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Original Article

Predictive value of physiological capacity and surgical stress scores for perioperative complications in radical resection for colorectal cancer: a propensity-matched analysis

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Abstract: Purpose: To investigate the predictive value of physiological capacity and surgical stress scores for perioperative complications in radical resection for colorectal cancer (CRC). Methods: A retrospective case-control study was performed from October 2021 to October 2023 at a single center, involving patients scheduled for radical resection of CRC. Patients were divided into groups with and without perioperative complications, and a propensity score matching was performed to minimize potential bias from clinical confounding variables. General patient data, including demographic information, comorbidities, tumor characteristics, surgical parameters, postoperative recovery, and Estimation of Physiologic Ability and Surgical Stress (E-PASS) scores, were collected and analyzed. Results: After propensity score matching, factors such as age, diabetes, pulmonary disease, heart disease, and American Society of Anesthesiologists (ASA) grade remained significant predictors for complications ($P < 0.05$). Prolonged operation, increased blood loss, specific surgery types, and emergent surgeries were linked to a higher risk of perioperative complications (all $P < 0.05$). Patients with complications experienced longer postoperative hospital stays, increased adjuvant chemotherapy use, and lower quality of life scores (all $P < 0.05$). Perioperative risk score (PRS), surgical stress score (SSS), and composite risk score (CRS) were positively correlated with the incidence of perioperative complications (all $P < 0.001$). The AUC values for PRS, SSS, and CRS were 0.848, 0.854, and 0.882 respectively, indicating moderate to high predictive value for perioperative complications. Conclusion: Physiological capacity and surgical stress scores, age, comorbidities, surgical parameters, postoperative recovery, and the E-PASS scores emerged as key predictive factors for perioperative complications in radical resection for CRC.

Keywords: Physiological capacity, surgical stress score, perioperative complications, radical resection, colorectal cancer

Introduction

Colorectal cancer (CRC) represents a significant global public health concern, ranking among the leading causes of cancer-related morbidity and mortality [1-3]. With approximately 1.9 million new cases of CRC and 935,000 deaths annually, CRC continues to impose a substantial burden on healthcare systems worldwide [4]. While incidence rates vary geographically, the increasing prevalence of risk factors such as sedentary lifestyles, high-calorie diets, obesity, and aging populations has contributed to the rising global burden of CRC [5, 6].

Radical resection, often referred to as curative or potentially curative surgery, involves the complete removal of the tumor along with the surrounding lymph nodes and any affected nearby tissues [7, 8]. This approach aims to achieve a complete cure by eradicating the primary tumor and any potential microscopic spread of cancer cells [9]. However, the perioperative period poses substantial challenges, as it is associated with various complications that

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can significantly impact patient outcomes and postoperative recovery. Identifying reliable predictive factors for perioperative complications is essential for optimizing patient care, guiding perioperative management, and improving surgical outcomes [10, 11].

There is a rising interest in developing predictive instruments to assist clinicians in evaluating preoperative risk and providing effective patient counseling. The integration of physiological capacity and surgical stress scores into risk stratification models has shown promise in predicting perioperative complications across various surgical settings. In the case of radical resection for CRC, the predictive value of these scores is particularly relevant due to the multifactorial nature of perioperative risk in this patient population [12-14]. Therefore, this study aims to investigate the predictive value of physiological capacity and surgical stress scores for perioperative complications in radical resection for CRC.

Materials and methods

Study design

This retrospective case-control study was conducted on patients scheduled for radical resection of CRC from October 2021 to October 2023 at Shenzhen Hospital of Guangzhou University of Chinese Medicine (Futian). Patients were divided into two groups with and without perioperative complications. A propensity score matching (PSM) analysis was performed to minimize potential bias caused by confounding variables. Propensity scores were calculated using a logistic regression model that included all identified potential confounders, such as age, body mass index (BMI), smoking history, drinking history, diabetes, pulmonary disease, heart disease, tumor size, and American Society of Anesthesiologists (ASA) grade. A 1:1 nearest neighbor matching without replacement was performed using the caliper method with a caliper width of 0.2 standard deviations of the logit of the propensity score. This method ensured that only patients with similar propensity scores were matched, thereby reducing residual confounding. Non-critical indicators in the general patient data were adjusted for imbalance using a 1:1 matching with multivariate regression models.

This study was approved by the Ethics Committee of Shenzhen Hospital of Guangzhou University of Chinese Medicine (Futian). Informed consent was waived for this retrospective study as it used de-identified patient data and posed no risk to patient care.

Inclusion and exclusion criteria

Inclusion criteria [15]: Patients diagnosed with CRC through clinical and pathological examinations, including chest X-ray, colonoscopy, ultrasound, and computed tomography scan; patients scheduled for radical resection of CRC, meeting surgical indications; patients aged 18 years or above; patients with a BMI of 18-30 kg/m^2; patients with ASA grade 1-3; patients with normal mental and cognitive function, and complete clinical data.

Exclusion criteria: Patients with pathologically confirmed benign colorectal tumors; patients who underwent palliative surgery or had surgical contraindications, such as severe heart, liver, and lung disease; patients with distant metastatic carcinoma affecting organs and infiltration of neighboring organs; patients with severe dysfunction of other vital organs like the liver and kidneys; patients with organic brain diseases, conditions like severe hypertension, coronary heart disease, cardiac insufficiency, pulmonary arterial hypertension, prior cardiac arrest, abnormal coagulation function, severe respiratory ailments; a history of alcohol or drug dependence; patients with epilepsy, mental illness, history of antipsychotic drug usage, or significant infectious diseases.

