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Systematic review

Incremental value of laboratory biomarkers beyond CT findings for detecting bowel ischemia in small bowel obstruction: A Systematic Review

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Abstract

Background: Bowel ischemia is a critical complication of small bowel obstruction (SBO), while computed tomography (CT) is the main imaging test for identifying strangulation and threatened bowel. Laboratory biomarkers offer physiologic information when CT findings are equivocal. In this study we aimed to analyze original articles on the incremental diagnostic value of laboratory biomarkers beyond CT findings for detecting bowel ischemia in SBO. **Methods:** A systematic review framework consistent with PRISMA 2020 and diagnostic-test-review principles was followed. Eligible studies enrolled adults with SBO, evaluated at least one laboratory biomarker, incorporated CT findings or CT-based classification, and used operative, histopathologic, or clinical outcomes for ischemia, necrosis, strangulation,

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CT findings or CT-based classification, and used operative, histopathologic, or clinical outcomes for ischemia, necrosis, strangulation, or resection. **Results:** Fourteen studies were included. Incremental evidence came from combined models incorporating inflammatory or hematologic markers with CT features. A 2026 model increased discrimination from an AUC of 0.88 for selected radiologic features to 0.96 after adding CRP and abdominal guarding. Other integrated models supported contributions from procalcitonin, leukocyte count, CRP, and lactate, while I-FABP and cell-free DNA showed biologic signal without CT-adjusted validation. Biomarker thresholds varied across cohorts, and external validation was limited. **Conclusion:** Laboratory biomarkers add important information to CT in SBO populations, with the most consistent evidence supporting CRP, procalcitonin, leukocyte-based measures, and lactate. Evidence for formal incremental performance remains limited.

Keywords: small bowel obstruction; bowel ischemia; strangulation; computed tomography; biomarkers; C-reactive protein; procalcitonin; lactate

Introduction

Small bowel obstruction (SBO) is a common surgical emergency in which the central management problem is distinguishing uncomplicated mechanical obstruction from strangulation with impaired perfusion. Adhesive SBO represents a major proportion of adult cases, and emergency-surgery guidance identifies peritonitis, strangulation, and ischemia as contraindications to routine nonoperative treatment while placing CT at the center of evaluation when these complications are suspected (1). Emergency-department studies show timely diagnosis because delayed recognition of ischemic SBO exposes patients to necrosis, perforation, sepsis, bowel resection, and death.

Contrast-enhanced CT provides anatomic and perfusion information that laboratory testing alone does not reproduce (2, 3). In a prospective evaluation of suspected obstruction, CT achieved 83% sensitivity and 93% specificity for intestinal ischemia (3). Another prospective series of 142 patients reported 96% sensitivity and 93% using a composite CT definition, individual signs varied (4). A meta-analysis confirmed this asymmetry, reduced bowel-wall enhancement carried the strongest rule-in value, whereas mesenteric fluid was the most sensitive of the commonly assessed CT signs (5).

Broader pooled study supports CT as a strong test for SBO and its complications, while documenting heterogeneity in ischemia detection across scanners, contrast protocols, study designs, and reference standards. A 2019 meta-analysis estimated pooled sensitivity of 82% and specificity of 92% for ischemia in SBO (6). An updated 2026 meta-analysis of 66 studies reported pooled ischemia sensitivity of 76% and specificity of 94%, with higher sensitivity for multiphase than single-phase CT. Laboratory biomarkers therefore attract interest as complementary physiologic signals of hypoperfusion, inflammation, enterocyte injury, coagulation activation, or cell death (7).

Incremental value is best demonstrated when a laboratory marker retains independent association after CT adjustment, improves discrimination or classification in a combined model, or meaningfully increases sensitivity (6). Existing studies examine lactate, leukocyte count, C-reactive protein (CRP), procalcitonin (PCT), intestinal fatty acid-binding protein (I-FABP), cell-free DNA, and related hematologic indices, although study designs and ischemia definitions differ considerably (7). This systematic review synthesizes original articles on the added diagnostic contribution of laboratory biomarkers beyond CT findings for identifying bowel

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ischemia, strangulation, necrosis, or resection-requiring nonviable bowel in adult SBO.

Methods

Design and reporting

This study was structured as a systematic review following PRISMA 2020 and PRISMA-DTA principles. The review question was framed around adults with acute SBO, laboratory biomarkers as index predictors, CT findings as the established imaging comparator, and operative, histopathologic, or adjudicated bowel ischemia as the target condition. The principal outcome was incremental diagnostic value beyond CT, defined as independent biomarker contribution in a CT-adjusted model, improvement in model discrimination or classification after biomarker addition, or complementary diagnostic performance in a cohort where CT findings were explicitly incorporated into assessment.

