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Original Research Article

Beyond Static Risk Scores: Dynamic Lactate Clearance and CRP–Albumin Response for Early Prediction of Adverse Outcomes Following Emergency Surgery for Gastrointestinal Perforation

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Abstract

Background: Static prognostic scores estimate severity at presentation but may not capture postoperative physiological recovery after emergency surgery for gastrointestinal perforation. This study evaluated dynamic lactate clearance and CRP–albumin ratio (CAR) response for early prediction of adverse outcomes.

Methods: A prospective observational study included 120 adults undergoing emergency surgery for gastrointestinal perforation at KIMS, Amalapuram, from November 2025 to June 2026. MPI, APACHE II and SOFA scores were recorded. Lactate was measured preoperatively and at 6 and 24 hours; CRP and albumin were measured preoperatively and at 24 and 48 hours. The primary endpoint was a composite adverse postoperative outcome.

Results: Adverse outcomes occurred in 38 (31.7%) patients and in-hospital mortality was 11.7%. Twenty-four-hour lactate clearance was lower in the adverse-outcome group (21.6±23.1% vs 50.8±19.6%; $p<0.001$), while 48-hour CAR was higher (8.1±3.1 vs 3.9±1.9; $p<0.001$). Lactate clearance <35% and a ≥25% rise in CAR independently predicted adverse outcomes. Their combined AUC was 0.91; adding them to static scores increased AUC from 0.83 to 0.94 ($p=0.018$).

Conclusion: Serial lactate clearance and CAR response provided incremental prognostic information beyond conventional risk scores and may support early postoperative risk reassessment. This approach may identify failure of recovery before overt clinical deterioration becomes established.

Keywords: Gastrointestinal Perforation; Lactate Clearance; CRP–albumin Ratio; Emergency Surgery; Postoperative Outcomes.

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Introduction

Gastrointestinal perforation requiring emergency surgery remains high risk because peritoneal contamination, sepsis, tissue hypoperfusion and postoperative organ dysfunction may evolve rapidly despite source control. Scores such as APACHE II, SOFA and Mannheim Peritonitis Index provide baseline stratification, but their static nature may not adequately reflect the patient's physiological response to resuscitation and surgery. Perioperative lactate kinetics are attractive dynamic markers; postoperative lactate and lactate clearance have demonstrated prognostic value for in-hospital mortality after surgery for gastrointestinal perforation [1]. The C-reactive protein-to-albumin ratio (CAR) integrates systemic inflammation with nutritional and physiological reserve and has shown utility for predicting morbidity and mortality after emergency abdominal surgery [2, 3]. However, the combined value of serial lactate clearance and change in CAR has not been sufficiently evaluated in gastrointestinal perforation. This study aimed to determine whether these dynamic biomarker responses improve prediction of postoperative complications, organ failure, intensive-care requirement and mortality beyond static risk scores.

Methods

This prospective observational cohort study was conducted in the Departments of General Surgery and Critical Care at KIMS, Amalapuram, from

November 2025 to June 2026. Consecutive adult patients aged ≥18 years who underwent emergency laparotomy for radiologically or intraoperatively confirmed gastrointestinal perforation were screened for inclusion. Patients with traumatic perforation, perforation secondary to malignancy with disseminated disease, chronic liver failure, end-stage renal disease, pre-existing severe hypoalbuminemia attributable to nephrotic or hepatic disease, immunosuppressive therapy, pregnancy, re-exploration following recent abdominal surgery, or incomplete serial biochemical measurements were excluded. After obtaining institutional ethics committee approval and written informed consent from patients or legally acceptable representatives, demographic characteristics, comorbidities, duration of symptoms, preoperative hemodynamic parameters, site and cause of perforation, degree of peritoneal contamination, operative procedure, and requirement for vasopressor or ventilatory support were recorded using a predefined case-record form. Baseline disease severity was assessed using the Mannheim Peritonitis Index (MPI), Sequential Organ Failure Assessment (SOFA) score, and APACHE II score. Venous or arterial lactate was measured immediately before operative intervention and repeated at 6 and 24 hours after surgery. Lactate clearance was calculated as: [(baseline lactate − subsequent lactate)/baseline lactate] ×100, with positive values indicating biochemical improvement. Serum C-reactive protein (CRP) and albumin were measured preoperatively and again at 24 and 48 hours postoperatively. The CAR was calculated at each time point, and the CRP–albumin response was expressed as the absolute and percentage change in CAR from baseline.

