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Nutrición Hospitalaria

Trabajo Original

Valoración nutricional

Preoperative nutritional factors as predictors of postoperative early outcomes in colorectal cancer — A prospective cohort study

Factores nutricionales preoperatorios como predictores de resultados postoperatorios precoces en cáncer colorrectal: un estudio prospectivo de cohortes

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Abstract

Introduction: in colorectal cancer (CRC) surgery, preoperative nutritional factors are often overlooked or underestimated. This situation represents a significant deficiency that may negatively affect patients' postoperative recovery processes.

Objective: the objective of this study was to evaluate the impact of preoperative malnutrition, sarcopenia, obesity, and dietary inflammatory potential on early postoperative outcomes in CRC.

Methods: preoperative sarcopenia was identified using European Working Group on Sarcopenia in Older People (EWGSOP2) criteria based on skeletal muscle obtained from computed tomography (CT) scans, and malnutrition was identified using Global Leadership Initiative on Malnutrition (GLIM) criteria. Visceral and subcutaneous obesity were assessed using CT scans. The energy-adjusted dietary inflammatory index (E-DII) was calculated from dietary records.

Results: a total of 121 patients were included in the study, and 45.5 % of them were malnourished according to GLIM, 15.7 % were sarcopenic according to EWGSOP2. Multivariate logistic regression analysis showed that sarcopenia [OR = 3.973 (1.028-15.353), $p = 0.043$], malnutrition [OR = 3.954 (1.479-10.575), $p = 0.006$], and E-DII [OR = 4.955 (1.397-17.571), $p = 0.013$] were independent risk factors for complications. Sarcopenia [OR = 6.894 (1.080-43.998), $p = 0.041$] was also risk factor for long-term hospitalization.

Conclusion: a comprehensive evaluation of preoperative nutrition and related factors in CRC surgery, along with timely interventions, has the potential to significantly reduce postoperative complications and length of hospital stays.

Keywords:

Sarcopenia. Malnutrition. Body composition. Colorectal surgery. Complications.

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Conflicts of interest: the authors declare that the research was conducted without any commercial or financial relationship that could be interpreted as a potential conflict of interest.

Artificial intelligence: the authors declare that they have not used artificial intelligence (AI) or any AI-enabled technology in the preparation of the manuscript.

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Resumen

Introducción: en la cirugía del cáncer colorrectal (CCR), los factores nutricionales preoperatorios suelen pasarse por alto o subestimarse. Esta situación representa una carencia importante que puede afectar negativamente a los procesos de recuperación postoperatoria de los pacientes.

Objetivo: el objetivo de este estudio fue evaluar el impacto de la desnutrición preoperatoria, la sarcopenia, la obesidad y el potencial inflamatorio de la dieta en los resultados postoperatorios tempranos en el CCR.

Métodos: la sarcopenia preoperatoria se identificó mediante los criterios del Grupo Europeo de Trabajo sobre Sarcopenia en Personas Mayores (EWGSOP2) basados en el músculo esquelético obtenido mediante tomografía computarizada (TC), y la malnutrición se identificó mediante los criterios de la Iniciativa de Liderazgo Global sobre Malnutrición (GLIM). La obesidad visceral y subcutánea se evaluó mediante TC. El índice inflamatorio dietético ajustado a la energía (E-DII) se calculó a partir de los registros dietéticos.

Resultados: un total de 121 pacientes fueron incluidos en el estudio; el 45,5 % de ellos estaban desnutridos según la GLIM, y el 15,7 % sarcopénicos según el EWGSOP2. El análisis de regresión logística multivariante mostró que la sarcopenia [OR = 3,973 (1,028-15,353), $p = 0,043$], la desnutrición [OR = 3,954 (1,479-10,575), $p = 0,006$] y el E-DII [OR = 4,955 (1,397-17,571), $p = 0,013$] eran factores de riesgo independientes de complicaciones. La sarcopenia [OR = 6,894 (1,080-43,998), $p = 0,041$] también fue un factor de riesgo de hospitalización a largo plazo.

Conclusiones: una evaluación exhaustiva de la nutrición preoperatoria y los factores relacionados en la cirugía del CCR, junto con intervenciones oportunas, tiene el potencial de reducir significativamente las complicaciones postoperatorias y la duración de las estancias hospitalarias.

Palabras clave:

Sarcopenia. Desnutrición. Composición corporal. Cirugía colorrectal. Complicaciones.

INTRODUCTION

Colorectal cancer (CRC) is the third most common malignancy and the second leading cause of mortality within the spectrum of all malignant neoplasms (1). Surgery is the main treatment for early-stage CRC. Despite advances in surgical techniques and improved perioperative care, about one third of patients still experience complications after colorectal surgery (2). Surgical treatment can lead to inflammation and metabolic stress. Nutritional factors such as preoperative malnutrition or sarcopenia prevent the patient from tolerating surgical stress and lead to poor postoperative outcomes (3). Preoperative malnutrition is a common occurrence in gastrointestinal cancers. Malnutrition has been reported in approximately 40 % of patients undergoing gastrointestinal surgery (4). Patients undergoing colorectal surgery are more susceptible to malnutrition due to various factors, including inadequate intake caused by intestinal obstruction or cancer-related anorexia, malabsorption, excessive losses from intestinal fistulas and a marked inflammatory response (5). Different diagnostic criteria for malnutrition have been used, but there was no universal consensus. The Global Leadership Initiative on Malnutrition (GLIM) has recently published international consensus-based diagnostic criteria for malnutrition (6). Previous studies have reported that a preoperative diagnosis of GLIM malnutrition in various types of cancer adversely affects postoperative outcomes (7,8).

