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Nomogram for Prediction of Postoperative Morbidity in Patients with Colon Cancer Requiring Emergency Therapy

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Background: Postoperative complications are the major cause of mortality and prolonged hospitalization after emergency surgery for colon cancer. This study aimed to propose an effective nomogram to predict postoperative complications in order to improve the outcomes.

Material/Methods: We retrospectively analyzed 449 patients who underwent emergency surgery for complicated colon cancer at the County Emergency Hospital Clinic "St. Apostle Andrei" in Galați, in the period from 2008 to 2017. Postoperative complications were intestinal obstruction, leakage, bleeding, peritonitis, wound infection, surgical wound dehiscence, respiratory failure, heart failure, acute renal failure, sepsis, and *Clostridium difficile* colitis, within a month after surgery. Logistic regression models were used to identify the independent prediction factors, and a nomogram was created, based on the best model.

Results: A total of 106 patients (21%) presented postoperative complications after emergency surgery for colon cancer; 51 patients (11.36%) died during the postoperative period. After identifying the risk factors through univariate regression analysis, we identified the independent prediction factors in 2 multivariate regression models. The model with the highest accuracy included the following 7 independent prediction factors: Eastern Cooperative Oncology Group performance status, Charlson score, white blood cell count, electrolyte and coagulation disorders, surgery time, and cachexia ($P < 0.05$ for all). This model showed good precision in predicting postoperative complications, with an area under curve of 0.83 and ideal accordance between the predicted and observed probabilities.

Conclusions: The nomogram developed in this study, which was based on a multivariate logistic regression model, had good individual prediction of postoperative complications.

Keywords: **Predictive Value of Tests • Colonic Neoplasms • Nomograms • Postoperative Complications**

Full-text PDF: <https://www.medscimonit.com/abstract/index/idArt/936303>



Background

Emergency colorectal cancer surgery is recognized as being associated with high rates of morbidity and mortality [1,2]. Emergency surgery represents a quarter of all colorectal surgeries and has a mortality rate of 10% to 25% and a morbidity rate of 30% to 50%, regardless of age group [3,4]. Several studies showed that postoperative morbidity and mortality are significantly higher for patients undergoing emergency surgery than for those undergoing elective surgery [3,5].

Management of complicated colon cancer raises 2 challenges: first, the need to urgently relieve the bowel obstruction to avoid dehydration, electrolyte imbalances, and intra-abdominal sepsis related to colonic ischemia and/or perforation; and second, the appropriate treatment of the malignant tumor, which is most often locally advanced or metastatic. In addition, complicated colon cancer is more common in elderly patients with significant comorbidities [6].

In an attempt to obtain the best postoperative results, surgeons try to adapt the surgical procedures to the presenting emergency. Conventionally, emergency colon surgeries were performed in stages, with the creation of a stoma minimizing the postoperative complications of an anastomotic fistula. In 1988, Mealy et al [7] reported that single-stage resection with anastomosis was not associated with increased morbidity or mortality, compared with conventional staged treatment. Subsequent studies supported this observation, showing that resection with primary anastomosis and intraoperative colonic irrigation has similar morbidity and mortality rates as multi-stage procedures [8].

For complicated cancers of the ascending colon, resection with primary anastomosis is a generally accepted strategy, even in the presence of peritonitis [9-11]. The Hartmann procedure was initially indicated for complicated tumors of the descending colon [12] but then was questioned because of its association with an increased risk of postoperative morbidity [13]. However, for other authors, the Hartman procedure remains an applicable option for the majority of patients with emergency surgery for left colon cancer [14].

To improve immediate results, other therapeutic alternatives were considered, such as internal bypass, resection with anastomosis and protective ileostomy [15], and stent decompression, followed by elective surgery [11].

Other authors also consider that resection with primary anastomosis can be used for selected patients. A fecal abscess or peritonitis is not a contraindication for anastomosis, but the presence of major comorbidities, such as diabetes, kidney failure, cardiovascular disease, decreased immunity, malnutrition, or a high American Society of Anesthesiologists' score is

associated with an increased risk of fistula [16,17]. The most feared surgical complication in colon pathology remains the anastomotic fistula. This complication has an incidence of 1% to 19%, and the associated mortality rate varies between 6% and 22%, being the third cause of death in patients undergoing colorectal surgery [18,19].

In this study, we aimed to identify risk factors for use in creating a nomogram in order to predict the postoperative complications in patients with colon cancer requiring emergency surgery.

Material and Methods

The study group included 449 patients with colon cancer who underwent emergency surgery during a 10-year period, from 2008 to 2017, at the County Emergency Clinical Hospital "St. Apostol Andrei" in Galați and who benefited from surgical treatment in Clinics I and II of General Surgery.

