ASTR

ORIGINAL ARTICLE
pISSN 2288-6575 • eISSN 2288-6796
https://doi.org/10.4174/astr.2026.110.3.170
Annals of Surgical Treatment and Research

Association of body composition and nutritional status with survival in stage IV colorectal cancer patients who underwent resection: a retrospective cohort study

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Purpose: Although host body composition, nutritional and systemic inflammatory status have been suggested to have an impact on prognosis in patients with colorectal cancer (CRC), their impact on patients with stage IV CRC remains unclear. This study investigated the prognostic effects of those parameters in patients initially diagnosed with stage IV CRC who underwent surgery.
Methods: Patients with stage IV CRC who underwent surgery were selected. Preoperative computed tomography images were evaluated for skeletal muscle index, skeletal muscle density (SMD), visceral fat area (VFA), and subcutaneous fat area (SFA). For nutritional status and systemic inflammation, prognostic nutritional index (PNI), neutrophil-to-lymphocyte ratio (NLR), lymphocyte-to-monocyte ratio (LMR), and platelet-to-lymphocyte ratio (PLR) were used. The Cox proportional hazard model was used to evaluate the prognostic significance of progression-free survival (PFS) after adjustment for the other covariates in the model.
Results: Data of 134 patients with stage IV CRC who underwent surgery between January 2005 and February 2014 were included. SMD, VFA, SFA, PNI, NLR, LMR, and PLR were associated with PFS in the univariable analysis. In the multivariable analysis, SFA (hazard ratio [HR], 0.612; 95% confidence interval [CI], 0.389–0.961; P = 0.033), and PNI (HR, 0.536; 95% CI, 0.345–0.832; P = 0.005) were identified to be independent prognostic factors for PFS.
Conclusion: SFA and PNI both demonstrated prognostic significance in patients with stage IV CRC. Accordingly, we believe further studies are warranted to determine whether incorporating these factors can aid in surgical decision-making for stage IV CRC patients.
[Ann Surg Treat Res 2026;110(3):170-179]

Key Words: Body composition, Colorectal neoplasms, Inflammation, Nutritional status

Received July 14, 2025, **Revised** August 11, 2025,
Accepted September 1, 2025

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INTRODUCTION

Colorectal cancer (CRC) is one of the most common malignancies of the digestive system and the third most common cause of cancer-related death in both males and females [1]. In Korea, CRC is the third most diagnosed cancer in males and in females, with an incidence of 33,158 newly diagnosed cases in 2022 alone [2].

Patients diagnosed with CRC receive postoperative chemotherapy or radiation treatment guided by the TNM staging [3,4]. Weiser et al. [5] reported that although the 5-year expected recurrence-free survival (RFS) was 48% in stage IIIB rectal cancer patients, the clinical calculator-predicted RFS ranged from 7% to 68%. These results confirm that, even if the staging is the same, the prognosis may be diverse. Therefore, the staging system requires additional factors to predict patient prognosis.

In the search for factors with predictive capacity, recent studies have found that general conditions, such as systemic inflammation at the time of diagnosis, have an impact on patient prognosis [6,7]. Systematic inflammatory status can be compared using various inflammatory markers, such as the platelet-to-lymphocyte ratio (PLR) or the neutrophil-to-lymphocyte ratio (NLR) [8]. Nutritional status was measured using the prognostic nutritional index (PNI). PNI was first introduced to show patients' immunological and nutritional aspect and it has been demonstrated to show greater prognostic ability using albumin and lymphocytes [7,9].

Moreover, body composition has been recognized as a prognostic factor. Sarcopenia, a state of low muscle strength and low skeletal muscle quantity and quality, and myosteatosis are associated with worse outcomes in patients diagnosed with solid tumors [10-13]. Additionally, several studies have reported a correlation between subcutaneous or visceral fat and survival in patients with CRC [14-16]. However, most of these studies were conducted in patients with non-metastatic CRC [14-16]. Hence, the impact of these physical characteristics on stage IV CRC remains unclear.