Computed tomography (CT) scans, a component of CRC cancer screening and therapy protocols, are also used to assess body composition factors such as skeletal muscle and adipose tissue (9). Sarcopenia, a condition marked by a reduction in both the quantity and functionality of skeletal muscle, has been shown to have an adverse impact on postoperative outcomes and survival rates in CRC (10,11). The majority of studies have diagnosed sarcopenia solely on the basis of skeletal muscle mass obtained from CT scans. However, a reduced in muscle strength is the main diagnostic criterion for sarcopenia, according the most recent guidelines published by European Working Group on Sarcopenia in Older People (EWGSOP2) (12). Not only sarcopenia or low skeletal muscle mass but also obesity affects surgical outcomes. Studies examining the effect of obesity on surgical outcomes in CRC based on CT-derived adipose tissue area (visceral or subcutaneous) are more limited and results are conflicting.

The Dietary Inflammatory Index (DII) was developed based on evidence of the relationship between diet and blood markers of inflammation (13). A higher DII score, indicating a diet high in inflammation, was found to correlate with an increased likelihood of developing CRC (14). The effect of dietary inflammatory potential on the outcomes of colorectal surgery has not been extensively studied, except for one research article that examined its impact on the duration of hospitalization (15).

The objective of the study was to evaluate the impact of preoperative malnutrition, sarcopenia (defined by EWGSOP2 criteria), obesity (assessed by CT scan), and dietary inflammatory potential on early postoperative outcomes in patients with CRC.

MATERIAL AND METHODS

STUDY POPULATION

This prospective cohort study included patients scheduled for colorectal surgery at Bilkent City Hospital between July 2021 and December 2022. The following were the inclusion criteria: being diagnosed with CRC; being at least 18 years old; and being planned for colorectal surgical treatment. The following were exclusion criteria: having received neoadjuvant therapy; currently receiving corticosteroid or hormone therapy; distant metastasis; any malignancy other than CRC; autoimmune disease; active infectious disease. The flow chart of the study was shown in figure 1. During the study period, a cohort of 147 consecutive individuals diagnosed with CRC and scheduled for colorectal surgery were included in the study. A total of 26 patients were excluded from the study as a result of surgery cancellation, neoadjuvant therapy, and missing data; as a result, 121 patients remained in the final analysis.

The Non-Invasive Clinical Research Ethics Committee at Hacettepe University gave its permission to this research (GO 21/499). The Declaration of Helsinki was followed in the conduct of the research, and the volunteer participants signed informed permission forms.

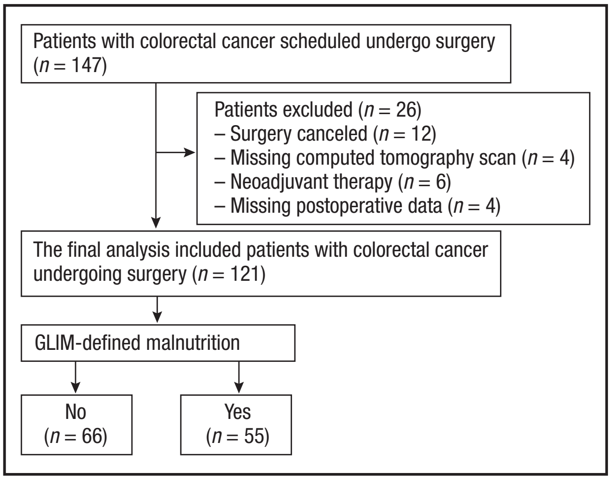

Figure 1.

Flow chart of the patients included and excluded. GLIM: Global Leadership Initiative on Malnutrition.

STUDY PROTOCOL

Researchers performed in-person interviews with patients during a timeframe of 1-3 days before to the operation. During these interviews, a questionnaire was administered that included general information, dietary records, and nutrition screening tests. Body weights were measured with the Tanita BC730 and height was measured using a stadiometer. Patients' self-reported body weights from 1, 3, and 6 months ago were recorded, and if weight loss was observed in the recorded data for the last 1, 3, and 6 months, the percentage of weight loss was calculated. The patients were asked whether the weight loss was intentional. A photographic food atlas was used to obtain the 24-hour dietary recall of patients. Energy and nutrient intakes were determined using the Nutrition Information System (BeBIS, version 8.1) software program.

Tumor location, TNM stage, comorbidities, information about surgery, and postoperative outcomes were obtained from hospital records. In order to assess comorbidities, the Charlson Comorbidity Index (CCI) was used (16).

Biochemical parameters analyzed within 48 hours prior to surgery were recorded from the hospital's data system. The delta neutrophil index (DNI), neutrophil lymphocyte ratio (NLR), and prognostic nutritional index (PNI) were used for the evaluation of systemic inflammation. The DNI was obtained directly from the records as a routine blood count parameter. NLR was calculated by dividing the quantity of neutrophils by lymphocytes. PNI was determined using the following formula: {10 x albumin (g/dL)} + {0.005 x total lymphocyte count}.

