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Independent Prognostic Role of Postoperative Carcinoembryonic Antigen in Stage II Colon Cancer

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What is already known on this topic?

- *The decision to administer adjuvant chemotherapy in stage II colon cancer remains a clinical challenge.*
- *Preoperative carcinoembryonic antigen (CEA) is sometimes considered in adjuvant therapy decisions for stage II colon cancer, but the role of postoperative CEA in guiding treatment is not clearly established.*
- *Previous studies in mixed-stage cohorts suggested that elevated postoperative CEA may be associated with worse outcomes.*

What this study adds to the literature?

- *This study demonstrates that elevated postoperative CEA (≥5 ng/mL) is an independent adverse prognostic factor in stage II colon cancer.*
- *Both relapse-free survival and overall survival were significantly poorer in patients with elevated postoperative CEA.*
- *The findings support considering postoperative CEA as a practical high-risk marker to guide adjuvant therapy decisions in stage II colon cancer, where treatment selection remains challenging.*

Abstract

Objective: Preoperative carcinoembryonic antigen (CEA) is often considered when making adjuvant therapy decisions for stage II colon cancer, whereas postoperative CEA is not routinely used. The aim was to evaluate its prognostic significance.

Methods: A total of 179 patients with stage II colon cancer who underwent curative resection between 2010 and 2024 were retrospectively analyzed. Postoperative CEA (post-CEA) was measured within 1 month after surgery. An elevated CEA was defined as 5.0 ng/mL, based on a cutoff confirmed by receiver operating characteristic analysis. Survival outcomes were analyzed using Kaplan–Meier and Cox regression models.

Results: Postoperative CEA was ≥5 ng/mL in 18 (10%) of patients. Elevated postoperative CEA was strongly associated with recurrence (67% vs. 7%, $P < .001$) and mortality (50% vs. 10%, $P < .001$). Five-year relapse-free survival was 90% in patients with CEA <5 ng/mL compared with 42% in those with CEA ≥5 ng/mL ($P < .001$). Five-year overall survival was 94% versus 63% ($P = .001$). In multivariate analysis, postoperative CEA ≥5 ng/mL and T4 stage remained independent adverse prognostic factors.

Conclusion: Elevated postoperative CEA is an independent prognostic biomarker in stage II colon cancer. Its low cost and availability support its consideration as a high-risk factor for adjuvant decision-making, though prospective validation is required to confirm its role and optimal cutoff.

Keywords: Adjuvant chemotherapy, postoperative CEA, prognostic marker, risk stratification, stage II colon cancer, survival outcomes

Introduction

Colorectal cancer remains a major global health burden, ranking among the most frequently diagnosed malignancies and leading causes of cancer mortality.[1] A substantial proportion of colon cancers are diagnosed at localized or regional stages, where curative-intent resection is possible.[2,3] Despite curative-intent resection, recurrence may still occur in a subset of patients, underscoring the role of adjuvant strategies in improving long-term outcomes.[4,5] For stage III colon cancer, adjuvant chemotherapy (AC) is standard of care, whereas the decision to administer AC in stage II disease is individualized. Current risk assessment commonly incorporates pathological and clinical features—such as T4 status, inadequate lymph node harvest, lymphovascular or perineural invasion, poor differentiation, obstruction, or perforation—to guide treatment selection.

Carcinoembryonic antigen (CEA) is an inexpensive, widely available biomarker; preoperative CEA has been included in several prognostic tools.[2] However, previous studies have shown that patients with elevated preoperative CEA who achieved normalization after surgery had survival outcomes comparable to those with normal baseline CEA, underscoring the prognostic relevance of postoperative CEA assessment.[6] By contrast, although postoperative CEA has been associated with inferior outcomes in stage II cohorts,[7,8] it has not been routinely used as a criterion for AC selection in stage II colon cancer.[2,9] A recently published meta-analysis also confirmed that elevated postoperative CEA levels are significantly associated with poorer prognosis,[10] further highlighting the need for greater attention to high postoperative CEA in clinical risk assessment.

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Against this background, there is a clinical need to determine whether postoperative CEA provides independent prognostic information in stage II disease. This study retrospectively assessed the independent prognostic significance of postoperative CEA in patients with stage II colon cancer, with the objective of determining whether this measure should be incorporated into adjuvant therapy decision-making.

Methods

Study Design and Patient Inclusion Criteria

This retrospective analysis included patients with pathologically confirmed stage II colon cancer who underwent curative-intent surgical resection between March 2010 and July 2024. Patients were eligible if they were 18 years of age or older and had complete clinicopathological information available. Exclusion criteria comprised patients younger than 18 years, those with stage III or IV disease, individuals with a prior history of another malignancy, cases with incomplete clinical or pathological records, patients who did not undergo surgery, patients with postoperative inflammatory complications or infections, and those whose follow-up duration was less than 1 year.

