

Postoperative C-Reactive Protein-to-Albumin Ratio as a Predictor of 90-Day Morbidity After Hartmann's Reversal

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Abstract

Background

Hartmann's reversal is a technically demanding colorectal procedure with substantial postoperative morbidity. The C-reactive protein-to-albumin ratio (CAR) combines inflammatory burden with albumin status and may aid postoperative risk stratification.

Methods

This retrospective cohort included 86 adults undergoing Hartmann's reversal with colorectal anastomosis between April 2019 and March 2025. The primary outcome was Clavien-Dindo grade $\geq$ II morbidity within 90 days. CAR was calculated as postoperative C-reactive protein (mg/L) divided by preoperative albumin (g/dL) and evaluated on postoperative days (POD) 3 and 5. ROC analysis and logistic regression assessed discrimination and association with morbidity.

Results

Twenty-three patients (26.7%) developed 90-day morbidity. POD5 CAR was higher with morbidity than without morbidity (32.82 [IQR 20.82–50.95] vs 19.98 [12.74–26.32]; $p = 0.016$); POD3 CAR was not significantly different ($p = 0.103$). POD5 CAR showed an AUC of 0.715 (95% CI 0.528–0.877). A cutoff of 28.77 yielded 66.7% sensitivity, 76.9% specificity, and 85.7% negative predictive value. Each 10-unit increase in POD5 CAR was associated with higher odds of morbidity (OR 1.65, 95% CI 1.13–2.41; $p = 0.009$), remaining significant after adjustment for operative time.

Conclusions

POD5 CAR was associated with 90-day morbidity after Hartmann's reversal and showed moderate discriminatory ability. External validation is required before clinical implementation.

Introduction

Hartmann's reversal remains a technically demanding colorectal procedure associated with substantial postoperative morbidity [1–4]. Although restoration of intestinal continuity can eliminate stoma-related burden, reversal may require extensive adhesiolysis and complex pelvic dissection, and published series continue to report heterogeneous morbidity and reintervention rates [2–6]. A bicentric study specifically evaluating 90-day outcomes reported postoperative complications in 42.8% of patients undergoing Hartmann's reversal [1].

Early recognition of an unfavorable postoperative course may facilitate closer surveillance and timely diagnostic or therapeutic intervention. C-reactive protein (CRP) is widely used to quantify the postoperative inflammatory response, and multiple colorectal studies and meta-analyses have shown that persistent CRP elevation on postoperative days 3–5 is associated with infectious complications and anastomotic leakage [7–12]. Recent evidence specifically after Hartmann’s reversal also suggests that early CRP kinetics may provide prognostic information [13]. However, CRP alone primarily reflects inflammation and does not incorporate the albumin response to surgical stress.

The C-reactive protein-to-albumin ratio (CAR) combines CRP with albumin in a readily available composite biomarker. Postoperative albumin changes reflect the magnitude of surgical stress and have been associated with adverse outcomes [14]. In major colorectal surgery, postoperative CAR has been associated with overall complications and has shown discriminatory performance that may exceed CRP alone [15,16]. CAR has also demonstrated utility for detecting anastomotic leakage after colorectal cancer surgery [17]. Nevertheless, evidence regarding CAR specifically after Hartmann’s reversal remains limited. We therefore evaluated the association and discriminatory performance of CAR on POD3 and POD5 for 90-day postoperative morbidity after Hartmann’s reversal.

Methods

Study design and population

This retrospective cohort included adult patients who underwent Hartmann’s reversal with colorectal anastomosis between April 2019 and March 2025. The analysis was restricted to patients with colorectal anastomosis in the source database. Demographic, operative, laboratory, and postoperative outcome data were obtained from the study dataset. The final cohort comprised 86 patients. The study was prepared in accordance with the STROBE statement for observational research [18].

Outcome definition

The primary outcome was 90-day postoperative morbidity, defined as any Clavien-Dindo grade $\geq$ II complication occurring within 90 days after Hartmann’s reversal [19,20]. A complication explicitly documented at 1 year was excluded from the 90-day endpoint. Anastomotic leakage, reintervention, readmission, and major morbidity were retained as secondary descriptive outcomes where available.

CAR calculation

CAR was calculated as postoperative CRP expressed in mg/L divided by preoperative serum albumin expressed in g/dL. CAR was evaluated on POD3 and POD5 according to laboratory availability. One non-numeric POD3 CRP entry was treated as missing rather than imputed.