MUSCLE STRENGTH

Hand grip strength was measured using a Takei 5401 digital hand dynamometer (Takei Scientific Instruments, Tokyo, Japan) to evaluate muscle strength. The measurement was taken three times from each hand while standing, with the forearm at thigh level and away from the body. The mean of the six measurements was used to determine the grip strength. Low muscle strength was considered to be < 27 kg for males and < 16 kg for females (12).

BODY COMPOSITION ANALYSIS FROM CT SCANS

CT scans taken within one month prior to surgery were received from the Picture Archiving and Communication System (PACS). Body composition analysis was performed on the third lumbar vertebra (L3) cross-sectional area using ImageJ 1.53j (National Institutes of Health, Bethesda, Maryland, USA) following the steps in the protocol detailed previously (17). Hounsfield unit (HU) thresholds specific for skeletal muscle, visceral, and subcutaneous adipose tissue were used in the analyses (Fig. 2). All analyses were performed by a trained researcher (TNYK) blinded to the patient's clinical information. To verify the accuracy and reproducibility of the results, 10 randomly selected patient images were independently analyzed by a second blinded trained researcher (HFY). The intraclass correlation coefficient was 0.99 (95 % CI, 0.98-1.00) for SMA, 1.00 (95 % CI, 0.99-1.00) for SATA and 1.00 (95 % CI, 0.99-1.00) for VATA.

SARCOPENIA AND CT-BASED OBESITY DEFINITION

Skeletal muscle area (SMA) were divided by the square of the patients' height (m^2) to obtain the skeletal muscle index (SMI). The SMI cutoff values determined by Martin et al. (18) were used to identify individuals with low skeletal muscle mass. For females, the cutoff was 41 cm^2/m^2. For males with a BMI < 25, the cutoff was 43 cm^2/m^2. For males with a BMI ≥ 25, the cutoff was 53 cm^2/m^2. Sarcopenia diagnosis was established according the revised criteria of the EWGSOP2, beginning with the identification of probable sarcopenia based on low muscle strength [10]. Within the probable sarcopenic patients, those with low skeletal muscle mass determined by CT have been diagnosed with sarcopenia. As our study did not measure physical performance, we did not evaluate the severity of sarcopenia.

There was no widely accepted CT-based cut-off point to define visceral and subcutaneous obesity. We determined visceral adipose tissue area (VATA) and subcutaneous adipose tissue area (SATA) cut-off points for CT-based obesity diagnosis by receiver operating characteristic (ROC). Figure 3 shows CT images of patients with different body composition from our study sample.

ASSESSMENT OF MALNUTRITION

A systematic two-step approach was used to identify malnutrition in patients. The initial assessment of patients for malnutrition

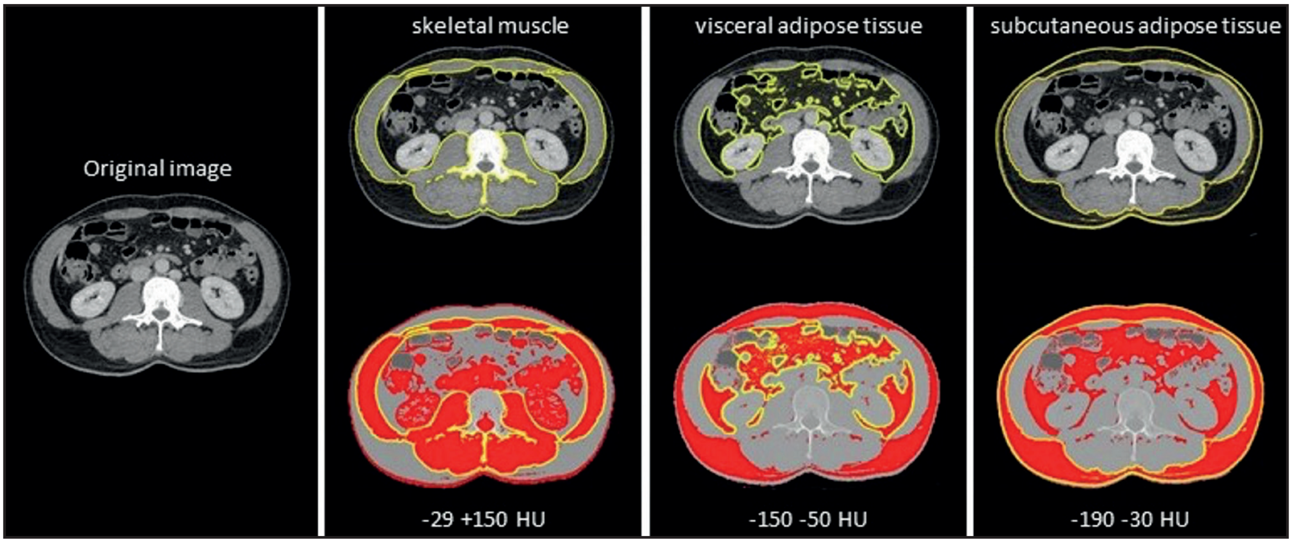

Figure 2.

Body composition analysis from third lumber vertebra cross-sectional area. Hounsfield unit (HU) values for skeletal muscle area, visceral or subcutaneous adipose tissue area were applied for each as indicated in the figure. Then, only the area within the yellow line was calculated from the resulting red area. The red area outside the yellow line was manually selected and subtracted from the final result.