Indications for radical resection: Histologically confirmed adenocarcinoma of the colon or rectum; Tumor stage T1-T4, N0-N2, M0, based on preoperative imaging and clinical evaluation; Absence of distant metastases; Adequate organ function to tolerate major surgery; Patient's willingness and ability to undergo the procedure.

Contraindications for radical resection: Presence of distant metastases (M1 stage); Severe comorbidities significantly increasing the surgical risk, such as uncontrolled heart disease, severe liver or kidney dysfunction, or active infections; Poor performance status (ASA grade 4 or 5); Inability to provide informed consent or comply with postoperative care;

Tumors that are technically unresectable due to extensive local invasion or adherence to critical structures.

General information

General patient information was obtained through systematic retrieval of medical records, including age, BMI, smoking history, gender, drinking history, marital status, place of residence, educational level, hypertension, diabetes, pulmonary disease, heart disease, tumor location, tumor size, histology and ASA grade.

Perioperative complications were defined as morbidities classified as Clavien - Dindo grade II or higher that occurred between the preoperative period and postoperative day 30.

Data on operative variables, including operation time, intraoperative blood loss, surgery type, emergent surgery, postoperative hospital stay, and adjuvant chemotherapy rate were recorded.

Quality of life score

Postoperative quality of life was assessed using the EORTC QLQ-C30, which comprises five functional dimensions (bodily, moving, character, social, and cognitive functions). Each item in the various dimensions was rated on a 1-7 Likert scale, with total scores ranging from 0 to 100, reflecting a positive correlation with quality of life. The Cronbach's α coefficient was 0.927 [16].

E-PASS scoring system

The E-PASS (Estimation of Physiologic Ability and Surgical Stress) scoring system is a validated tool used to evaluate perioperative risk by integrating patient-specific physiological capacity and the stress imposed by surgical procedures. It comprises three components: the Perioperative Risk Score (PRS), the Surgical Stress Score (SSS), and the Comprehensive Risk Score (CRS). Each score is derived from a specific formula that considers various patient and surgical factors known to influence perioperative outcomes.

The PRS is designed to assess the patient's physiological reserve and overall health status. The formula for PRS is: PRS = -0.0686 + 0.00345X1 + 0.323X2 + 0.205X3 + 0.153X4 + 0.148X5 + 0.0666X6, where X1 represents age, X2 indicates the presence (1) or absence (0) of severe heart disease, X3 signifies the presence (1) or absence (0) of severe pulmonary disease, X4 denotes the presence (1) or absence (0) of diabetes, X5 reflects the performance status index (ranging from 0 to 4), and X6 corresponds to the American Society of Anesthesiologists physiological status classification (ranging from 1 to 5). The inclusion of age in the PRS formula is based on the well-established relationship between advanced age and increased perioperative risk. Severe heart and pulmonary diseases, diabetes, performance status, and ASA classification are also critical factors that significantly affect a patient's ability to tolerate surgical stress [17].

The SSS evaluates the surgical stress imposed on the patient during the operation. The formula for SSS is: SSS = -0.342 + 0.0139X1 + 0.0392X2 + 0.352X3, where X1 represents blood loss in relation to body weight (g/kg), X2 represents operation time (in hours), and X3 indicates the extent of skin incision (0 for a minor incision in laparoscopic or thoracoscopic surgery, 1 for laparotomy or thoracotomy alone, and 2 for both laparotomy and thoracotomy procedures). The SSS formula includes blood loss relative to body weight because significant blood loss can lead to hemodynamic instability and increase perioperative complications. Operation time is another critical factor, as longer surgeries are associated with a higher risk of complications. The extent of skin incision is also considered, as larger incisions generally result in more tissue trauma and increased postoperative pain and recovery time [18].

The CRS combines the PRS and SSS to provide a comprehensive assessment of perioperative risk. The formula for CRS is: CRS = -0.328 + 0.936 (PRS) + 0.976 (SSS) [19].

The PRS is calculated based on admission data, reflecting the patient's preoperative condition. The SSS is determined intraoperatively, taking into account the actual surgical stress experienced by the patient. The CRS score is computed after the operation, providing a holistic view of the patient's perioperative risk. By integrating these three components, the E-PASS scoring system offers a robust and reliable method for predicting perioperative com-

plications, aiding clinicians in preoperative risk stratification and patient counseling.

Statistical analysis

Statistical analysis was performed using SPSS 29.0 statistical software (SPSS Inc., Chicago, IL, USA). Categorical data were presented as [n (%)] and analyzed using the chi-square test. Continuous variables were first tested for normality using the Shapiro-Wilk method. Normally distributed data were expressed as means ± standard deviation (X ± s) and compared using t-test. Non-normally distributed data were presented as median (25% quantile, 75% quantile) and analyzed using Wilcoxon rank-sum test. Spearman correlation analyses (with 1 defined as the presence of complications and 0 defined as the absence of complications) were used to assess associations between categorical variables. The diagnostic performance was assessed using the receiver operating characteristic (ROC) curve. For post hoc analysis of the t-test, G*Power 3.1.9.7 was used to calculate the power (1-β error probability) based on the "Means: Difference between two independent means (two groups)" option. The settings included a two-tailed test, an effect size of d=0.5, and an α error probability of 0.05. After entering the sample sizes of the two groups, the analysis yielded a power of 0.825. $P < 0.05$ was considered with statistical significance.

