Early Physiologic Derangements for Detection of Major Complications After Bariatric Surgery: A Multicenter Cohort Study

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Abstract

Background

Early recognition of major postoperative complications after bariatric surgery remains challenging. This study evaluated the diagnostic performance of early postoperative clinical and laboratory abnormalities.

Methods

A multicenter retrospective cohort study included 9,182 consecutive adults who underwent primary or revisional bariatric surgery at four tertiary centers between September 2016 and December 2020. Prespecified thresholds for routinely monitored postoperative clinical and laboratory parameters were evaluated.

Results

Among 9,182 patients, 87 (0.95%) developed major postoperative complications. Oxygen desaturation (SpO_2 ≤94%) was the strongest independent predictor (adjusted OR 28.88, 95% CI 14.08–59.24), followed by revisional surgery (adjusted OR 14.94, 95% CI 6.45–34.61), tachypnea, leukocytosis, anemia, severe postoperative pain, older age, and prolonged operative time. Oxygen desaturation demonstrated the highest diagnostic performance (specificity 99.3%; positive likelihood ratio [PLR], 106.7), while severe anemia (Hb ≤ 10 g/dL), fever (≥ 38°C), and severe postoperative pain also showed excellent rule-in performance (PLRs 10.3, 87.0, and 6.9, respectively). In contrast, tachycardia and tachypnea were sensitive but poorly specific screening indicators. Based on these findings, a practical bedside risk stratification framework integrating baseline procedural risk and early postoperative abnormalities was developed to support timely escalation of care. Internal bootstrap validation demonstrated excellent discrimination (optimism-corrected AUC 0.957) with minimal model optimism.

Conclusions

Major postoperative complications are characterized by physiologic and laboratory abnormalities. Oxygen desaturation, severe anemia, fever, and severe postoperative pain provide highly specific bedside indicators that should prompt early diagnostic evaluation. A structured postoperative assessment framework incorporating these variables may facilitate earlier recognition, timely intervention, and improved patient outcomes.

Trial Registration

ClinicalTrials.gov Identifier: NCT03556995

Introduction

The global burden of obesity continues to rise, contributing substantially to morbidity, mortality, and health care utilization worldwide [1]. In parallel, the rapid expansion of pharmacologic therapies, particularly glucagon-like peptide-1 receptor agonists, has reshaped obesity management and underscores the need for robust data to guide safety and evidence-based decision-making across treatment modalities [2, 3]. Despite advances in medical therapy, bariatric surgery remains the most effective intervention for durable weight loss [4] and is associated with sustained reductions in obesity-related comorbidity and all-cause mortality [5].

Although perioperative care has improved, early postoperative complications remain clinically consequential. Patients with severe obesity have physiologic characteristics that may obscure early recognition of complications [6]. Major events still contribute to morbidity, unplanned reoperation, prolonged hospitalization, and intensive care unit admission [7], and delays in diagnosis are associated with worse outcomes and increased resource use [8]. The early postoperative period is also characterized by physiologic changes that can mimic complications, including tachycardia, low-grade fever, discomfort, nausea, and transient respiratory changes [9, 10]. These findings may be subtle or atypical even when they represent early signals of serious pathology such as leak, hemorrhage, pulmonary embolism, abscess, or bowel obstruction [11].

Most prior bariatric studies have emphasized incidence, procedure-related risk factors, or comparisons between techniques [12]. Less attention has been directed toward the bedside presentation of early complications, leaving clinicians to rely on subjective judgment that may delay evaluation [13]. This challenge is amplified by altered physiology and atypical inflammatory responses in bariatric populations [14]. In addition, cognitive and system factors may normalize deviations from expected recovery and delay escalation [15], particularly when symptoms are considered “typical” after surgery [10]. Multicenter analyses can improve generalizability by capturing heterogeneity in patients and perioperative practices [16, 17].

Despite the widespread use of early warning signs, there is no standardized, evidence-based framework defining which postoperative abnormalities should trigger escalation of care after bariatric surgery, resulting in variability in clinical decision-making and potential delays in diagnosis. Therefore, this study evaluated the diagnostic performance of early postoperative clinical signs and laboratory abnormalities for the early recognition of major postoperative complications.

Materials and Methods

Study Design and Ethical Approval

Among 9,664 consecutive bariatric procedures performed between September 2016 and December 2020, 9,182 patients met the inclusion criteria and were included in the study. Surgical volume varied across the four participating centers (northern, 3,153; southern, 1,104; central, 3,357; suburban, 1,568). A

total of 482 patients (5.0%) were excluded because of incomplete postoperative vital sign or laboratory data required for the diagnostic-performance analyses.

The study protocol was approved by the local ethics committee (Helsinki approval 2015073), registered at ClinicalTrials.gov (NCT03556995), and the requirement for written informed consent was waived because of the retrospective design and use of de-identified data.

Study Population

Eligible patients were consecutive adults undergoing primary or revisional bariatric surgery at the four participating centers between September 2016 and December 2020, without restriction according to sex, body mass index, or procedure type.

Data Collection

Data were extracted from electronic medical records using MDClone (MDClone Ltd., Beer Sheva, Israel), a validated platform for structured querying and de-identification.

The following variables were extracted a priori from the electronic medical records: demographic characteristics (age, sex, BMI), operative characteristics (procedure type, revisional status, operative time), postoperative clinical variables (heart rate, respiratory rate, temperature, oxygen saturation, pain score, vomiting/oral intolerance), laboratory parameters (white blood cell count and hemoglobin), and clinical outcomes (complications, reoperation, mortality).

Postoperative values were recorded during the index hospitalization. Missing data accounted for less than 5% of observations for all variables; therefore, complete-case analysis was considered appropriate.

Baseline comorbidities, including hypertension, diabetes mellitus, obstructive sleep apnea (OSA), gastroesophageal reflux disease, asthma, atrial fibrillation, ischemic heart disease, and nonalcoholic fatty liver disease, were recorded. Perioperative variables included revisional surgery, concomitant procedures, and routine postoperative thromboprophylaxis according to institutional protocols.

Definitions and Outcomes

The primary outcome was the occurrence of early major postoperative complications during the index hospitalization that required diagnostic or therapeutic intervention. Early postoperative complications were defined as events occurring during the index hospitalization, typically within postoperative days 0–2 before discharge. Major complications were predefined a priori and included anastomotic leak, intra-abdominal bleeding, intra-abdominal abscess, bowel obstruction, severe infections, severe respiratory complications, and other events requiring reoperation or invasive intervention. Isolated superficial surgical site infections were excluded from the diagnostic-performance analyses.

Thresholds for postoperative clinical and laboratory abnormalities were prespecified a priori based on published bariatric literature, ERAS recommendations, commonly used early warning systems, and institutional postoperative monitoring protocols.

Evaluated variables included heart rate ≥ 100 and ≥ 110 beats/min, respiratory rate ≥ 24 and ≥ 30 breaths/min, temperature ≥ 38.0°C, white blood cell count ≥ 14,000/mm³, hemoglobin ≤ 12 g/dL and ≤ 10 g/dL (with hemoglobin ≤ 10 g/dL defining severe anemia), oxygen saturation (SpO_2) ≤ 94%, and pain score ≥ 6 on a 10-point visual analog scale (VAS).

Oxygen desaturation was defined as a persistent SpO_2 ≤94% documented on at least two consecutive measurements during routine postoperative monitoring. Pulse oximetry was performed according to institutional practice, and supplemental oxygen was administered when clinically indicated. Hemoglobin values used for diagnostic analyses corresponded to the first postoperative laboratory assessment obtained during the index hospitalization.