Adjuvant Chemotherapy and Patient Follow-Up

The decision to initiate AC was made individually by the treating oncologist, taking into account patient age, comorbidities, functional status, and pathological risk factors. Among stage II cases, chemotherapy was primarily considered for patients with major high-risk characteristics such as T4 tumors, bowel obstruction or perforation, or insufficient lymph node evaluation. Lymphovascular invasion (LVI) and perineural invasion (PNI) were regarded as minor risk factors and were also incorporated into the treatment decision-making process. Adding oxaliplatin was not a common recommendation; rather, it was decided based on the patient's overall health and the characteristics of the disease.

Follow-up was conducted according to the institutional protocols. During the first 2 years, thoracoabdominal computed tomography (CT) scans were scheduled every 3-6 months. After that, they were scheduled every 6 to 12 months until year 5, and then every year after that. Colonoscopy was recommended at 1 year postoperatively, and subsequently at 3-5 year intervals, unless earlier surveillance was indicated.

Data Collection, Study Variables, and Outcome Definitions

Clinical, pathological, and treatment-related data were retrieved from institutional electronic medical records and archived patient files. The collected variables comprised demographic features (age, sex), comorbidities, Eastern Cooperative Oncology Group (ECOG) performance status, body mass index (BMI), tumor location (classified as right- or left-sided colon), tumor stage (determined according to the 7th or 8th editions of the Tumor–Node–Metastasis (TNM) classification system, depending on the year of diagnosis), histological grade, LVI, PNI, number of dissected lymph nodes, microsatellite instability status, preoperative and postoperative CEA, and AC characteristics. Follow-up information included disease recurrence, date of last contact, and survival status.

The primary outcomes of interest were overall survival (OS) and relapse-free survival (RFS). Overall survival was determined from the date of curative-intent surgery until death from any etiology. Relapse-free survival was defined as the interval between curative-intent surgery and the initial radiologically or pathologically confirmed recurrence.

Carcinoembryonic Antigen Assessment

Preoperative CEA (pre-CEA) was defined as the most recent CEA measurement obtained before surgery.

Postoperative CEA (post-CEA) was defined as the first CEA measurement obtained within 1 month after surgery. For patients with elevated postoperative CEA, restaging with thoracic and abdominal CT was performed within 6 weeks to exclude the presence of metastatic disease.

Receiver operating characteristic (ROC) curve analysis was used to establish the appropriate cutoff value for postoperative CEA. The area under the curve was 0.777 (95% CI: 0.660-0.894, $P < .001$)(Supplementary Figure 1. The optimal cutoff value was 5.0 ng/mL, which provided a sensitivity of 69% and a specificity of 94%, consistent with previous studies using the same threshold.[6,8] Accordingly, patients were categorized into 2 groups: low CEA (<5.0 ng/mL) and high CEA (≥5.0 ng/mL).

Ethical Considerations

This research was conducted in accordance with the ethical standards of the Declaration of Helsinki. Approval for the study protocol was obtained from the Ethics Committee of Istanbul University–Cerrahpaşa, Cerrahpaşa Faculty of Medicine., (Approval No: 2025/180, Date: March 5, 2025). Because this study was retrospective and based on anonymized data, informed consent was not required, as confirmed by the approval of the institutional ethics committee.

Statistical Analysis

Statistical analyses were carried out using SPSS software, version 26.0 (IBM Corp., Armonk, NY, USA). The distribution of continuous variables was examined with the Shapiro–Wilk test, as well as visual methods including Q–Q plots and histograms. Continuous variables are presented as mean ± SD or median with range, whereas categorical variables are expressed as counts and percentages.

For group comparisons, the independent samples *t*-test or Mann–Whitney *U*-test was applied to continuous data, while categorical data were analyzed with the Chi-square test or Fisher's exact test when appropriate. Survival outcomes were estimated using the Kaplan–Meier method, and group differences were compared with the log-rank test. To determine prognostic factors, univariate and multivariate Cox proportional hazards regression models were constructed. In addition, ROC curve analysis was performed to determine the optimal cutoff value for postoperative CEA. Statistical significance was defined as a 2-sided *P*-value less than .05.

Results

Baseline Clinic and Demographic Findings

A total of 179 patients with stage II colon cancer were included in the study. The median age was 67 years (range, 36-90 years), and 44% were aged ≥ 70 years. Men comprised 56% of the group, and 74% of the patients had at least 1 comorbidity. Eastern Cooperative Oncology Group performance status was 0-1 in 97% of cases and performance status 2 in 3%.