Stage IV CRC has an especially worse prognosis, and in most patients, the standard therapy is palliative chemotherapy with or without surgery [17,18]. Although the clinical association of various factors with prognosis has been evaluated in patients with stage IV CRC, the results vary among studies [19,20]. In a study focused on stage IV CRC patients, nutritional and inflammatory status were assessed without taking body composition into account [20]. Other studies that examined the psoas muscle index or skeletal muscle index (SMI) as a prognostic factor in patients with stage IV CRC had relatively small sample sizes [19,21]. Furthermore, many studies have been undertaken on a diverse patient cohort, comprising individuals who did not undergo surgery and a mixed group that underwent either surgery or exclusively received chemotherapy [22,23], making studies on patients with stage IV CRC who underwent surgery even rarer. In stage IV CRC, the initial impression of resectability impacts patient survival [24]. Thus, evaluation of the prognostic effect of inflammatory and nutritional conditions, as well as body composition, in stage IV CRC patients is necessary.

This study aimed to investigate the prognostic effect of systemic inflammation, nutritional conditions, and body composition variables in patients initially diagnosed with stage IV CRC who underwent surgery for the primary or metastatic tumor for palliative or curative purposes.

METHODS

Ethics statement

The Institutional Review Board of Gangnam Severance Hospital approved this study (No. 3-2021-0455) and waived the requirement for written informed consent due to the retrospective nature of the study.

Study design and settings

We conducted a retrospective study involving patients diagnosed with CRC who underwent surgery at Gangnam Severance Hospital, Yonsei University College of Medicine. Medical records from January 2005 to February 2014 were initially analyzed, and 1,609 patients who underwent resection for CRC were identified. Patients were excluded based on cell type, tumor location, tumor stage, and type of treatment received. Furthermore, patients who underwent emergency operations, were suspected of having inflammatory bowel disease, and whose body composition data were unavailable were excluded. Supplementary Fig. 1 shows the details of the patient selection.

Variables associated with body composition

CT images of each patient were used to compare their body composition. To maintain consistency, CT images of the third lumbar vertebral level were analyzed. As we already stated in our previous study, portal phase or arterial phase images were selected to measure body composition [25]. The visceral fat area (VFA), subcutaneous fat area (SFA), and skeletal muscle area (SMA) were measured using BMI_CT, an in-house open-source software (available online at https://sourceforge.net/projects/muscle-fat-area-measurement/) [26]. Additionally, to measure the skeletal muscle density (SMD) at the selected level, a 3-dimensional slicer open-source software was used (https://www.slicer.org) [27]. In our previous study, the intra-class correlation coefficients for SMA, SMD, VFA, and SFA were 0.97, 0.99, 0.99, and 1, respectively [25]. Hence, the body composition of our cohort was assessed by a sole investigator (JK).

The area of each variable was measured in Hounsfield units (HU), with each variable described in different ranges. VFA was obtained in the HU range of –150 to –50; SFA, –190 to –30; and SMA, –29 to 150. Using this HU threshold range, SMD was calculated as the mean HU value of the obtained SMA. SMI was calculated by dividing the measured SMA value by the patient's height (cm^2/m^2).

Variables associated with the nutritional index

We used PNI, derived from the patients' preoperative blood data, to assess their nutritional status. This was calculated as 10 × serum albumin concentration (g/dL) added to 0.005 × total lymphocyte count ($/mm^3$) [28].

Variables associated with systemic inflammation

To assess the patients' inflammatory status, their preoperative serum data were used. The NLR was measured by dividing the number of neutrophils ($/mm^3$) by the number of lymphocytes ($/mm^3$); lymphocyte-to-monocyte ratio (LMR), by dividing the number of lymphocytes ($/mm^3$) by the number of monocytes ($/mm^3$); PLR, by dividing the number of platelets ($/mm^3$) by the number of lymphocytes ($/mm^3$).

Statistical analysis

Categorical data were analyzed using the chi-square test, and continuous variables were analyzed using the Student t-test or Mann-Whitney U-test. Progression-free survival (PFS) was defined as the period from the date of surgery to the date of disease progression or death, whichever came first [29]. PFS was estimated using the Kaplan-Meier survival curve, and its difference was evaluated using the log-rank test.

For the statistical analysis of body composition and inflammatory variables, the cutoff values for PFS of VFA and SFA for both male and female patients, PNI, NLR, LMR, and PLR were obtained using the 'X-tile' program [30]. The X-tile program (Yale University) produced the optimal cutoff value by choosing the value that produced the largest chi-square on the Mantel-Cox test.

Univariable and multivariable analyses for PFS were performed using the Cox proportional hazards model, which was used to determine the factors associated with PFS. After we entered all the variables significant in the univariable analysis ($P < 0.05$), multivariable analysis was done using the backward selection method.