Pain intensity was assessed using a 10-point VAS beginning on postoperative day 1 after implementation of the institutional postoperative analgesic protocol, thereby minimizing confounding related to immediate anesthetic recovery.

Postoperative monitoring, including assessment of vital signs, laboratory parameters, and pain scores, was performed according to similar institutional protocols across the participating centers. Only the first abnormal postoperative value recorded before diagnostic imaging, reoperation, or other therapeutic intervention for a suspected complication was included in the analyses, ensuring evaluation of bedside indicators for early recognition rather than post diagnostic findings.

Statistical Analysis

Continuous variables are presented as mean (SD) or median (IQR), and categorical variables as frequency (percentage). Groups were compared using Student's t test or Mann–Whitney U test for continuous variables and χ^2 or Fisher exact test for categorical variables. For each sign/abnormality, sensitivity, specificity, likelihood ratios, and 95% CIs were calculated. Multivariable logistic regression evaluated independent predictors; covariates were prespecified (age, sex, BMI, ASA class, procedure type, revisional status, operative time, and postoperative variables).

Variables included in the multivariable model were selected a priori based on clinical relevance and previous literature rather than univariate significance alone. Internal validation of the multivariable model was performed using bootstrap resampling to estimate model optimism and calibration.

Two-sided $P < .05$ was considered statistically significant. Analyses were performed with SPSS (version 23, IBM Corp., Armonk, NY, USA).

Results

Study population

The study included 9,182 consecutive patients undergoing bariatric surgery during the study period. The mean age was 40.5 years, with a predominance of female patients. The cohort was characterized by severe obesity (mean BMI 41.0 kg/m²) and short operative times, reflecting a predominantly elective, minimally invasive surgical population.

Laparoscopic single-anastomosis gastric bypass and laparoscopic sleeve gastrectomy accounted for more than 90% of all procedures, and ~ 7% of patients underwent revisional surgery. Obesity-related comorbidities were highly prevalent, particularly dyslipidemia, metabolic syndrome, and nonalcoholic fatty liver disease (Table 1).

Table 1
Baseline demographic characteristics.

Continuous Variable	**Mean ± SD (N 9182)**
Age (Years)	40.48 ± 12.07
Height (m)	1.66 ± 0.09
Weight (kg)	113.93 ± 18.44
BMI (kg/m^2)	41.01 ± 4.87
Operative time (minutes)	79.92 ± 25.03
Length of hospital stay (days)	2.30 ± 1.37
Categorical variables	**Number (%)**
Sex	
Male	2618 (28.51%)
Female	6564 (71.49%)
ASA class 1	742 (8.08%)
ASA class 2	6689 (72.85%)
ASA class 3	1734 (18.88%)
ASA class 4	17 (0.19%)
Type of bariatric surgery	
LBPD/DS/SADI	16 (0.17%)
LSAGB	5836 (63.56%)
LSG	2794 (30.46%)
LRYGB	531 (5.78%)
Open RYGB	2 (0.02%)
Open SAGB	2 (0.02%)
LBPD Conversion to open	1 (0.01%)
Revisional surgery	
S/P LSG	9 (0.10%)
S/P LAGB	617 (6.71%)
Values are presented as mean ± standard deviation for continuous variables and number (percentage) for categorical variables.	

Continuous Variable	Mean ± SD (N 9182)
S/P SRVG	3 (0.03%)
S/P SAGB	1 (0.01%)
Other simultaneous procedures	
Repair of hiatal hernia	678 (7.38%)
Cholecystectomy	526 (5.73%)
Umbilical hernia repair	40 (0.44%)
Ventral hernia repair	51 (0.56%)
Adhesiolysis	11 (0.12%)
Epigastric hernia repair	5 (0.05%)
Liver biopsy	8 (0.09%)
Femoral Hernia Repair	1 (0.01%)
Appendectomy	1 (0.01%)
Excision of lipoma	3 (0.03%)
Heller Myotomy	1 (0.01%)
Comorbidities	
HTN	3372 (36.72%)
Hyperlipidemia	5724 (62.34%)
NIDDM	2997 (32.64%)
NAFLD	5365 (58.43%)
OSA	3552 (38.69%)
Metabolic Syndrome	4709 (51.28%)
GERD	3619 (39.41%)
Asthma	428 (4.66%)
Chronic atrial fibrillation	298 (3.25%)
Ischemic heart disease	804 (8.76%)
Values are presented as mean ± standard deviation for continuous variables and number (percentage) for categorical variables.	

Abbreviations: ASA, American Society of Anesthesiologists physical status classification; BMI, body mass index; LSAGB, laparoscopic single-anastomosis gastric bypass; LSG, laparoscopic sleeve

gastrectomy; LRYGB, laparoscopic Roux-en-Y gastric bypass; LBPD/DS/SADI, laparoscopic biliopancreatic diversion/duodenal switch/single-anastomosis duodeno-ileal bypass; OSA, obstructive sleep apnea; NAFLD, nonalcoholic fatty liver disease; GERD, gastroesophageal reflux disease.

Comparison groups

Patients who developed major postoperative complications were significantly older than those without complications (p<.001). Operative time was also markedly longer in the complication group, indicating greater procedural complexity (p<.001).

In contrast, baseline surgical risk as assessed by ASA class and the degree of obesity were not associated with the occurrence of complications. Neither ASA score nor BMI differed significantly between groups.

Revisional surgery was strongly associated with early complications, occurring in approximately one-fifth of complicated cases compared with less than 6% of uncomplicated cases (p<.001). With respect to procedure type, Roux-en-Y gastric bypass and biliopancreatic diversion were more frequently associated with complications, whereas laparoscopic sleeve gastrectomy was less frequent among complicated cases (Table 2).

Table 2
Comparison between patients with and without early postoperative complications.

Continuous variables	**No complications N = 9095**	**Complications N = 87**	**p-value**
	Mean ± SD	**Mean ± SD**	
Age (years)	40.37 ± 12.50	47.87 ± 11.35	**< .001**
ASA class	2.11 ± 0.51	2.11 ± 0.45	.95
BMI (kg/m^2)	41.00 ± 4.86	40.26 ± 5.40	.18
Operative time (min)	79.57 ± 23.85	118.76 ± 75.33	**< .001**
Categorical Variables	**N (%)**	**N (%)**	
Revisional surgery	543 (5.97%)	17 (19.54%)	**< .001**
RYGB	524 (5.76%)	9 (10.34%)	.048
SAGB	5780 (63.55%)	58 (67.82%)	.42
LSG	2775 (30.51%)	19 (20.69%)	.06
BPD	16 (0.18%)	1 (1.15%)	**.041**

Values are presented as mean ± SD for continuous variables and number (percentage) for categorical variables. P values were calculated using the independent-samples t-test for continuous variables and the χ^2 or Fisher exact test for categorical variables, as appropriate.

Abbreviations: ASA, American Society of Anesthesiologists physical status classification; BMI, body mass index; MIN, minutes; RYGB, Roux-en-Y gastric bypass; SAGB, single-anastomosis gastric bypass;

LSG, laparoscopic sleeve gastrectomy; BPD, biliopancreatic diversion.

Diagnostic performance

Early postoperative abnormalities in vital signs and laboratory parameters were strongly associated with the occurrence of complications (Fig. 1). Tachycardia (heart rate ≥ 100 beats/min) was present in 91.9% of patients with complications compared with 78.3% of uncomplicated patients (p=.002), whereas a higher threshold (heart rate ≥ 110 beats/min) showed only a modest difference between groups (33.3% vs 24.3%, p=.050).