Patients were prospectively followed throughout hospitalization for postoperative clinical course and outcomes. The primary outcome was a composite of adverse postoperative outcome comprising 30-day or in-hospital mortality, postoperative organ failure, septic shock, or requirement for prolonged intensive-care support. Secondary outcomes included surgical-site infection, intra-abdominal abscess, anastomotic leak, reoperation, duration of mechanical ventilation, intensive-care-unit admission and length of stay, and total hospital stay. Organ dysfunction was classified using postoperative SOFA criteria, while complications were graded according to the Clavien–Dindo system. Laboratory personnel were unaware of subsequent clinical outcomes wherever feasible. Continuous variables were summarized as mean±standard deviation or median with interquartile range according to distribution, whereas categorical variables were expressed as frequency and percentage. Comparisons between patients with and without adverse outcomes were performed using Student's t test or Mann–Whitney U test for continuous variables and chi-square or Fisher's exact test for categorical variables. Receiver-operating-characteristic curves were generated to determine the predictive performance and optimal cut-off values of 6-hour and 24-hour lactate clearance, baseline and serial CAR, and their dynamic changes. Multivariable logistic regression was performed to identify independent predictors after adjustment for age, comorbidities, perforation site, MPI, APACHE II and baseline SOFA scores. Incremental predictive value of dynamic biomarkers beyond static scores was assessed by comparing areas under the ROC curves. A two-sided p value <0.05 was considered statistically significant.

Results:

A total of 120 patients were included, of whom 38 (31.7%) developed the composite adverse outcome and 82 (68.3%) had an uncomplicated or favorable course. Fourteen patients (11.7%) died during hospitalization. Patients with adverse outcomes were older and had significantly higher MPI, APACHE II and baseline SOFA scores. Preoperative shock, vasopressor requirement, delayed presentation and diffuse peritoneal contamination were also more frequent in this group (Table 1). Baseline lactate was significantly higher among patients with adverse outcomes, whereas baseline CAR did not differ significantly.

Dynamic measurements separated the groups more clearly: 6-hour and 24-hour lactate clearance were markedly lower in the adverse-outcome group, while CAR increased progressively at 24 and 48 hours (Table 2). Twenty-four-hour lactate clearance <35% yielded an AUC of 0.84, and a ≥25% rise in 48-hour CRP–albumin ratio yielded an AUC of 0.82. Combining both dynamic markers improved discrimination to an AUC of 0.91, compared with 0.83 for the static-score model. Addition of the dynamic markers to MPI, APACHE II and SOFA increased the AUC to 0.94 (p=0.018). On multivariable analysis, impaired 24-hour lactate clearance, rising CAR and SOFA ≥6 remained independently associated with adverse outcomes (Table 3) after adjustment for relevant clinical covariates.

Table 1: Baseline clinical and operative characteristics according to postoperative outcome

Variable	Outcome		Statistic	p value
	Adverse	Favorable		
Age, years, mean ± SD	61.8 ± 13.2	52.6 ± 14.6	t=3.39	0.001
Age ≥65 years*	17 (44.7)	18 (22.0)	χ^2=5.47	0.019
Diabetes mellitus*	15 (39.5)	17 (20.7)	χ^2=3.76	0.053
Presentation >24 h*	25 (65.8)	35 (42.7)	χ^2=4.66	0.031
Preoperative shock*	20 (52.6)	12 (14.6)	χ^2=17.28	<0.001
Vasopressor requirement*	24 (63.2)	16 (19.5)	χ^2=20.34	<0.001
Diffuse/feculent contamination*	24 (63.2)	28 (34.1)	χ^2=7.76	0.005
Mannheim Peritonitis Index	27.1 ± 6.4	20.3 ± 5.8	t=5.24	<0.001
APACHE II score	17.6 ± 5.1	10.8 ± 4.2	t=6.66	<0.001
Baseline SOFA score	7.2 ± 2.8	3.9 ± 2.1	t=5.99	<0.001
Postoperative ventilation*	27 (71.1)	24 (29.3)	χ^2=16.88	<0.001
*n (%)				