Statistical analysis

Normality of continuous variables was assessed using the Shapiro-Wilk test. Normally distributed variables were summarized as mean $\pm$ standard deviation and compared using Student's t-test. Non-normally distributed variables were summarized as median and interquartile range (IQR) and compared using the Mann-Whitney U test. Categorical variables were reported as frequencies and percentages and compared using chi-square or Fisher's exact test as appropriate. CAR values are presented uniformly as median [IQR]. Discriminatory performance was evaluated using receiver operating characteristic (ROC) curves and area under the curve (AUC) with 95% confidence intervals. The optimal cutoff was selected using the Youden index [21]; sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated. Logistic regression estimated odds ratios (ORs) for morbidity per 10-unit increase in CAR. Because only 23 primary-outcome events occurred, multivariable adjustment was deliberately parsimonious to limit overfitting; operative time was included in the adjusted POD5 model because it differed between outcome groups. All tests were two-sided and $p < 0.05$ was considered statistically significant. Analyses used complete available observations for each CAR time point; no missing laboratory values were imputed.

Use of generative artificial intelligence

A generative artificial intelligence language model (ChatGPT, OpenAI) was used to assist with statistical coding, language editing, manuscript organization, and drafting. The authors remain responsible for verification of the source data, statistical results, references, interpretation, and final manuscript content.

Results

Patient characteristics

A total of 86 patients were included; 23 (26.7%) experienced Clavien-Dindo grade $\geq$ II morbidity within 90 days. Patients with morbidity had longer operative times than patients without morbidity (210 [177.5–277.5] vs 180 [141.0–222.5] min; $p = 0.016$). Preoperative albumin was similar between groups (4.48 [4.14–4.71] vs 4.41 [4.15–4.73] g/dL; $p = 0.918$). Postoperative length of stay was longer among patients who developed morbidity (8 [7–11] vs 6 [6–8] days; $p < 0.001$) (Table 1).

Table 1
Baseline and perioperative characteristics according to 90-day morbidity

Variable	No morbidity (n = 63)	90-day morbidity (n = 23)	p value
Age, years	50.0 ± 13.7	48.7 ± 14.6	0.699
BMI, kg/m ²	25.8 [24.5–27.4]	25.9 [24.3–27.6]	1.000
Operative time, min	180 [141.0–222.5]	210 [177.5–277.5]	0.016
Estimated blood loss, mL	100 [50–200]	100 [75–300]	0.261
Preoperative albumin, g/dL	4.41 [4.15–4.73]	4.48 [4.14–4.71]	0.918
Postoperative length of stay, days	6 [6–8]	8 [7–11]	< 0.001

Values are mean ± standard deviation or median [IQR] according to distribution. BMI, body mass index; IQR, interquartile range.

Postoperative CAR

CAR was evaluable in 67 patients on POD3 and 54 patients on POD5. POD3 CAR was numerically higher among patients who developed morbidity but did not reach statistical significance (52.43 [29.00–69.21] vs 37.53 [27.08–45.48]; $p = 0.103$). POD5 CAR was significantly higher among patients with morbidity (32.82 [20.82–50.95] vs 19.98 [12.74–26.32]; $p = 0.016$) (Table 2).

Table 2
Discriminatory performance of postoperative CAR for 90-day morbidity

Measure	POD3	POD5
Evaluable patients	67	54
Morbidity events	21	15
CAR, morbidity	52.43 [29.00–69.21]	32.82 [20.82–50.95]
CAR, no morbidity	37.53 [27.08–45.48]	19.98 [12.74–26.32]
p value	0.103	0.016
AUC	0.625	0.715
95% CI for AUC	0.466–0.774	0.528–0.877
Youden cutoff	52.43	28.77
Sensitivity	52.4%	66.7%
Specificity	82.6%	76.9%
PPV	57.9%	52.6%
NPV	79.2%	85.7%

CAR, C-reactive protein-to-albumin ratio; POD, postoperative day; AUC, area under the receiver operating characteristic curve; CI, confidence interval; PPV, positive predictive value; NPV, negative predictive value.

Discriminatory performance

POD3 CAR showed limited discrimination for 90-day morbidity (AUC 0.625; 95% CI 0.466–0.774). Discrimination was higher on POD5 (AUC 0.715; 95% CI 0.528–0.877). The optimal POD5 cutoff was 28.77, with sensitivity 66.7%, specificity 76.9%, PPV 52.6%, and NPV 85.7% (Fig. 1).

Logistic regression

Each 10-unit increase in POD5 CAR was associated with a 65% increase in the odds of 90-day morbidity (OR 1.65, 95% CI 1.13–2.41; $p = 0.009$). Adjustment for operative time did not materially change the estimate (adjusted OR 1.65, 95% CI 1.13–2.40; $p = 0.009$). Preoperative albumin alone was not associated with postoperative morbidity in the preliminary analysis (Table 3).