Tachypnea (respiratory rate ≥ 24 breaths/min) occurred in 57.5% of complicated cases compared with 38.0% of uncomplicated cases (p<.001), while respiratory rates ≥ 30 breaths/min were less discriminatory (19.5% vs 13.0%, p=.072).

Fever (temperature ≥ 38°C) was observed in 64 patients (0.7%) without complications and in 6 patients (6.9%) with complications (p<.001).

Laboratory and gas-exchange abnormalities demonstrated the strongest associations. Leukocytosis (WBC 14,000/mm³) was present in 60.9% of patients with complications compared with 27.1% of those without complications during the index hospitalization (p<.001). Oxygen desaturation (SpO_2) showed the largest absolute difference, occurring in 74.7% of complicated cases and in only 0.73% of uncomplicated patients during the index hospitalization (p<.001).

Similarly, anemia was highly prevalent among complicated patients, with hemoglobin ≤ 12 g/dL in 79.3% and ≤ 10 g/dL in 50.6%, compared with 33.4% and 4.9% of uncomplicated patients, respectively (both p<.001).

Severe postoperative pain (VAS ≥ 6) was observed in 57.5% of patients with complications and in 8.4% of those without complications (p<.001).

The diagnostic performance of early postoperative clinical and laboratory indicators is presented in Table 3. Oxygen desaturation (SpO_2 ≤94%) was the most informative bedside indicator of major postoperative complications, demonstrating excellent rule-in performance (positive likelihood ratio [PLR], 106.7). Severe anemia (Hb ≤ 10 g/dL), fever (≥ 38°C), and severe postoperative pain (VAS ≥ 6) also demonstrated strong diagnostic utility, whereas leukocytosis and mild anemia provided modest rule-in value. In contrast, tachycardia and tachypnea exhibited limited diagnostic performance when considered individually despite their relatively high sensitivity.

Table 3
Diagnostic Performance of Early Postoperative Clinical and Laboratory Indicators for Predicting Major Postoperative Complications After Bariatric Surgery.

Variable	Sensitivity %	Specificity %	PLR	Clinical interpretation
HR ≥ 100 bpm	92.0	21.7	1.18	Poor discrimination
HR ≥ 110 bpm	33.3	75.7	1.37	Poor discrimination
RR ≥ 24 /min	57.5	62.0	1.51	Limited discrimination
RR ≥ 30 /min	19.5	87.0	1.50	Limited discrimination
WBC ≥ 14,000 mm^3	60.9	72.9	2.25	Modest rule-in
Fever ≥ 38°C	6.9	99.3	9.86	Strong rule-in
SpO_2 ≤94%	74.7	99.3	106.7	Excellent rule-in
Hb ≤ 12 g/dL	79.3	66.6	2.37	Modest rule-in
Hb ≤ 10 g/dL	50.6	95.1	10.33	Strong rule-in
Pain VAS ≥ 6	57.5	91.6	6.85	Moderate rule-in

Sensitivity, specificity, and positive likelihood ratios were calculated for each prespecified postoperative clinical and laboratory abnormality using major postoperative complications as the reference standard (87 patients with complications and 9,095 without complications). Oxygen desaturation (SpO_2 ≤94%), severe anemia (Hb ≤ 10 g/dL), fever (≥ 38°C), and severe postoperative pain (VAS ≥ 6) demonstrated the greatest rule-in value, whereas tachycardia and tachypnea showed limited diagnostic utility when considered individually.

Abbreviations: PLR, positive likelihood ratio; HR, heart rate; RR, respiratory rate; WBC, white blood cell count; Hb, hemoglobin; SpO_2, Peripheral oxygen saturation; VAS, Visual Analog Scale; PLR, positive likelihood ratio.

Univariate and Multivariable Predictors of Major Postoperative Complications

In univariate analysis, increasing age (OR, 1.04 per year; 95% CI, 1.03–1.06; P<.001) and longer operative time (OR, 1.012 per minute; 95% CI, 1.008–1.016; P<.001) were significantly associated with major postoperative complications (Fig. 2). Revisional surgery was the strongest baseline predictor (OR, 12.8; 95% CI, 6.1–26.8; P<.001), whereas sex, body mass index, and ASA class were not significantly associated with complication risk. Among postoperative variables, oxygen desaturation (SpO_2 ≤94%) demonstrated the strongest association (OR, 32.1; 95% CI, 17.8–57.9; P<.001), followed by tachypnea, leukocytosis, severe postoperative pain, tachycardia, and anemia.

In multivariable logistic regression (Fig. 3), increasing age and prolonged operative time remained independently associated with complications. Revisional surgery remained the strongest baseline

predictor (adjusted OR [aOR], 14.94; 95% CI, 6.45–34.61; P<.001), while oxygen desaturation was the strongest independent postoperative predictor (aOR, 28.88; 95% CI, 14.08–59.24; P<.001). Tachypnea, leukocytosis, anemia, and severe postoperative pain also remained independently associated with complications, whereas sex, body mass index, ASA class, surgical procedure, and tachycardia were no longer independently associated. Overall, the coexistence of multiple postoperative abnormalities was associated with a substantially greater likelihood of major complications than isolated findings, supporting a cumulative risk approach to postoperative assessment.

Clinical framework

A total of 93 (1.01%) patients suspected to developed major postoperative clinical findings suggestive of major complications. Of these, 87 fulfilled the prespecified criteria and were included in the diagnostic-performance analyses. Six patients were excluded because their clinical abnormalities were ultimately attributed to pre-existing systemic comorbidities rather than to a postoperative surgical complication. Based on the clinical suspicion of a major surgical complication, 71 patients (0.77% of the cohort) underwent surgical exploration. Intraoperative pathology confirming the suspected diagnosis was identified in 61 patients (85.9%), whereas 10 patients (14.1%) underwent negative explorations without identifiable surgical pathology.

Internal validation of the multivariable prediction model was performed using bootstrap resampling. In the complete-case cohort of 8,335 patients, including 61 confirmed major complications, the model demonstrated excellent discrimination, with an apparent AUC of 0.960 and an optimism-corrected AUC of 0.957. Calibration remained acceptable after bootstrap correction, with an optimism-corrected calibration slope of 0.935 and an optimism-corrected Brier score of 0.0057, indicating minimal model optimism and no substantial overfitting.

The most common complications were postoperative bleeding (0.35%) and anastomotic leak (0.22%); bowel obstruction was rare (0.07%), and infectious events, pneumonia, intra-abdominal abscess, were uncommon (Table 4). Pulmonary aspiration and pneumonia each occurred in 0.02%, and other medical complications (pancreatitis, pericarditis, ureterolithiasis) each occurred in < 0.02%. Six patients (0.06%) required ICU admission, and there was one death (0.01%) after revisional surgery due to an anastomotic leak.

Table 4
Early postoperative Complications after bariatric surgery

A. Clinically diagnosed postoperative complications		
Complication	**N**	**Percent**
Anastomotic leak	20	0.22%
Abdominal bleeding	32	0.35%
Small bowel obstruction	6	0.07%
Small bowel perforation	1	0.01%
Pulmonary aspiration	2	0.02%
Atelectasis	4	0.04%
Pneumonia	4	0.04%
Pancreatitis	1	0.01%
Pancreatic tail injury	1	0.01%
Diaphragmatic laceration	1	0.01%
Intra-abdominal abscess	2	0.02%
Gastrojejunal stricture	2	0.02%
Incisura angularis stricture	2	0.02%
Deep wound infection	1	0.01%
Pericarditis	1	0.01%
Obstructive ureterolithiasis	1	0.01%
Large bowel volvulus	1	0.01%
Vomiting	4	0.04%
Superficial site infection	6	0.06%
Allergic reaction	1	0.01%
B. Surgical re-exploration outcomes		
Outcome	**N**	**Percent**

Values are presented as number of patients (N) and percentage of the total cohort (N = 9,182). Percentages were calculated using the entire study population as the denominator. Clinically diagnosed complications represent adverse events identified during the index hospitalization. Surgical re-exploration outcomes are reported separately and include positive revisions (with intraoperative pathological findings) and negative explorations (no intraoperative abnormality identified). Superficial surgical site infections were not included in diagnostic-performance analyses.

