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ORIGINAL RESEARCH

Prognostic Role of Pre-Treatment Body Composition Parameters in Patients Undergoing First-Line Immunotherapy for Metastatic Renal Cell Carcinoma

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Purpose: We investigated the relationship between body mass index (BMI), radiological body composition, and survival outcomes in patients with metastatic renal cell carcinoma (mRCC) underwent first-line immune checkpoint inhibitor (ICI)-based therapy.

Methods: Analyzing data from 102 patients treated between November 2019 and March 2023, pre-treatment computed tomography (CT) scans assessed fat and muscle areas. BMI and body composition indices were examined, including skeletal muscle index, subcutaneous fat index (SFI), visceral fat index, and total fat index. Kaplan–Meier curves and Log rank tests compared progression-free survival (PFS) and overall survival (OS), while multivariable Cox proportional regression analysis was performed to identify the variables significantly associated with survival outcomes.

Results: 54 patients (52.9%) experienced disease progression, and 26 (25.5%) died during a median follow-up of 17.4 months. High SFI was significantly associated with improved OS (p = 0.018) but not PFS (p = 0.090). Multivariable analysis confirmed the positive impact of high SFI on OS (adjusted HR: 0.37, $p = 0.029$) and suggested a trend towards improved PFS (adjusted HR: 0.61, $p = 0.088$). Notably, in the ipilimumab + nivolumab subgroup, high SFI significantly correlated with both PFS and OS ($p = 0.047$ and $p = 0.012$, respectively).

Conclusion: High SFI predicts favorable OS in patients with mRCC receiving first-line ICI-based therapy, especially patients treated with ipilimumab + nivolumab displayed a significant association between high SFI and favorable PFS and OS.

Keywords: immunotherapy, renal cell carcinoma, body composition, prognosis

Introduction

Obesity is a risk factor for renal cell carcinoma (RCC). However, an intriguing phenomenon known as the "obesity paradox" has emerged in metastatic RCC (mRCC), where it is paradoxically associated with a favorable prognosis.[1] In the current era of first-line immune checkpoint inhibitor (ICI)-based therapies for mRCC, several studies have explored the association between body mass index (BMI) and treatment outcomes. A few studies have reported a positive correlation between high BMI and improved overall survival (OS).[2,3] Conversely, other studies have reported no significant relationship between BMI and OS during first-line ICI-based therapy,[3–6] and certain studies have demonstrated a potential association between low BMI and improved progression-free survival (PFS).[4,6] This controversy arises

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from the constraint that BMI, despite its ease of measurement, inadequately captures the true muscle and fat composition of individuals.[7]

Therefore, researchers are shifting their focus from obesity to investigating the relationship between body composition, via radiological measurements of muscle and fat, and patient outcomes. Specifically, the potential significance of radiologic body composition as a prognostic factor for patients undergoing ICI-based therapy is being actively investigated to optimize treatment strategies for mRCC.

A previous study involving patients with mRCC, receiving ICIs across several lines of therapy, reported correlations between low skeletal muscle quantity and poor OS.[8] Another study assessing patients undergoing ICI-based treatment in any line of therapy revealed worse OS outcomes among those with a low total fat area.[9] However, studies on patients treated with first-line ICI therapy have shown conflicting results. One study indicated that lower skeletal muscle mass was correlated with both poorer OS and PFS.[10] In contrast, another pattern emerged with first-line ICI therapy, where low skeletal muscle mass and low subcutaneous fat were associated with significantly improved PFS in patients with mRCC.[6] In contrast, another study indicated that lower skeletal muscle mass was correlated with both poorer OS and PFS. This finding suggests that the relationship between body composition parameters, specific lines of ICI therapy, and treatment outcomes in mRCC is intricate and warrants further investigation, potentially offering room for improving the prognosis of these patients. Altogether, we explored the associations among BMI, radiologic body composition variables, OS, and PFS in patients with mRCC undergoing first-line ICI-based therapy.

Methods

Study Population and Variables

This study was approved by the Institutional Review Board of Samsung Medical Center (IRB no. 2023–12-089), which waived the requirement for written informed consent due to the retrospective design of the study. All study protocols were performed in accordance with the Declaration of Helsinki, and all patient data complied with relevant privacy regulations and data protection.