Preoperative CEA were available in 45 patients (25%), with a median value of 22 ng/mL (range: 3-356). Postoperative CEA was <5 ng/mL in 161 patients (90%) and ≥5 ng/mL in 18 patients (10%).

When patients were categorized based on postoperative CEA (<5 vs. ≥5 ng/mL), there were no notable differences in baseline demographic or clinical characteristics, including age, sex, comorbidity, ECOG status, BMI, tumor location, surgical type, histological subtype, grade, T stage, or mismatch repair status. However,

Table 1. Baseline Clinicopathological Characteristics of Patients According to Postoperative Carcinoembryonic Antigen

		Overall (n = 179)		CEA < 5 (n = 161)		≥5 CEA (n = 18)		*P*
Age (years), median (min-max)		67 (36-90)		68 (38-90)		66 (36-82)		.573
Age, n (%)	<70	101	56	90	56	11	61	.672
	≥70	78	44	71	44	7	39	
Gender, n (%)	Male	101	56	91	57	10	56	.938
	Female	78	44	70	43	8	44	
Comorbidity, n (%)	Absent	46	26	42	26	4	22	.722
	Present	133	74	119	74	14	78	
ECOG, n (%)	0-1	173	97	156	97	17	94	.584
	2	6	3	5	3	1	6	
BMI, n (%)	<25	69	39	61	38	8	44	.588
	≥25	110	61	100	62	10	56	
Postoperative CEA, median (min-max)		2 (0.5-11.9)		1.9 (0.5-4.4)		6.4 (5.4-11.9)		<.001
Preoperative CEA	Not available, n (%)	134 (75)		–		–		–
	Available, n (%)	45 (25)						
Preoperative CEA, median (min-max)		22 (3-356)		–		–		–
Tumor location, n (%)	Left	108	60	95	59	13	72	.277
	Right	71	40	66	41	5	28	
Type of surgery, n (%)	Urgent	24	13	20	12	4	22	.247
	Elective	155	87	141	88	14	78	
<12 LN dissection, n (%)	Absent	178	99	160	99	18	100	–
	Present	1	1	1	1	0	0	
Histology, n (%)	ADC	149	83	136	84	13	72	.187
	Other*	30	17	25	16	5	28	
Grade, n (%)	1	137	77	122	76	15	83	.473
	2-3	42	23	39	24	3	17	
T stage, n (%)	T3	105	59	97	60	8	44	.197
	T4	74	41	64	40	10	56	
LI, n (%)	Absent	37	21	35	22	2	11	.291
	Present	142	79	126	78	16	89	
VI, n (%)	Absent	72	40	67	42	5	28	.256
	Present	107	60	94	58	13	72	
PNI, n (%)	Absent	45	25	44	27	1	6	.043
	Present	134	75	117	73	17	94	
MMR, n (%)	pMMR	131	73	120	75	11	61	.188
	dMMR	18	10	14	9	4	22	
	Not available	30	17	27	17	3	17	
Adjuvant CTx	Not received	91	51	85	53	6	33	.005
	Received	88	49	76	47	12	67	
Recurrence	Absent	155	87	149	93	6	33	<.001
	Present	24	13	12	7	12	67	
Current Status	Alive	154	86	145	90	9	50	<.001
	Exitus	25	14	16	10	9	50	

ADC, adenocarcinoma; BMI, body mass index; CEA, carcinoembryonic antigen; CTx, chemotherapy; dMMR, deficient MMR; ECOG, Eastern Cooperative Oncology Group; LI, lymphatic invasion; LN, lymph node; MMR, mismatch repair; pMMR, proficient MMR; PNI, perineural invasion; VI, vascular invasion.
*Other histology includes mucinous and signet-ring cell subtypes.

perineural invasion was significantly more frequent in the elevated postoperative CEA group (94% vs. 73%, $P = .043$).

Adjuvant chemotherapy was administered to 49% of the overall cohort and was more common among patients with postoperative CEA ≥5 ng/mL compared to those with lower levels (67% vs. 47%, $P = .005$). Disease recurrence was observed in 13% of all patients, with a markedly higher rate in the elevated postoperative CEA group (67% vs. 7%, $P < .001$). At the time of last follow-up, 86% of patients were alive; however, mortality was significantly higher among those with postoperative CEA ≥5 ng/mL (50% vs. 10%, $P < .001$).

Baseline clinicopathological characteristics are summarized in Table 1.