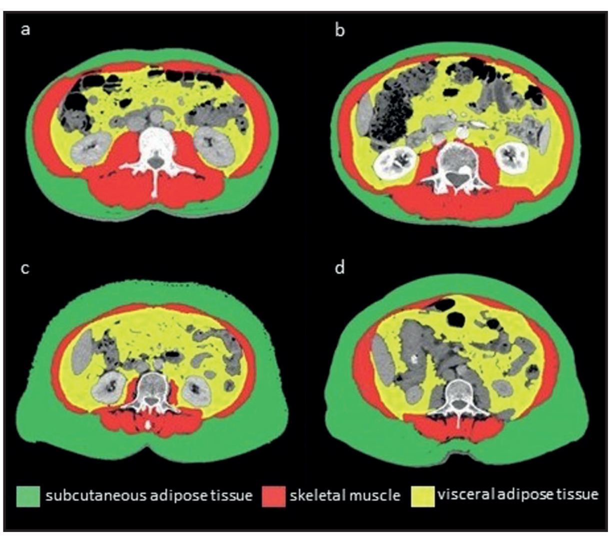

Figure 3.

Computed tomography 3rd lumbar vertebra cross-sectional area images of patients with different body compositions: A. Male with a healthy body composition. B. Male with sarcopenia. C. Female with sarcopenia and visceral and subcutaneous obesity. D. Female with visceral and subcutaneous obesity.

risk was conducted using NRS2002. Patients with scores of 3 or higher were identified as at-risk. Subsequently, these individuals underwent a second evaluation to determine if they met the criteria for a malnutrition diagnosis, using the GLIM criteria. The GLIM criteria required that at least one phenotypic (involuntary weight loss, low BMI, decreased muscle mass) and one etiologic criterion (decreased food intake or assimilation, disease burden/inflammation) be satisfied in order to diagnose malnutrition (6). As cancer met the etiological criterion, the presence of at least one phenotypic criterion was sufficient for the diagnosis of malnutrition in this study.

CALCULATION OF E-DII

We assessed the inflammatory potential of the diet using the Dietary Inflammatory Index (DII) developed by Shivappa et al. based on 24-hour dietary recalls (13). The DII uses 45 food parameters to assess the inflammatory potential of the diet. Since we were able to obtain data on 37 food parameters from 24-hour dietary recalls and the BeBIS program, we included 37 of the 45 food parameters. Food parameters not included were trans fatty acid, flavon-3-ol, flavonones, flavonols, flavones, anthocyanidins, isoflavones, eugenol. By summing the DIIs calculated separately for each food parameter, an overall DII score for the daily diet of individuals is obtained. We used the energy-adjusted E-DII in our research. For the E-DII, the individual's food intakes were calculated per 1000 kcal and adjusted so that the global average food intakes were also per 1000 kcal. E-DII scores were then calculated for each individual following the same formula as in the DII calculation (19). Greater inflammatory potential of the diet was indicated by higher E-DII scores. The E-DII scores were classified into tertiles, with the inflammatory potential progressively increasing from the first tertile to the third tertile.

POSTOPERATIVE OUTCOMES

The postoperative outcomes encompassed the occurrence of complications within a 30-day period and the length of hospital stays after the surgery. The investigator responsible for monitoring postoperative outcomes was blinded to the results of the preoperative assessments. Postoperative complications were evaluated using the Clavien-Dindo classification (20), and only complications classified as Grade 2 or higher were considered in the analysis. A hospital stay was deemed long-term if it exceeded 7 days.

STATISTICAL ANALYSIS

The sample size was established using the G*Power software program version 3.1, based on the association between nutritional risk status and the frequency of postoperative complications. Accordingly, the minimum sample size for our research was 117 (error rate: 0.05; power: 80 %; effect size: 0.26). The data were analyzed using SPSS v22.0 (Chicago, USA). Statistical significance was determined by a two-sided *p*-value of less than 0.05. Based on data distribution, continuous variables were presented as the mean ± standard deviation (SD) or the median and interquartile range (IQR). The categorical variables were shown as frequencies and percentages. The Chi-square test was used to compare categorical variables, while the Student t-test or Mann-Whitney U-test was utilized to compare continuous variables, according to the normality of the distribution. The cutoff points for VATA and SATA values for defining visceral and subcutaneous obesity were determined separately for males and females using ROC curve analysis, with obesity characterized as BMI ≥ 25 kg/m². For the purpose of identifying risk factors for long-term postoperative hospital stays and complications, univariate logistic analysis was followed by multivariate logistic regression analysis. To identify risk factors for long-term postoperative hospital stays and complications, we conducted univariate logistic analysis followed by multivariate logistic regression analysis.

RESULTS

CLINICAL CHARACTERISTICS

Table I presents the clinical characteristics of the patients. Of the 121 patients included in the study, 55 (45.5 %) were diagnosed with malnutrition according to GLIM criteria. The mean age of the patients was 62.3 ± 12.08 years and the majority of patients (62.8 %) were male. There was no significant difference observed between those with malnutrition and those without in terms of gender, tumor location, stage, stoma presence, operation duration, and postoperative oral feeding time. Malnourished patients had a higher mean age, Charlson comorbidity index, and length of postoperative hospital stay ($p < 0.05$). Postoperative complications (Clavien-Dindo ≥ 2) developed in a total of 39 (32.2 %) patients. The frequency of complications in malnourished patients was 54.5 %, while in without malnutrition patients, it was 13.6 % ($p < 0.05$).