Differences were considered statistically significant at $P < 0.05$. All statistical analyses were performed using the R program ver. 4.2.0 (R Foundation for Statistical Computing).

RESULTS

In total, 134 patients were included in the analysis. The median follow-up period was 37.18 months (interquartile range, 16.98–84.86 months).

Patients' characteristics

This study included 134 patients who underwent resection for stage IV CRC. Of these, 57 (42.5%) were female and 77 (57.5%) were male. Fifty-three (39.6%) were less than 60 years old, while 81 (60.4%) were 60 years old or above. A total of 43 patients (32.1%) underwent neoadjuvant chemotherapy before resections. One hundred seven patients (79.9%) had 1 metastatic site, while others (20.1%) had 2 or more metastatic sites. Eighty-four patients (62.7%) underwent curative resection, and the others (37.3%) underwent palliative resections. A microsatellite instability (MSI) test was done for 68 patients; among them, only 1 patient showed MSI-high. In case of Kirsten rat sarcoma viral oncogene homolog (KRAS) status, 35 patients (26.1%) were KRAS wild type, while 20 patients (14.9%) were KRAS mutated (Table 1). Detailed metastatic site was illustrated in Supplementary Table 1.

When comparing overall body composition and inflammatory status between the curative and palliative resection groups, there were no significant differences in SMI, SMD, VFA, or SFA. Conversely, the palliative resection group demonstrated

Table 1. Baseline demographic and clinical characteristics of patients with stage IV CRC

Characteristic	Data
No. of patients	134
Sex, female/male	57 (42.5)/77 (57.5)
Age (yr)	
<60	53 (39.6)
≥60	81 (60.4)
Body mass index (kg/m^2)	
<25	104 (77.6)
≥25	30 (22.4)
CEA (ng/mL)	
<5	38 (28.4)
≥5	92 (68.7)
Unknown	4 (3.0)
Tumor location	
Colon	111 (82.8)
Rectum	23 (17.2)
Histologic grade	
G1 and G2	122 (91.0)
G3, MC, and SRC	12 (9.0)
LVI	
Absent	61 (45.5)
Present	64 (47.8)
Unknown	9 (6.7)
Neoadjuvant chemotherapy	43 (32.1)
No. of metastatic site(s)	
1	107 (79.9)
≥2	27 (20.1)

Table 1. Continued

Characteristic	Data
Postoperative palliative chemotherapy	
FOLFOX or XELOX	82 (61.2)
FOLFIRI or XERIRI	12 (9.0)
FOLFOX + target agents	9 (6.7)
FOLFIRI + target agents	4 (3.0)
Xeloda + bevacizumab	3 (2.2)
IV 5-FU/LV or Xeloda	6 (4.5)
No treatment	13 (9.7)
Unknown	5 (5.2)
Surgical treatment	
Curative resection	84 (62.7)
Palliative resection	50 (37.3)
MSI	
MSS	67 (50.0)
MSI-high	1 (0.7)
Unknown	66 (49.3)
KRAS	
KRAS wild type	35 (26.1)
KRAS mutated	20 (14.9)
Unknown	79 (59.0)
SMI	48.32 ± 8.77
SMD	42.13 ± 8.14
VFA	97.24 ± 58.80
SFA	116.03 ± 46.61
PNI	48.49 ± 7.32
NLR	3.20 ± 3.74
LMR	4.60 ± 2.10
PLR	195.49 ± 167.45

Values are presented as number only, number (%), or mean ± standard deviation.
CRC, colorectal cancer; MC, mucinous carcinoma; SRC, signet ring cell carcinoma; LVI, lymphovascular invasion; FOLFOX, fluorouracil, leucovorin, and oxaliplatin; XELOX, capecitabine and oxaliplatin; FOLFIRI, fluorouracil, leucovorin, and irinotecan; XERIRI, capecitabine and irinotecan; 5-FU, fluorouracil; LV, leucovorin; MSI, microsatellite instability; MSS, microsatellite stable; KRAS, Kirsten rat sarcoma viral oncogene homolog; SMI, skeletal muscle index; SMD, skeletal muscle density; VFA, visceral fat area; SFA, subcutaneous fat area; PNI, prognostic nutritional index; NLR, neutrophil-to-lymphocyte ratio; LMR, lymphocyte-to-monocyte ratio; PLR, platelet-to-lymphocyte ratio.
Target agents included cetuximab and bevacizumab.

lower PNI and LMR levels, alongside higher NLR and PLR values (Supplementary Table 2).