Relapse-Free Survival Outcomes

The median follow-up time was 58.8 months. In the overall cohort, the median RFS was not reached during the follow-up period. When stratified by postoperative CEA status, a marked difference in RFS was observed. The 5-year RFS was 90% in the CEA <5 ng/mL group compared with 42% in the CEA ≥5 ng/mL group. The difference between the 2 groups was statistically significant ($P < .001$, log-rank test) (Figure 1).

To further evaluate prognostic factors for RFS, Cox regression analyses were performed. In the univariate analysis, elevated postoperative CEA (≥5 ng/mL), T4 stage, grade 2-3 histology, and urgent surgery were significantly associated with worse outcomes, while receipt of AC was associated with improved RFS. In the multivariate model, postoperative CEA ≥5 ng/mL (HR: 10.1, 95% CI: 4.52-22.95, $P < .001$) and T4 stage (HR: 3.95, 95% CI: 1.54-10.13, $P = .004$) remained as the only independent predictors of inferior RFS (Table 2).

Overall Survival Outcomes

In the overall cohort, the median OS was 164.1 months (95% CI: 148.3-179.9). When stratified by postoperative CEA status, the 5-year OS rate was 94% for patients with postoperative CEA <5 ng/mL, whereas it was 63% for those with CEA ≥5 ng/mL. The survival difference between the 2 groups was statistically significant ($P = .001$, log-rank test) (Figure 2).

In the univariate Cox regression analysis, postoperative CEA ≥5 ng/mL and T4 stage were significantly associated with poorer OS. In the multivariate model, both postoperative CEA ≥5 ng/mL (HR: 3.64, 95% CI: 1.53-8.62, $P = .003$) and T4 stage (HR: 2.76, 95% CI: 1.17-6.46, $P = .019$) remained independent predictors of poorer OS (Table 3).

Discussion

This retrospective study evaluated the prognostic role of postoperative CEA in 179 patients with stage II colon cancer treated with curative resection. Baseline characteristics were comparable between patients with postoperative CEA <5 and ≥5 ng/mL, however elevated postoperative CEA was strongly associated with higher recurrence and mortality. Survival analyses confirmed significantly poorer RFS and OS in the elevated group, and multivariate Cox regression identified high postoperative CEA and T4 stage as independent adverse prognostic factors for outcome. These findings suggest that postoperative CEA may serve as a valuable biomarker for risk stratification in stage II colon cancer.