A. Clinically diagnosed postoperative complications		
Complication	**N**	**Percent**
Positive revision surgery	61	0.66%
Negative explorations	10	0.11%

Values are presented as number of patients (N) and percentage of the total cohort (N = 9,182). Percentages were calculated using the entire study population as the denominator. Clinically diagnosed complications represent adverse events identified during the index hospitalization. Surgical re-exploration outcomes are reported separately and include positive revisions (with intraoperative pathological findings) and negative explorations (no intraoperative abnormality identified). Superficial surgical site infections were not included in diagnostic-performance analyses.

Based on the independent predictors and diagnostic performance identified in the present study, a proposed clinical framework integrating baseline procedural risk factors and early postoperative clinical abnormalities was developed to facilitate bedside risk stratification and timely escalation of care (Table 5).

Table 5
Proposed Clinical Framework for Early Recognition and Escalation of Major Postoperative Complications After Bariatric Surgery.

Clinical variable	Clinical significance	Proposed points
SpO_2 ≤94%	Very high-risk indicator; immediate diagnostic evaluation recommended	4
Hb ≤ 10	Strong indicator of postoperative bleeding	3
Fever ≥ 38°C	High-risk indicator requiring evaluation for infectious complications	2
Pain VAS ≥ 6	Suggests evolving intra-abdominal complication when persistent or unexplained	2
Revisional surgery	Baseline risk factor associated with major postoperative complications.	2
WBC ≥ 14,000/mm³	Supportive indicator of systemic inflammatory response	1
Tachypnea ≥ 24/min	Sensitive screening indicator; warrants closer observation	1
Heart rate ≥ 110 bpm	Clinical warning sign that should prompt reassessment, particularly when associated with other abnormalities	1
Proposed risk stratification		
• Low risk (0–2 points): Continue routine postoperative monitoring.		
• Moderate risk (3–5 points): Increased clinical surveillance and reassessment; consider additional laboratory tests or imaging according to the clinical scenario.		
• High risk (≥ 6 points): Immediate senior surgical review and expedited diagnostic evaluation. Early operative exploration should be considered when clinically indicated.		
The proposed point allocation and risk categories are intended as a pragmatic clinical framework derived from the relative diagnostic performance of the identified predictors. Prospective validation is required before routine clinical implementation.		

Abbreviations: SpO_2, peripheral oxygen saturation; Hb, hemoglobin; WBC, white blood cell count; VAS, Visual Analog Scale; bpm, beats per minute.

Discussion

This study moves beyond descriptive associations by quantifying the diagnostic performance of individual postoperative abnormalities and defining their complementary roles as screening versus rule-in indicators in major complication detection. From a clinical perspective, these findings support a structured escalation strategy. Isolated abnormalities such as tachycardia may warrant observation, whereas the presence of highly specific findings, particularly oxygen desaturation, severe anemia, fever,

or severe pain, should prompt immediate diagnostic evaluation, including imaging or early surgical consultation. This approach may help distinguish patients requiring urgent intervention from those undergoing expected postoperative recovery.

These findings have direct implications for postoperative decision-making, highlighting that specific early physiologic abnormalities can identify patients at increased risk for major complications [18].

In this large multicenter cohort of more than 9,000 consecutive bariatric surgeries, we evaluated the diagnostic performance of early postoperative clinical signs and laboratory abnormalities for the detection of major complications. To our knowledge, this is among the largest studies to quantify the diagnostic accuracy of individual postoperative findings using likelihood ratios and multivariable modeling in bariatric surgery [19, 20]. The principal findings are threefold. First, major postoperative complications were uncommon, occurring in approximately 1% of patients, but were associated with marked physiologic and laboratory derangements; notably, this rate is lower than the previously reported benchmark of 5.5% [21]. Second, commonly monitored vital signs such as heart rate and respiratory rate, although highly sensitive, demonstrated limited specificity and poor rule-in value. Third, a limited set of abnormalities, particularly oxygen desaturation, severe anemia, fever, and severe postoperative pain, showed high specificity and strong discriminatory power, identifying patients at markedly increased risk of clinically significant complications, consistent with prior reports [22].

Early recognition of postoperative complications after bariatric surgery remains a central challenge. Several investigations have emphasized tachycardia as an early warning sign, particularly for anastomotic or staple-line leaks [23, 24]. Persistent tachycardia has been incorporated into institutional algorithms as a trigger for urgent imaging or surgical exploration [25]. However, most studies have evaluated tachycardia qualitatively rather than as a diagnostic test with quantifiable performance characteristics [26].

Our data refine this concept. Although tachycardia was present in more than 90% of patients with complications, it was also observed in nearly 80% of uncomplicated patients. Consequently, its specificity was low and its positive likelihood ratio approached unity, indicating limited diagnostic value in isolation. This finding aligns with reports showing that postoperative tachycardia often reflects pain, hypovolemia, atelectasis, or sympathetic activation rather than intra-abdominal pathology [26, 27]. In broader acute care settings, tachycardia is recognized as a core component of systemic inflammatory response and a marker of clinical deterioration, forming part of early warning and escalation systems despite limited specificity [28]. These observations support interpreting tachycardia primarily as a screening signal that warrants closer observation rather than a definitive indicator of complication.

Similar considerations apply to tachypnea. Although elevated respiratory rate was more frequent among complicated patients, its diagnostic performance remained modest. Prior studies have shown that postoperative tachypnea is often multifactorial, related to pain, anxiety, obesity hypoventilation, or residual anesthetic effects [29], and may reflect pulmonary or systemic conditions rather than intra-abdominal complications [30].

In contrast, laboratory and gas-exchange abnormalities demonstrated substantially greater discriminatory power. Leukocytosis was strongly associated with complications, consistent with prior reports linking systemic inflammatory response to intra-abdominal infection and sepsis [25]. Although additional biomarkers have been proposed for risk prediction, they are not routinely incorporated into standard perioperative assessment [31, 32].

Anemia was also highly predictive, reflecting the role of postoperative bleeding as a major source of morbidity. Importantly, anemia should not be considered an inevitable postoperative finding but interpreted in clinical context, particularly when associated with other abnormalities [33].

Oxygen desaturation emerged as the strongest predictor in both univariate and multivariable analyses. Even modest hypoxemia (≤ 94%) was associated with a markedly increased risk of complications. Although hypoxemia has been linked to pulmonary and systemic pathology, these findings suggest that it may represent an integrative signal of severe physiologic derangement, including sepsis, bleeding, or intra-abdominal catastrophe, consistent with observations from critical care and emergency surgery literature [34, 35].

Severe postoperative pain and fever also demonstrated high specificity and rule-in value [36]. While pain is common after bariatric surgery, higher-intensity pain appears strongly associated with underlying pathology. In contrast, postoperative fever alone is frequently noninfectious and should be interpreted cautiously [37]. The proposed point allocation is intended as a pragmatic clinical framework based on the relative strength and diagnostic performance of the identified predictors. Prospective validation is required before routine clinical implementation.