Search strategy

A reproducible search strategy was constructed for PubMed, Scopus, Web of Science Core Collection, and the Cochrane Library from database inception through August 2026. Search concepts combined controlled vocabulary and free-text terms for "small bowel obstruction," "strangulation," "bowel ischemia," "intestinal ischemia," "necrosis," "computed tomography," "CT," "lactate," "C-reactive protein," "procalcitonin," "white blood cell," "neutrophil," "D-dimer," "intestinal fatty acid-binding protein," "cell-free DNA," and "biomarker." Reference lists of eligible studies and relevant systematic reviews were also examined for additional primary studies. Database-specific record counts are not stated in this draft because direct Scopus, Web of Science, and Cochrane exports were not available for independent verification; these counts require insertion from the final search log before submission.

Eligibility criteria and study selection

Eligible studies included adults with acute mechanical SBO and evaluated at least one blood or urine laboratory biomarker in relation to ischemia, strangulation, necrosis, or ischemia-related bowel resection. Studies had to report CT findings, use CT in the diagnostic pathway, or construct a multivariable model containing CT variables. Cohort, case-control, prospective diagnostic, retrospective diagnostic, and prediction-model studies were eligible. We exclude pediatric-only studies, animal experiments, isolated acute mesenteric ischemia without SBO, large-bowel obstruction without separable SBO data, case reports, narrative reviews, editorials, and studies lacking an ischemia-related reference standard.

Data extraction, quality assessment, and analysis

Extraction fields comprised study design, setting, sample size, obstruction type, ischemia prevalence, biomarker, assay timing, CT variables, reference standard, adjusted associations, sensitivity, specificity, predictive values, and area under the receiver operating characteristic curve. Diagnostic-accuracy studies were appraised with QUADAS-2 domains, and multivariable prediction studies were additionally assessed through PROBAST domains covering participants, predictors, outcome, and analysis. Because biomarker thresholds, CT definitions, outcome definitions, and modeling strategies were heterogeneous, quantitative pooling was not undertaken. Findings were analyzed qualitatively with priority given to direct CT-adjusted evidence, followed by combined clinic-

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radiologic models and then supportive biomarker studies lacking a formal CT-only comparator.

Results

Fourteen primary studies were included in the focused evidence synthesis, with individual sample sizes ranging from 21 to 713 participants and with most cohorts using operative findings, bowel resection, histopathology, or a combined operative-clinical reference standard for ischemia or strangulation (8). In 192 operated adults, reduced bowel-wall enhancement was the strongest independent predictor of strangulation, with 56% sensitivity, 94% specificity, and a likelihood ratio of 9.3, while elevated WBC and guarding contributed weaker independent signals, illustrating that laboratory inflammation added context without replacing the dominant CT sign (8). A 100-patient cohort found ischemia associated with lactate of 2.7±1.6 versus 1.3±0.6 mmol/L and with CT findings including free fluid, mesenteric edema, closed-loop obstruction, pneumatosis, and portal venous gas (9). A 233-patient clinic-radiologic study integrated CRP ≥75 mg/L, WBC ≥10×10^9/L, CT free fluid ≥500 mL, reduced bowel-wall enhancement, prolonged pain, and guarding; a score ≥3 produced 67.7% sensitivity and 90.8% specificity, with AUC 0.87 for ischemia requiring resection (10).

PCT show one of the strongest biomarker associations in a 166-patient SBO analysis, where concentrations were 1.16 versus 0.21 ng/mL among surgically treated patients with versus without ischemia and PCT remained associated with ischemia in multivariable analysis with OR 46.9, although a CT-only comparator was not reported (11). In a 21-patient validation cohort, urinary I-FABP at a 1000 pg/mL threshold had 100% sensitivity, 83% specificity, and 100% NPV for necrosis, while plasma I-FABP at 100 pg/mL had 100% sensitivity, 78% specificity, and 100% NPV (12). A separate 37-patient study found I-FABP AUC 0.854, exceeding lactic acid AUC 0.735 and WBC AUC 0.664, while I-FABP >6.5 ng/mL remained the only independent biochemical predictor of strangulated SBO with OR 19.826 (13). Among 116 surgically explored patients, hyponatremia ≤134 mmol/L and CT wall thickening or suspected closed loop were independently associated with ischemic bowel, whereas leukocytosis and acidosis were not significant, demonstrating inconsistency across conventional laboratory markers (14). In a prospective 58-patient SBO cohort, cell-free DNA was higher at admission in the ischemic or necrotic group, which contained 10 operative ischemia cases, although the study did not provide a CT-adjusted discrimination analysis (15).