Table I. Clinical characteristics of patients

Variables	Total (*n* = 121)	Malnutrition		*p*
		No (*n* = 66)	Yes (*n* = 55)	
Gender				
Male	76 (62.8 %)	38 (57.6 %)	38 (69.1 %)	0.192
Female	45 (37.2 %)	28 (42.4 %)	17 (30.9 %)	
Age (years)	62.3 ± 12.08	60.0 ± 11.86	65.0 ± 11.88	0.023*
< 65	58 (47.9 %)	36 (54.5 %)	22 (40.0 %)	0.111
≥ 65	63 (52.1 %)	30 (45.5 %)	33 (60.0 %)	
Charlson comorbidity index	4.0 ± 1.72	3.7 ± 1.76	4.4 ± 1.61	0.025*
Tumor location				
Colon	50 (41.3 %)	27 (40.9 %)	23 (41.8 %)	0.919
Rectum	71 (58.7 %)	39 (59.1 %)	32 (58.2 %)	
Surgical approach				
Laparoscopic	51 (42.1 %)	34 (51.5 %)	17 (30.9 %)	0.022*
Open	70 (57.9 %)	32 (48.5 %)	38 (69.1 %)	
TNM stage				
I	18 (14.9 %)	11 (16.7 %)	7 (12.7 %)	
II	47 (38.8 %)	27 (40.9 %)	20 (36.4 %)	0.625
III	56 (46.3 %)	28 (42.4 %)	28 (50.9 %)	

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Table I (Cont.). Clinical characteristics of patients

Variables	Total (n = 121)	Malnutrition		p
		No (n = 66)	Yes (n = 55)	
Stoma No Yes	 68 (56.2 %) 53 (43.8 %)	 37 (56.1 %) 29 (43.9 %)	 31 (56.4 %) 24 (43.6 %)	0.973
Clavien-Dindo < 2 ≥ 2	 82 (67.8 %) 39 (32.2 %)	 57 (86.4 %) 9 (13.6 %)	 25 (45.5 %) 30 (54.5 %)	< 0.001*
Operation duration (min)	260.1 ± 71.14	259.5 ± 71.86	260.7 ± 70.92	0.928
Postoperative oral feeding time (days)	2.0 (2.00)	2.0 (2.00)	2.0 (4.00)	0.727
Length of postoperative hospital stay (days)	7.0 (5.00)	7.0 (2.00)	10.0 (7.00)	< 0.001*

$p < 0.05$ is significant.

VISCERAL AND SUBCUTANEOUS OBESITY CUT-OFF VALUES

According to the ROC analysis, the VATA cut-off values indicating visceral obesity were 172.03 cm² (AUC = 0.817; 95 % CI, 0.719-0.916; $p < 0.001$) for males and 128.43 cm² (AUC = 0.845; 95 % CI, 0.708-0.982; $p < 0.001$) for females. The SATA cut-off values indicating subcutaneous obesity were 145.75 cm² (AUC = 0.895; 95 % CI, 0.825-0.965; $p < 0.001$) and 218.81 cm² (AUC = 0.875; 95 % CI, 0.772-0.978; $p < 0.001$) in males and females, respectively.

NUTRITIONAL AND INFLAMMATORY PARAMETERS

The nutritional and inflammatory parameters of the patients are presented in table II. The patients' mean BMI was 27.1 ± 5.09 kg/m² and those with malnutrition had a lower mean BMI than those without malnutrition ($p < 0.001$). Additionally, SMI, VATA, and SATA were lower in patients with malnutrition. The prevalence of sarcopenia was 27.3 % among patients with malnutrition and 6.1 % in those without malnutrition ($p = 0.001$). The prevalence of visceral and subcutaneous obesity was lower in patients with malnutrition ($p = 0.028$, $p = 0.017$, respectively). There was no significant difference in mean grip strength between patients with and without malnutrition ($p = 0.139$). Nevertheless, the frequency of low grip strength was higher in malnourished patients (45.5 %) ($p = 0.037$). The E-DII was 0.5 ± 1.46 in the patients with malnutrition and -0.2 ± 1.19 in those without malnutrition ($p = 0.010$), and individuals in E-DII tertile 3 (higher pro-inflammatory diet indicator) accounted for approximately half (47.3 %) of the patients with malnutrition. While there was no significant difference in inflammatory biochemical parameters such as DNI and PNI, the frequency NLR ≥ 3 was higher in patients with malnutrition (56.4 %) compared to those without (34.8 %) ($p = 0.018$).