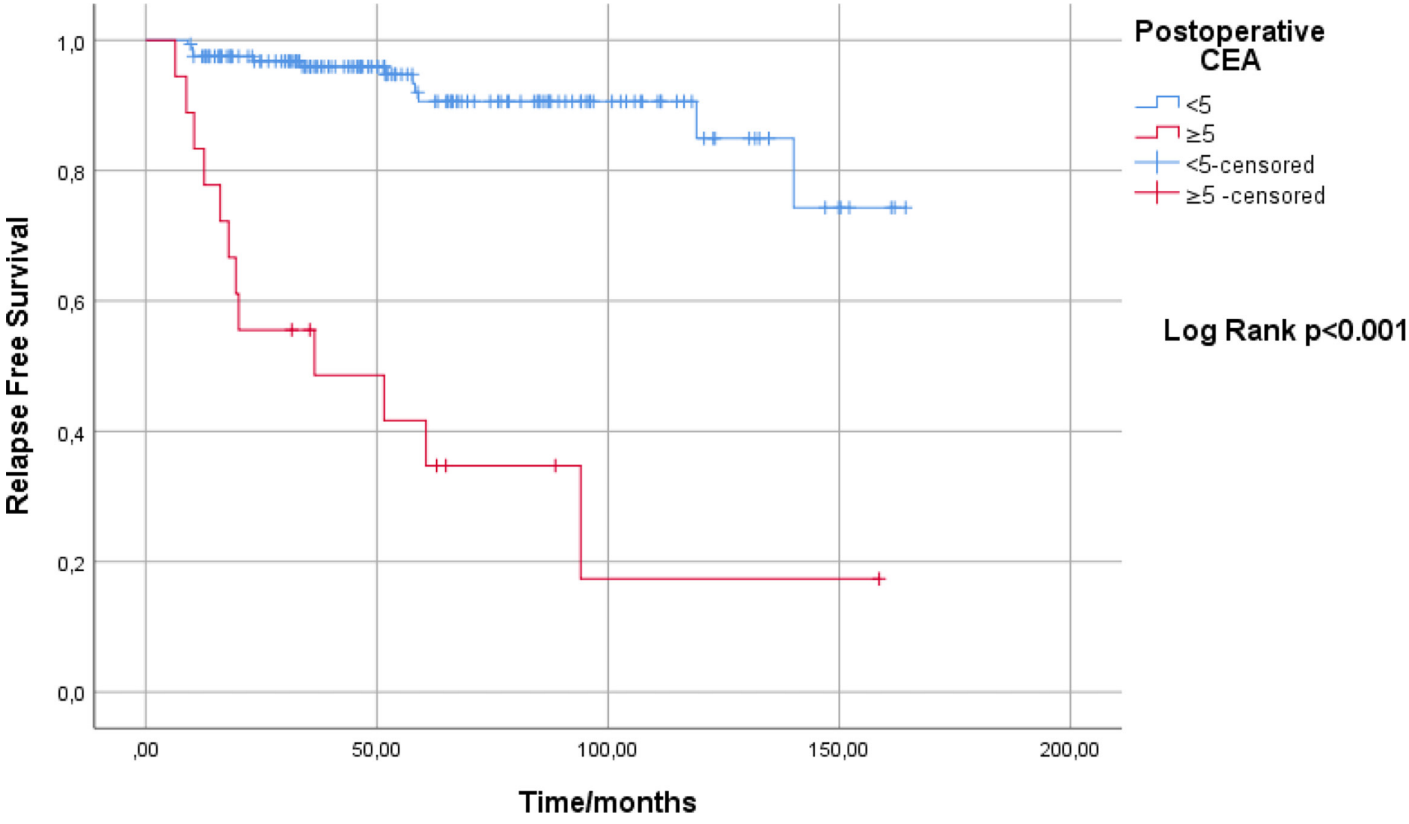

Figure 1. Relapse-free survival (RFS) according to postoperative carcinoembryonic antigen (CEA) in stage II colon cancer. Kaplan–Meier curves showing RFS stratified by postoperative CEA. The blue line represents patients with postoperative CEA <5 ng/mL, and the red line represents patients with postoperative CEA ≥5 ng/mL. Patients with elevated postoperative CEA had significantly worse RFS compared to those with lower levels (Log-rank $P < .001$). Censored observations are indicated by cross marks on each curve.

Table 2. Univariate and Multivariate Cox Regression Analysis for Relapse-Free Survival in Patients with Stage 2 Colon Cancer

		Univariate analysis		Multivariate analysis	
		HR (95% CI)	*P*	**HR (95% CI)**	*P*
Age, years	<70	1.05 (0.47-2.35)	.902		
	≥70				
Gender	Female	1.65 (0.70-3.87)	.246		
	Male				
Comorbidty	Absent	0.82 (0.34-1.99)	.668		
	Present				
BMI	<25	0.67 (0.30-1.49)	.328		
	≥25				
Postoperative CEA	<5	11.2 (5.01-25.01)	<.001	10.1 (4.52-22.95)	<.001
	≥5				
T stage	T3	4.43 (1.75-11.17)	.002	3.95 (1.54-10.13)	.004
	T4				
LI	Absent	1.36 (0.40-4.58)	.620		
	Present				
VI	Absent	1.33 (0.55-3.22)	.524		
	Present				
PNI	Absent	1.31 (0.44-3.87)	.618		
	Present				
Tumor location	Right	0.91 (0.39-2.10)	.831		
	Left				
Histology	ADC	1.29 (0.48-3.47)	.608		
	Other*				
Grade	1	2.94 (1.07-8.11)	.036	1.49 (0.55-4.03)	.428
	2-3				
Type of surgery	Urgent	3.13 (1.28-7.63)	.012	1.71 (0.67-4.36)	.261
	Elektive				
MMR	pMMR	1.87 (0.93-8.89)	.185		
	dMMR-NA				
Adjuvant CTx	Received	0.42 (0.18-0.99)	.049	0.864 (0.30-2.45)	.784
	Not received				

ADC, adenocarcinoma; BMI, body mass index; CEA, carcinoembryonic antigen; CTx, chemotherapy; dMMR, deficient MMR; HR, hazards ratio; LI, lymphatic invasion; MMR, mismatch repair; NA, not available; pMMR, proficient MMR; PNI, perineural invasion; VI, vascular invasion.
*Other histology includes mucinous and signet-ring cell subtypes.