Results

General data of patients in the two groups before propensity score matching

In the unadjusted analysis, several baseline characteristics demonstrated statistically significant differences between the non-complication group (n=197) and the complication group (n=79). The mean age of patients who experienced complications was significantly higher compared to those without complications (63.38 ± 8.86 vs. 60.15 ± 11.58 years, t=2.494, P=0.013). Additionally, gender distribution differed significantly between the two groups (χ^2=8.227, P=0.004), with a higher proportion of male patients in the complication group. Similarly, BMI, smoking history, alcohol consumption, diabetes, pulmonary disease, heart disease, tumor size, and ASA grade showed significant differences between the two groups, as depicted in **Table 1**. Notably, marital status, place of residence, educational level, hypertension, tumor location, and histology, all did not demonstrate significant differences between the groups ($P > 0.05$). Following propensity score matching, further analysis was conducted to assess the predictive value of physiological capacity and surgical stress score for perioperative complications, accounting for these baseline differences.

Perioperative complications of radical surgery for CRC before propensity score matching

Perioperative complications of radical resection for CRC were assessed before propensity score matching (**Table 2**). Among the 276 patients included in the study, the most common complications were ileus (14.86%), followed by anastomotic leakage (7.97%) and pneumonia (5.07%). The incidence of other complications, including heart failure, surgical site infection, urinary infection, urinary dysfunction, intraabdominal bleeding, anastomotic bleeding, cerebral hemorrhage, delirium, pulmonary embolus, and incisional hernia, ranged from 0.72% to 2.90%.

General characteristics of the two patient groups after propensity score matching

After the propensity score matching in patients undergoing radical resection for CRC, the non-complication group exhibited a mean age of 61.29 years (± 10.58), whereas the complication group had a slightly higher mean age of 65.59 years (± 8.74) (t=2.583, P=0.011) (**Table 3**). Gender distribution, BMI, smoking and alcohol consumption history, marital status, place of residence, educational level, tumor size, and histology did not show significant differences between the two groups (all $P > 0.05$). However, a significant difference was observed between the two groups in terms of diabetes (17.65% vs. 2.94%, χ^2=6.45, P=0.011), pulmonary disease (16.18% vs. 4.41%, χ^2=3.902, P=0.048), heart disease (22.06% vs. 7.35%, χ^2=4.748, P=0.029), and ASA grade (P=0.010). These findings suggest that age, diabetes, pulmonary disease, heart disease, and ASA grade may be predictive factors for perioperative complications in this patient population.

Perioperative complications of radical surgery for CRC after propensity score matching

After propensity score matching, the incidence of perioperative complications following radical

Table 1. General data of patients in the two groups before propensity score matching

Parameter	Non-complication Group (n=197)	Complication Group (n=79)	t/χ^2	P
Age (years)	60.15 ± 11.58	63.38 ± 8.86	2.494	0.013
Gender (Male/Female)	78 (39.59%)/119 (60.41%)	47 (59.49%)/32 (40.51%)	8.227	0.004
BMI (kg/m^2)	23.37 ± 3.25	22.16 ± 3.21	2.829	0.005
Smoking history [n (%)]	19 (9.64%)	16 (20.25%)	4.813	0.028
Drinking history [n (%)]	23 (11.68%)	19 (24.05%)	5.769	0.016
Marital status			2.969	0.085
Married (%)	135 (68.53%)	63 (79.75%)		
Single (%)	62 (31.47%)	16 (20.25%)		
Place of Residence			1.775	0.183
Urban	98 (49.75%)	47 (59.49%)		
Rural	99 (50.25%)	32 (40.51%)		
Educational Level			2.386	0.122
Secondary School or Below	59 (29.95%)	32 (40.51%)		
High School or Above	138 (70.05%)	47 (59.49%)		
Hypertension [n (%)]	30 (15.23%)	9 (11.39%)	0.404	0.525
Diabetes [n (%)]	12 (6.09%)	13 (16.46%)	6.149	0.013
Pulmonary disease [n (%)]	11 (5.58%)	12 (15.19%)	5.612	0.018
Heart disease [n (%)]	32 (16.24%)	22 (27.85%)	4.116	0.042
Tumor location [n (%)]			2.386	0.122
Colon	138 (70.05%)	47 (59.49%)		
Rectum	59 (29.95%)	32 (40.51%)		
Tumor size (cm)	5.64 ± 1.28	6.15 ± 1.36	2.861	0.005
Histology [n (%)]			0.844	0.358
Differentiated	167 (84.77%)	71 (89.87%)		
Undifferentiated	30 (15.23%)	8 (10.13%)		
ASA grade [n (%)]			7.880	0.019
I	19 (9.64%)	9 (11.39%)		
II	138 (70.05%)	42 (53.16%)		
III	40 (20.3%)	28 (35.44%)		

Heart diseases include angina pectoris, myocardial infarction, heart failure, and atrial fibrillation. Pulmonary diseases included interstitial pneumonia and chronic obstructive pulmonary disease. BMI, Body Mass Index; ASA, American Society of Anesthesiologists.

resection for CRC in the cohort (n=136) was as follows: heart failure (0.74%), surgical site infection (2.21%), urinary infection (3.68%), ileus (11.76%), pneumonia (4.41%), urinary dysfunction (1.47%), intraabdominal bleeding (0.00%), anastomotic bleeding (1.47%), cerebral hemorrhage (0.00%), delirium (0.74%), pulmonary embolus (0.74%), incisional hernia (1.47%), and anastomotic leakage (7.35%) (**Table 4**). Notably, the rates of heart failure, intraabdominal bleeding, and cerebral hemorrhage were minimal, while ileus and anastomotic leakage were the most common complications observed in this cohort.