The inclusion criteria were as follows. The study included adult patients with complicated malignant tumors of the colon (obstruction, perforation, hemorrhage) treated during that period. Patients with acute symptoms of complicated colon cancer (occlusive, perforated, or hemorrhagic) with admission without investigations or previous treatment and who underwent surgery without standard preoperative preparation were classified as patients with complicated colon cancer requiring emergency surgery and were included in this study, along with patients with obstructive colon cancer in whom conservative treatment (nasogastric tube placement and enema) in the first 24 h had failed.

The exclusion criteria from the study were as follows: patients with malignant colon tumors treated according to schedule, patients with benign colon diseases, patients with complicated tumors operated in emergencies in which only laparotomy and biopsy were performed, and patients whose medical records were incomplete.

The observation sheets, analysis charts, surgical protocols, and anatomopathological records of the included patients were analyzed.

Data Collection and Variables Definition

The clinical and epidemiological data collected were age, sex, nonneoplastic personal history, comorbidities, performance status by the Eastern Cooperative Oncology Group (ECOG), presence of cachexia, and time from onset of symptoms to presentation to a specialist. Three scores were used to assess comorbidities: Davies, Charlson, and the age-adjusted Charlson score.

Cachexia was defined as a body mass index (BMI) <18.5. Pathological values of white blood cells (WBC), platelets, hemoglobin, glycemia, creatinine, proteins, albumin, electrolyte disorders, acidosis, and coagulation disorders, and the results of abdominal radiographs and computed tomography were noted.

Metabolic acidosis was defined by changes in the assessment of acid-base balance: blood pH <7.35 and HCO₂- <22 mmol/L. The septic condition at admission was assessed with at least 3 of the following criteria: fever/hypothermia, chills, altered general condition, hypotension, leukocytosis/leukopenia, and metabolic acidosis. All these preoperative laboratory variables were analyzed as dichotomous variables using the normal value and pathologic value, respectively.

Imagistic investigations, such as plain abdominal radiography, abdominal ultrasonography, and computed tomography, were performed. Preoperative diagnosis was dichotomized into intestinal obstruction, peritonitis due to colic perforation, and lower digestive hemorrhage.

Intraoperative and treatment data included: the location of the tumor, presence of local invasion or metastases, type of surgery, duration of surgery, abdominal wall closure type, and antibiotic therapy used.

We noted the following 4 surgery types: type 1, colostomy; type 2, colonic resection with stomy; type 3, internal derivation; and type 4, colonic resection with anastomosis. The duration of the surgery was divided into 9 categories, starting with 1 h and then adding 30 min increments up to 5 h. Regarding antibiotic therapy, we noted 4 regimens: regimen 1, patients with third-generation cephalosporins as the only antibiotic; regimen 2, third-generation cephalosporins in combination with metronidazole; regimen 3, piperacillin with tazobactam; and regimen 4, carbapenems.

Postoperative complications were defined as the presence of surgical complications, such as postoperative obstruction, leakage, bleeding, peritonitis, wound infection, or surgical wound dehiscence, and medical complications, such as acute respiratory failure, heart failure, acute renal failure, *Clostridium difficile* colitis, and sepsis within 30 days after emergency surgery.

Postoperative obstruction was defined based on clinical features in conjunction with plain abdominal radiography. Anastomotic leakage was defined as anastomotic dehiscence confirmed by clinical symptoms, including the appearance of digestive contents through the drains, development of colo-cutaneous fistula, development of systemic sepsis associated with peritonitis, and/or by radiological contrast study. Peritonitis was defined based on clinical features, with turbid peritoneal effluent containing >100 leukocytes/mL, with >50% neutrophils on drains,

and computed tomography aspect. Wound infection was noted when pus was found in the surgical wound or germs were identified in the wound secretion. Surgical wound dehiscence was recorded when a partial or total separation of previously approximated wound edges was produced, due to a failure of proper wound healing.

Acute respiratory failure was diagnosed with clinical symptoms of dyspnea, arterial oxygen pressure lower than 60 mm Hg, and a normal or low arterial carbon dioxide tension. Acute renal failure was based on the presence of one of the following parameters: a threefold increase in the serum level of creatinine, a decrease of more than 75% in the rate of glomerular filtration, or a drop in the volume of urine output below 0.5 mL/kg hourly for more than 24 h or anuria for more than 12 h. *C. difficile* enterocolitis was suspected on clinical symptoms of watery diarrhea and confirmed by identifying toxin A or B by enzyme immunoassay of the stool.

Study Design

We performed a retrospective study on a group of patients with complicated colon cancer who underwent emergency surgery in which epidemiologic, clinical, paraclinical, and therapeutic factors were analyzed and correlated with the occurrence of postoperative complications. We performed univariate logistic regression to identify predictive factors, based on which we created 2 multivariate logistic regression models. A nomogram was developed on the best model obtained.