Consistent with prior observations, complications are rarely heralded by a single isolated abnormality [38]. Instead, patients with complications more often exhibit concurrent or evolving abnormalities, supporting a cumulative risk paradigm. Diagnostic accuracy appears to increase when abnormalities cluster or persist over time rather than occur transiently. Accordingly, dynamic reassessment and timely escalation of diagnostic evaluation remain central to preventing progression to severe morbidity and mortality [39]. Clinically significant events meeting prespecified criteria of postoperative complication, even in the absence of definitive confirmation, should prompt early intervention to avoid catastrophic delay [24]. Current practice in many centers continues to rely on isolated vital sign abnormalities as triggers for imaging or surgical exploration [40], an approach that may benefit from refinement through integration of multiple parameters.

This study’s strengths include its large, multicenter cohort of consecutive patients, minimizing selection bias and enhancing generalizability. The use of likelihood ratios alongside odds ratios improves clinical interpretability, and the focus on clinically significant complications strengthens relevance.

Limitations include the retrospective design and potential residual confounding. All centers were high-volume bariatric units, which may limit generalizability. Differences in monitoring practices, supplemental oxygen use, and documentation may have influenced diagnostic performance. External validation in

independent cohorts is warranted to confirm generalizability and support implementation in clinical pathways.

Taken together, these findings support a pragmatic bedside framework in which postoperative abnormalities are stratified by diagnostic value (Fig. 4). This approach provides a structured pathway for escalation based on the differential diagnostic value of abnormalities. High-sensitivity findings function as screening indicators, whereas high-specificity abnormalities serve as rule-in triggers for escalation of care. Integration of these parameters into standardized postoperative pathways may enhance diagnostic efficiency and reduce failure-to-rescue. Future work should focus on the development and external validation of a composite risk score to support clinical implementation.

In an era of increasing emphasis on failure-to-rescue, timely recognition of physiologic derangements may represent the most modifiable determinant of postoperative outcomes.

Conclusions

Major early postoperative complications are characterized by distinct physiologic and laboratory abnormalities. Although common vital sign changes serve primarily as sensitive screening indicators, oxygen desaturation, severe anemia, fever, and severe postoperative pain provide highly specific rule-in signals that should prompt early diagnostic evaluation and escalation of care. Integration of these markers into a structured bedside assessment framework may facilitate earlier recognition, reduce diagnostic delay, and improve patient outcomes.

Declarations

Author Contribution

S.S. conceived and designed the study, interpreted the data, drafted the manuscript, and prepared the figures and tables. I.B. and A.R. contributed to study design, data acquisition, data interpretation, and critical revision of the manuscript for important intellectual content. All authors reviewed and approved the final manuscript and agree to be accountable for all aspects of the work.

References

1. GBD 2021 Risk Factors Collaborators. Global burden and strength of evidence for 88 risk factors in 204 countries and 811 subnational locations, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. Lancet. 2024;403(10440):2162–2203. doi: 10.1016/S0140-6736(24)00933-4. Erratum in: Lancet. 2024;404(10449):244. 10.1016/S0140-6736(24)01458-2
2. Xu Y, Echouffo Tcheugui JB, Coresh J, et al. Trends in obesity and glucagon-like peptide-1 receptor agonist prescriptions in type 1 diabetes in the United States. Diabetes Obes Metab. 2025;27(6):2967–76. 10.1111/dom.16300.

3. Lah S, Hocking SL. Treatment of obesity: will incretin agonists make bariatric surgery a thing of the past? Intern Med J. 2025;55(3):369–75. 10.1111/imj.16625.
4. Crewe C, Black P, Nevins EJ. Metabolic Bariatric Surgery Is Superior to Non-surgical Intervention for the Long-Term Management of Obesity-Related Primary Hypertension: A Systematic Review and Meta-analysis of Randomised Controlled Trials. Obes Surg. 2025;35(8):3291–300. 10.1007/s11695-025-08075-1.
5. Wiggins T, Guidozzi N, Welbourn R, et al. Association of bariatric surgery with all-cause mortality and incidence of obesity-related disease at a population level: A systematic review and meta-analysis. PLoS Med. 2020;17(7):e1003206. 10.1371/journal.pmed.1003206.
6. Pelosi P, Gregoretti C. Perioperative management of obese patients. Best Pract Res Clin Anaesthesiol. 2010;24(2):211–25. 10.1016/j.bpa.2010.02.001.
7. Stenberg E, Dos Reis Falcão LF, O'Kane M et al. Guidelines for Perioperative Care in Bariatric Surgery: Enhanced Recovery After Surgery (ERAS) Society Recommendations: A 2021 Update. World J Surg. 2022;46(4):729–751. 10.1007/s00268-021-06394-9. Epub 2022 Jan 4. Erratum in: World J Surg. 2022;46(4):752. doi: 10.1007/s00268-022-06459-3.
8. Chang SH, Freeman NLB, Lee JA, et al. Early major complications after bariatric surgery in the USA, 2003–2014: a systematic review and meta-analysis. Obes Rev. 2018;19(4):529–37. 10.1111/obr.12647.
9. Ortiz VE, Kwo J. Obesity: physiologic changes and implications for preoperative management. BMC Anesthesiol. 2015;15:97. 10.1186/s12871-015-0079-8.
10. Coblijn UK, Karres J, de Raaff CAL, et al. Predicting postoperative complications after bariatric surgery: the Bariatric Surgery Index for Complications, BASIC. Surg Endosc. 2017;31(11):4438–45. 10.1007/s00464-017-5494-0.
11. Monkhouse SJ, Morgan JD, Norton SA. Complications of bariatric surgery: presentation and emergency management–a review. Ann R Coll Surg Engl. 2009;91(4):280–6. 10.1308/003588409X392072.
12. Balla A, Batista Rodríguez G, Corradetti S, et al. Outcomes after bariatric surgery according to large databases: a systematic review. Langenbecks Arch Surg. 2017;402(6):885–99. 10.1007/s00423-017-1613-6.
13. Montravers P, Augustin P, Zappella N, et al. Diagnosis and management of the postoperative surgical and medical complications of bariatric surgery. Anaesth Crit Care Pain Med. 2015;34(1):45–52. 10.1016/j.accpm.2014.06.002.
14. Milano W, Carizzone F, Foia M, et al. Obesity and Its Multiple Clinical Implications between Inflammatory States and Gut Microbiotic Alterations. Diseases. 2022;11(1):7. 10.3390/diseases11010007.
15. Hu YY, Arriaga AF, Roth EM, et al. Protecting patients from an unsafe system: the etiology and recovery of intraoperative deviations in care. Ann Surg. 2012;256(2):203–10. 10.1097/SLA.0b013e3182602564.