Comparison of surgical parameters

The operative time was slightly longer in the complication group (287.38 ± 11.43 minutes) compared to the non-complication group (282.16 ± 10.79 minutes) (t=2.738, P=0.007) (**Table 5**). Similarly, the blood loss was marginally higher in the complication group (51.84 ± 9.72 mL) compared to the non-complication group (48.19 ± 8.54 mL) (t=2.325, P=0.022). Furthermore, a significant difference was observed in surgery types (χ^2=7.813, P=0.020) and the incidence of emergent surgeries (14.71% in the complication group vs. 2.94% in

Table 2. Perioperative complications of radical surgery for CRC before propensity score matching

Complication	N (n=276)	Percentage
Heart failure	5	1.81%
Surgical site infection	6	2.17%
Urinary infection	8	2.90%
Ileus	41	14.86%
Pneumonia	14	5.07%
Urinary dysfunction	6	2.17%
Intraabdominal bleeding	2	0.72%
Anastomotic bleeding	3	1.09%
Cerebral hemorrhage	2	0.72%
Delirium	4	1.45%
Pulmonary embolus	3	1.09%
Incisional hernia	3	1.09%
Anastomotic leakage	22	7.97%

the non-complication group, χ^2=4.478, P= 0.034) between the two groups. These findings suggest that prolonged operative time, increased blood loss, specific surgery types, and emergent surgeries may be associated with a higher risk of perioperative complications in this patient population.

Comparison of postoperative recovery

Postoperative recovery was compared between the two groups following radical resection for CRC. The postoperative hospital stay was significantly longer in the complication group (13.38 ± 5.67 days) compared to the non-complication group (10.74 ± 4.26 days) (t=3.073, P=0.003) (**Table 6**). Additionally, a significantly higher proportion of patients in the complication group received adjuvant chemotherapy (17.65%) compared to the non-complication group (4.41%) (χ^2=4.796, P=0.029). Moreover, the quality-of-life scores were lower in the complication group (74.29 ± 9.63) than that in the non-complication group (78.16 ± 9.58) (t=2.355, P=0.020). These findings suggest that a longer postoperative hospital stay, increased utilization of adjuvant chemotherapy, and lower quality of life scores may be associated with the occurrence of perioperative complications in this patient population.

Comparison of physiological reserve and surgical stress scores

The PRS was significantly higher in the complication group (0.52 ± 0.07) compared to the non-complication group (0.41 ± 0.08) (t=8.361, P < 0.001) (**Figure 1**). Similarly, the surgical stress score (SSS) was significantly elevated in the complication group (0.14 ± 0.04) in contrast to the non-complication group (0.08 ± 0.04) (t=8.894, P < 0.001). Moreover, the CRS was notably higher in the complication group (0.18 ± 0.05) as compared to the non-complication group (0.11 ± 0.03) (t=9.586, P < 0.001). These findings indicate that higher PRS and surgical stress scores may be predictive of perioperative complications in patients undergoing radical resection for CRC.

Correlation analysis

In the correlation analysis of physiological reserve and surgical stress scores with the incidence of perioperative complications in patients undergoing radical surgery for CRC, strong positive correlations were observed. The PRS demonstrated a notable positive correlation with the incidence of perioperative complications (r=0.586, R^2=0.343, P < 0.001) (**Figure 2**), indicating that higher PRS values were associated with a greater likelihood of complications. Similarly, the surgical stress score (SSS) exhibited a strong positive correlation with the incidence of perioperative complications (r=0.609, R^2=0.371, P < 0.001), suggesting that elevated SSS values were linked to an increased incidence of complications. Additionally, the CRS also displayed a robust positive correlation with the incidence of perioperative complications (r=0.638, R^2=0.407, P < 0.001), emphasizing the association between higher CRS values and a heightened risk of perioperative complications in this patient population. These findings underscore the relevance of physiological reserve and surgical stress scores in identifying patients at increased risk of perioperative complications after radical resection for CRC.

ROC

In the analysis evaluating the predictive value of physiological reserve and surgical stress scores for perioperative complications in patients undergoing radical surgery for CRC, the findings revealed strong diagnostic performance with notable sensitivities, specificities, and area under the curve (AUC) values (**Figure 3**). The PRS exhibited a high sensitivity of 0.882 and a specificity of 0.647, with an AUC of 0.848 and a Youden index of 0.529. Similarly, the SSS

Table 3. General characteristics of the two patient groups after propensity score matching