Statistical Analysis

Using SPSS version 23.0 (IMB Corp, Armonk, NY, USA), statistical associations were obtained, indicating the *P* value with the Pearson chi-square and likelihood ratio tests for the nominal categorical variables. For continuous variables (Charlson score, age-adjusted Charlson score) we used the receiver operating characteristics (ROC) curves to identify a threshold value. To identify the prediction factors, the univariate logistic regression analysis was performed, specifying the estimated odds ratio (OR), and its 95% confidence interval (CI). To determine the best prediction model for postoperative complications, we performed a multivariate logistic regression analysis using the stepwise method. For each model, we determined the values of the Cox & Snell and Nagelkerke coefficients, the Hosmer-Lemeshow test (*P*>0.05 showed good agreement), and the area under the ROC curve (AUC) for quantifying predictive accuracy, whereby the area of 0.5 indicated “discriminating power not better than chance” and the area of 1.0 indicated “perfect discriminating power”.

The model with the best accuracy was tested for calibration using the bootstrapping, and concordance was tested using

the Harrell concordance index (C-index). All tests were 2-sided, and statistical significance was established at a level of $P < 0.05$. Based on this model, we created a nomogram using the program R Project for Statistical Computing version 4.0.5.

Results

Patient Characteristics and Incidence of Postoperative Complications

The clinical characteristics of the 449 patients included in this study with complicated colon cancer are shown in **Table 1**. Of these, 61.10% of patients were men; the patients' median age was 68 years; 65.29% of patients had anemia at admission; 39.42% had increases in creatinine levels; 30.06% had electrolyte disturbances; 21.82% presented metabolic acidosis; 9.13% had sepsis; and 78.61% presented air-fluid levels on plain abdominal radiography. Most of the tumors were located in the sigmoid colon (35.41%). All tumors were classified as adenocarcinomas, not otherwise specified.

The surgical procedures performed were in the order of frequency as follows: 37.63% colectomies with colostomy; 36.97% colic resections with anastomosis segmental resections, hemicolectomies, and total colectomies; 16.26% diverting stoma; and 9.13% bypass procedures, represented by ileo-coloanastomosis or colo-coloanastomosis.

A total of 106 patients (24%) presented postoperative complications within 1 month after surgery. Postoperative complications were, in order of frequency, wound infections (23.58%), fistula (19.81%), sepsis (18.86%), heart failure (15.09%), postoperative obstruction (6.6%), localized peritonitis (4.71%), respiratory failure (3.77%), acute renal failure (2.83%), colitis with *C. difficile* (2.83%), and surgical wound dehiscence (1.88%).

The average length of hospitalization was 15 days. Reinterventions were performed in 21 patients. A total of 51 patients (11.36%) died in the hospital.

Risk Factors Associated with Postoperative Complications

The comparison between individuals undergoing emergency surgery who were with or without postoperative complications after complicated colon cancer indicated that postoperative complications were more common in older or cachectic patients with comorbidities or a history of abdominal surgery and with an ECOG performance status of 3 or 4. In addition, patients with complications after emergency colon cancer surgery usually had preoperative colic perforation, higher levels of fasting blood glucose, pathologic values of WBC and creatinine, lower levels of hemoglobin, and a prolonged operating time.

On univariate analysis, age > 68 years, presence of personal non-neoplastic pathological history, Charlson score > 3 or age-adjusted Charlson score > 9 , ECOG performance status of 2, 3, or 4, cachexia, pathological values of WBC, platelets, fasting blood glucose, creatinine, serum protein, serum albumin, anemia, acidosis, electrolyte, and coagulation disturbances, sepsis, aspect of pneumoperitoneum, preoperative diagnosis of digestive perforation, presence of complications detected intraoperatively, presence of metastases, history of abdominal surgery, use of antibiotics such as piperacilin with tazobactam or carbapenems, were associated with postoperative morbidity (**Table 1**).

Multivariate Analysis Showed the Independent Predictive Factors in 2 Models

In model 1, age < 68 years (OR=0.52, 95% CI=0.30-0.90, $P=0.0216$), coagulation disturbances (OR=2.42, 95% CI=1.18-4.87, $P=0.0152$), pathologic value of creatinine (OR=1.96 95% CI=1.11-3.47, $P=0.0159$), electrolyte disturbances (OR=2.01, 95% CI=1.13-3.58, $P=0.0173$), cachexia (OR=3.95, 95% CI=2.24-6.98, $P < 0.0001$), pathologic value of WBC (OR=4.75, 95% CI=2.73-8.47, $P < 0.0001$), and antibiotic regimen (OR=3.68, 95% CI=1.41-9.54, $P=0.0074$) were independent predictive factors of postoperative morbidity. This model explained 25.05% of the observed data (Cox & Snell R^2) and up to 37.76% (Nagelkerke R^2). The analysis of the ROC curve constructed for this model shows an AUC of 0.825 with 95% CI=0.787-0.859.