Table 2: Serial lactate and CRP–albumin response according to postoperative outcome

Biomarker	Outcome		Statistic	p value
	Adverse	Favorable		
Baseline lactate, mmol/L	4.6 ± 1.8	3.1 ± 1.3	t=4.45	<0.001
6-h lactate clearance, %	10.8 ± 18.4	27.9 ± 16.7	t=4.73	<0.001
24-h lactate clearance, %	21.6 ± 23.1	50.8 ± 19.6	t=6.33	<0.001
Baseline CRP/albumin ratio	4.9 ± 2.1	4.2 ± 1.8	t=1.77	0.081
24-h CRP/albumin ratio	6.7 ± 2.7	4.8 ± 2.1	t=3.75	<0.001
48-h CRP/albumin ratio	8.1 ± 3.1	3.9 ± 1.9	t=7.11	<0.001
Change in CAR at 48 h, %	+72.2 ± 55.4	−6.9 ± 35.8	t=7.35	<0.001

Table 3: Predictive performance and multivariable predictors of adverse postoperative outcomes

Predictor/model	Cut-off	AUC (95% CI)	Sensitivity (%)	Specificity (%)	Adjusted OR (95% CI)
Mannheim Peritonitis Index	≥25	0.74 (0.65–0.83)	68.4	70.7	—
APACHE II	≥15	0.79 (0.71–0.87)	73.7	75.6	—
SOFA score	≥6	0.78 (0.69–0.86)	71.1	73.2	2.48 (1.09–5.64)
24-h lactate clearance	<35%	0.84 (0.77–0.91)	81.6	78	4.62 (1.92–11.11)
48-h CAR increase	≥25%	0.82 (0.74–0.89)	76.3	80.5	3.76 (1.55–9.10)
Static-score model	—	0.83 (0.75–0.90)	78.9	76.8	—
Lactate clearance + CAR response	—	0.91 (0.85–0.96)	86.8	84.1	—
Static scores + dynamic markers	—	0.94 (0.89–0.98)	89.5	86.6	—

Data are expressed as mean ± standard deviation or number (%), as appropriate. CAR: C-reactive protein-to-albumin ratio; AUC: area under the receiver-operating-characteristic curve; CI: confidence interval; OR: odds ratio; APACHE II: Acute Physiology and Chronic Health Evaluation II; SOFA: Sequential Organ Failure Assessment. †Comparison of the full model with the static-score model.

Discussion

Emergency surgery for gastrointestinal perforation remains a high-risk setting because operative source control is performed against a background of peritonitis, sepsis, fluid shifts, tissue hypoperfusion, and evolving organ dysfunction. In the present cohort, 31.7% developed the composite adverse outcome and in-hospital mortality was 11.7%. Patients with adverse outcomes were older and had significantly higher MPI, APACHE II, and SOFA scores, while preoperative shock, vasopressor use, delayed presentation, and diffuse contamination were more frequent. These findings agree with recent studies showing that MPI and organ-failure scores remain useful for prognostication in perforation peritonitis and that age, physiological impairment, and emergency surgical severity influence postoperative complications and mortality [4, 5]. Gaurav et al. confirmed the utility of MPI in hollow-viscus perforation [6], whereas Sung et al. identified postoperative SOFA and albumin among the strongest prognostic variables in gastrointestinal perforation [7].

Recent emergency laparotomy models have similarly demonstrated that serious postoperative

complications depend on multiple preoperative and perioperative dimensions rather than a single risk variable [5]. Importantly, conventional scores largely characterize risk at a defined time point. They cannot fully distinguish a severely ill patient who responds rapidly after source control from one with apparently moderate baseline risk who develops persistent hypoperfusion and inflammatory organ injury. Our findings therefore support supplementing, rather than replacing, conventional scores with serial markers that capture early physiological recovery.

The clearest dynamic metabolic signal was lactate clearance. Baseline lactate was higher in the adverse-outcome group (4.6±1.8 vs 3.1±1.3 mmol/L), but serial response provided greater clinical separation: 24-hour lactate clearance was 21.6±23.1% in patients with adverse outcomes compared with 50.8±19.6% in those with favorable outcomes. Clearance <35% produced an AUC of 0.84 and remained independently associated with adverse outcome (adjusted OR 4.62). Kang et al., specifically evaluating surgery for gastrointestinal perforation, found postoperative lactate to be more predictive of in-hospital mortality than the preoperative measurement [8].

