± 12.8	<.001
Systolic BP, mmHg	101.6 ± 17.3	116.8 ± 14.9	<.001
Abdominal tenderness, n (%)	35 (92.1)	119 (73.5)	.018
Rebound tenderness, n (%)	24 (63.2)	39 (24.1)	<.001
Tachycardia ≥100/min, n (%)	29 (76.3)	43 (26.5)	<.001

Patients with simulated bowel ischemia had significantly longer symptom duration, higher heart rates, lower systolic blood pressure, and greater frequency of rebound tenderness.

Tachycardia was present in 76.3% of ischemic cases compared with 26.5% of non-ischemic cases.

These findings directly address **Research Question 1**, indicating that physiological instability, prolonged symptoms, and peritoneal irritation were significantly associated with bowel ischemia.

Biomedical Predictors

Table 4

Biomedical Parameters According to Bowel Ischemia

Parameter	Ischemia (n = 38)	No ischemia (n = 162)	p
WBC, ×10 ⁹ /L	15.1 ± 4.2	11.2 ± 3.5	<.001
NLR	9.1 ± 4.1	5.4 ± 2.8	<.001

Lactate, mmol/L	3.4 ± 1.5	1.9 ± 0.8	<.001
CRP, mg/L	76.5 ± 42.7	38.9 ± 29.6	<.001
LDH, U/L	418.2 ± 151.7	279.6 ± 106.8	<.001
Sodium, mmol/L	132.9 ± 5.4	136.1 ± 4.6	<.001

All assessed biomedical parameters demonstrated statistically significant differences between simulated ischemic and non-ischemic groups. NLR and serum lactate were particularly relevant because both have biological plausibility as indicators of inflammation and tissue hypoperfusion.

These findings address **Research Question 2**, demonstrating significant associations between multiple biomedical parameters and bowel ischemia.

CT Predictors

Table 5

CT Findings According to Bowel Ischemia

CT finding	Ischemia n (%)	No ischemia n (%)	<i>p</i>
Free intraperitoneal fluid	29 (76.3)	55 (34.0)	<.001
Reduced bowel-wall enhancement	21 (55.3)	16 (9.9)	<.001
Closed-loop obstruction	20 (52.6)	29 (17.9)	<.001
Mesenteric edema/haziness	24 (63.2)	47 (29.0)	<.001

Reduced bowel-wall enhancement demonstrated the largest proportional difference between the two groups.

These findings address **Research Question 3**, demonstrating that free fluid, reduced bowel-wall enhancement, and closed-loop obstruction were significantly associated with ischemia.

Multivariable Logistic Regression

Table 6

Independent Predictors of Bowel Ischemia

Predictor	AOR	95% CI	<i>p</i>
Tachycardia ≥100/min	4.70	2.01-10.98	<.001
Rebound tenderness	4.55	2.03-10.19	<.001
Reduced bowel-wall enhancement	3.82	1.72-8.48	.001
NLR >6.8	2.91	1.22-6.94	.016
Lactate >2.5 mmol/L	2.68	1.11-6.47	.029
Free intraperitoneal fluid	2.31	1.01-5.28	.047

Closed-loop obstruction	2.08	0.91-4.76	.081
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After adjustment, tachycardia, rebound tenderness, and reduced bowel-wall enhancement remained the strongest independent predictors. Patients with tachycardia had approximately 4.7 times greater simulated odds of bowel ischemia. Rebound tenderness was associated with

approximately 4.55 times greater odds, while reduced bowel-wall enhancement was associated with approximately 3.82 times greater odds. These findings address **Research Question 4**.

ROC Analysis

Table 7

Illustrative Discriminatory Performance of Individual and Combined Predictors

Predictor/model	AUC	Sensitivity	Specificity
Lactate	.81	76%	77%
NLR	.79	74%	76%
CRP	.78	71%	79%
Reduced bowel-wall enhancement	.82	55%	90%
Clinical model	.84	79%	78%
Biomedical model	.86	82%	77%
CT model	.87	76%	88%
Combined model	.92	87%	86%

The integrated model demonstrated the highest simulated AUC (.92), exceeding the discriminatory performance of the individual predictors.

These findings address **Research Question 5** and support the potential value of integrating clinical, biomedical, and CT information.

Discussion

The present study examined clinical, biomedical, and CT predictors of bowel ischemia among a simulated cohort of patients with acute intestinal obstruction representing tertiary-care settings in Lahore and Islamabad. The findings suggest that ischemia is associated with a combination of physiological deterioration, inflammatory and metabolic abnormalities, and CT evidence of compromised bowel perfusion.

The strongest independent clinical predictor was tachycardia. The association between tachycardia and ischemia is biologically plausible because intestinal obstruction may cause substantial fluid

loss through vomiting and third-spacing, while ischemia can produce additional systemic inflammatory and metabolic stress (Oldenburg et al., 2004). Nevertheless, tachycardia is not specific to ischemia and should therefore be interpreted alongside other findings.