In model 2, ECOG 4 (OR=3.30 95% CI=1.30-8.39, $P=0.0118$), Charlson score > 3 (OR=1.92, 95% CI=1.11-3.31, $P=0.0187$), pathologic value of WBC (OR=4.54, 95% CI=2.58-7.96, $P < 0.0001$), electrolyte disturbances (OR=2.05, 95% CI=1.17-3.58, $P=0.0111$), coagulation disturbances (OR=2.93, 95% CI=1.40-6.15, $P=0.0043$), surgery duration (OR=1.53, 95% CI=1.26-1.87, $P < 0.0001$), and cachexia (OR=3.51, 95% CI=1.96-6.26, $P < 0.0001$) were independent predictive factors of postoperative morbidity. This model explained 27.09% of the observed data (Cox & Snell R^2) and up to 40.75% (Nagelkerke R^2 ; **Table 2**). The analysis of the ROC curve constructed for this model showed an AUC of 0.832 (95% CI=0.74-0.86), with a cut-off value of 0.282, sensitivity of 0.70, and specificity of 0.83, which suggested that this model had considerable predictive potential (**Figure 1**).

The AUC calculated for these curves showed how high the discriminatory power of the values predicted by the model was in discriminating cases with postoperative complications from those without postoperative complications.

Because the accuracy of the prediction was better in model 2 than in model 1 (0.832 $>$ 0.825), we performed additional

Table 1. Univariate analysis results of relationship between clinicopathological characteristics and postoperative complications in patients undergoing emergency surgery for complicated colon cancer.

		PO COMPL=yes	PO COMPL=no	p value
Age	>68 years	71/106 (67.0%)	174/343 (50.7%)	0.003312*
	≤68 years	35/106 (33.0%)	169/343 (49.3%)	
SEX	F	38/106 (35.8%)	137/343 (39.9%)	0.450160*
	M	68/106 (64.2%)	206/343 (60.1%)	
DAVIES Score	1	40/106 (37.7%)	145/343 (42.3%)	0.035678#
	2	36/106 (34%)	142/343 (41.4%)	
	3	26/106 (24.5%)	52/343 (15.2%)	
	4	3/106 (2.8%)	4/343 (1.2%)	
	6	1/106 (0.9%)	0/343 (0.0%)	
CHARLSON Score	≤3	47/106 (44.3%)	227/343 (66.2%)	0.000056*
	>3	59/106 (55.7%)	116/343 (33.6%)	
Age-adjusted CHARLSON Score	≤9	28/106 (26.4%)	169/343 (49.3%)	0.000027*
	>9	78/106 (73.6%)	174/343 (50.4%)	
Onset	≤1 day	5/106 (4.7%)	24/343 (7.0%)	0.006675*
	2-5 days	30/106 (28.3%)	155/343 (45.2%)	
	6-14 days	57/106 (53.8%)	136/343 (39.7%)	
	>14 days	14/106 (13.2%)	28/343 (8.1%)	
ECOG	0	8/106 (7.5%)	75/343 (21.9%)	0.000003*
	1	14/106 (13.2%)	60/343 (17.4%)	
	2	45/106 (42.5%)	137/343 (40%)	
	3	20/106 (18.9%)	57/343 (16.8%)	
	4	19/106 (17.9%)	14/343 (4.1%)	
Cachexia	Yes	48/106 (45.3%)	50/343 (14.6%)	0.000000*
WBC	P	81/106 (76.4%)	122/343 (35.6%)	0.000000*
Anemia	Yes	86/106 (81.1%)	210/343 (61.2%)	0.000157*
Platelets	P	33/106 (31.1%)	33/343 (9.6%)	0.000000*
Glycemia	P	31/106 (29.2%)	69/343 (20.0%)	0.045060*
Creatinine	P	64/106 (60.4%)	113/343 (32.9%)	0.000000*
Electrolyte disturbance	Yes	54/106 (50.9%)	81/343 (23.6%)	0.000000*
Acidosis	Yes	39/106 (36.8%)	59/343 (17.2%)	0.000020*
Coagulation disturbance	Yes	28/106 (26.4%)	25/343 (7.2%)	0.000000*
Sepsis	Yes	24/105 (22.9%)	17/343 (5.0%)	0.000000*
Preop diagnosis	H	2/106 (1.9%)	14/343 (4.1%)	0.000001*
	O	75/106 (70.8%)	301/343 (87.8%)	
	P	29/106 (27.4%)	28/343 (8.2%)	
Location	C18.0	12/106 (11.3%)	30/343 (8.7%)	0.605099*
	C18.2	6/106 (5.7%)	14/343 (4.1%)	
	C18.3	8/106 (7.5%)	25/343 (7.2%)	
	C18.4	13/106 (12.3%)	28/343 (8.1%)	
	C18.5	9/106 (8.5%)	35/343 (10.1%)	
	C18.6	9/106 (8.5%)	38/343 (11%)	
	C18.7	39/106 (36.8%)	120/343 (35.0%)	
C19.0	10/106 (9.4%)	53/343 (15.5%)		
IO COMPL	Yes	17/106 (16.0%)	30/343 (8.7%)	0.032094*

Table 1 continued. Univariate analysis results of relationship between clinicopathological characteristics and postoperative complications in patients undergoing emergency surgery for complicated colon cancer.