This retrospective study assessed 110 patients with mRCC who received first-line ICI-based treatment at our hospital between November 2019 and March 2023. Patients without a computed tomography (CT) scan performed > 120 days before the initiation of systemic therapy or those with CT scans unsuitable for a fat distribution measuring program were excluded from the study. Eight patients were excluded due to inappropriate pre-treatment CT scans. Finally, 102 patients were included in this analysis.

We collected clinical information reported at the initiation of treatment including age, sex, BMI, ICI regimen, cytoreductive nephrectomy, International Metastatic RCC Database Consortium (IMDC) risk (favorable/intermediate/poor risk),[11] time from diagnosis to systemic therapy, Karnofsky performance status, hemoglobin (g/dL), number of neutrophils (cells/L), number of platelets (cells/μL), corrected calcium (mg/dL), histology type, and the number of metastases. Moreover, BMI was calculated as follows: BMI (kg/m²) = ([weight]/[height]²). Cytoreductive nephrectomy was defined as the resection of the primary tumor in cases of metastatic lesions. PFS was defined as the duration between the initiation of ICI-based treatment and disease progression or death from any cause. OS was defined as the time from the start of treatment to the date of death or last follow-up. The best response to systemic treatment was classified based on radiological measurements using RECIST version 1.1[12] encompassing complete response (CR), partial response (PR), stable disease (SD), and progressive disease (PD).

Radiologic Analysis of Anthropometry

Abdominal CT scans acquired before the initial ICI treatment were analyzed using the open-source semi-automated software (BMI_CT, version 1.0; available at https://sourceforge.net/projects/muscle-fat-area-measurement/) based on MATLAB version R2010a (Mathworks Inc., Natick, MA, USA). The cross-sectional areas (cm^2) of skeletal muscles (including the rectus, transverse, and oblique abdominal muscles, psoas muscles, and paraspinal muscles), subcutaneous fat, and visceral fat were measured at the level of the third lumbar vertebra[13] using a semiautomated method comprising three steps, namely, preprocessing, boundary detection, and identification.[14] During preprocessing, the background image

(including the CT table and noise) was removed from the original image. In the boundary detection step, the boundary between the muscle and inner organs (including the liver, spleen, and soft tissues) was semiautomatically detected using the active contour method and morphological image processing techniques. In the identification step, subcutaneous fat, muscle, and visceral fat were detected on preprocessed CT images using fuzzy c-means clustering algorithms (Figure 1).

Patients were grouped according to a BMI cutoff of 25 kg/m², as determined from previous studies on the relationship between BMI and outcomes in patients with cancer treated with ICI.[2–5] Muscle and fat areas (cm^2) were normalized by dividing them by the square of the patient's height (m^2) to calculate the following standardized indices:[15] skeletal muscle index (SMI), subcutaneous fat index (SFI), visceral fat index (VFI), and total fat index (TFI) (cm^2/m^2). We applied SMI cutoff values of 40.8 cm²/m² for males and 34.9 cm²/m² for females, which are generally used among patients with cancer in Asian countries.[16,17] As no validated cutoff points existed for the VFI, SFI, and TFI, these variables were dichotomized based on sex-specific medians within the cohorts. The cutoff values were as follows: VFI (males: 37.0 cm^2/m^2, females: 53.4 cm^2/m^2), SFI (males: 32.8 cm^2/m^2, females: 17.6 cm^2/m^2), and TFI (males: 69.9 cm^2/m^2, females: 74.3 cm^2/m^2).

Statistical Analysis

Continuous variables are presented as mean ± standard deviation (SD), and they were compared using independent *t*-tests. For categorical variables, absolute counts (percentages) were reported, and comparisons were performed using either Pearson's chi-squared test or Fisher's exact test, depending on the applicability. Based on the best response, patients were classified by combining CR and PR as responders, and SD and PD as non-responders. Subsequently, the distribution of responses was analyzed according to high or low BMI and body composition. Kaplan–Meier curves were constructed, and the Log rank test was used to compare the PFS and OS between individuals with low and high BMI or body composition indices. Multivariable Cox proportional regression analysis was conducted to identify variables significantly predicting OS and PFS with ICI-based therapy. Multivariate models for BMI were adjusted for age, sex, treatment regimen (ICI with tyrosine kinase inhibitor (TKI) vs ipilimumab + nivolumab), histological type (non-clear cell