16. Jacobsen HJ, Bergland A, Raeder J, et al. High-volume bariatric surgery in a single center: safety, quality, cost-efficacy and teaching aspects in 2,000 consecutive cases. Obes Surg. 2012;22(1):158–66. 10.1007/s11695-011-0557-0.
17. Ibrahim AM, Ghaferi AA, Thumma JR, et al. Variation in Outcomes at Bariatric Surgery Centers of Excellence. JAMA Surg. 2017;152(7):629–36. 10.1001/jamasurg.2017.0542.
18. Staiger RD, Gerns E, Castrejón Subirà M, et al. Can Early Postoperative Complications Predict High Morbidity and Decrease Failure to Rescue Following Major Abdominal Surgery? Ann Surg. 2020;272(5):834–9. 10.1097/SLA.0000000000004254.
19. Finks JF, Kole KL, Yenumula PR, Banerjee M, Birkmeyer JD, Birkmeyer NJ, et al. Michigan Bariatric Surgery Collaborative, from the Center for Healthcare Outcomes and Policy. Predicting risk for serious complications with bariatric surgery: results from the Michigan Bariatric Surgery Collaborative. Ann Surg. 2011;254(4):633–40. 10.1097/SLA.0b013e318230058c.
20. Stenberg E, Cao Y, Szabo E, et al. Risk Prediction Model for Severe Postoperative Complication in Bariatric Surgery. Obes Surg. 2018;28(7):1869–75. 10.1007/s11695-017-3099-2.
21. Gero D, Raptis DA, Vleeschouwers W, et al. Defining Global Benchmarks in Bariatric Surgery: A Retrospective Multicenter Analysis of Minimally Invasive Roux-en-Y Gastric Bypass and Sleeve Gastrectomy. Ann Surg. 2019;270(5):859–67. 10.1097/SLA.0000000000003512.
22. Farooqi S, Montrief T, Koyfman A, et al. High risk and low incidence diseases: Bariatric surgery complications. Am J Emerg Med. 2025;87:113–22. 10.1016/j.ajem.2024.10.050.
23. Bellorin O, Abdemur A, Sucandy I, et al. Understanding the significance, reasons and patterns of abnormal vital signs after gastric bypass for morbid obesity. Obes Surg. 2011;21(6):707–13. 10.1007/s11695-010-0221-0.
24. Kassir R, Debs T, Blanc P, et al. Complications of bariatric surgery: Presentation and emergency management. Int J Surg. 2016;27:77–81. 10.1016/j.ijsu.2016.01.067.
25. Car Peterko A, Kirac I, Gaurina A, et al. Diagnosis and management of acute and early complications of/after bariatric surgery. Dig Dis. 2012;30(2):178–81. 10.1159/000336677.
26. Sayida S, Obeid A, Jubran L, et al. The Relationship Between Tachycardia After Laparoscopic Sleeve Gastrectomy and the Development of Postoperative Complications. Obes Surg. 2022;32(5):1479–85. 10.1007/s11695-022-05938-9.
27. Ogunnaike BO, Jones SB, Jones DB, et al. Anesthetic considerations for bariatric surgery. Anesth Analg. 2002;95(6):1793–805. 10.1097/00000539-200212000-00061.
28. Hotchkiss RS, Moldawer LL, Opal SM, et al. Sepsis and septic shock. Nat Rev Dis Primers. 2016;2:16045. 10.1038/nrdp.2016.45.
29. Yurcisin BM, Gaddor MM, DeMaria EJ. Obesity and bariatric surgery. Clin Chest Med. 2009;30(3):539–53. 10.1016/j.ccm.2009.05.013.
30. Miskovic A, Lumb AB. Postoperative pulmonary complications. Br J Anaesth. 2017;118(3):317–34. 10.1093/bja/aex002.

31. AziziKia H, Shojaei S, Mousavi A, et al. Periprocedural Changes of Serum Biomarkers in Predicting Complications Following Bariatric Surgery for Obesity: Systematic Review and Meta-analysis. Obes Surg. 2024;34(6):2198–215. 10.1007/s11695-024-07234-0.
32. Salgado W Jr, de Queiroz Cunha F, dos Santos JS, et al. Early identification of infectious complications in bariatric surgery by the determination of peritoneal and systemic cytokines. Obes Surg. 2009;19(7):867–72. 10.1007/s11695-009-9851-5.
33. Abeysiri S, Baikady RR. Postoperative anemia: prevention without cure is not enough. Blood Transfus. 2025;23(1):37–41. 10.2450/BloodTransfus.946.
34. Rudiman R, Hanafi RV. Perioperative Care for Bariatric Surgery. Diagnostics (Basel). 2024;14(18):2095. 10.3390/diagnostics14182095.
35. Wang D, Ding X, Su Y, et al. Incidence, Risk Factors, and Outcomes of Severe Hypoxemia After Cardiac Surgery. Front Cardiovasc Med. 2022;9:934533. 10.3389/fcvm.2022.934533.
36. De Simone B, Ansaloni L, Sartelli M, et al. OBA trial supporters; Catena F. The Operative management in Bariatric Acute abdomen (OBA) Survey: long-term complications of bariatric surgery and the emergency surgeon's point of view. World J Emerg Surg. 2020;15(1):2. 10.1186/s13017-019-0281-y.
37. Lim L, Lee J, Hwang SY, et al. Early Postoperative Fever and Atelectasis in Patients Undergoing Upper Abdominal Surgery. J Am Coll Surg. 2023;237(4):606–13. 10.1097/XCS.0000000000000789.
38. Santo MA, Pajecki D, Riccioppo D, et al. Early complications in bariatric surgery: incidence, diagnosis and treatment. Arq Gastroenterol. 2013;50(1):50–5. 10.1590/s0004-28032013000100010.
39. Aseni P, Orsenigo S, Storti E, et al. Current concepts of perioperative monitoring in high-risk surgical patients: a review. Patient Saf Surg. 2019;13:32. 10.1186/s13037-019-0213-5.
40. Fagan K, Sabel A, Mehler PS, et al. Vital sign abnormalities, rapid response, and adverse outcomes in hospitalized patients. Am J Med Qual. 2012;27(6):480–6. 10.1177/1062860611436127.