		PO COMPL=yes	PO COMPL=no	p value
Metastasis	Yes	32/106 (30.2%)	63/343 (18.4%)	0.009201*
History of abdominal surgery	Yes	44/106 (41.5%)	103/343 (30.0%)	0.027703*
Operation type	1	13/106 (12.3%)	60/343 (17.5%)	0.541510*
	2	41/106 (38.7%)	128/343 (37.3%)	
	3	12/106 (11.3%)	29/343 (8.5%)	
	4	40/106 (37.7%)	126/343 (36.7%)	
Operating time	1 h	5/106 (4.7%)	16/343 (4.7%)	0.000000*
	1.5 h	10/106 (9.4%)	56/343 (16.3%)	
	2 h	36/106 (34.0%)	204/343 (59.5%)	
	2.5 h	25/106 (23.6%)	35/343 (10.2%)	
	3 h	24/106 (22.6%)	25/343 (7.3%)	
	3.5 h	2/106 (1.9%)	1/343 (0.3%)	
	4 h	2/106 (1.9%)	2/343 (0.6%)	
	4.5 h	1/106 (0.9%)	1/343 (0.3%)	
Abdominal closure	Open	3/106 (2.8%)	0/343 (0.0%)	0.00000*
	Closed	94/106 (88.7%)	340/343 (99.1%)	
	Semi-open	9/106 (8.5%)	3/343 (0.9%)	
Antibiotic	1	49/106 (46.2%)	221/343 (64.4%)	0.000089*
	2	31/106 (29.2%)	90/343 (26.1%)	
	3	12/106 (11.3%)	20/343 (5.8%)	
	4	14/106 (13.2%)	12/343 (3.5%)	

* Pearson chi-square; # likelihood ratio. PO COMPL – postoperative complications; Onset – duration from onset of symptoms to admission; ECOG – Eastern Cooperative Oncology Group performance status; WBC – white blood cell count; H – lower gastrointestinal hemorrhage; O – intestinal occlusion; P – peritonitis; C18.0 – cecum; C18.2 – ascending colon; C18.3 – hepatic flexure of colon; C18.4 – transverse colon; C18.5 – splenic flexure of colon; C18.6 – descending colon; C18.7 – sigmoid; C19 – rectosigmoid junction; IO COMPL – intraoperative complications; operation type 1 – colostomy; operation type 2 – colic resection with stoma; operation type 3 – internal by-pass; operation type 4 – colic resection with anastomosis; h – hours; P – pathologic value.

calibration and discrimination tests only for model 2 to create a nomogram for predicting postoperative complications.

For model 2, the bootstrapping method was used with 1000 samples to produce a calibration graph, and the predictive accuracy was evaluated by the Harrell concordance index (C-index). The C-index value of this model was 0.835, indicating the excellent predictive ability of the estimated risk of postoperative complications. The calibration graph showed that the model was close to the ideal state, indicating a good calibration (**Figure 2**).

The calibration plot detected that the nomogram was well calibrated, with no significant difference between the predicted and observed probabilities (Hosmer-Lemeshow test, chi-square=11.96, $P=0.153$).

We developed a nomogram based on the above independent prognostic factors for the occurrence of postoperative

complications (**Figure 3**). The different subtypes of each independent prognostic factor were designed on the score scale to obtain the score for each item. The scores corresponding to the independent prognostic factors were summed to obtain the total score. By drawing a vertical line on the scale of the total score, the individual risk of postoperative complications was obtained. The higher the total score, the worse the prognosis. Using the patients' variables, with this nomogram, we could obtain the individualized prediction of the occurrence of postoperative complications.

Discussion

In the present study, the postoperative morbidity rate was 24%. Postoperative complications were, in order of frequency, wound infections (23.58%), fistula (19.81%), sepsis (18.86%), heart failure (15.09%), postoperative obstruction (6.6%), localized peritonitis (4.71%), respiratory failure (3.77%), acute

Table 2. Models of multivariate logistic regression analysis.

	Model 1		Model 2	
	p value	OR (95% CI)	p value	OR (95% CI)
Age ≤68 years	0.0216	0.52 (0.30, 0.90)		
CHARLSON Score >3			0.0187	1.90 (1.11, 3.31)
ECOG. 4			0.0118	3.30 (1.30,8.39)
Cachexia=yes	<0.0001	3.95 (2.24, 6.98)	<0.0001	3.51 (1.88, 6.25)
WBC=P	<0.0001	4.75 (2.73, 8.47)	<0.0001	4.54 (2.58, 7.96)
Creatinine=P	0.0195	1.96 (1.11, 3.47)		
Electrolyte disturbance=yes	0.0173	2.01 (1.13, 3.58)	0.0111	2.05 (1.17, 3.58)
Coagulation disturbance=yes	0.0152	2.42 (1.18, 4.87)	0.0043	2.93 (1.40, 6.15)
Operating time 5 h			<0.0001	1.53 (1.27, 1.87)
Antibiotic 4	0.0074	3.68 (1.41, 9.54)		
Cox & Snell R ²	25.05%		27.09%	
Nagelkerke R ²	37.76%		40.75%	
Hosmer & Lemeshow test	P=0.3973		P=0.1530	
AUC	0.825 95% CI (0.78, 0.85)		0.832 95% CI (0.74, 0.86)	