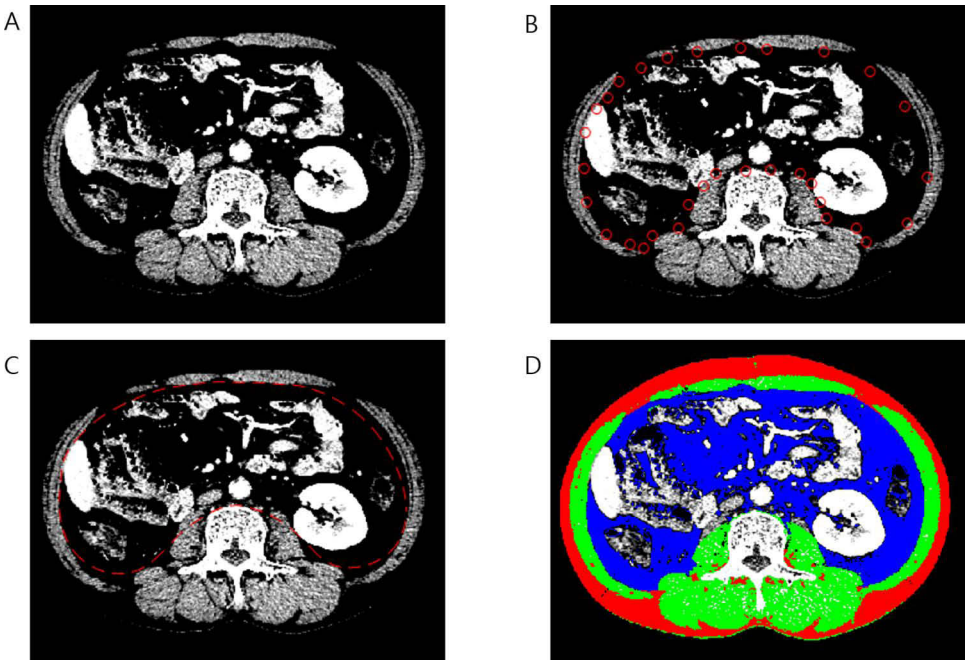

Figure 1 Semiautomatic quantification of body composition in a 58-year-old male with metastatic renal cell carcinoma. To enhance the visibility of muscle boundaries, computed tomography (CT) image intensity was linearly transformed into a range of 0 to +100 Hounsfield Units (HU) (**A**). Following semiautomatic manipulation (**B**), the active contour method is used to detect the boundary between muscles and inner tissues by minimizing a cost function, thereby segmenting CT images into inner and outer regions (**C**). Subsequently, pixels corresponding to fat and muscle are identified using predefined cut-off values of −300 to −50 HU and −29 to +150 HU, respectively. Regions of muscle, subcutaneous fat, and visceral fat are displayed as color-coded in green, red, and blue, respectively (**D**). The cross-sectional areas of muscle, subcutaneous fat, and visceral fat are quantified at 140.18 cm², 94.95 cm², and 186.46 cm², respectively. CT, computed tomography; HU, Hounsfield unit.

vs clear cell), cytoreductive nephrectomy, IMDC risk (favorable risk as the reference), and the number of metastasis site (multiple vs single). Multivariable models for body composition variables (SMI, SFI, VFI, and TFI) were adjusted for age, treatment regimen (ICI with TKI vs ipilimumab + nivolumab), histological type (non-clear cell vs clear cell), cytoreductive nephrectomy, IMDC risk, and the number of metastasis site (multiple vs single). Sex was not included as a cutoff for these variables, which is inherently sex-specific. Subgroup analyses were subsequently conducted by categorizing patients into a clear cell RCC subgroup, a subgroup treated with ipilimumab + nivolumab, and a subgroup treated with a combination of ICI and TKI. Statistical analyses were performed using SPSS (version 29.0; IBM, Armonk, New York, USA), with statistical significance set at $p < 0.05$.

Results

Demographic Information and Baseline Disease Characteristics

A total of 102 patients were analyzed, of whom 75.5% were male with an average age of 59.8 years (Table 1). Within the cohort, 31 (30.4%) patients had a high BMI, and 72 (70.6%) displayed a high SMI. The first-line ICI-based therapy regimen included ipilimumab + nivolumab (n = 62), pembrolizumab + axitinib (n = 28), nivolumab + cabozantinib (n = 5), pembrolizumab + lenvatinib (n = 4), and avelumab + axitinib (n = 3). Most patients were classified as either at intermediate (52.9%) or poor (39.2%) risk. Clear cell-type histology was dominant, accounting for 87.3% of the cases.