Parameter	Non-complication Group (n=68)	Complication Group (n=68)	t/χ^2	P
Age (years)	61.29 ± 10.58	65.59 ± 8.74	2.583	0.011
Gender (Male/Female)	34 (50.00%)/34 (50.00%)	38 (55.88%)/30 (44.12%)	0.266	0.606
BMI (kg/m^2)	23.19 ± 3.48	23.47 ± 3.29	0.486	0.628
Smoking history [n (%)]	10 (14.71%)	14 (20.59%)	0.455	0.500
Drinking history [n (%)]	12 (17.65%)	15 (22.06%)	0.185	0.667
Marital status			0.045	0.832
Married (%)	55 (80.88%)	53 (77.94%)		
Single (%)	13 (19.12%)	15 (22.06%)		
Place of Residence			0.034	0.853
Urban	48 (70.59%)	46 (67.65%)		
Rural	20 (29.41%)	22 (32.35%)		
Educational Level			1.059	0.303
Secondary School or Below	38 (55.88%)	31 (45.59%)		
High School or Above	30 (44.12%)	37 (54.41%)		
Hypertension [n (%)]	13 (19.12%)	8 (11.76%)	0.901	0.343
Diabetes [n (%)]	2 (2.94%)	12 (17.65%)	6.45	0.011
Pulmonary disease [n (%)]	3 (4.41%)	11 (16.18%)	3.902	0.048
Heart disease [n (%)]	5 (7.35%)	15 (22.06%)	4.748	0.029
Tumor location [n (%)]			0.034	0.853
Colon	48 (70.59%)	46 (67.65%)		
Rectum	20 (29.41%)	22 (32.35%)		
Tumor size (cm)	4.89 ± 1.37	5.24 ± 1.73	1.286	0.201
Histology [n (%)]			0.071	0.790
Differentiated	59 (86.76%)	61 (89.71%)		
Undifferentiated	9 (13.24%)	7 (10.29%)		
ASA grade [n (%)]			9.226	0.010
I	18 (26.47%)	8 (11.76%)		
II	38 (55.88%)	34 (50.00%)		
III	12 (17.65%)	26 (38.24%)		

Table 4. Perioperative complications of radical surgery for CRC after propensity score matching

Complication	N (n=136)	Percentage
Heart failure	1	0.74%
Surgical site infection	3	2.21%
Urinary infection	5	3.68%
Ileus	16	11.76%
Pneumonia	6	4.41%
Urinary dysfunction	2	1.47%
Intraabdominal bleeding	0	0.00%
Anastomotic bleeding	2	1.47%
Cerebral hemorrhage	0	0.00%
Delirium	1	0.74%
Pulmonary embolus	1	0.74%
Incisional hernia	2	1.47%
Anastomotic leakage	10	7.35%

demonstrated a sensitivity of 0.765, specificity of 0.779, AUC of 0.854, and a Youden index of 0.544. Moreover, the CRS showed a sensitivity of 0.779, specificity of 0.824, AUC of 0.882, and a Youden index of 0.603. These results suggest that the PRS, SSS, and CRS are valuable predictive tools for identifying patients at risk of perioperative complications following radical resection for CRC, with the CRS demonstrating the highest overall predictive accuracy.

Discussion

Colorectal cancer stands as a predominant factor in global cancer-related deaths [20-22]. Radical resection surgery was the primary curative treatment for this malignancy [23]. However, perioperative complications can signifi-

Table 5. Comparison of surgical parameters between the two groups

Parameter	Non-complication Group (n=68)	Complication Group (n=68)	t/χ^2	P
Operative time (min)	282.16 ± 10.79	287.38 ± 11.43	2.738	0.007
Blood loss (mL)	48.19 ± 8.54	51.84 ± 9.72	2.325	0.022
Surgery type [n (%)]			7.813	0.020
Minor incision	39 (57.35%)	24 (35.29%)		
Laparoscopy/thoracotomy alone	22 (32.35%)	28 (41.18%)		
Laparotomy and thoracotomy	7 (10.29%)	16 (23.53%)		
Emergent surgery	2 (2.94%)	10 (14.71%)	4.478	0.034

Table 6. Comparison of postoperative recovery

Parameter	Non-complication Group (n=68)	Complication Group (n=68)	t/χ^2	P
Postoperative hospital stay (days)	10.74 ± 4.26	13.38 ± 5.67	3.073	0.003
Adjuvant chemotherapy [n (%)]	3 (4.41%)	12 (17.65%)	4.796	0.029
Quality of Life Scores	78.16 ± 9.58	74.29 ± 9.63	2.355	0.020