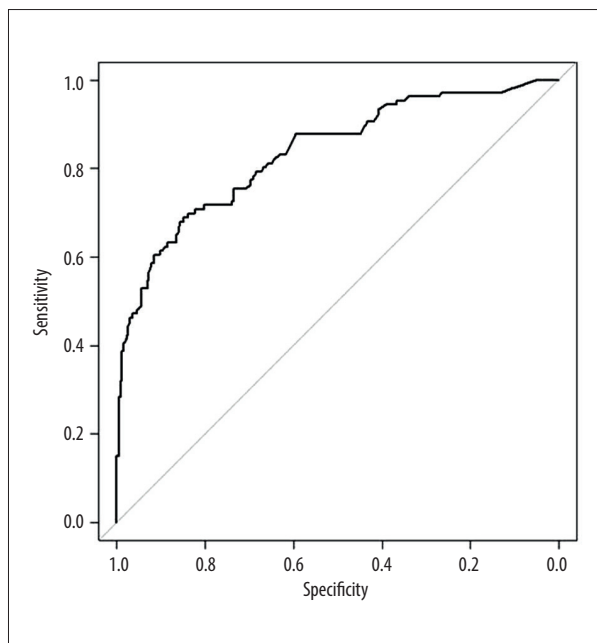


Figure 1. Receiver operating characteristic curve of the multivariate logistic regression model 2.

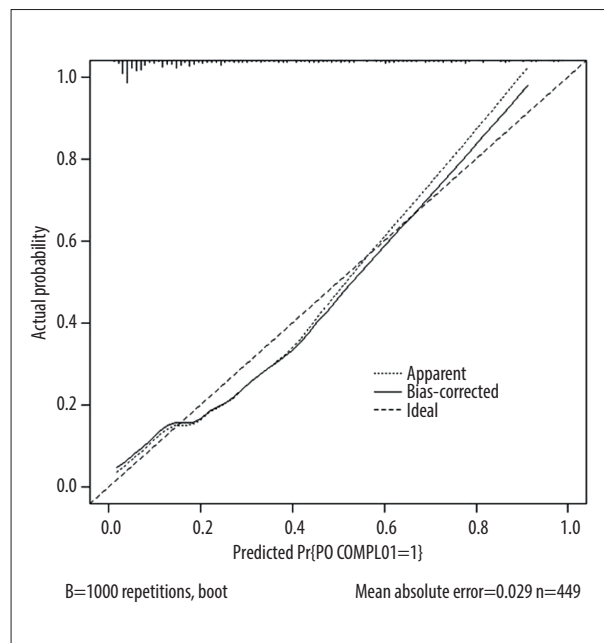


Figure 2. Nomogram calibration curve. The Y-axis represents the real probability of a postoperative complication. The X-axis represents the estimated probability of a postoperative complication. The ideal line is a perfect prediction model. The apparent line represents the performance of the nomogram, and a close match to the ideal line is a good prediction.