Defining the cutoff value

There was a significant sex-dependent difference in VFA and SFA, indicating that their cutoff values were sex-specific, whereas those for PNI, NLR, LMR, and PLR were not. The cutoff values for VFA were 34.23 cm^2 in males and 47.95 cm^2 in females, and those for SFA were 78.71 cm^2 and 110.37 cm^2, respectively (Supplementary Fig. 2). The cutoff values for PNI, NLR, LMR, and PLR were 48.20, 2.47, 2.72, and 251.2, respectively (Supplementary Fig. 3). For SMI or SMD, cutoff values were adopted from the existing literature without additional determination [31].

Kaplan-Meier survival curves according to progression-free survival

In the Kaplan-Meier analysis of PFS, the patients with lower SMD in preoperative CT images had worse PFS than those with higher SMD ($P = 0.009$). Similarly, the patients with lower VFA and SFA in the CT images had worse PFS than those with higher VFA and SFA ($P = 0.036$ and $P < 0.001$, respectively) (Fig. 1).

Furthermore, survival rates were computed based on variations in serum inflammatory and nutritional markers. NLR and PLR showed prognostic value, as patients with higher scores had better PFS ($P = 0.002$ and $P < 0.001$, respectively). A lower LMR was associated with a worse PFS ($P = 0.011$). PNI was also shown to have a prognostic effect in patients with a low index, resulting in a worse PFS than in patients with a higher index ($P < 0.001$) (Fig. 2).

Univariable and multivariable analysis of progression-free survival

In the univariable analysis of PFS, lymphovascular invasion ($P < 0.001$), number of metastatic site(s) ($P = 0.002$), surgical treatment ($P < 0.001$), postoperative chemotherapy ($P < 0.001$), KRAS status ($P = 0.03$), SMD ($P = 0.010$), VFA ($P = 0.030$), SFA ($P < 0.001$), PNI ($P < 0.001$), NLR ($P = 0.002$), LMR ($P = 0.012$), and PLR ($P < 0.001$) were significantly associated with PFS (Table 2).

In the multivariable analysis, surgical treatment (hazard ratio [HR], 2.662; 95% confidence interval [CI], 1.730–4.098; $P < 0.001$), postoperative chemotherapy (yes *vs.* no, HR 4.637, 95% CI, 2.486-8.646, $P < 0.001$), SFA (HR 0.612, 95% CI, 0.389-0.961, $P = 0.033$), and PNI (HR 0.536, 95% CI, 0.345-0.832, $P = 0.005$) were found to be independent prognostic factors for PFS (Table 3).

DISCUSSION

We measured the body composition and nutritional and inflammatory statuses of patients with stage IV CRC who underwent surgery, and investigated their impact as prognostic factors. We found that SFA and PNI were significant prognosticators for advanced-stage patients at diagnosis; thus, emphasizing the need for evaluation of preoperative host status and body composition in management.

The host response to tumors is of great interest and importance because of its impact on cancer treatment outcomes. Of various host-related factors, body composition is a representative factor and can roughly be compared through obesity. Obesity has been traditionally assessed through body mass index (BMI) or waist circumference; however, some reports suggest that BMI and waist circumference may not be adequate