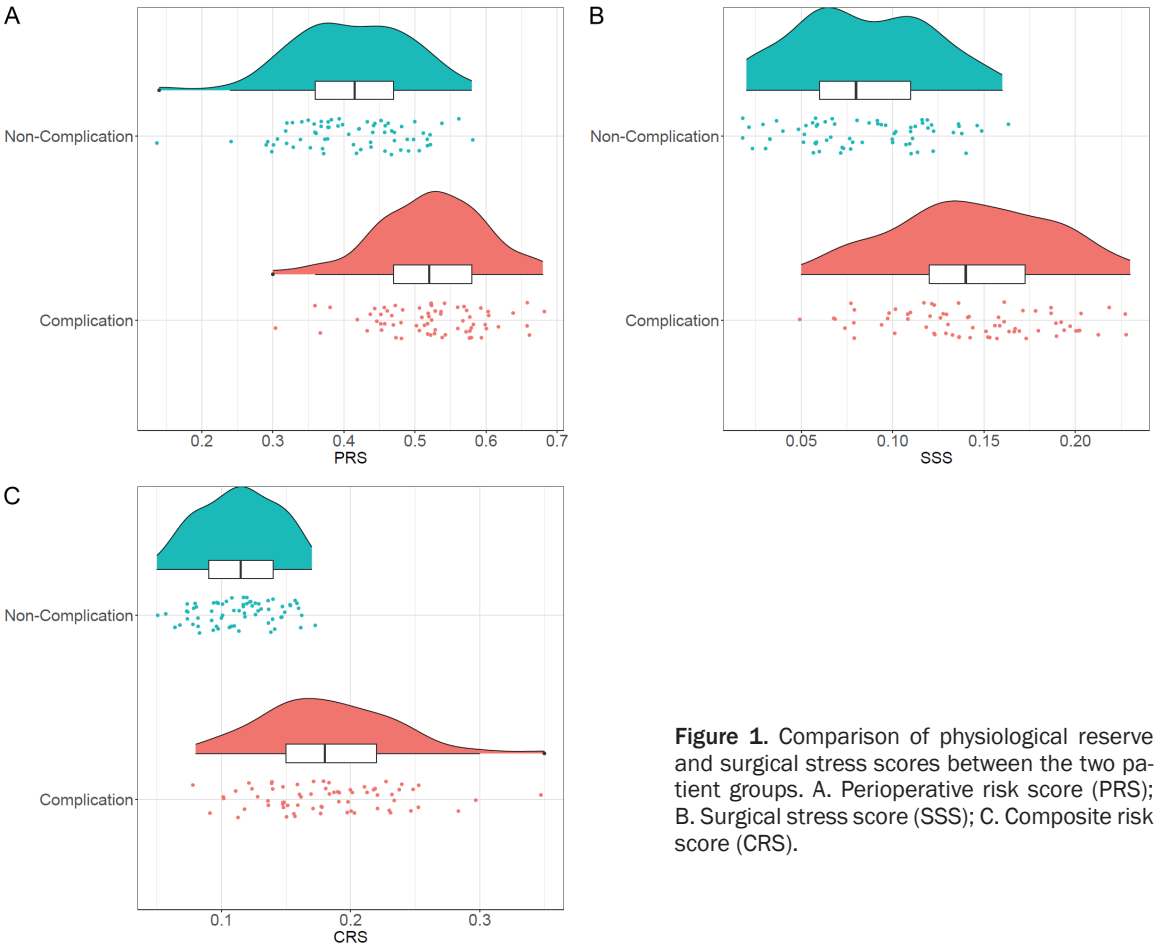

Figure 1. Comparison of physiological reserve and surgical stress scores between the two patient groups. A. Perioperative risk score (PRS); B. Surgical stress score (SSS); C. Composite risk score (CRS).

cantly impact patient outcomes and quality of life [24, 25]. Therefore, identifying reliable predictive factors for perioperative complications is crucial for enhancing patient care and surgical outcomes [26]. In this study, we conducted a propensity-matched analysis to

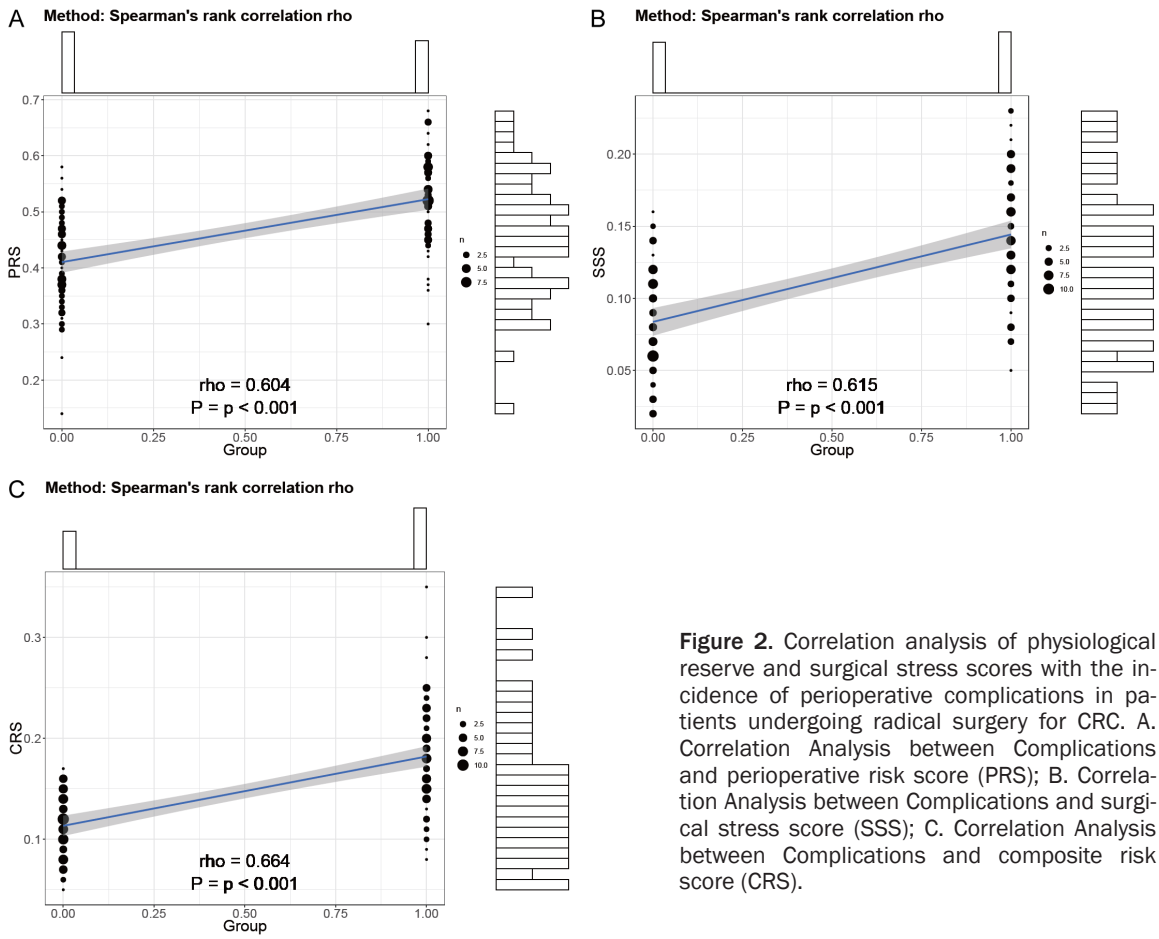

Figure 2. Correlation analysis of physiological reserve and surgical stress scores with the incidence of perioperative complications in patients undergoing radical surgery for CRC. A. Correlation Analysis between Complications and perioperative risk score (PRS); B. Correlation Analysis between Complications and surgical stress score (SSS); C. Correlation Analysis between Complications and composite risk score (CRS).

assess the predictive value of physiological capacity and surgical stress scores in the occurrence of perioperative complications among patients undergoing radical resection for CRC.