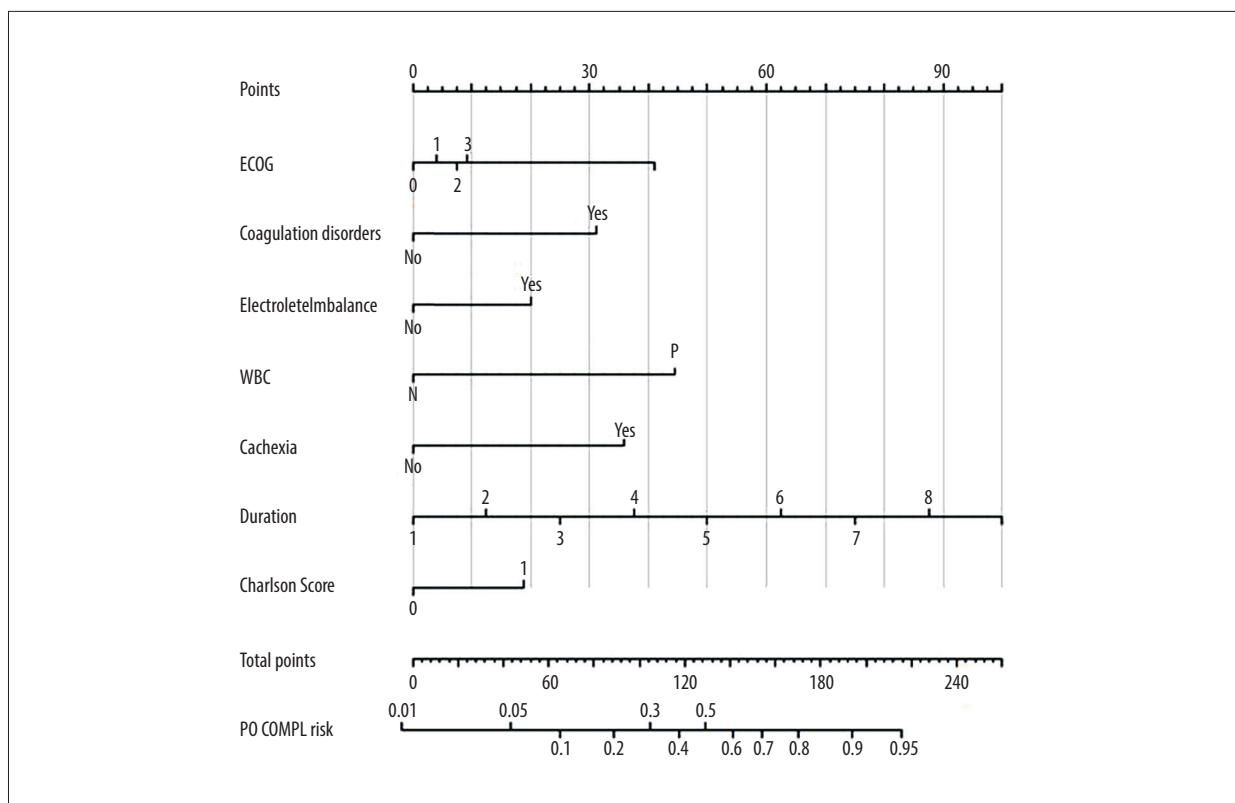


Figure 3. Nomogram for predicting postoperative complications using the independent risk factors obtained in model 2. ECOG – Eastern Cooperative Oncology Group performance status; WBC – white blood cell count; PO COMPL – postoperative complication.

renal failure (2.83%), colitis with *C. difficile* (2.83%), and surgical wound dehiscence (1.88%). Similar data were reported by Enciu et al in a study of emergency interventions for colon cancer, which had a 37% morbidity rate [20].

The independent factors found to predict the occurrence of postoperative complications in the study group were age >68 years, ECOG performance status of 4, Charlson score >3, presence of cachexia, pathologic value of WBC and creatinine, coagulation, electrolyte disorders, duration of surgery, and use of antibiotic regimen (carbapenems). Other authors also reported advanced age as a risk factor for postoperative complications [21,22].

The association of comorbidities with the occurrence of postoperative complications in patients with colon cancer is also supported by data in the literature. Among preexisting conditions, liver cirrhosis and chronic liver disease [23], obesity, diabetes, a history of operated digestive cancer or other major abdominal interventions, lung disease, and preexisting renal failure [22] are factors that increase morbidity [24,25]. Given that a large proportion of the patients included in the present study had more comorbidities, we considered it appropriate to use Davies, Charlson, or Charlson age-adjusted comorbidity

scores, which are widely used in current practice. Also, cachexia or malnutrition has been identified as an independent risk factor in other studies [26-28].

Complications of colon cancer lead to profound disruptions of homeostasis, which is directly reflected in blood laboratory results. The state of dehydration is described by disturbances of electrolyte balance, blood loss can be identified by hemoglobin values, and sepsis-induced by colic perforations is identified through the WBC count. All these data reflect the biological condition of the patient, which has an impact on the immediate results.

In the present study, anemia was present in 66.07% of patients analyzed and was found to be a risk factor for postoperative complications, and similar results were reported in other studies [29,30]. A total of 43.75% of patients with long-term treatment with anti-Vitamin K anticoagulants or those with preexisting liver disease developed postoperative complications. We found that 73.33% of patients with obstructive colic tumors had electrolyte disturbances and that a preexisting renal pathology was found in 6.66% of patients. Without being specific to the condition itself, these laboratory data specifically characterized each patient by reflecting the comorbidities and

complications of neoplastic disease. Other authors also found that the presence of diffuse peritonitis, from colon tumor perforation or diastatic cecum perforation, was a risk factor for postoperative complications [30].

Regarding the duration from admission to surgery in the present study, 51.88% of patients had surgery in the first 12 h and 16.41% of patients had surgery between 12 and 24 h, which is similar to the data in the literature [31]. We did not find statistically significant correlations with the occurrence of postoperative complications.

We found no statistically significant correlations between tumor location and complications, similar to other data in the literature [32]. Lee et al did not report differences in the rate of fistulas among patients with emergency surgery of the right and left colon (5.2% and 6.9%, respectively) [33]. Other studies showed anastomotic fistulas of 0.5% to 4.6% following right colon perforation, and from between 3.5% and 30% after occlusive tumors of the left colon [34].

Consistent with findings in the published data, we also found that the presence of intraoperative detected complications was a risk factor in the occurrence of postoperative complications [35].

Data from the literature show similar postoperative morbidity between patients who underwent an ileostomy at the first surgical time and those with colectomy with primary anastomosis; we also did not find statistical correlations between the type of surgery and the occurrence of postoperative complications [35].