Table 1 Baseline Characteristics of the Study Cohort at the Initiation of ICI-Based Therapy

Variables	
No. of patients, *n* (%)	102 (100)
Age, mean ± SD	59.8 ± 12.5
Sex, *n* (%)	
Male	77 (75.5)
Female	25 (24.5)
IO regimens, *n* (%)	
Ipilimumab + Nivolumab	62 (60.8)
Pembrolizumab + Axitinib	28 (27.5)
Nivolumab + Cabozantinib	5 (4.9)
Pembrolizumab + Lenvatinib	4 (3.9)
Avelumab + Axitinib	3 (2.9)
Cytoreductive Nephrectomy, *n* (%)	30 (29.4)
BMI (kg/m^2), mean ± SD	23.5 ± 3.6
< 25, *n* (%)	71 (69.6)
≥ 25, *n* (%)	31 (30.4)
IMDC risk, *n* (%)	
Favorable	8 (7.8)
Intermediate	54 (52.9)
Poor	40 (39.2)

(*Continued*)

Table 1 (Continued).

Variables	
<1 year from time of diagnosis to systemic therapy, *n* (%)	77 (75.5)
Karnofsky performance status <80%, *n* (%)	13 (12.7)
Hemoglobin < 13.6 g/dL, *n* (%)	82 (80.4)
Neutrophils > 8.30×10^9 cells/L, *n* (%)	9 (8.8)
Platelets > 316×10^3 cells/μL, *n* (%)	31 (30.4)
Corrected calcium > 10 mg/dL, *n* (%)	13 (12.7)
Histology, *n* (%)	
Clear cell	89 (87.3)
Non-clear cell	13 (12.7)
No. of metastasis site, *n* (%)	
Single	37 (36.3)
Multiple	65 (63.7)
SMI (cm^2/m^2), mean ± SD	44.4 ± 10.5
Low SMI, *n* (%)	30 (29.4)
High SMI, *n* (%)	72 (70.6)

Abbreviations: BMI, body mass index; IMDC, International Metastatic RCC Database Consortium; SD, standard deviation; SMI, skeletal muscle index.

Patients were categorized into two groups based on a BMI cutoff of 25. Additionally, the distribution of body composition parameters was also assessed (Table 2). In the group with a BMI ≥ 25, a significant number of patients demonstrated elevated values for fat measurement indices (SFI, VFI, TFI; $p = 0.001$, <0.001, and <0.001, respectively). Conversely, no statistically significant difference was observed in the muscle measurement index (ie, SMI) between the two groups ($p = 0.087$). In addition, baseline characteristics were analyzed to compare patients with high and low SFI

Table 2 Distribution of Radiologic Body Composition Parameters According to BMI Categories

Parameters, *n* (%)		BMI < 25	BMI ≥ 25	*p-value*
SMI	Low	25 (35.2)	5 (16.1)	0.087
	High	46 (64.8)	26 (83.9)	
SFI	Low	44 (62.0)	7 (22.6)	0.001
	High	27 (38.0)	24 (77.4)	
VFI	Low	45 (63.4)	6 (19.4)	<0.001
	High	26 (36.6)	25 (80.6)	
TFI	Low	46 (64.8)	5 (16.1)	<0.001
	High	25 (35.2)	26 (83.9)	

Abbreviations: BMI, body mass index; SMI, skeletal muscle index; SFI, subcutaneous fat index; TFI, total fat index; VFI, visceral fat index.