The baseline characteristics of the study population revealed significant differences in age, gender, BMI, smoking and alcohol consumption history, comorbidities (diabetes, pulmonary disease, heart disease), tumor size, and ASA grade between the groups with and without perioperative complications. These differences highlight the diverse patient profiles and the multifactorial nature of perioperative risk in CRC surgery. Importantly, after propensity score matching, age, diabetes, pulmonary disease, heart disease, and ASA grade remained as predictive factors for perioperative complications. These results align with the existing literature [27-29], indicating that advanced age and comorbidities such as diabetes, pulmonary disease, and heart disease are known risk factors for surgical complications.

Before propensity score matching, significant differences were observed in several baseline characteristics, including gender, BMI, smoking and alcohol consumption history, and the presence of pulmonary disease. These differences highlight the importance of controlling potential confounders in the analysis. Specifically, a higher proportion of male patients, higher BMI, and a history of smoking and alcohol consumption were associated with the complication group. Additionally, the presence of pulmonary disease was more prevalent in the complication group. These factors may contribute to a higher risk of perioperative complications and should be carefully considered in clinical practice.

Obesity, characterized by a high BMI, is a known risk factor for CRC and has been associated with increased perioperative complications. In our study, the BMI was significantly higher in the complication group compared to the non-complication group. This finding is consistent with previous research, suggesting that higher

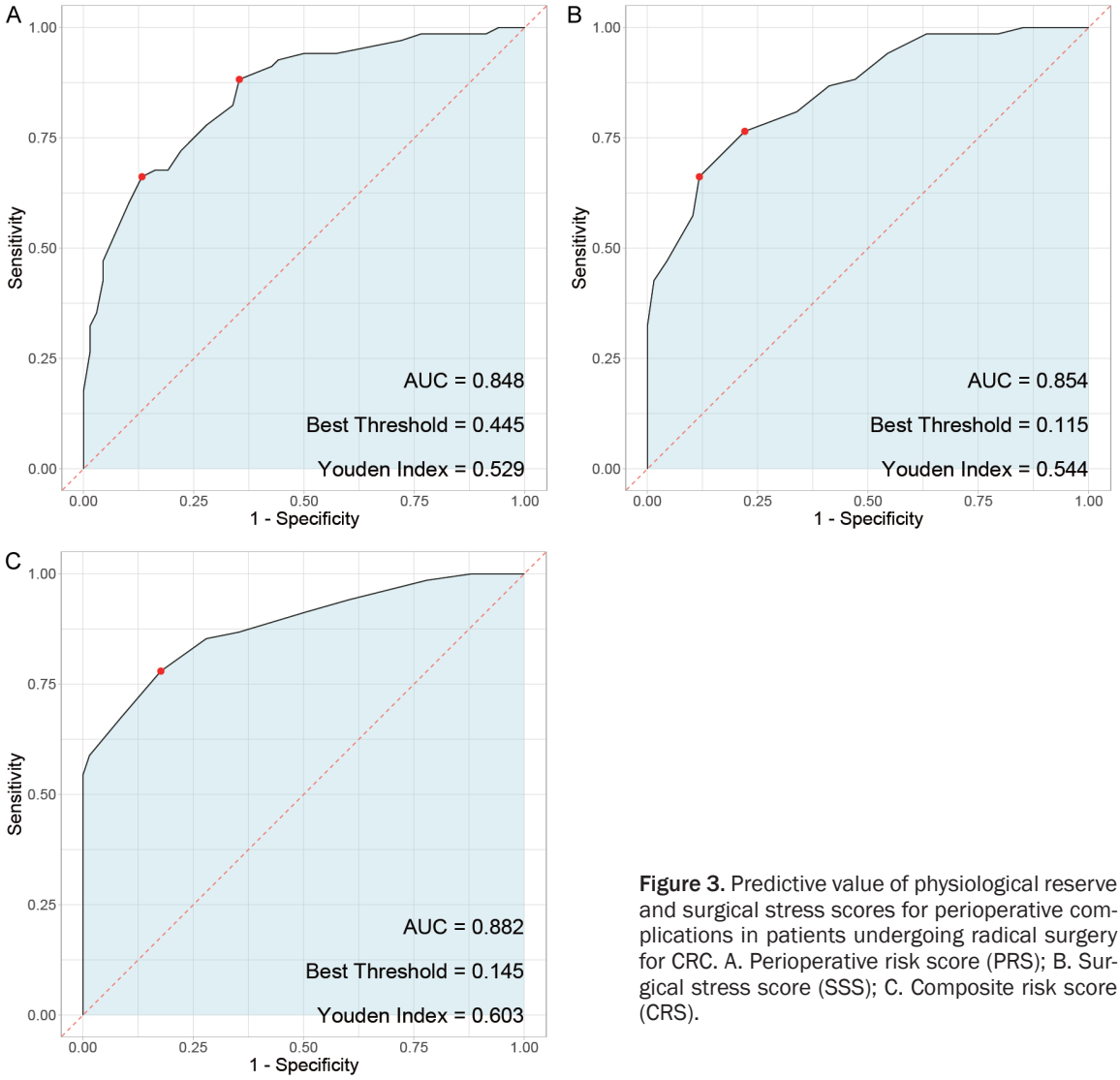

Figure 3. Predictive value of physiological reserve and surgical stress scores for perioperative complications in patients undergoing radical surgery for CRC. A. Perioperative risk score (PRS); B. Surgical stress score (SSS); C. Composite risk score (CRS).