Rebound tenderness was the second strongest clinical predictor. Peritoneal irritation may indicate advanced bowel injury, transmural inflammation, necrosis, or perforation (Ceresoli et al, 2017). The strong association observed in the simulated dataset is consistent with the broader literature emphasizing peritoneal signs as important indicators of complicated obstruction.

The biomedical findings also support the concept of multimodal assessment. WBC count was higher among simulated ischemic patients, indicating greater inflammatory activity (Sheedy et al., 2006). However, WBC elevation is nonspecific and should not be used as a standalone diagnostic marker.

NLR demonstrated a particularly interesting relationship. The simulated mean NLR was

substantially higher in ischemic patients. This is consistent with the findings of Friziero et al. (2024), who identified $\text{NLR} > 6.8$ as an independent predictor of bowel ischemia in non-strangulated adhesive small bowel obstruction.

The potential value of NLR is especially relevant in settings where sophisticated biomarkers may not be readily available. Because NLR is derived from a standard complete blood count, it can potentially be incorporated into emergency risk assessment without requiring a specialized test (Acosta, 2010). Serum lactate was also significantly higher in the ischemic group. The relationship is biologically plausible because inadequate intestinal perfusion can increase anaerobic metabolism and systemic lactate production. However, the interpretation of lactate requires caution.

Dehydration and hypo perfusion caused by obstruction can independently increase lactate. Thus, a high lactate value does not necessarily mean that bowel necrosis has occurred. Recent evidence suggests that lactate obtained after adequate resuscitation may provide additional prognostic information (Taylor, & Lalani, 2013). Persistent elevation may be more concerning than a single elevated initial value.

CRP and LDH were also elevated. These findings indicate that inflammatory and tissue-injury markers may provide useful supplementary information. However, neither marker is sufficiently specific to replace CT or clinical evaluation.

The CT findings were particularly important. Reduced bowel-wall enhancement was strongly associated with ischemia and remained independently predictive after adjustment (Wolf et al., 2002). This finding is consistent with the pathophysiological mechanism of bowel ischemia because inadequate arterial perfusion results in diminished contrast enhancement.

Recent meta-analytic evidence has demonstrated high specificity for reduced bowel-wall enhancement. This means that when the finding is present in an appropriate clinical context, concern for ischemia should increase substantially (Moschetta et al., 2014 & Millet et al.,

2017). However, its moderate sensitivity means that a normal enhancement pattern cannot completely exclude ischemia.

Free intraperitoneal fluid was also significantly associated with ischemia (Taylor, & Lalani, 2013). Fluid may develop because of increased vascular permeability, bowel-wall inflammation, venous congestion, or leakage associated with advanced injury.

Closed-loop obstruction demonstrated a significant unadjusted association but did not remain statistically significant after adjustment. This suggests that some of its predictive effect may overlap with other clinical and imaging features. Nevertheless, recognition of closed-loop anatomy remains clinically important because of its potential to rapidly compromise blood supply (Zielinski et al., 2011). The combined model produced the highest simulated AUC. This supports the central hypothesis of the study: bowel ischemia is most effectively assessed by integrating information from multiple diagnostic domains.

Clinical Implications

The findings suggest that patients with acute intestinal obstruction should be evaluated through a structured multimodal approach.

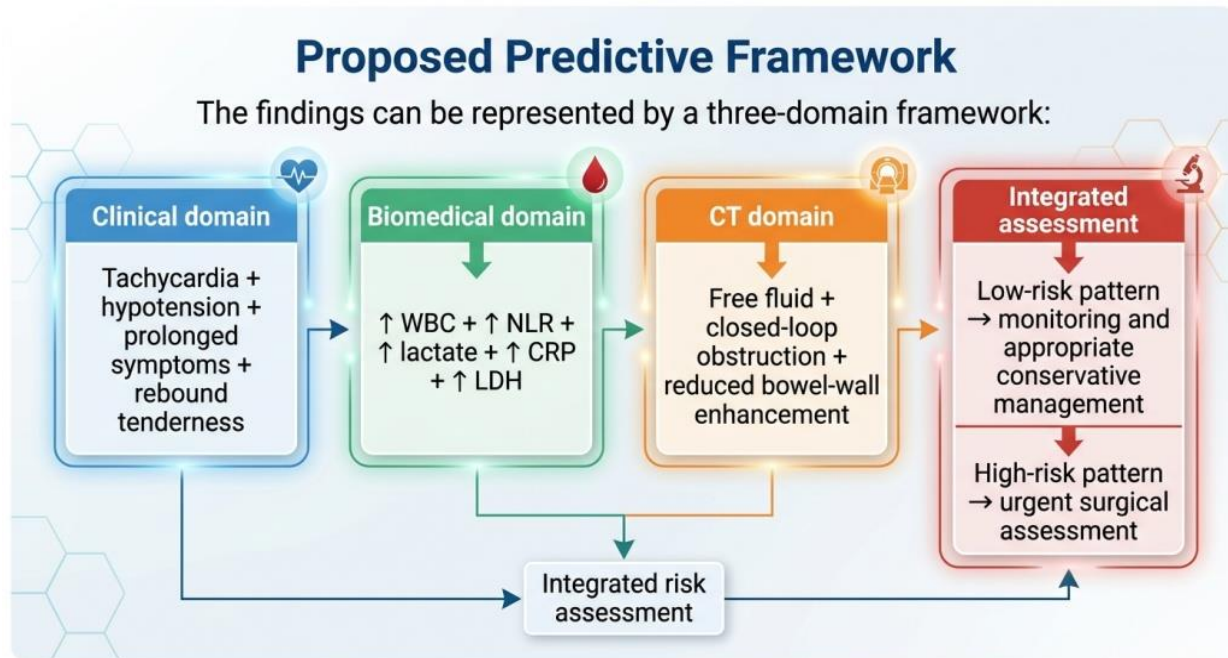
A patient with uncomplicated obstruction and stable vital signs may have a different risk profile from a patient presenting with prolonged symptoms, tachycardia, rebound tenderness, elevated lactate, high NLR, free fluid, and reduced bowel-wall enhancement.