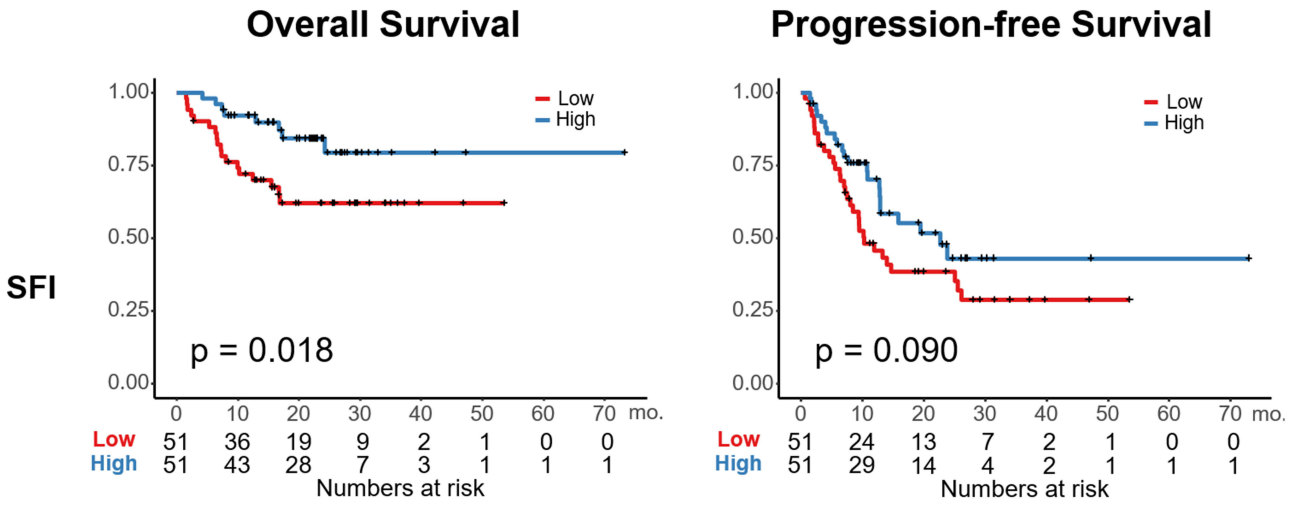

Figure 2 Kaplan–Meier analysis of overall survival and progression-free survival according to high and low subcutaneous fat indexes (SFI).

scores, as demonstrated in Supplementary Table 1. None of the characteristics exhibited significant differences between the two groups except for BMI distribution and histological type.

Association Between Survival Outcome and Body Composition

The median follow-up duration was 17.4 months, ranging from 11.7–27.2 months. During follow-up, 54 patients (52.9%) experienced disease progression, and 26 patients (25.5%) died. The Kaplan–Meier analysis demonstrated a notable advantage in OS for high SFI compared to that in low SFI (log-rank $p = 0.018$) (Figure 2). Although patients with high SFI exhibited a trend toward improved survival in terms of PFS, no statistically significant difference was noted in PFS between the high- and low-SFI groups (log-rank $p = 0.090$). No differences in PFS or OS between the low- and high-index groups were observed for BMI, SMI, VFI, and TFI (Supplementary Figure 1).

The multivariable Cox proportional regression analysis revealed that following adjustment, high SFI exhibited a significant association with improved OS (adjusted hazard ratio [HR]: 0.37, 95% confidence interval [CI]: 0.15 −0.90, $p = 0.029$) (Table 3). A tendency toward improved PFS was observed, although statistical significance was not achieved (adjusted HR: 0.61, 95% CI: 0.34–1.08, $p = 0.088$). In addition, an analysis of other parameters, such as BMI, SMI, VFI, and TFI, failed to reveal statistically significant associations with survival outcomes.

Table 3 Cox Proportional Regression Analysis for Overall Survival and Progression-Free Survival

	Overall Survival			Progression-Free Survival		
	Adjusted HR	**95% CI**	***p***	**Adjusted HR**	**95% CI**	***p-value***
BMI (high vs low)	0.58	0.21–1.59	0.292	0.98	0.52–1.84	0.943
SMI (high vs low)	1.02	0.42–2.44	0.966	1.15	0.62–2.11	0.659
SFI (high vs low)	0.37	0.15–0.90	0.029	0.61	0.34–1.08	0.088
VFI (high vs low)	0.50	0.21–1.18	0.114	0.79	0.44–1.41	0.422
TFI (high vs low)	0.54	0.23–1.25	0.150	0.73	0.41–1.28	0.272

Notes: The BMI was adjusted for age, sex, treatment regimen, histological type, cytoreductive nephrectomy, IMDC risk, and the number of metastasis site. The SMI, SFI, VFI, and TFI were adjusted for age, treatment regimen, histological type, cytoreductive nephrectomy, IMDC risk, and the number of metastasis site.
Abbreviations: BMI, body mass index; SMI, skeletal muscle index; SFI, subcutaneous fat index; TFI, total fat index; VFI, visceral fat index; HR, hazard ratio; CI, confidence interval.