Table II. Nutritional and inflammatory parameters of patients

Variables	Total (n = 121)	Malnutrition		p
		No (n = 66)	Yes (n = 55)	
BMI (kg/m²)	27.1 ± 5.09	28.7 ± 5.14	25.11 ± 4.29	< 0.001*
SMI (cm²/m²)	48.6 ± 9.81	51.1 ± 7.94	45.6 ± 11.01	0.002*
VATA (cm²)	157.4 (115.31)	185.7 (98.63)	139.8 (121.70)	0.027*
SATA (cm²)	171.7 (134.48)	207.1 (160.10)	144.4 (101.47)	0.001*
Grip strength (kg)	25.8 ± 8.70	26.9 ± 9.20	24.5 ± 7.95	0.139
Low grip strength No Yes	 78 (64.5 %) 43 (35.5 %)	 48 (72.7 %) 18 (27.3 %)	 30 (54.5 %) 25 (45.5 %)	0.037*

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Table II (Cont.). Nutritional and inflammatory parameters of patients

Variables	Total (*n* = 121)	Malnutrition		*p*
		No (*n* = 66)	Yes (*n* = 55)	
Low skeletal muscle				
No	76 (62.8 %)	50 (75.8 %)	26 (47.3 %)	0.001*
Yes	45 (37.2 %)	16 (24.2 %)	29 (52.7 %)	
Sarcopenia				
No	102 (84.3 %)	62 (93.9 %)	40 (72.7 %)	0.001*
Yes	19 (15.7 %)	4 (6.1 %)	15 (27.3 %)	
Visceral obesity				
No	55 (45.5 %)	24 (36.4 %)	31 (56.4 %)	0.028*
Yes	66 (54.5 %)	42 (63.6 %)	24 (43.6 %)	
Subcutaneous obesity				
No	56 (46.3 %)	24 (36.4 %)	32 (58.2 %)	0.017*
Yes	65 (53.7 %)	42 (63.6 %)	23 (41.8 %)	
E-DII	0.1 ± 1.35	-0.2 ± 1.19	0.5 ± 1.46	0.010*
E-DII				
Tertile 1 (-3.87 to -0.57)	40 (33.1 %)	27 (40.9 %)	13 (23.6 %)	0.008*
Tertile 2 (0.57 to 0.75)	41 (33.9 %)	25 (37.9 %)	16 (29.1 %)	
Tertile 3 (0.75 to 3.17)	40 (33.1 %)	14 (21.2 %)	26 (47.3 %)	
DNI				
< 0.1	94 (77.7 %)	54 (81.8 %)	40 (72.7 %)	0.232
≥ 0.1	27 (22.3 %)	12 (18.2 %)	15 (27.3 %)	
NLR				
< 3	67 (55.4 %)	43 (65.2 %)	24 (43.6 %)	0.018*
≥ 3	54 (44.6 %)	23 (34.8 %)	31 (56.4 %)	
PNI				
≥ 45	16 (13.2 %)	7 (10.6 %)	9 (16.4 %)	*0.352*
< 45	105 (86.8 %)	59 (89.4 %)	46 (83.6 %)	

*BMI: body mass index; SMI: skeletal muscle index; VATA: visceral adipose tissue area; SATA: subcutaneous adipose tissue area; E-DII: energy-adjusted dietary inflammatory index; DNI: delta neutrophil index; NLR: neutrophil lymphocyte ratio; PNI: prognostic nutritional index. *p < 0.05 is significant*

POSTOPERATIVE OUTCOMES

The results of the logistic regression analysis for risk factors predicting postoperative complications in CRC are shown in table III. Surgical approach ($p = 0.034$), sarcopenia ($p = 0.003$), visceral obesity ($p = 0.041$), malnutrition ($p < 0.001$), E -DII ($p = 0.001$) and NLR ($p = 0.011$) were risk factors associated with complications in univariate analysis. The multivariate analysis revealed that sarcopenia [OR = 3.973 (1.028-15.353), $p = 0.043$], malnutrition [OR = 3.954 (1.479-10.575), $p = 0.006$] and E-DII [OR = 4.955 (1.397-17.571), $p = 0.013$] were independent risk factors to predict postoperative complications.

In the univariate analysis of factors associated with long-term postoperative hospital stay, age ($p = 0.039$), surgical approach ($p = 0.001$), Charlson comorbidity index ($p = 0.023$), postoperative complication ($p < 0.001$) sarcopenia ($p = 0.002$), malnutrition ($p = 0.005$), and NLR ($p = 0.022$) were significant. In the multivariate analysis surgical approach [OR = 2.962 (1.133-7.747), $p = 0.027$], postoperative complication [OR = 16.993 (4.616-62.558), $p < 0.001$] and sarcopenia [OR = 6.894 (1.080-43.998), $p = 0.041$] were independent risk factors for long-term postoperative hospital stay (Table IV).

DISCUSSION

Our study has demonstrated the predictive role of various nutritional parameters in postoperative complications and long-term hospital stay in CRC.

Tabla III. Logistic regression analysis for predicting postoperative complications (Clavien-Dindo ≥ 2) in colorectal cancer