Table 3
Logistic regression for 90-day postoperative morbidity

Model / predictor	OR	95% CI	p value
POD5 CAR, per 10-unit increase	1.65	1.13–2.41	0.009
POD5 CAR, per 10-unit increase, adjusted for operative time	1.65	1.13–2.40	0.009

CAR, C-reactive protein-to-albumin ratio; OR, odds ratio; CI, confidence interval.

Discussion

In this cohort of 86 patients undergoing Hartmann's reversal, POD5 CAR was associated with 90-day postoperative morbidity and showed greater discriminatory performance than POD3 CAR. The POD5 AUC was 0.715, and a cutoff of 28.77 yielded an NPV of 85.7%. Moreover, each 10-unit increase in POD5 CAR was associated with approximately 65% higher odds of morbidity, and this estimate was essentially unchanged after adjustment for operative time.

These findings are consistent with evidence from broader colorectal surgical populations. Ge et al evaluated 359 patients undergoing major colorectal surgery and reported an AUC of 0.779 for POD3 CAR compared with 0.756 for CRP alone [15]. Xu et al subsequently reported an AUC of 0.872 for POD3 CAR in 312 patients undergoing colorectal cancer surgery [16]. In a larger multicenter cohort of 1,183 patients, postoperative CAR also demonstrated good discrimination for anastomotic leakage (AUC 0.825) and outperformed CRP and albumin alone [17]. Together, these findings support the concept that combining inflammatory and albumin-related information may improve postoperative risk assessment.

Our study extends this concept to the specific setting of Hartmann's reversal. Dimas et al recently evaluated 83 patients undergoing Hartmann's reversal and found that early CRP kinetics between POD1 and POD3 were associated with surgical outcomes, with an AUC of 0.754 [13]. CAR addresses the same clinical need from a complementary perspective by integrating postoperative inflammatory burden with baseline albumin status. The present findings suggest that the discriminatory signal may become more apparent by POD5 in this population.

The 90-day endpoint was selected to capture clinically relevant morbidity beyond the conventional 30-day window. This approach has precedent in Hartmann's reversal: Christou et al used complications within the first 90 postoperative days as the primary outcome and reported overall morbidity of 42.8% [1]. Other contemporary Hartmann series also emphasize that postoperative outcomes remain clinically relevant despite increasing use of minimally invasive approaches [3–6]. In our cohort, 26.7% developed Clavien-Dindo grade $\geq$ II morbidity within 90 days.

Absolute CAR cutoff values should not be compared directly across studies. Published studies differ in the timing of CRP and albumin measurement, laboratory units, surgical populations, and outcome definitions [15–17]. In the present study, CAR was calculated as postoperative CRP in mg/L divided by

preoperative albumin in g/dL. Accordingly, the POD5 threshold of 28.77 should be regarded as cohort- and methodology-specific rather than a universal clinical cutoff.

The relatively high NPV of POD5 CAR may be clinically useful. This pattern is biologically and clinically plausible because postoperative CRP has repeatedly shown greater value as a rule-out than a rule-in marker for colorectal anastomotic complications [10–12]. CAR should not be considered a stand-alone diagnostic test; rather, it may serve as an adjunctive risk-stratification marker. A low POD5 CAR could contribute to identifying patients with a lower probability of subsequent morbidity, whereas persistently elevated values may support continued surveillance or further investigation when interpreted together with clinical findings.

This study has several limitations. Its retrospective, single-center design introduces potential selection and information bias. The cohort was modest, with 23 primary-outcome events, limiting the number of covariates that could be included in multivariable models. CAR was available in only 67 patients on POD3 and 54 on POD5, creating the possibility of selection bias related to laboratory testing. The cutoff was derived and evaluated in the same cohort and therefore requires external validation. Finally, our CAR definition used preoperative rather than contemporaneous postoperative albumin; this differs from some published CAR studies and should be considered when comparing absolute thresholds [15–17].

Conclusion

POD5 CAR was associated with 90-day postoperative morbidity after Hartmann's reversal and demonstrated moderate discriminatory ability. A POD5 CAR below the identified threshold had a relatively high negative predictive value, supporting a potential adjunctive role in postoperative risk stratification. Prospective and external validation is required before the proposed cutoff is incorporated into clinical decision-making.

Declarations

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Consent to participate: Individual informed consent was not required because this retrospective study used anonymized clinical data.

Consent to publish: Not applicable.

Data availability: The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request, subject to institutional and patient-confidentiality requirements.

Authors' contributions: Conceptualization: Daniel Iván Astorga Guardado and Ana Jimena Iberri Jaime. Data collection: Gerardo Joel Maya Vacío, Jorge de León Rendón, and Billy Jiménez Bobadilla. Literature review: Gerardo Joel Maya Vacío, Bertha Dimas, and Lucero Ortiz Pacheco. Manuscript drafting: Bertha Dimas and Daniel Iván Astorga Guardado. Critical revision: All authors. Guarantor: Daniel Iván Astorga Guardado.