A 417-patient prediction study combined fever, peritoneal irritation, WBC >10×10^9/L, CT bowel-wall thickening, and ascites, producing an AUC of 0.935 for strangulated SBO and supporting the value of mixed physiologic and imaging predictors (16). In 124 adults with adhesive SBO, an ischemia score incorporating age, pain duration, temperature, WBC, reduced wall enhancement, and segmental mesenteric fluid reached an AUC of 0.92, with risk increasing sharply across the score strata (17). A model derived from 83 patients with strangulated obstruction combined WBC ≥12,000/µL with peritoneal-fluid attenuation ≥20 HU on CT, reaching AUC 0.814 and cross-validated AUC 0.807; a score ≥2 was associated with irreversible ischemia requiring resection with OR 15.938 (18). A larger 713-patient cohort developed and validated a severity score containing CRP ≥50 mg/L plus three CT features and four clinical variables, yielding 65% sensitivity, 88% specificity,

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and AUC 0.84 for small-bowel necrosis or resection (19). In 79 patients with adhesive SBO, PCT >0.5 ng/mL, reduced bowel-wall enhancement, and rebound tenderness were independent predictors, with ORs of 11.7, 12.2, and 7.8 and a combined AUC of 0.848; ischemia prevalence rose from 0% with no factors to 100% with all three (20). The clearest formal incremental analysis came from 150 surgically treated SBO patients in 2026: a selected radiologic model using ascites density plus mesenteric fluid had AUC 0.88, sensitivity 81%, and specificity 88%, while addition of CRP and guarding increased AUC to 0.96 and sensitivity to 94%, with specificity 86% (21).

The evidence base was dominated by single-center retrospective or observational cohorts, data-derived thresholds, and selective verification because definitive ischemia was frequently established only in operated patients (8). Several studies used bowel resection as a surrogate for irreversible ischemia, creating dependence on intraoperative judgment and institutional treatment thresholds rather than a uniform histopathologic endpoint (10). External validation was uncommon, although cross-validation was reported in the two-factor irreversible-ischemia model and a distinct validation cohort was used for the 713-patient severity score (18,19). Direct comparisons of CT-only versus CT-plus-biomarker models were rare, leaving the 2026 combined-model study as the most explicit evidence of incremental diagnostic gain rather than simple biomarker association (21).

Table 1. Characteristics of the original studies included in the results

Study	Design and population	N	Laboratory markers	CT component	Ischemia-related outcome
Jancelewicz et al., 2009 (8)	Operated SBO cohort	192	WBC	Reduced enhancement and other CT findings	Strangulation; 44 cases
Zielinski et al., 2010 (9)	SBO cohort with blinded CT review	100	Lactate, WBC	Free fluid, edema, closed loop, pneumatosis, portal gas	Ischemia; 11 cases
Schwenter et al., 2010 (10)	Clinicoradiologic cohort	233	CRP, WBC	Reduced enhancement; free fluid ≥500 mL	Ischemia requiring resection
Cosse et al., 2013 (11)	Secondary analysis of SBO trial cohort	166	PCT	Imaging incorporated in SBO assessment	Intraoperative ischemia; 12 surgical cases
Cronk et al., 2006 (12)	Validation cohort of mechanical SBO	21	Plasma and urine I-FABP	CT accepted within diagnostic pathway	Bowel necrosis; 3 cases
Kittaka et al., 2014 (13)	Retrospective SBO cohort	37	I-FABP, lactate, WBC	Enhanced CT classification	Strangulated SBO; 21 cases
O'Leary et al., 2016 (14)	Operated SBO cohort	116	Sodium, WBC, acidosis	Wall thickening; suspected closed loop	Ischemic bowel or ischemic perforation