Figures

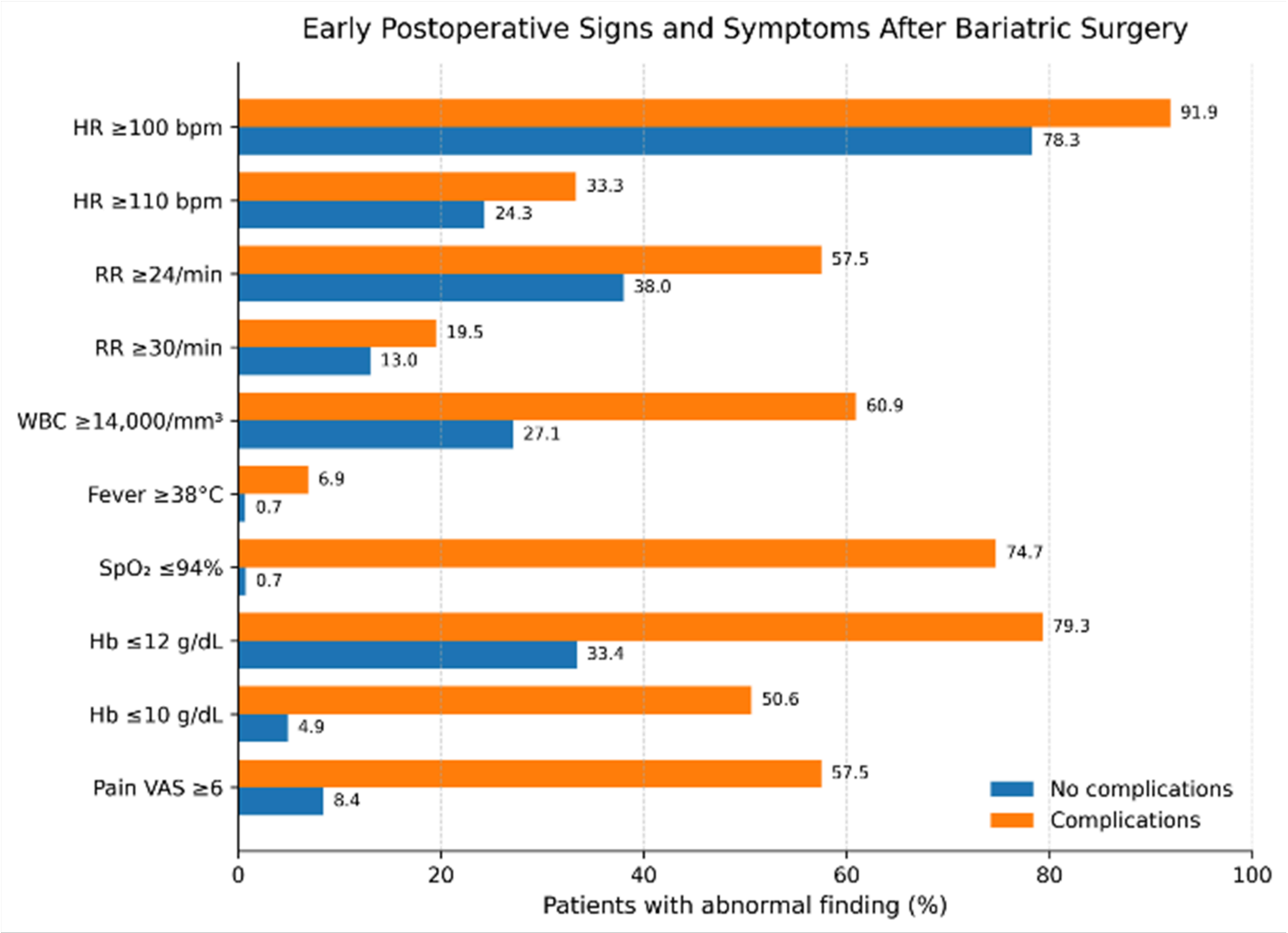

Figure 1

Early Postoperative Signs and Symptoms After Bariatric Surgery.

Bar graph comparing the prevalence of early postoperative signs and symptoms among patients with and without postoperative complications. Bars indicate the percentage of patients in each group meeting prespecified thresholds for heart rate, respiratory rate, temperature, oxygen saturation, white blood cell count, hemoglobin, and pain score.

Abbreviations: HR, heart rate; RR, respiratory rate; WBC, white blood cell count; HGB, hemoglobin; Sat O_2, oxygen saturation; VAS, visual analog scale.

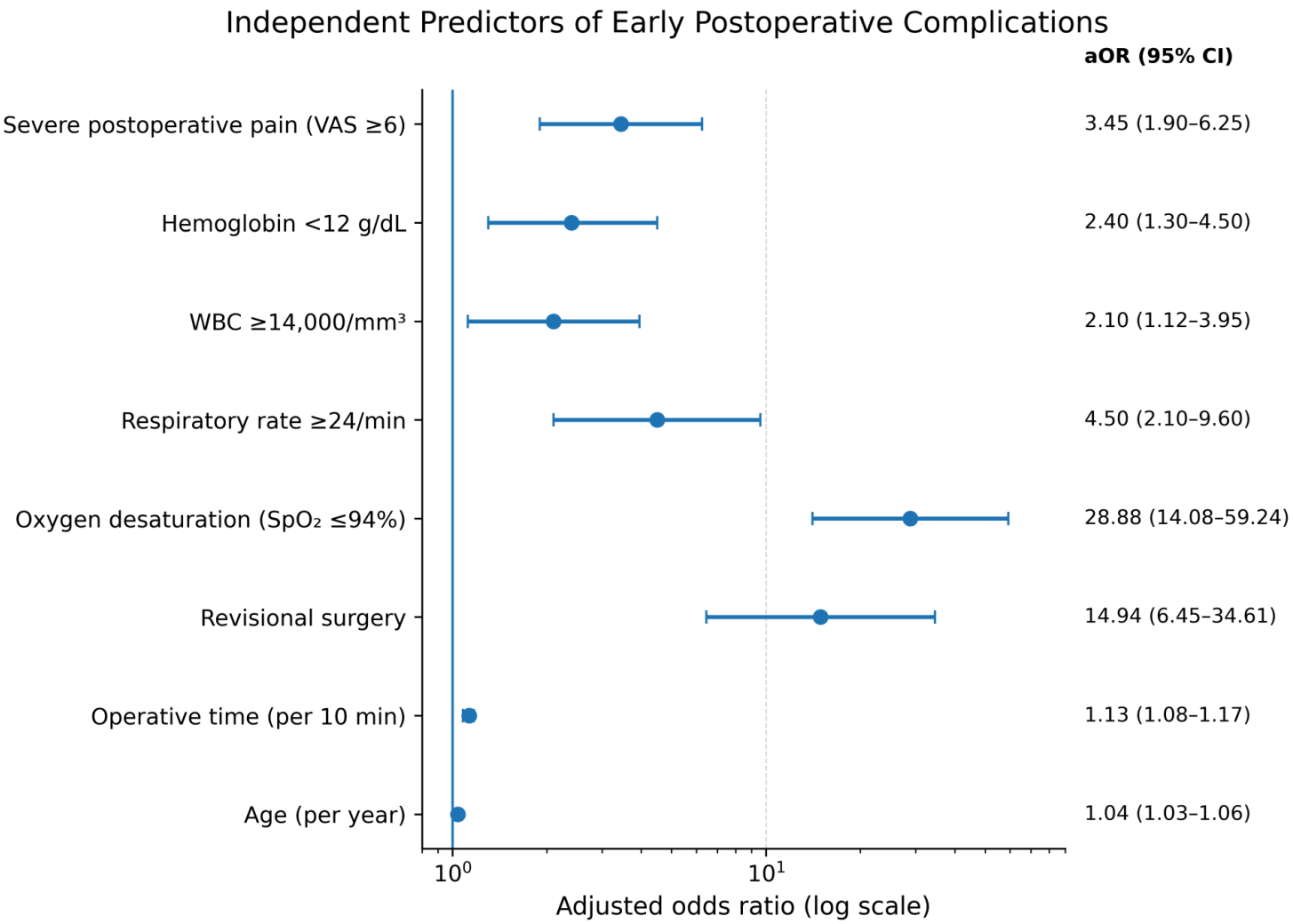

Figure 2

Independent Predictors of Early Postoperative Complications After Bariatric Surgery.

Univariate Predictors of Early Postoperative Complications After Bariatric Surgery.

Forest plot showing crude odds ratios (ORs) with 95% CIs for variables associated with early postoperative complications. Odds ratios are shown on a logarithmic scale; the vertical reference line indicates an OR of 1.