The analysis of a subgroup comprising 89 patients with clear cell RCC revealed a sustained favorable association of high SFI with OS (adjusted HR: 0.40, 95% CI: 0.16–0.99, p = 0.049) (Supplementary Table 2). Further subgroup analyses were conducted based on the treatment regimen received, with 62 patients in the ipilimumab + nivolumab subgroup and 40 in the ICI with the TKI subgroup. In the ipilimumab + nivolumab subgroup, high SFI was significantly associated with improved OS (log-rank p = 0.027) (Figure 3). Although an association with PFS was observed, no statistical significance was attained (log-rank, p = 0.074). Conversely, no significant associations were observed between the ICI and TKI subgroup. Multivariable Cox regression analysis in the ipilimumab + nivolumab subgroup revealed a pronounced impact of high SFI on OS (adjusted HR: 0.20, 95% CI: 0.06–0.71, p = 0.012) and a significant association with PFS emerged (adjusted HR: 0.47, 95% CI: 0.22–0.99, p = 0.047) (Supplementary Table 3). However, the analysis failed to demonstrate the prognostic impact of high SFI on OS in the ICI and TKI subgroups (adjusted HR: 1.14, 95% CI: 0.20–6.56, p = 0.882) (Supplementary Table 4).

Association Between Treatment Response and Body Composition

In the patient cohort, nine individuals achieved CR, 51 demonstrated PR, 24 maintained SD, and 18 experienced PD. The distribution of responders and non-responders in relation to low or high BMI and body composition indices is displayed in Table 4; however, no statistical significance was observed within the distribution of the treatment response. Detailed information on the best responses is provided in Supplementary Table 5.