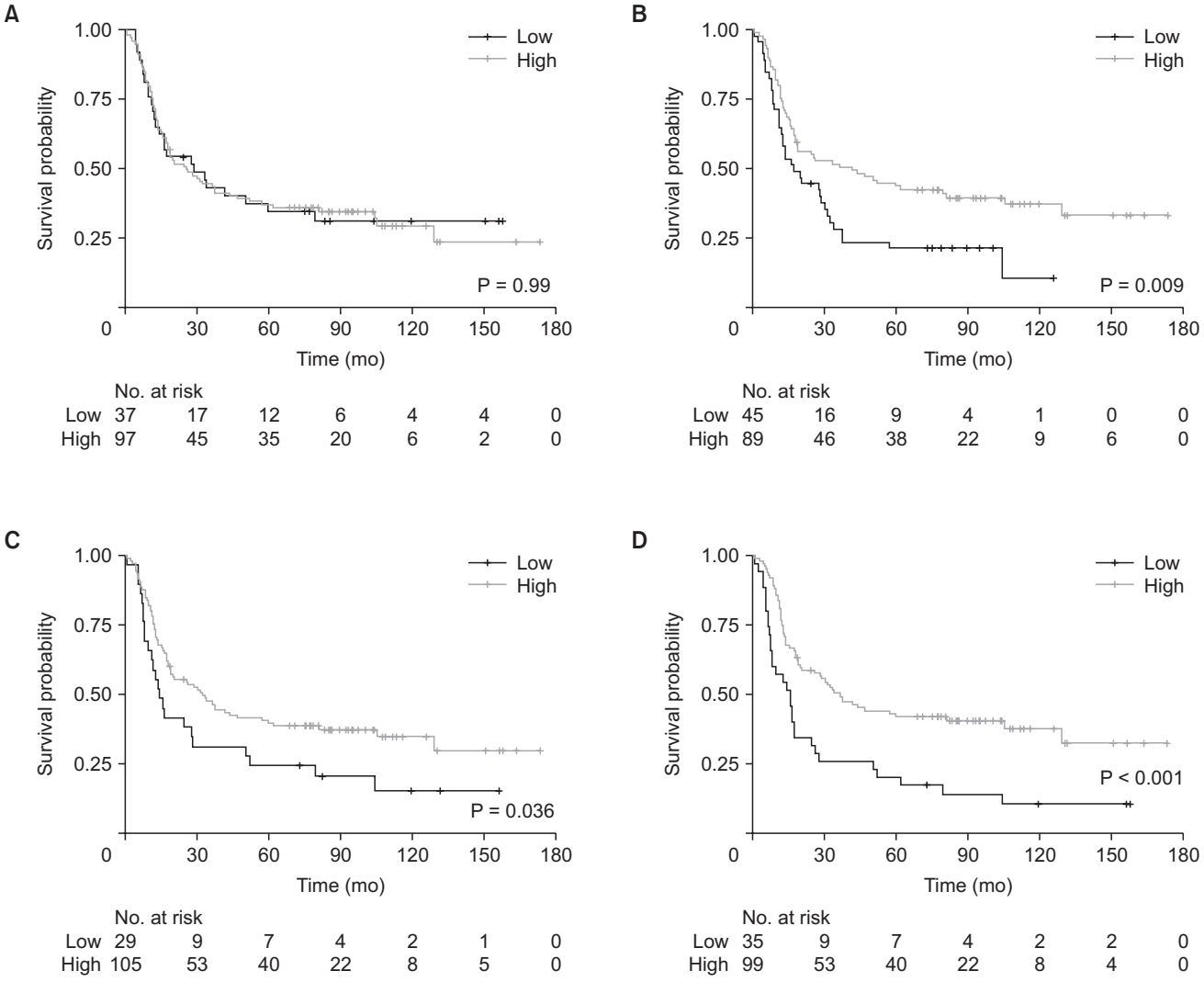

Fig. 1. Kaplan-Meier survival curve according to the body composition. Patients with higher skeletal muscle index did not show a significant difference in progression-free survival (PFS) (P = 0.99) (A). The Kaplan-Meier survival curve showed significantly better PFS in patients with higher skeletal muscle density (P = 0.009) (B), visceral fat area (P = 0.036) (C), and subcutaneous fat area (P < 0.001) (D), respectively.

measures [32]. Comparing muscle mass and quality measured by CT scan has been increasingly proposed and may be more useful for prognostication in patients [13,33]. Advanced cancer can create metabolic abnormalities in skeletal muscle through host-related factors such as pro-inflammatory cytokines and inadequate nutritional intake [34]. Skeletal muscle status, indicated by SMI and SMD, has been suggested as a prognostic factor in various types of cancers [13,33]. However, our study showed that neither SMI nor SMD had a significant prognostic impact in the multivariable analysis; therefore, skeletal muscle measured at a certain point may not be useful in the prognostication of advanced CRC patients. According to some studies, the optimal cutoff values of SMI and SMD differ per clinical situation [35,36]. If a more appropriate cutoff value for advanced CRC patients is applied, the result may be different. In addition, skeletal muscle loss during the treatment can be a more useful prognosticator in advanced CRC patients [37]. Thus, the serial changes of skeletal muscle during the treatment need to be evaluated in further study.