BMI may contribute to a greater risk of perioperative complications, possibly due to increased surgical complexity and higher rates of comorbidities such as diabetes and cardiovascular disease.

Advanced age was identified as a significant predictor of perioperative complications in both the unadjusted and propensity-matched analyses. The mean age of patients in the complication group was significantly higher compared to those in the non-complication group, both before and after propensity score matching. This finding is consistent with the literature [30], which suggests that older patients are at a higher risk of perioperative complications due to decreased physiological reserve and the presence of multiple comorbidities. Clinicians should be particularly vigilant when managing older patients undergoing radical resection for CRC, as they may require more intensive preoperative optimization and postoperative monitoring.

Furthermore, our study investigated the relationship between surgical parameters and perioperative complications. Prolonged operative time, increased blood loss, specific types of surgery, and emergent surgeries were found to be significantly associated with a higher risk of perioperative complications. These findings were in line with previous studies [31-33] that have highlighted the impact of surgical duration, blood loss, specific types of surgery, and emergent procedures on the occurrence of postoperative complications. The identification

of these parameters as predictive factors underscores the importance of meticulous surgical planning, intraoperative management, and careful consideration of surgical approaches to minimize the risk of complications in CRC resection.

Comorbidities such as diabetes, pulmonary disease, and heart disease were significant predictors of perioperative complications in our study. These conditions are known to increase the risk of surgical complications by compromising physiological reserve and increasing the likelihood of adverse events. Specifically, diabetes can impair wound healing and increase the risk of infections, while pulmonary and heart diseases can exacerbate perioperative respiratory and cardiovascular complications. Our findings underscore the importance of preoperative assessment and management of these comorbidities to reduce the risk of perioperative complications.

In addition to surgical parameters, our study evaluated postoperative recovery and quality of life outcomes. The complication group exhibited a significantly longer postoperative hospital stay, increased utilization of adjuvant chemotherapy, and lower quality of life scores compared to the non-complication group. These findings emphasize the broader implications of perioperative complications on patient recovery and postoperative well-being. Prolonged hospital stay, additional treatments such as adjuvant chemotherapy, and compromised quality of life highlight the substantial burden faced by patients who experience perioperative complications. Therefore, strategies aimed at reducing the incidence of perioperative complications could potentially improve overall postoperative recovery and quality of life for patients undergoing radical resection for CRC.

The E-PASS scoring system, comprising PRS, SSS, and CRS, emerged as a valuable tool for predicting perioperative complications in our study. The PRS, SSS, and CRS demonstrated strong positive correlations with the incidence of perioperative complications, suggesting that higher physiological reserve and surgical stress are indicators of higher perioperative complications. These findings align with the growing interest in using risk stratification tools to guide preoperative risk assessment and improve patient counseling [34, 35]. The E-PASS scoring system offers a quantitative approach to evaluate perioperative risk, helping clinicians make informed decisions regarding operative strategies, perioperative management, and tailored patient counseling.

The ROC analysis further confirmed the predictive value of the E-PASS scoring system, showing notable sensitivities, specificities, and AUC values for PRS, SSS, and CRS. These results underscore the potential utility of the E-PASS scoring system as a reliable predictive tool for perioperative complications in patients undergoing radical resection for CRC. The high sensitivity and specificity of the E-PASS scoring system highlight its ability to discriminate between patients at low and high risk of perioperative complications, holding promise for personalized risk assessment and tailored perioperative management strategies.

Several constraints of this research merit attention. To begin with, the study's retrospective design could introduce inherent biases, restricting the ability to establish causal relationships. Moreover, the research was conducted at a single center, potentially undermining the generalizability of its conclusions. Additionally, the medication history, including the use of chemotherapy and anti-infective drugs during the perioperative period, was not comprehensively included in this study. Future research should consider the impact of these medications on perioperative complications, as they may play a significant role in patient outcomes. Preoperative and postoperative chemotherapy regimens, as well as the administration of antibiotics and other anti-infective agents, could influence the incidence and severity of perioperative complications. Subsequent prospective multicenter investigations with expanded sample sizes are essential to affirm the predictive value of physiological capacity and surgical stress scores in perioperative complications following radical resection for CRC.

Conclusion

In conclusion, our study demonstrates the predictive value of physiological capacity and surgical stress scores in perioperative complications of radical resection for CRC. Age, comorbidities, surgical parameters, postoperative recovery, and the E-PASS scoring system emerged as key predictive factors, underscor-

ing the multifaceted nature of perioperative risk in CRC surgery. The results of this study carry significant consequences for risk evaluation, patient counseling, and personalized perioperative management strategies. By integrating these predictive factors into clinical practice, clinicians can strive to optimize perioperative care and enhance surgical outcomes for patients undergoing radical resection for CRC.

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Disclosure of conflict of interest

None.

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