Study	Design and population	N	Laboratory markers	CT component	Ischemia-related outcome
Netz et al., 2017 (15)	Prospective SBO cohort	58	cfDNA	Imaging included in clinical assessment	Ischemic or necrotic bowel; 10 cases
Huang et al., 2018 (16)	CT-confirmed SBO database	417	WBC	Wall thickening; ascites	Strangulated SBO; 76 cases
Bouassida et al., 2020 (17)	Retrospective ASBO cohort	124	WBC	Reduced enhancement; mesenteric fluid	Intestinal ischemia
Kobayashi et al., 2022 (18)	Emergency surgery cohort	83	WBC	Peritoneal-fluid attenuation	Irreversible ischemia requiring resection
Wassmer et al., 2023 (19)	Development and validation SBO cohorts	713	CRP	Transition point, absent enhancement, fluid volume	Necrosis or bowel resection
Li et al., 2024 (20)	Operated ASBO observational cohort	79	PCT	Reduced bowel-wall enhancement	Histologically assessed ischemia
Sepahvand et al., 2026 (21)	Surgically treated acute SBO cohort	150	CRP plus other laboratory tests	Ascites density and mesenteric fluid	Strangulated SBO; 51 cases

Table 2. Diagnostic contribution of laboratory biomarkers in relation to CT

Study	Laboratory finding	CT/combined performance	Interpretation
Jancelewicz et al. (8)	Elevated WBC provided a weaker independent signal	Reduced enhancement: sensitivity 56%, specificity 94%, LR 9.3	Laboratory information complementary; CT remained dominant
Zielinski et al. (9)	Lactate 2.7±1.6 vs 1.3±0.6 mmol/L in ischemic vs nonischemic groups	Multiple CT ischemia signs associated with outcome	Lactate association present; no CT-plus-lactate discrimination estimate
Schwenter et al. (10)	CRP ≥75 mg/L and WBC ≥10×10^9/L entered score	Combined AUC 0.87; sensitivity 67.7%; specificity 90.8%	Strong integrated evidence; CT-only AUC not reported
Cosse et al. (11)	PCT: OR 46.9 for ischemia	CT-only model not presented	Strong biochemical association; incremental magnitude unresolved
Cronk et al. (12)	Urine I-FABP sensitivity 100%, specificity 83%; plasma sensitivity 100%, specificity 78%	CT used within SBO diagnostic pathway	Promising enterocyte marker; only three necrosis cases
Kittaka et al. (13)	I-FABP AUC 0.854; OR 19.826	CT used for clinical classification	Strong biochemical signal; no CT-plus-I-FABP model

Study	Laboratory finding	CT/combined performance	Interpretation
O'Leary et al. (14)	Hyponatremia independently associated; leukocytosis and acidosis not significant	Wall thickening and suspected closed loop independently associated	Demonstrates laboratory contribution beside CT predictors
Netz et al. (15)	Admission cfDNA higher with ischemia/necrosis	No CT-adjusted AUC	Exploratory evidence
Huang et al. (16)	WBC >10×10^9/L entered final model	Combined AUC 0.935	Strong integrated model; no CT-only comparator
Bouassida et al. (17)	WBC incorporated with clinical variables	Combined CT-clinical-laboratory AUC 0.92	Supports multimodal risk stratification
Kobayashi et al. (18)	WBC ≥12,000/µL independently predictive	WBC plus CT-fluid attenuation AUC 0.814; cross-validated 0.807	Direct two-domain integration
Wassmer et al. (19)	CRP ≥50 mg/L entered validated score	Combined AUC 0.84; sensitivity 65%; specificity 88%	Validated integrated evidence
Li et al. (20)	PCT >0.5 ng/mL: OR 11.7	PCT + reduced enhancement + rebound tenderness AUC 0.848	Strong CT-plus-biomarker association
Sepahvand et al. (21)	CRP AUC 0.79 individually	Selected CT model AUC 0.88; CT + CRP + guarding AUC 0.96	Strongest direct evidence of incremental value

Discussion

The present study indicates that laboratory biomarkers provide the greatest value when they complement CT rather than function as isolated screening tests, and the evidence is strongest for inflammatory or hematologic variables embedded within multivariable clinic-radiologic models. The 2026 study show direct demonstration of incremental value, increasing AUC from 0.88 for selected radiologic findings to 0.96 after adding CRP and guarding, while sensitivity rose from 81% to 94% with only a small reduction in specificity (21). This pattern is important because CT signs such as reduced enhancement often have strong rule-in value, while sensitivity for ischemia remains incomplete across pooled CT studies (5-7).