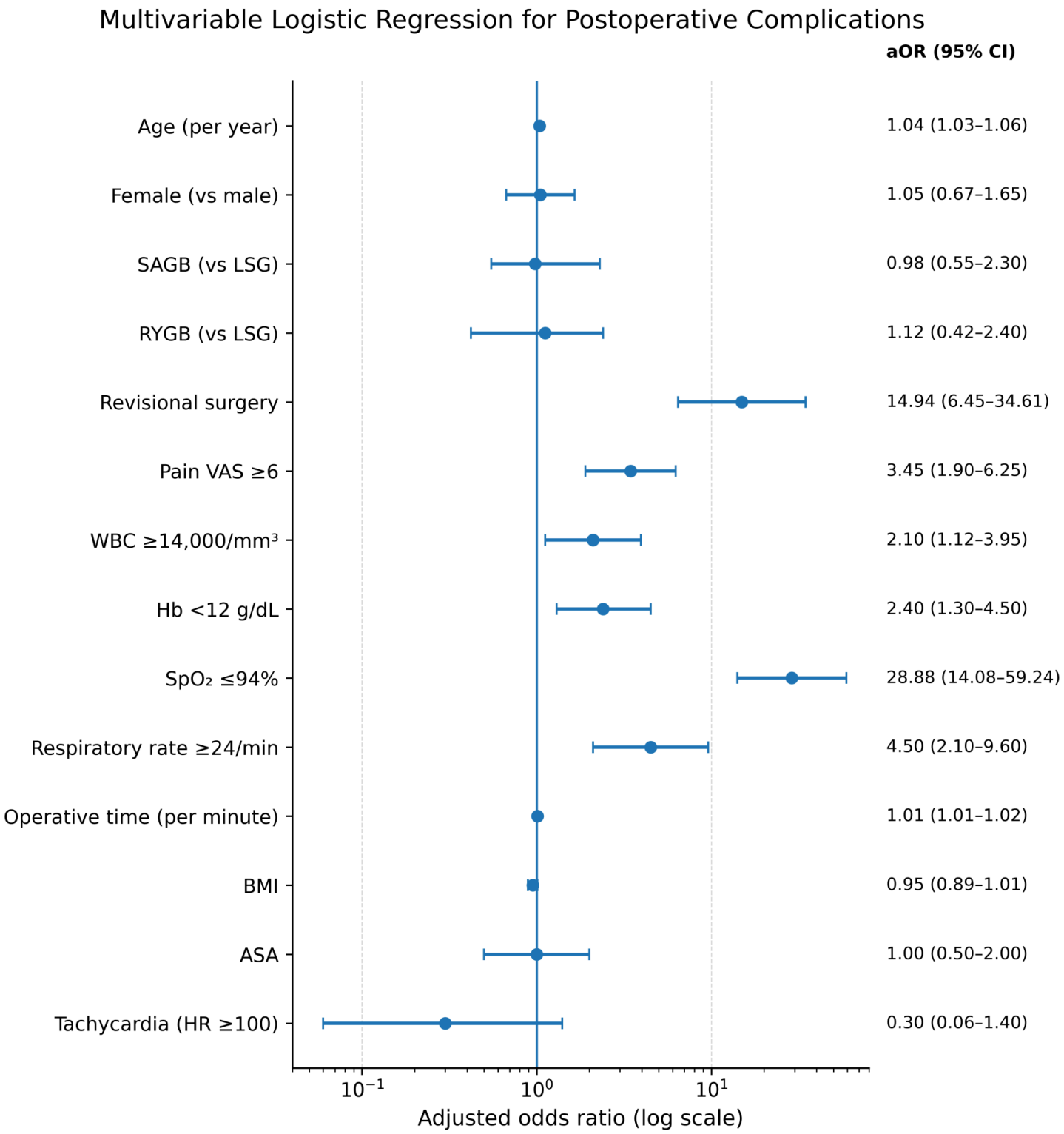

Figure 3

Multivariable Logistic Regression Model for Postoperative Complications.

Forest plot showing aORs with 95% CIs for factors associated with in-hospital postoperative complications. Odds ratios are shown on a logarithmic scale; the vertical reference line indicates an odds ratio of 1. Sleeve gastrectomy was the reference category for procedure type.

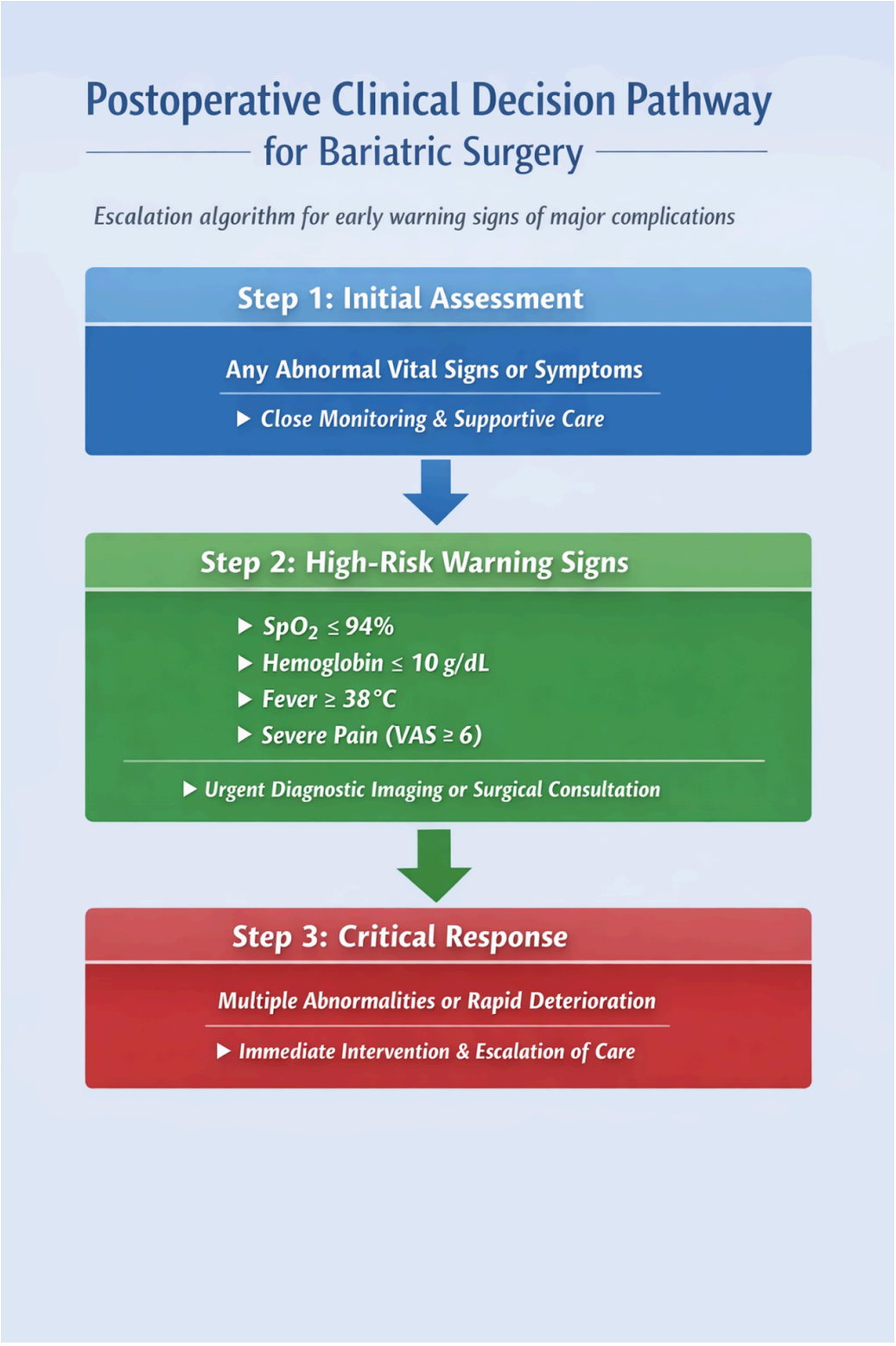

Figure 4

Clinical Decision Pathway for Early Detection of Major Complications After Bariatric Surgery.

This figure depicts a postoperative escalation pathway based on early clinical abnormalities. In Step 1, nonspecific findings (eg, tachycardia, tachypnea, mild symptoms) prompt close monitoring. In Step 2, high-specificity signs—oxygen desaturation (SpO_2 ≤94%), severe anemia (hemoglobin ≤10 g/dL), fever

(≥38 °C), or severe pain (VAS ≥6)—should trigger diagnostic evaluation or surgical consultation. In Step 3, multiple abnormalities or rapid deterioration require immediate escalation of care and consideration of intervention. This framework distinguishes sensitive screening findings from specific rule-in indicators to support timely recognition of major complications.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table6sup.docx
- Table7sup.docx