Visceral and subcutaneous fat are both well-known adipose tissues but have different effects, and studies have shown different results with respect to their prognostic impact [14,38,39]. Some studies have shown favorable results for visceral fat based on the finding that visceral fat, compared with subcutaneous fat, produces more pro-inflammatory cytokines and less adiponectin [38]. Adiponectin is a negative regulator of tumor angiogenesis, and it has been found that adiponectin can inhibit CRC growth in animal models [40]. Contrarily, another study reported that visceral fat level does not have a prognostic impact on patient mortality or survival [39]. Recently, our group

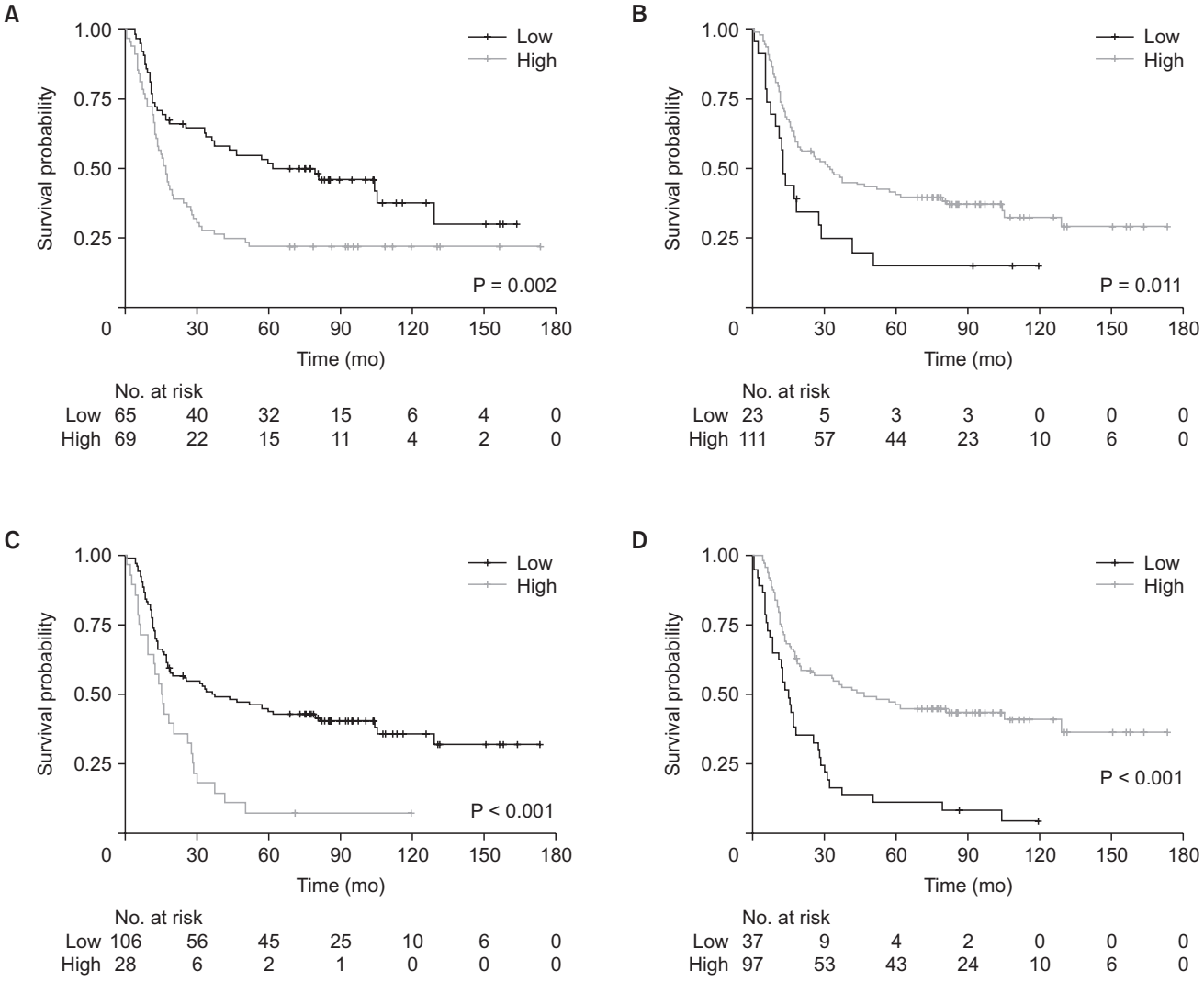

Fig. 2. Kaplan-Meier survival curve according to the nutritional and inflammatory variables. The Kaplan-Meier survival curve showed significantly better progression-free survival (PFS) in patients with lower neutrophil-to-lymphocyte ratio (P = 0.002) (A) and platelet-to-lymphocyte ratio (P < 0.001) (C). Patients with higher lymphocyte-to-monocyte ratio and prognostic nutritional index showed significantly better PFS (P = 0.011 [B] and P < 0.001 [D]).