The method of closing the abdomen has not been identified as a risk factor for postoperative complications. The usefulness of surgery with an open abdomen is highest where compartment syndrome is expected to occur, with the recommendation being to close it as early as possible [34,36].

In the present study, the duration of surgery of less than 2.5 h was associated with the absence of postoperative complications. The duration of surgery was an independent predictor of complications, which is in accordance with the data reported in the literature [21,32].

Regarding antibiotic therapy, the use of carbapenems has been identified as an independent risk factor for postoperative complications. In the present study, their use was dictated by the severity of the cases. This scheme was used especially in patients with sepsis from admission, with carbapenem administration for 5 to 7 days, which is similar to the recommendations in the literature [37].

To make use of the results of our study in clinical practice, we constructed a nomogram that incorporated predictive factors. The presented model demonstrated the best accuracy and an excellent distinction in predicting the risk of postoperative complications, with an AUC of 0.83.

In the literature, it is reported that an AUC value >0.7 indicates that the model has clinical utility [38,39]. We suggest that through using the model developed in the present study, surgeons could better assess the risk of individual postoperative complications and may match interventions for patients who need more intensive treatment. To the best of our knowledge, our study is the first to specifically concentrate on a nomogram for predicting postoperative complications after emergency surgery for colon cancer, which is unlike the current nomograms for colon cancer that mainly focus on the evaluation of the overall survival prognosis, from an oncological point of view [40], or focus on the prediction of anastomosis fistula after colic resections [41].

Our results can be easily applied and could have an impact on clinical practice. The proposed postoperative morbidity prediction nomogram included easily identifiable clinical variables that are used in usual preoperative evaluations, such as the ECOG performance status, BMI, Charlson score, laboratory data, including WBC, coagulation disorders, and electrolyte disturbances, and duration of surgery. If the first 3 factors of ECOG performance status, BMI, and Charlson score are unchangeable variables for a patient, the laboratory data entered in the nomogram represent elements that could be influenced by a clinician to reduce the risk of postoperative complications. However, correcting these variables requires time, and sometimes the emergency situation does not allow the intervention to be postponed.

Data related to surgery could be predicted by relating the complexity of the surgery to the duration of the surgery; however, a conscious effort to limit operative time is required in patients who accumulate a consistent risk of postoperative complications from preoperatively identified risk factors.

The prediction of postoperative complications can have a significant impact on limited resources, as it would allow for the individualization of care, with more resources directed at patients who are at a high risk. This category includes patients with perforations and peritonitis, for whom immediate surgical treatment is mandatory; however, in patients with obstructions and no signs of perforation, the prediction of postoperative complications would help optimize treatment by selecting patients for other therapeutic strategies, such as the use of endoscopic decompression methods by mounting stents and transforming the emergency intervention into a scheduled intervention. This method is reserved especially for those at a

high risk of postoperative complications, and the use of this strategy would allow adequate preparation for an elective intervention, a correct staging of the disease, and the performance of interventions appropriate to the stage of the disease.

The strengths of this study include the use of a large database, which allowed the identification of independent predictive factors and the creation of models. These predictive factors are very easy to obtain, and the nomogram was well calibrated and had a remarkable capacity for discrimination, being the first proposed for the prediction of postoperative complications in patients with colon cancer that requires emergency surgical treatment.

Our study had some significant limitations, which were mainly related to its retrospective nature and the long period (10 years) over which the cases were included. During the cohort period of the study, improvements in healthcare could have been implemented and this could certainly have led to different results in recent years. However, postoperative morbidity rates were not significantly different during the whole period, and we have even recorded a higher number of events in recent years, which can be explained by the improvement in data collection and the increasing number of resections performed in an emergency.

Moreover, we believe that this issue of chronology had a limited effect on our findings because all predictors of postoperative morbidity have not been part of any healthcare change over the years of the study. The comorbidities that were introduced into the model had benefited from better management throughout the study period, but their impact on surgical outcomes does not appear to have changed much. Finally, we believe that despite the internal validation that has was

conducted in this study, external validation in further studies is needed to confirm these findings.

Conclusions

Preexisting comorbidities, ECOG performance status, and the values of specific blood tests are data that can be easily obtained and can be included in the proposed nomogram. If the final score is high, we strongly recommend limiting the duration of surgery to as short a time as possible, or, if possible, the patient should be oriented toward another therapeutic strategy.

Therapeutic management needs to be individualized for each patient with colon cancer who presents to the emergency department, and the nomogram proposed in this study may be a fit for this purpose.

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Ethics Approval

The study protocol was approved by the Ethical Committee of "Sf. Apostol Andrei" Clinic County Emergency Hospital of Galați, with approval no. 4519/18.02.2022.

Declaration of Figures' Authenticity

All figures submitted have been created by the authors, who confirm that the images are original with no duplication and have not been previously published in whole or in part.

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