Author Contribution

D.I.A.G. and A.J.I.J. contributed to the conceptualization of the study. G.J.M.V., J.L.R., B.J.B., and A.F.H.T. contributed to data collection. G.J.M.V., B.D., L.O.P., and A.F.H.T. performed the literature review. B.D. and D.I.A.G. drafted the manuscript. All authors critically revised the manuscript, read and approved the final version. D.I.A.G. is the guarantor of the study.

Data Availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request, subject to institutional and patient-confidentiality requirements.

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Figures

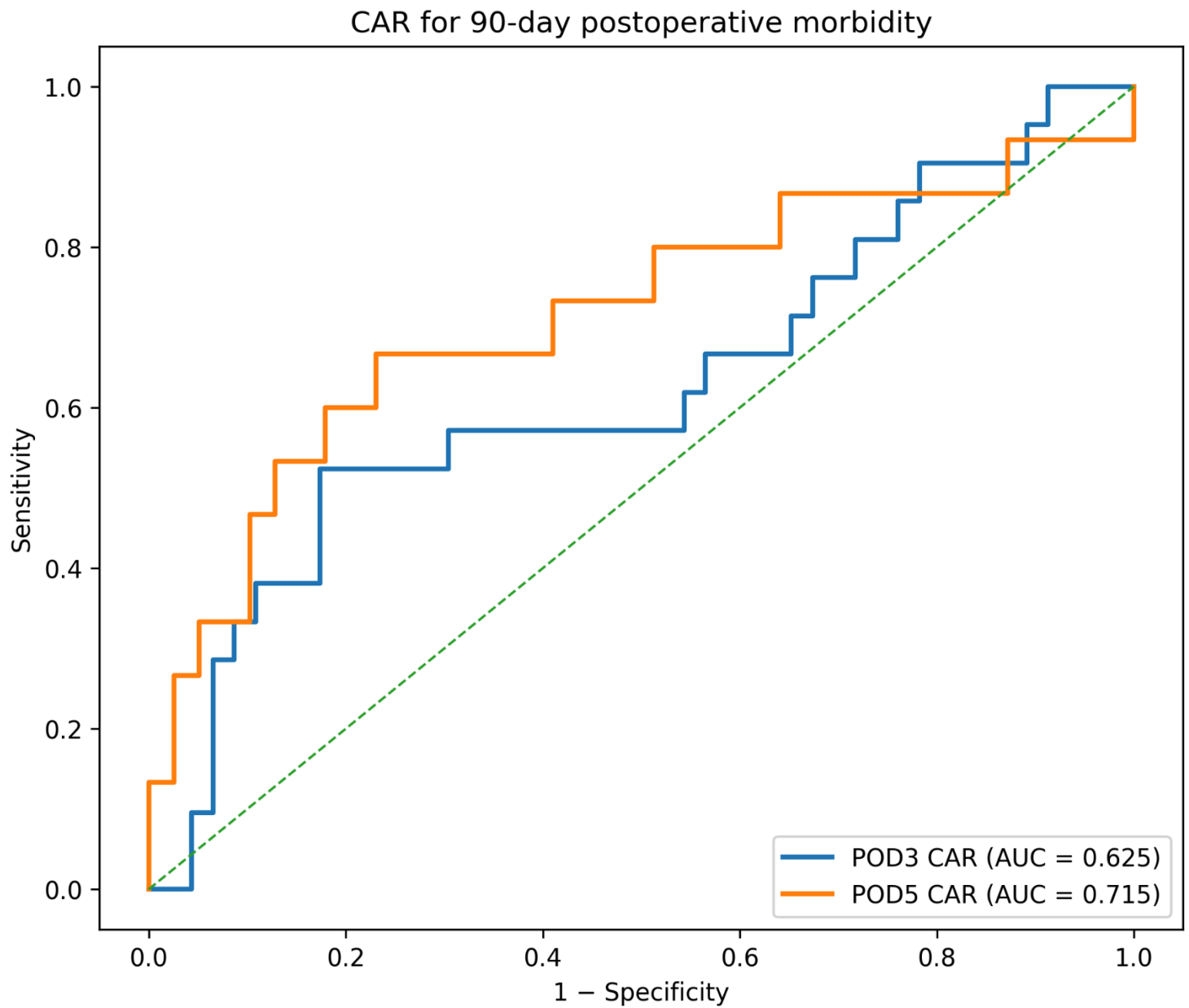


Figure 1

Receiver operating characteristic curves of CAR on postoperative days 3 and 5 for discrimination of 90-day postoperative morbidity after Hartmann’s reversal. POD3 AUC=0.625; POD5 AUC=0.715.