Numerous studies have examined the predictive significance of perioperative CEA in stage II colon cancer.[7,11] Preoperative CEA has traditionally been considered a prognostic marker, and many guidelines have suggested its use in guiding adjuvant therapy decisions.[2] However, Konishi et al[6] analyzed 1027 patients with stage I-III colon cancer and found that patients with elevated preoperative CEA who normalized after surgery had survival outcomes similar to those with normal baseline CEA. Conversely, consistently elevated postoperative CEA was linked to markedly reduced survival outcomes.[6] Similarly, Morimoto et al[8] retrospectively analyzed 199 patients with stage II disease and confirmed that normalization of high preoperative CEA after surgery was not

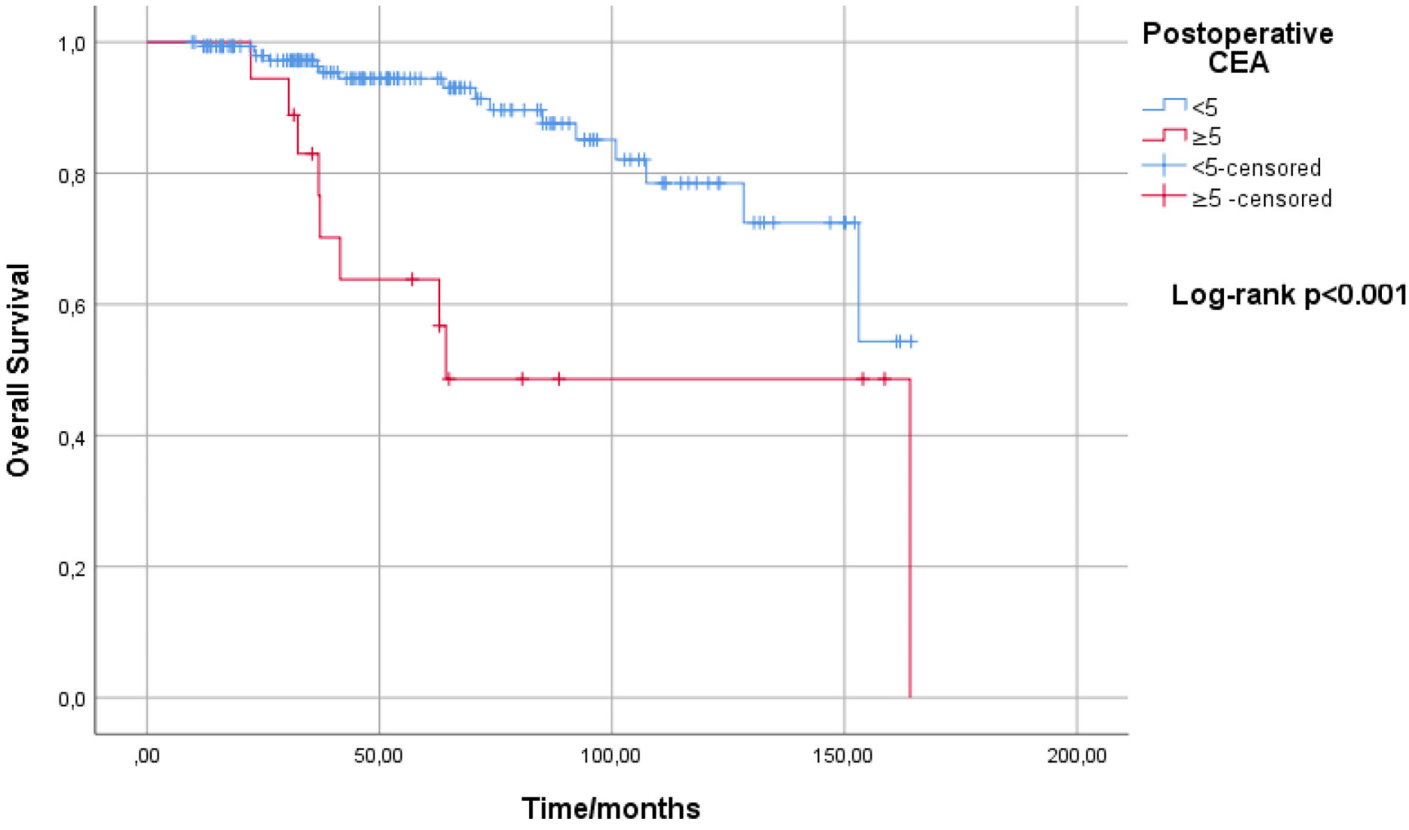

Figure 2. Overall survival (OS) according to postoperative carcinoembryonic antigen (CEA) in stage II colon cancer. Kaplan–Meier curves showing OS stratified by postoperative CEA. The blue line represents patients with postoperative CEA <5 ng/mL, and the red line represents patients with postoperative CEA ≥5 ng/mL. Patients with elevated postoperative CEA had significantly worse OS compared to those with lower levels (Log-rank *P* = .001). Censored observations are indicated by cross marks on each curve.

associated with inferior outcomes, whereas elevated postoperative CEA predicted poorer OS and RFS. Lin et al[12] additionally indicated that postoperative CEA served as an independent prognostic predictor, whereas preoperative CEA lacked significance in multivariate analyses. More recently, a large multicohort retrospective study reached consistent conclusions and suggested that postoperative CEA should be incorporated as a high-risk factor to guide AC decisions in stage II colon cancer.[13] These results are consistent with these findings. In this cohort, preoperative CEA measurements were available for only a limited number of patients, possibly due to urgent surgical interventions and institution-related factors. However, postoperative CEA were available for all patients, and elevated postoperative CEA was consistently correlated with inferior outcomes.