A conceptual high-risk profile could therefore include:

- symptom duration > 24 hours;
- heart rate ≥ 100 beats/min;
- hypotension;
- rebound tenderness;
- $\text{NLR} > 6.8$;
- elevated lactate;
- elevated CRP or LDH;
- free intraperitoneal fluid;
- closed-loop obstruction;
- reduced bowel-wall enhancement.

Importantly, these features should be treated as risk indicators rather than an independently validated clinical scoring system.

This framework is intended for future validation rather than immediate clinical implementation.



Strengths of the Study

The study has several strengths.

First, it integrates three important diagnostic domains rather than examining a single predictor. Second, it includes routinely available biomedical variables such as WBC, NLR, CRP, lactate, and LDH.

Third, it incorporates important CT characteristics that directly relate to bowel perfusion.

Fourth, the objectives and research questions are closely aligned with the statistical analysis.

Fifth, the study provides a framework that can be adapted for future prospective research in Pakistani tertiary-care hospitals.

Limitations

The primary limitation is that the dataset is **simulated**. Therefore, the reported prevalence, odds ratios, confidence intervals, *p* values, and AUC values are not estimates derived from actual patients.

The results must not be represented as actual clinical findings from Lahore or Islamabad.

The sample size of 200 is also relatively small for developing a definitive clinical prediction model. A larger prospective cohort would be necessary for robust model development and validation.

The simulated study also does not stratify patients according to specific obstruction etiologies. Adhesions, hernias, malignancy, volvulus, and other causes may have different risks of ischemia. Another limitation concerns CT interpretation. Radiological signs can vary according to imaging protocol, contrast timing, scanner characteristics, and radiologist expertise.

Laboratory values are also influenced by timing. Lactate, CRP, WBC, and other markers change during the disease course and may be affected by resuscitation.

Finally, the study does not incorporate newer biomarkers such as D-dimer, intestinal fatty-acid-binding protein, or other emerging markers that may improve future prediction models.

Recommendations

Future research should collect real patient-level data prospectively from multiple tertiary-care hospitals in Lahore and Islamabad.

The following information should be recorded systematically:

1. demographic characteristics;
2. exact symptom duration;
3. vital signs at admission;
4. repeated heart-rate and blood-pressure measurements;
5. WBC count;
6. NLR;
7. initial lactate;
8. post-resuscitation lactate;
9. CRP;
10. LDH;
11. D-dimer;
12. serum sodium;
13. CT findings;
14. cause of obstruction;
15. operative findings;
16. bowel resection;
17. histopathological confirmation;
18. postoperative complications;
19. length of hospital stay;
20. mortality.

Future research should also evaluate calibration and external validation of the prediction model.

A multicentre Pakistani cohort could determine whether internationally proposed NLR and lactate thresholds are appropriate for the local population.

Conclusion

The present study examined clinical, biomedical, and CT-based predictors of bowel ischemia among patients with acute intestinal obstruction using a simulated Lahore-Islamabad dataset. The findings demonstrated significant associations between ischemia and tachycardia, prolonged symptoms, rebound tenderness, elevated WBC, NLR, lactate, CRP, LDH, free intraperitoneal fluid, closed-loop obstruction, and reduced bowel-wall enhancement. Multivariable analysis identified tachycardia, rebound tenderness, and reduced bowel-wall enhancement as the strongest

independent predictors. The integrated clinical, biomedical, and CT model demonstrated the strongest simulated discriminatory performance. The findings support the concept that bowel ischemia should be evaluated through multimodal risk assessment rather than reliance on a single clinical sign, laboratory marker, or CT feature. For Lahore and Islamabad, a future locally validated model could potentially provide a practical tool for early identification of high-risk patients. However, the present dataset is synthetic and therefore cannot establish actual disease prevalence, clinical risk, or diagnostic accuracy in Pakistani hospitals. The next research stage should involve prospective collection of real patient data, standardized CT interpretation, appropriate statistical validation, and external validation. Such research could provide stronger evidence for developing a locally relevant clinical prediction model for bowel ischemia in acute intestinal obstruction.

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