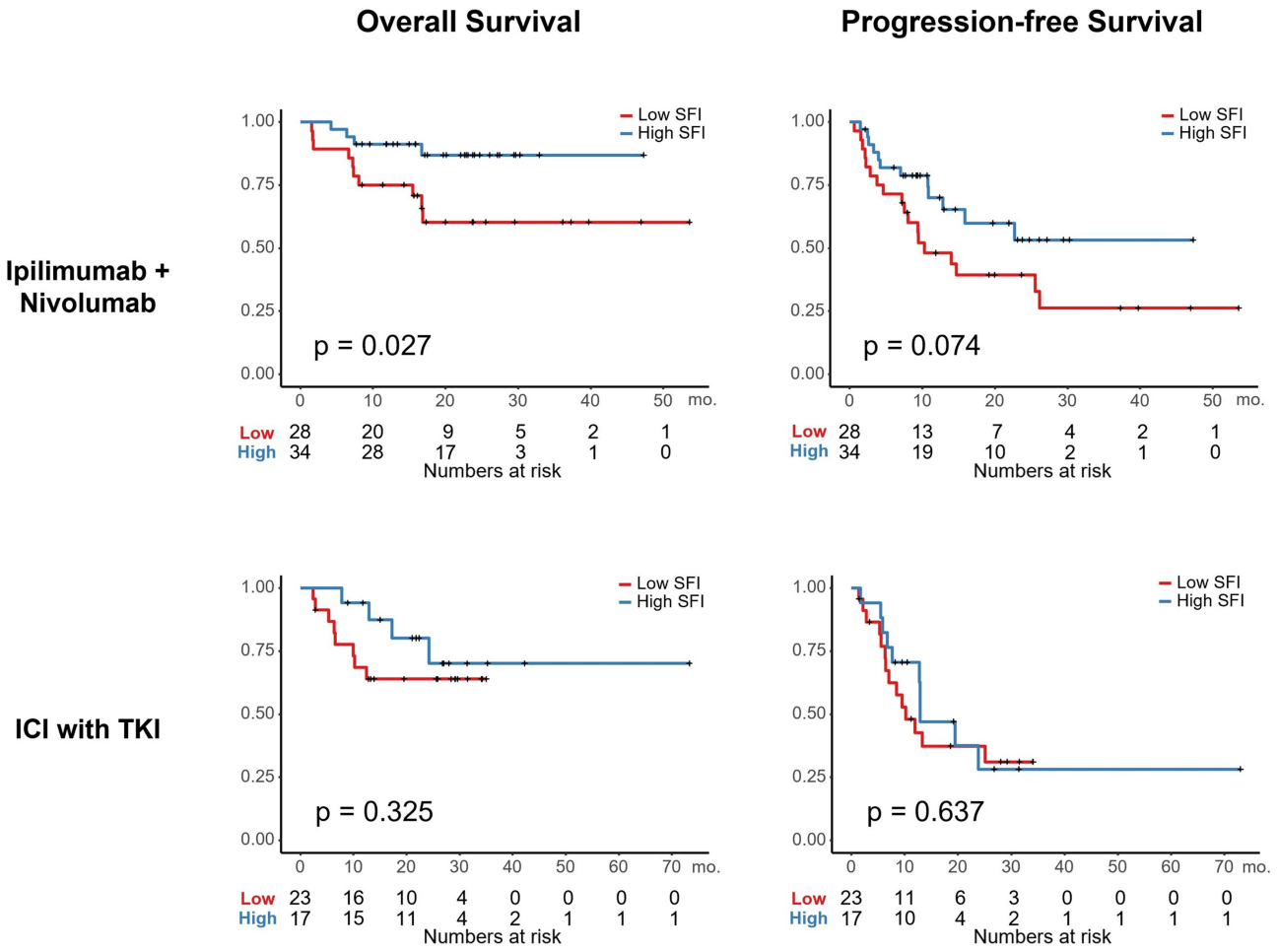

Figure 3 Kaplan–Meier analysis of overall survival and progression-free survival according to high and low subcutaneous fat indexes (SFI) in the ipilimumab + nivolumab subgroup and immune checkpoint inhibitors with tyrosine kinase inhibitor (ICI with TKI) subgroup.

Table 4 Distribution of Best Response According to the BMI and Body Composition Indexes

Parameters, *n* (%)		Responder	Non-Responder	*p-value*
BMI	Low	42 (59.2)	29 (40.8)	0.918
	High	18 (58.1)	13 (41.9)	
SMI	Low	22 (73.3)	8 (26.7)	0.055
	High	38 (52.8)	34 (47.2)	
SFI	Low	29 (56.9)	22 (43.1)	0.687
	High	31 (60.8)	20 (39.2)	
VFI	Low	30 (58.8)	21 (41.2)	1
	High	30 (58.8)	21 (41.2)	
TFI	Low	32 (62.7)	19 (37.3)	0.421
	High	28 (54.9)	23 (45.1)	

Abbreviations: BMI, body mass index; SMI, skeletal muscle index; SFI, subcutaneous fat index; TFI, total fat index; VFI, visceral fat index.

Discussion

In the present study, we investigated the correlation between BMI and several radiologic body composition parameters identified through pre-treatment CT, and the clinical outcomes observed in patients with mRCC undergoing first-line ICI-based therapy. Although BMI and other body composition indices did not demonstrate significant prognostic significance, we identified a significant association between high SFI and favorable OS. Moreover, in patients receiving ipilimumab + nivolumab, a high SFI was not only linked to OS but also to PFS. These findings contribute significantly to the expanding body of research, highlighting the efficacy of radiographic body composition variables as prognostic biomarkers in immunotherapy for RCC.

Several studies have explored the prognostic role of BMI in patients receiving first-line ICI-based therapy; however, the results remain controversial. A previous study involving patients with mRCC treated with first-line ICI-based therapy demonstrated that a BMI of 25 or higher was a significant predictor for favorable OS in the intermediate-risk group of 654 individuals (adjusted HR: 0.71, 95% CI: 0.55–0.92, $p = 0.009$).[2] In contrast, several studies have indicated a lack of a substantial correlation between BMI and OS in the context of first-line ICI-based therapy.[3–6] In particular, studies targeting Asian populations, such as our investigation involving 98 patients, demonstrated no correlation between BMI (using a cutoff of 25) and either PFS or OS (log-rank $p = 0.306$ and $p = 0.701$, respectively). We did not observe a correlation between BMI and survival outcomes, further contributing to the ongoing controversy on this issue. However, the mechanisms underlying the association between BMI and prognosis during ICI-based therapy remain unclear. Moreover, although BMI is easily measurable, the parameter may have limitations in accurately representing body composition, which actively influences biological mechanisms.[7]