The post hoc analysis of the MOSAIC trial demonstrated that elevated postoperative CEA is an independent prognostic factor.[14] Importantly, this analysis also suggested that only patients with high postoperative CEA appeared to derive a survival benefit from the addition of oxaliplatin to LV5FU2 (leucovorin plus 5-fluorouracil, biweekly regimen), underscoring the potential predictive value of postoperative CEA.[14] Moreover, Morimoto et al[8] reported that 94.4% of patients with elevated postoperative CEA did not receive AC and experienced poorer survival, further supporting its consideration as a high-risk factor. Although this study was not specifically designed to evaluate the benefit of AC in this subgroup, it was observed that 67% of patients with elevated postoperative CEA received adjuvant therapy. However, due to the limited number of cases, it was not possible to determine whether chemotherapy mitigated the adverse prognostic effect in this cohort.

The post hoc analysis of the MOSAIC trial identified a postoperative CEA cutoff of 2.35 ng/mL as prognostically relevant.[14] However, most studies in the literature have used 5.0 ng/mL as the clinically meaningful threshold. In line with this, ROC curve analysis in this cohort validated 5.0 ng/mL as the optimal cutoff, supporting its use for categorizing patients into low and high postoperative CEA group.[6,8] On the other hand, 1 report suggested that even small postoperative CEA fluctuations (≥1.1 ng/mL), while remaining within the normal range, might be associated with recurrence risk.[15] These findings highlight the need for prospective studies to establish a standardized definition of high postoperative CEA.

Recently, circulating tumor DNA (ctDNA) has been identified as a promising biomarker for prognostic and predictive evaluation in stage II colon cancer.[16,17] However, ctDNA testing remains costly and has not yet replaced high-risk clinicopathological factors in routine practice.[9,17] In this context, postoperative CEA represents an inexpensive and widely available marker with clear prognostic implications.[6,8,13,14] These findings indicate that elevated postoperative CEA may serve as a potential prognostic marker for stage II colon cancer.

This study has several limitations. First, its retrospective and single-center design inherently limits the generalizability of the findings. Second, the number of patients with elevated postoperative CEA was relatively small, reducing the statistical power for subgroup analyses. In addition, the difference in AC rates observed in the CEA <5 ng/mL group may also have been influenced by this small subgroup size. Moreover, preoperative CEA was unavailable for most patients, preventing direct comparison between pre- and

Table 3. Univariate and Multivariate Cox Regression Analysis for Overall Survival in Patients with Stage 2 Colon Cancer

		Univariate Analiz		Multivariate Analiz	
		HR (95% CI)	*P*	**HR (95% CI)**	*P*
Age, years	<70	1.24 (0.56-2.76)	.590		
	≥70				
Gender	Female	0.67 (0.29-1.53)	.349		
	Male				
Comorbidty	Absent	1.12 (0.44-2.87)	.806		
	Present				
BMI	<25	0.82 (0.37-1.82)	.639		
	≥25				
Postoperative CEA	<5	4.09 (1.75-9.56)	.001	3.64 (1.53-8.62)	.003
	≥5				
T stage	T3	3.07 (1.32-7.13)	.009	2.76 (1.17-6.46)	.019
	T4				
LI	Absent	0.76 (0.28-2.08)	.601		
	Present				
VI	Absent	0.85 (0.37-1.94)	.704		
	Present				
PNI	Absent	0.72 (0.28-1.83)	.495		
	Present				
Tumor location	Right	1.42 (0.65-3.14)	.375		
	Left				
Histology	ADC	1.54 (0.61-3.88)	.361		
	Other*				
Grade	1	0.64 (0.21-3.88)	.426		
	2-3				
Type of surgery	Urgent	2.28 (0.93-5.56)	.069	1.35 (0.51-3.60)	.541
	Elektive				
MMR	pMMR	2.54 (0.71-9.11)	.356		
	dMMR-NA				
Adjuvant CTx	Received	0.45 (0.20-1.03)	.061	0.87 (0.32-2.36)	.787
	Not received				

ADC, adenocarcinoma; BMI, body mass index; CEA, carcinoembryonic antigen; CTx, chemotherapy; dMMR, deficient MMR; HR, hazards ratio; LI, lymphatic invasion; MMR, mismatch repair; NA, not available; pMMR, proficient MMR; PNI, perineural invasion; VI, vascular invasion.
*Other histology includes mucinous and signet-ring cell subtypes.

postoperative CEA measurements and limiting the ability to assess their relative impact on recurrence and survival outcomes. In addition, the long inclusion period (2010-2024) may have introduced variability in treatment approaches over time, which could have influenced clinical outcomes.