reported that subcutaneous fat had a better prognostic effect than visceral fat in patients with stage I–III CRC [14]. However, a complete conclusion was not reached regarding the effect of visceral or subcutaneous fat in CRC patients, as further research was needed, especially in patients with stage IV CRC. This study demonstrated that a higher SFA led to a longer PFS, which supported SFA as a better prognostic variable than VFA, similar to our prior report on patients with stages I–III CRC.

The PNI was used to evaluate the patients' nutritional status. Several guidelines recommend that nutritional support may be useful for improving patient outcomes after surgery [41]. Nutritional status must be measured to help determine which patients should be treated beforehand, and objective nutritional scores are needed to maintain consistency in patient selection. Ucar et al. [42] reported that patients with high PNI showed better survival (HR, 0.61; 95% CI, 0.42–0.87) than those with low PNI in 308 metastatic CRC patients. Our study also showed that the PNI can be useful in predicting outcomes in stage IV patients.

Previous studies found that inflammatory variables, including NLR, LMR, and PLR, can be used as predictive factors in patients with CRC [43]. Neutrophil activation can lead to the release of growth factors (such as vascular endothelial growth factor) and chemokines (such as interleukin-8), which contribute to tumor angiogenesis [44]. NLR can provide useful information by balancing the tumorigenic activity of neutrophils and the lymphocyte's immune activity [45]. Although a high NLR showed a lower survival probability than a low NLR in the univariable analysis in our analysis, this significance was not maintained in the multivariable analysis. Thus, the usefulness

Table 2. Univariable analysis of factors associated with progression-free survival

Variable	HR (95% CI)	P-value
Sex		
Female	1	
Male	0.983 (0.649–1.491)	0.938
Age (yr)		
<60	1	
≥60	0.772 (0.510–1.170)	0.224
Body mass index (kg/m^2)		
<25	1	
≥25	0.719 (0.424–1.221)	0.222
CEA (ng/mL)		
<5	1	
≥5	0.858 (0.549–1.342)	0.503
Unknown	0.220 (0.029–1.620)	0.137
Tumor location		
Colon	1	
Rectum	1.120 (0.651–1.926)	0.681
Histologic grade		
G1 and G2	1	
G3, MC, and SRC	1.068 (0.516–2.209)	0.860
LVI		
Absent	1	
Present	2.184 (1.405–3.394)	<0.001
Unknown	1.143 (0.446–2.923)	0.780
Neoadjuvant chemotherapy		
No	1	
Yes	0.970 (0.618–1.522)	0.896
Number of metastatic site(s)		
1	1	
≥2	2.071 (1.283–3.344)	0.002
Surgical treatment		
Curative resection	1	
Palliative resection	3.044 (1.996–4.641)	<0.001
Postoperative chemotherapy		
Yes	1	
No	5.752 (3.101–10.667)	<0.001
Unknown	1.911 (0.695–5.254)	0.210
KRAS		
Wild type	1	
Mutated	2.031 (1.042–3.959)	0.037
Unknown	1.434 (0.864–2.381)	0.163
SMI		
Low	1	
High	1.003 (0.632–1.590)	0.990
SMD		
Low	1	
High	0.574 (0.375–0.879)	0.010
VFA		
Low	1	
High	0.608 (0.381–0.971)	0.037
SFA		
Low	1	
High	0.461 (0.298–0.713)	<0.001
NLR		
Low	1	
High	1.898 (1.245–2.895)	0.002
LMR		
Low	1	
High	0.523 (0.314–0.870)	0.012
PLR		
Low	1	
High	2.380 (1.496–3.787)	<0.001

HR, hazard ratio; CI, confidence interval; MC, mucinous carcinoma; SRC, signet ring cell carcinoma; LVI, lymphovascular invasion; SMI, skeletal muscle index; SMD, skeletal muscle density; VFA, visceral fat area; SFA, subcutaneous fat area; PNI, prognostic nutritional index; NLR, neutrophil-to-lymphocyte ratio; LMR, lymphocyte-to-monocyte ratio; PLR, platelet-to-lymphocyte ratio.