Variables	Univariate analysis			Multivariate analysis		
	OR	95 % CI	*p*	OR	95 % CI	*p*
Gender Male Female	 Ref 0.463	0.200-1.074	0.073			
Age (years) < 65 ≥ 65	 Ref 1.111	0.518-2.386	0.787			
BMI (kg/m²) < 25 ≥ 25	0.934 Ref 0.671	0.860-1.013 0.308-1.464	0.100 0.316			
Tumor location Colon Rectum	 Ref 0.747	0.346-1.613	0.457			
Surgical approach Laparoscopic Open	 Ref 2.424	 1.067-5.509	 0.034*	 Ref 1.557	 0.581-4.170	 0.379
Charlson comorbidity index	1.160	0.924-1.455	0.201			
TNM stage I II III	 Ref 1.342 1.232	 0.406-4.433 0.381-3.984	 0.630 0.728			
Stoma No Yes	 Ref 1.563	 0.725-3.367	 0.254			
Operation duration (min)	1.003	0.998-1.009	0.256			
Sarcopenia No Yes	 Ref 4.762	 1.699-13.348	 0.003*	 Ref 3.973	 1.028-15.353	 0.043*
Visceral obesity No Yes	 Ref 0.445	 0.205-0.968	 0.041*	 Ref 0.586	 0.222-1.545	 0.280
Subcutaneous obesity No Yes	 Ref 0.547	 0.253-1.183	 0.125			
Malnutrition No Yes	 Ref 7.600	 3.150-18.339	 < 0.001*	 Ref 3.954	 1.479-10.575	 0.006*
E-DII Tertile 1 (-3.87 to -0.57) Tertile 2 (0.57 to 0.75) Tertile 3 (0.75 to 3.17)	 Ref 2.631 5.667	 0.885-7.817 1.951-16.462	 0.082 0.001*	 Ref 4.955	 1.397-17.571	 0.013*

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Table III (Cont.). Logistic regression analysis for predicting postoperative complications (Clavien-Dindo ≥ 2) in colorectal cancer

Variables	Univariate analysis			Multivariate analysis		
	OR	95 % CI	*p*	OR	95 % CI	*p*
DNI						
< 0.1	Ref					
≥ 0.1	1.985	0.823-4.790	0.127			
NLR						
< 3	Ref			Ref		
≥ 3	2.773	1.263-6.087	0.011*	1.779	0.676-4.682	0.243
PNI						
≥ 45	Ref					
< 45	1.351	0.629-2.902	0.441			

*BMI: body mass index; E-DII: energy-adjusted dietary inflammatory index; DNI: delta neutrophil index; NLR: neutrophil lymphocyte ratio; PNI: prognostic nutritional index. *p < 0.05 is significant.*

Table IV. Logistic regression analysis for risk factors predicting long-term (> 7 days) postoperative hospital stay in colorectal cancer

	Univariate analysis			Multivariate analysis		
Variables	OR	95 % CI	*p*	OR	95 % CI	*p*
Gender						
Male	Ref					
Female	0.992	0.474-2.074	0.983			
Age (years)						
< 65 years	Ref			Ref		
≥ 65 years	2.153	1.041-4.453	0.039*	1.488	0.459-4.820	0.508
BMI (kg/m²)						
< 25	Ref					
≥ 25	0.569	0.269-1.202	0.140			
Tumor location						
Colon	Ref					
Rectum	1.642	0.792-3.405	0.182			
Surgical approach						
Laparoscopic	Ref			Ref		
Open	3.600	1.683-7.700	0.001*	2.962	1.133-7.747	0.027*
Charlson comorbidity index	1.296	1.037-1.620	0.023*	1.088	0.750-1.578	0.656
TNM stage						
I	Ref					
II	1.611	0.539-4.817	0.393			
III	0.750	0.259-2.175	0.596			
Stoma						
No	Ref					
Yes	1.930	0.931-4.003	0.077			
Operation duration (min)	1.003	0.998-1.009	0.208			

(Continues on next page)

Tabla IV (Cont.). Logistic regression analysis for risk factors predicting long-term (> 7 days) postoperative hospital stay in colorectal cancer

	Univariate analysis			Multivariate analysis		
Variables	**OR**	**95 % CI**	***p***	**OR**	**95 % CI**	***p***
Postoperative complication						
No	Ref			Ref		
Yes	17.824	5.744-55.308	<0.001*	16.993	4.616-62.558	< 0.001*
Sarcopenia						
No	Ref			Ref		
Yes	10.767	2.363-49.051	0.002*	6.894	1.080-43.998	0.041*
Visceral obesity						
No	Ref					
Yes	0.523	0.253-1.080	0.080			
Subcutaneous obesity						
No	Ref					
Yes	0.561	0.272-1.157	0.118			
Malnutrition						
No	Ref			Ref		
Yes	2.915	1.386-6.131	0.005*	0.722	0.258-2.017	0.534
E-DII						
Tertile 1 (-3.87 to -0.57)	Ref					
Tertile 2 (0.57 to 0.75)	0.864	0.361-2.066	0.742			
Tertile 3 (0.75 to 3.17)	1.353	0.560-3.267	0.502			
DNI						
< 0.1	Ref					
≥ 0.1	1.518	0.637-3.614	0.346			
NLR						
< 3	Ref			Ref		
≥ 3	2.368	1.135-4.940	0.022*	1.723	0.662-4.481	0.265
PNI						
≥ 45	Ref					
< 45	1.414	0.490-4.080	0.521			

*BMI: body mass index; E-DII: energy-adjusted dietary inflammatory index; DNI: delta neutrophil index; NLR: neutrophil lymphocyte ratio; PNI: prognostic nutritional index. *p < 0.05 is significant.*

Malnutrition was diagnosed using the recently validated GLIM criteria for CRC patients in our study (21). The use of the GLIM criteria can provide an objective and standardized assessment of malnutrition and can be an important tool in clinical practice. The prevalence of malnutrition defined by GLIM criteria was 45.5 % in our study. Studies defining malnutrition in CRC using GLIM criteria are still limited. However, in a few recent studies, this prevalence has been reported to be approximately 23.6 % to 60.7 % (22-24). This wide range is thought to be due to differences in age, cancer stage and application of GLIM criteria (such as muscle measurement technique) in the study populations. We also found that the risk of complications was four times higher in patients with malnutrition defined according to GLIM criteria compared to those without. Previous studies have previously shown that malnutrition, as defined by different nutritional screening tools, affects postoperative outcomes in CRC patients (25,26). Furthermore, malnutrition, defined according to GLIM criteria in recent years, has also been shown to negatively affect postoperative outcomes in CRC, similar to our results (22,27,28).