Elevated postoperative CEA was identified as an independent adverse prognostic factor in stage II colon cancer, associated with significantly worse survival. Given its low cost and widespread availability, postoperative CEA may serve as a practical indicator for postoperative risk stratification and may be considered in future adjuvant treatment algorithms for stage II colon cancer. However, prospective studies are warranted to validate its prognostic significance and to define the optimal cutoff value.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of İstanbul University-Cerrahpaşa, Cerrahpaşa Faculty of Medicine (Approval No.: 2025/180; Date: March 5, 2025).

Informed Consent: The requirement for informed consent was waived due to the retrospective nature of the study and the use of de-identified data, as approved by the Ethics Committee of Istanbul University-Cerrahpaşa, Cerrahpaşa Faculty of Medicine.

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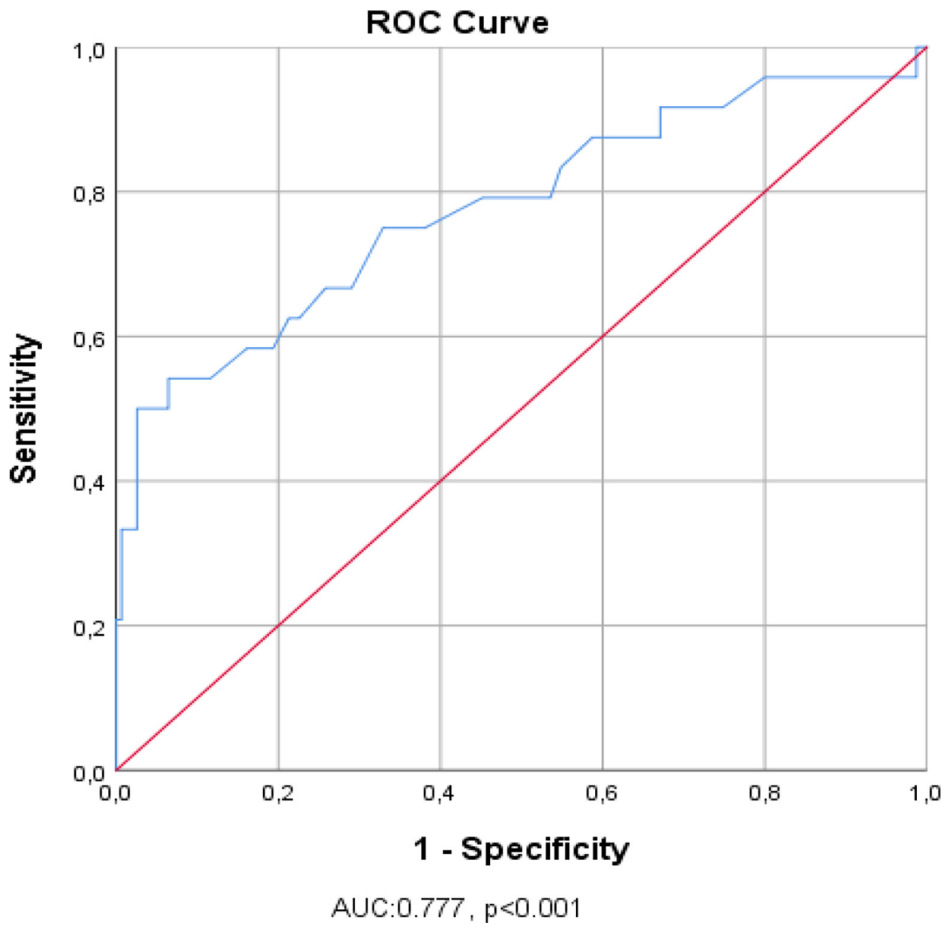

Supplementary Figure 1. ROC curve analysis for postoperative CEA cutoff in stage II colon cancer. ROC curve for postoperative CEA in predicting recurrence. The analysis identified 5.0 ng/mL as the optimal cutoff, consistent with prior studies. The area under the curve was 0.777 ($P < .001$), indicating good discriminative ability.