Table 3. Multivariable analysis of factors associated with progression-free survival

Variable	HR (95% CI)	P-value
Surgical treatment		
Curative resection	1	
Palliative resection	2.662 (1.730–4.098)	<0.001
Postoperative chemotherapy		
Yes	1	
No	4.637 (2.486–8.646)	<0.001
Unknown	1.513 (0.533–4.294)	0.436
SFA		
Low	1	
High	0.612 (0.389–0.961)	0.033
PNI		
Low	1	
High	0.536 (0.345–0.832)	0.005

HR, hazard ratio; CI, confidence interval; SFA, subcutaneous fat area; PNI, prognostic nutritional index.
Multivariable analysis was adjusted for surgical treatment, postoperative chemotherapy, SFA, and PNI.

of NLR as a prognostic factor in stage IV patients needs to be validated in future research.

Our study had several merits. Although several studies have presented the interrelation between systemic inflammation and body composition, or nutritional status and body composition of patients with CRC, few studies have considered all of these variables at once. The strength of our study was that the prognostic impact of various host-related factors such as body composition, nutritional status, and inflammatory status were evaluated at the same time. Each of the selected factors in this study was used for daily patient care and was, therefore, meaningful. Nevertheless, the interactions among these parameters were complex and often unclear; therefore,

our study suggests that further research is needed to clarify the interplay among these factors. In recent times, novel molecular markers have been employed to improve the prognostic stratification of CRC. Nonetheless, their application is hindered by the substantial expenses involved and the requirement for a considerably invasive procedure—either a biopsy or surgery—to obtain the specimen for thorough analysis. Contrarily, our study used factors that can be acquired through minimally invasive techniques (CT scan and serum data); therefore, it has the advantage of being easy to use clinically. In case of patients with stage IV CRC, there are various options such as surgery, chemotherapy, or radiotherapy. Therefore, identifying the factors that can affect the prognosis can help determine the appropriate treatment. There are often situations in which the morbidity of surgery must be considered when deciding whether to perform surgical treatment for stage IV patients. Therefore, if the prognosis of the patient is predicted by considering these host factors, it can be helpful in deciding whether or not to perform surgery, although our retrospective study could not suggest clear guidelines.

The study was limited by its retrospective nature and patient enrollment. Selection bias may be present as data was collected from a single institution. In light of the unavailability of accurate data for Eastern Cooperative Oncology Group performance status or Karnofsky Performance Scale, we chose to exclude these variables from our analysis. The inability to ascertain the role of this readily measurable performance status in patients with stage IV CRC can be considered a limitation of this study. Molecular test results are a particularly important guideline for selecting chemotherapy drugs for patients with stage IV CRC, and MSI is regarded as an important indicator for immunotherapy. However, only some of these tests were confirmed clinically during the study period, and some were not performed at all. It cannot be ruled out that the patients received more appropriate treatment when these tests were performed accurately. However, since there is no way to confirm this, this point is judged to be important to be dealt with when planning a follow-up prospective study. Additionally, our study only included Asian patients. Since body composition can vary among ethnic groups, further studies evaluating various ethnic groups are warranted. Also, further research exploring whether reverse causality was involved in each of our factors with prognostic capacity will be needed. In addition, CT images were only used at a single point; follow-up images of the patient were not provided for comparison.

In conclusion, we found that among various inflammatory, nutritional, and body composition-related factors, SFA and PNI had a prognostic impact on the survival of patients with stage IV CRC. Accurate evaluation of these host factors before making a surgical plan for patients with stage IV CRC is expected to be helpful in prognostication.

SUPPLEMENTARY MATERIALS

Supplementary Tables 1, 2 and Supplementary Fig. 1–3 can be found via https://doi.org/10.4174/astr.2026.110.3.170.

ACKNOWLEDGEMENTS

The data supporting the findings of this study were obtained from the Institutional Review Board of Gangnam Severance Hospital. These data are not publicly available; however, they may be obtained from the authors upon reasonable request and with permission from the Institutional Review Board of Gangnam Severance Hospital.

Fund/Grant Support

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. 2022R1F1A1074811).

Conflict of Interest

Jeonghyun Kang, serving as an Associate Editor of *Annals of Surgical Treatment and Research*, did not participate in the review process of this article. No other potential conflicts of interest pertinent to this article were reported.

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Methodology: ESC
Resources: SJS
Visualization: JWL, JHL, SJS
Writing – Original Draft: JWL, JK
Writing – Review & Editing: All authors

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