This supports the concept that the metabolic state after resuscitation and source control contains prognostic information unavailable at presentation. Studies in sepsis have similarly demonstrated associations between delayed or inadequate lactate clearance and mortality or organ dysfunction [9, 10]. Rehman et al. found delayed clearance associated with substantially poorer outcomes, while Lee et al. showed that both repeat lactate and clearance carried prognostic information in patients with sepsis and septic shock [9, 10]. Lactate should nevertheless be interpreted as a trajectory rather than a pure measure of anaerobic metabolism, because production and elimination may be influenced by adrenergic stimulation, organ dysfunction, medications, and resuscitative interventions. Persistent elevation or poor clearance should therefore prompt reassessment for inadequate perfusion, unresolved sepsis, occult ischemia, or evolving organ failure rather than being regarded as an isolated biochemical abnormality.

The CRP–albumin trajectory supplied a complementary inflammatory signal. Baseline CAR was not significantly different between groups, whereas the ratio diverged substantially at 24 and 48 hours; a ≥25% increase at 48 hours yielded an AUC of 0.82 and independently predicted adverse outcome (adjusted OR 3.76).

This behavior is biologically plausible because CRP rises during cytokine-driven systemic inflammation, while albumin commonly decreases during major infection and surgery, allowing CAR to integrate inflammatory burden with physiological reserve. Shrihari et al. reported prognostic utility of CAR for morbidity and mortality after emergency abdominal surgery [2], and Siwach et al. demonstrated excellent discrimination for major complications when CAR was evaluated alongside APACHE II [3]. Donlon et al. found postoperative CAR to be informative for complications after major abdominal surgery [11], while Nikolouzakis et al. reported that postoperative CAR could identify septic events during the early postoperative period [12]. These observations closely parallel our finding that change in CAR, rather than its baseline value alone, provided useful separation of postoperative trajectories. Furthermore, recent data from emergency gastrointestinal surgery indicate that immune-nutritional indices incorporating inflammatory and protein parameters have prognostic value for short-term survival [13]. Thus, serial CAR assessment may capture persistence of the host inflammatory response even when initial operative source control appears satisfactory.

The principal contribution of the present study was the gain in discrimination when both dynamic domains were combined. Lactate clearance plus CAR response achieved an AUC of 0.91, while adding these markers to MPI, APACHE II, and SOFA increased the AUC from 0.83 to 0.94 ($p=0.018$).

This suggests that perfusion recovery and inflammatory resolution are related but nonredundant processes: lactate kinetics reflect metabolic and circulatory recovery, whereas CAR reflects persistence of systemic inflammation and reduction in physiological reserve. A clinically practical approach may therefore use baseline scores for initial triage and subsequently repeat lactate at 6–24 hours and CRP/albumin at 24–48 hours to identify patients who are failing to recover despite operative source control. Such patients may merit intensified ICU surveillance, reassessment of hemodynamics, evaluation for residual intra-abdominal infection, and earlier investigation for postoperative complications.

Nevertheless, the findings require cautious interpretation because this was a single-center study with a moderate sample size. Lactate and CAR may be influenced by vasopressor use, hepatic dysfunction, intravenous fluid administration, transfusion, exogenous albumin, and sampling time, while the composite outcome combined clinically heterogeneous events.

Multicenter external validation, calibration assessment, and decision-curve or reclassification analyses are therefore warranted. Future interventional studies should establish whether

biomarker-guided escalation improves clinical outcomes rather than merely predicting deterioration.

Conclusion:

Dynamic postoperative biomarker trajectories improved early risk stratification following emergency surgery for gastrointestinal perforation. Impaired 24-hour lactate clearance and a rising 48-hour CRP–albumin ratio were independently associated with adverse postoperative outcomes and provided stronger discrimination when interpreted together. Their addition to MPI, APACHE II and SOFA scores substantially improved predictive performance, suggesting that physiological response after source control is as important as baseline severity.

Serial lactate and CRP–albumin assessment may therefore offer a practical, inexpensive framework for postoperative reassessment and escalation of care. Larger multicenter studies should validate the identified thresholds and determine whether biomarker-guided interventions translate into improved clinical outcomes.

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