Our findings showed that a high preoperative pro-inflammatory diet increased the risk of postoperative complications. Previously published studies have reported that a high DII score increases the risk of developing CRC (14,29) and is even associated with post-diagnosis mortality (30). As far as we know, this is the first study investigating the impact of dietary inflammatory potential, as assessed by the E-DII, on the risk of postoperative complications in CRC. However, it has been reported that n-3 polyunsaturated fatty acids taken in the habitual diet in CRC patients lead to a decrease in the frequency of postoperative complications (31). In another study, a high intake of dietary fiber in the preoperative diet was associated with a lower risk of postoperative complications (32). Considering the anti-inflammatory properties of both n-3 fatty acids and dietary fiber, it can be said that these results parallel the findings of our study, which addressed the preoperative diet with the E-DII, incorporating both of these dietary components. In our study, we did not find a significant association between the E-DII and the risk of long-term hospitalization; however, a previous study has shown that an anti-inflammatory DII score reduced the length of hospital stay (15). The DII, being an index created based on the relationship between dietary components and inflammatory processes (13), is likely to have an impact on surgical outcomes. However, studies assessing not only the nutritional status of patients before surgery but also their overall dietary consumption, including nutrient compositions, diet quality, and the inflammatory potential of the diet, are needed.

In our research, we employed CT images at the level of the third lumbar vertebra for the assessment of body composition. As CT scanning is part of the diagnostic process in CRC patients, it does not require additional expenses and radiation exposure. Moreover, it has been widely utilized for the measurement of body composition in cancer patients in recent years. Despite advances in treatment approaches, high mortality rates in colorectal cancer patients highlight the importance of the prognostic role of body composition-related parameters such as sarcopenia and obesity (1,33,34). Our study revealed that the prevalence of sarcopenia according to EWGSOP2 criteria was 15.7 % and, as expected, the prevalence of sarcopenia was higher in malnourished patients. In a recent meta-analysis, the prevalence of sarcopenia, defined on the basis of CT-based low skeletal muscle mass, was reported to be 34 % (35). Similarly, in our study, the prevalence of CT-based low skeletal muscle mass was 37.2 %. However, in the revised sarcopenia criteria, muscle strength has been established as the primary criterion, as it is considered better at predicting adverse outcomes than muscle mass (12). According to our findings, sarcopenia as defined by the revised criteria is an independent risk factor for postoperative complications and long-term hospitalization. Consistent with our findings, previous studies on CRC have reported that preoperative sarcopenia increases the risk of postoperative morbidity and mortality (10,11,33,36). Nevertheless, all of these studies defined sarcopenia based on skeletal muscle mass alone. As far as we know, the association between sarcopenia determined by EWGSOP2 criteria and postoperative outcomes in CRC has not been previously reported. The lack of universally accepted criteria for diagnosing sarcopenia, as well as variations in measurement techniques and cutoffs for skeletal muscle mass in studies, complicates the interpretation of results.

In contrast to sarcopenia, the effect of visceral or subcutaneous obesity on postoperative outcomes has been less studied and remains unclear. A recent meta-analysis reported that CT-derived visceral obesity had no effect on overall postoperative complications and mortality (37). Similarly, in our study, both visceral and subcutaneous obesity showed no significant impact on postoperative complications and length of hospital stay. However, some studies have found that visceral obesity increases the risk of postoperative ileus and general complications (38,39). On the contrary, some studies have shown favorable effects of visceral and subcutaneous obesity on survival in CRC (34,40). In a recent study, no association was found between visceral obesity and survival and length of hospital stay (33). Although the reason for these inconsistent results has not been clearly explained, different methods of determining adipose tissue area between studies, different cutoff values and population-specific factors such as ethnicity may influence clinical outcomes. Furthermore, our study determined CT-based cut-off values for visceral and subcutaneous adipose tissues using ROC curve analysis to overcome the lack of population-specific cut-off values not available in the literature. These cut-off values are important for future studies as they provide confirmatory and comparable data.

Our study has some limitations such as being single-centered and the observational design limiting causal inference. In addition, although our aim was to obtain a 3-day dietary consumption record to assess the preoperative dietary inflammatory potential, we were only able to obtain a 1-day dietary record using the 24-hour recall method due to the preoperative fasting status of the patients. However, unlike most retrospective studies in this field, the strength of our study was its prospective design and comprehensive assessment of preoperative nutritional factors.

CONCLUSION

Preoperative sarcopenia, malnutrition, and inflammatory capacity of the diet can be used as determinants of early outcomes in CRC surgery. As part of perioperative care, it is important to conduct a comprehensive examination of nutrition-related factors, including nutritional status, body composition, and inflammatory capacity of the diet. Timely intervention based on these factors can improve postoperative outcomes, which is beneficial for both patient welfare and hospital costs.

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