To address the constraints of BMI, a previous study investigated radiologic body composition within the same treatment setting. An investigation of 99 patients with mRCC treated with first-line ipilimumab + nivolumab revealed that low SMI (adjusted HR: 2.433, 95% CI: 1.397–4.238, $p = 0.0017$) and SFI (adjusted HR: 1.641, 95% CI: 1.023–2.632, $p = 0.0398$) were associated with significantly improved PFS, but not OS.[6] The findings of an earlier study contradicted our research results, which indicated a positive correlation between high SFI and improved OS. This discrepancy between the two studies could be attributed to differences in the characteristics of study populations. Specifically, a study centered on Western patients with a median BMI of 27.3 kg/m^2 reported a value significantly higher than that observed in the current study (median BMI of 23.5 kg/m^2). Consequently, the high-SFI group in the earlier study likely included a significant proportion of morbidly obese patients, leading to a poor prognosis.

Furthermore, differences in treatment regimens between the two studies should be considered. A previous study exclusively included patients undergoing ipilimumab + nivolumab treatment, whereas the present study included 39.2% of patients treated with a combination of ICI and TKI. The potential impact of concurrently administered TKI cannot be disregarded; however, our subgroup analysis of patients treated with ipilimumab + nivolumab demonstrated that a high SFI was associated not only with OS but also with PFS. Another study examined the relationship between body composition and prognosis in patients with mRCC who received first-line ICI therapy.[10] The study included 26 patients (43% of the cohort) who received a combination of ICI and TKI treatments. The researchers found that low SMI was associated with poorer OS and PFS. However, the study did not conduct additional analysis comparing the effects of pure ICI versus ICI-TKI combination therapy, which presents an opportunity for further research. This highlights a limitation in these studies and suggests the influence of additional factors, including concurrent TKI use, beyond the response to ICI therapy alone. These factors could include improved energy and nutritional reserves as well as potential implications for non-cancer-related deaths, highlighting the need for additional studies to further explore the aforementioned considerations.

The biological mechanisms underlying the effect of obesity or fat quantity on the prognosis of patients with mRCC receiving ICI have not been completely elucidated. However, obesity has been determined to increase T-cell aging, resulting in high programmed cell death protein-1 (PD-1) expression and dysfunction, which are associated with leptin signaling.[18] Leptin downregulates exhaustive T-cell markers, such as PD-1. Notably, leptin concentration is largely regulated by subcutaneous abdominal fat, and the effect of visceral fat is minor.[19–21] Therefore, an elevated quantity of subcutaneous fat, which leads to increased leptin levels and subsequent overexpression of PD-1, along with PD-1-mediated T-cell dysfunction, could enhance the responsiveness of tumors to ICI therapy.[18] The divergent results between the previous study and ours indicate the need to conduct additional studies with a large sample size and focus on biological mechanisms to explore how body composition parameters, especially SFI, are associated with prognosis after first-line ICI-based therapy in patients with mRCC.

This study had several limitations. Firstly, because the study was conducted retrospectively, ICI-based therapy regimens were not uniformly standardized, and not all potential confounding factors were assessed. Secondly, given that it has only been a few years since the initiation of this treatment regimen, the relatively small number of sample size and short follow-up duration (median 17.4 months) might limit the thorough assessment of survival outcomes. Nevertheless, we could ascertain the direction in which body composition affected prognosis. Thirdly, although we established sex-specific median values as cutoff points, the absence of validated cutoff values for body composition parameters (excluding SMI) introduced statistical errors into the analysis. Lastly, the significant association observed between high SFI and OS, but not with PFS or response rate, suggested the possibility of factors beyond the ICI therapy response, such as improved energy and nutritional reserves, as well as potential implications for non–cancer-related deaths. This aspect was constrained in our study, highlighting the need for additional studies to further explore these considerations.

Conclusion

High SFI predicts favorable overall survival in patients with mRCC receiving first-line ICI-based therapy, particularly in those treated with ipilimumab + nivolumab. This finding highlights the potential of radiographic body composition parameters as prognostic biomarkers in immunotherapy for mRCC, though further research is needed to fully elucidate the underlying biological mechanisms.

Data Sharing Statement

The datasets generated during and/or analyzed during the current study are not publicly available due to patient confidentiality requirements, but are available from the corresponding author on reasonable request.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically

reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare no competing interests in this work.

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