CRP and PCT are the most consistent inflammatory markers in integrated models, although the depth of validation differs between them (10,11,19-21). CRP appeared repeatedly in larger scores and, in the direct 2026 comparison, materially improved a model already containing informative CT variables, giving CRP the clearest evidence for added value within the present literature (19,21). PCT showed a strong adjusted association with intraoperative ischemia in the 166-patient analysis and is independently associated with ischemia beside reduced enhancement and rebound tenderness in adhesive SBO, supporting a biologically and statistically coherent signal (11,20). The absence of a CT-only comparator in the earlier PCT study limits conclusions about the exact gain attributable to PCT itself (11).

WBC is inexpensive and available in emergency care, though its performance was inconsistent across studies (8,10,14,16-18). It contributed to several successful integrated scores, including models with AUCs of 0.935, 0.92, and 0.814, and another surgical cohort found leukocytosis unrelated to ischemia after analysis, indicating that WBC is context-dependent and weak as a stand-alone discriminator (14,16-18). Lactate showed higher values in ischemic SBO in the 100-patient cohort, whereas a prospective study of acute intestinal obstruction found post-resuscitation lactate useful for irreversible ischemia, with AUC 0.884 and a negative predictive value of 96.3% at a 19.1 mg/dL threshold, although that cohort was not restricted to SBO and therefore provides indirect support for this review question (9,22). Timing relative to fluid resuscitation, systemic hypoperfusion, hepatic clearance, and the transition from reversible to irreversible injury probably explain part of the variation in lactate performance across cohorts (9,22).

More specialized biomarkers showed promising diagnostic signal without sufficient evidence of incremental value beyond modern CT (12,13,15). I-FABP demonstrated complete sensitivity in the small 21-patient validation cohort and high specificity in the later 37-patient study, where its AUC also exceeded those of lactate and WBC, linking enterocyte injury more directly to intestinal mucosal damage than general inflammatory markers (12,13). Cell-free DNA also increased in ischemic or necrotic SBO, though the small number of ischemic cases and absence of a CT-adjusted model place it in an exploratory category (15). D-dimer has an attractive mechanistic relationship to coagulation activation, although a prospective 53-patient SBO study reported only 60% sensitivity and 68% specificity for strangulation, arguing against reliance on D-dimer as an isolated diagnostic marker (23). These findings prioritize availability, reproducibility, and added discrimination over

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biological plausibility alone when selecting candidate biomarkers for clinical algorithms (12,15,23).

Limitations

Many cohorts were retrospective, single-center, restricted to operated patients, or used resection as the endpoint, which introduces verification bias and conflates ischemia severity with surgical judgment. Biomarker thresholds were frequently derived within the same dataset used for performance estimation, while CT definitions ranged from qualitative enhancement assessment to quantitative ascites attenuation, limiting direct comparison and precluding a defensible pooled incremental-effect estimate. Cohort overlap is also possible among studies from the same institutions across different periods, so simple summation of sample sizes would overstate the independent evidence base.

Recommendation

Future research needs prospective multicenter designs that prespecify a CT baseline model and then test the same model after addition of one or more biomarkers. Reporting needs to include discrimination, calibration, sensitivity and specificity at clinically meaningful thresholds, decision-curve analysis, and changes in classification for patients with equivocal CT rather than only unadjusted biomarker differences. Serial sampling deserves attention because biomarker kinetics differ in early venous congestion, reversible mucosal ischemia, transmural necrosis, and post-resuscitation states.

Conclusion

Laboratory biomarkers provide incremental diagnostic information beyond CT in SBO when incorporated into multivariable assessment, mainly in patients with equivocal imaging. CRP has the clearest direct evidence of added discrimination, while PCT, WBC-based measures, and lactate contribute supportive information in several cohorts. I-FABP and cell-free DNA remain promising research biomarkers with limited CT-adjusted validation. Current evidence is heterogeneous, dominated by single-center observational designs.

List of abbreviations

Abbreviation	Definition
ASBO	Adhesive small bowel obstruction
AUC	Area under the receiver operating characteristic curve
cfDNA	Cell-free DNA
CI	Confidence interval
CRP	C-reactive protein
CT	Computed tomography
HU	Hounsfield units
I-FABP	Intestinal fatty acid-binding protein
NPV	Negative predictive value
OR	Odds ratio
PCT	Procalcitonin
PPV	Positive predictive value

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Abbreviation	Definition
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PRISMA-DTA	PRISMA extension for Diagnostic Test Accuracy
PROBAST	Prediction model Risk Of Bias ASsessment Tool
QUADAS-2	Quality Assessment of Diagnostic Accuracy Studies 2
ROC	Receiver operating characteristic
SBO	Small bowel obstruction
SSBO	Strangulated small bowel obstruction
WBC	White blood cell

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