Predictive value of nutritional indicators with regard to the survival outcomes in patients with metastatic esophageal squamous cell carcinoma treated with camrelizumab

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Abstract. Nutritional indicators have been implicated in the survival outcomes of various malignant tumors. However, there are few studies on the association between nutritional indicators and immunotherapy for esophageal cancer. The present study aimed to explore the value of nutritional indicators with regard to the survival outcomes in patients with metastatic esophageal squamous cell carcinoma (ESCC) treated with camrelizumab. A retrospective cohort analysis of 158 metastatic ESCC patients treated with camrelizumab in The Affiliated Xinghua People's Hospital, Medical School of Yangzhou University (Xinghua, China) between September 2019 and July 2022 was conducted. A receiver operating characteristic curve was used to determine the optimal cut-off values of prognostic nutritional index (PNI) and albumin (ALB). The cut-off value for body mass index (BMI) was set at the normal lower limit (18.5 kg/m^2). Progression-free survival (PFS) and overall survival (OS) were evaluated using the Kaplan-Meier method, and the differences in PFS or OS between groups were compared using the log-rank test. The prognostic value of each variable was analyzed based on the univariate and multivariate Cox proportional hazards regression models. The optimal cutoff values of PNI, ALB and BMI were 41.35, 36.8 g/l and 18.5 kg/m^2, respectively. Lower PNI, ALB and BMI were closely associated with shorter PFS [hazard ratio (HR) for PNI, 3.599; P<0.001; HR for ALB, 4.148; P<0.001; HR for BMI, 5.623; P<0.001) and OS (HR for PNI, 7.605; P<0.001; HR for ALB, 7.852; P<0.001; HR for BMI, 7.915; P<0.001) times. Univariate and multivariate Cox regression analyses indicated that lower PNI, ALB and BMI were independent risk factors of PFS and OS in patients with metastatic ESCC receiving camrelizumab treatment. In conclusion, PNI, ALB and BMI are promising predictive indicators to assess the survival outcomes in patients with metastatic ESCC treated with camrelizumab. Moreover, PNI, ALB and BMI may have prognostic significance in these patients.

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Introduction

Esophageal squamous cell carcinoma (ESCC) is one of the common malignant tumors threatening human health in China (1). Due to the lack of specific symptoms in early esophageal cancer and the low rate of gastroscopy in China, most patients lose the opportunity for surgery at the time of diagnosis, and the 5-year survival rate is poor (2). With the major breakthrough of immunotherapy in the treatment of cancer, esophageal cancer therapy has entered a new era. The significant efficacy of immunotherapy was demonstrated in the second-line treatment of esophageal cancer in several studies (3-6). Moreover, the results of other studies (7-10) further indicated that first-line immunotherapy combined with chemotherapy could significantly prolong survival time in patients with metastatic esophageal cancer, providing a strong basis for the use of first-line immunotherapy for esophageal cancer. However, there are still a considerable number of patients with primary or acquired resistance. To date, certain biomarkers, such as programmed cell death-ligand 1 (PDL-1), mismatch repair defects (MMR) and tumor mutation burden (TMB), have been frequently used to select the population that would best benefit from treatment (11-13). However, they are not ideal biomarkers owing to the differences in detection platforms and cutoff values, as well as the lack of sufficient tumor tissues to perform testing. There is therefore an urgent clinical need to explore biomarkers related to the efficacy of tumor immunotherapy.

A certain degree of malnutrition is present in a considerable number of patients with esophageal cancer. In recent years, more studies (14,15) have emphasized the importance of the nutritional

and immune statuses in patients with tumors, indicating that they play an important role in tumorigenesis, evolution and prognosis. In clinical practice, albumin (ALB), body mass index (BMI) and total lymphocyte count are often adopted to evaluate the nutritional status of patients with tumors. Buzby *et al* (16) first put forward the concept of the prognostic nutritional index (PNI), which is obtained by combining serum ALB level and peripheral blood lymphocyte count, and can to some extent reflect the nutritional and immune statuses of patients with tumors. Some studies (17-19) have reported that PNI is closely associated with the response and survival prognosis of esophageal cancer, metastatic non-small cell lung cancer and colorectal cancer. In addition, since PNI has the characteristic of being non-invasive and can be dynamically monitored, it has a potential clinical application value. However, whether nutritional indicators can predict the therapeutic efficacy and prognosis of patients with metastatic ESCC treated with immunotherapy is still unknown. Therefore, the present study explores the association between nutritional indicators and the efficacy and prognostic value of immunotherapy in patients with metastatic ESCC, in order to further guide clinical practice.

Patients and methods

Patient selection. The clinical data of 158 patients with metastatic ESCC treated with camrelizumab in The Affiliated Xinghua People's Hospital, Medical School of Yangzhou University (Xinghua, China) between September 2019 and July 2022 was collected. The inclusion criteria were as follows: i) Patients >18 years old; ii) patients who were pathologically diagnosed with ESCC; iii) patients who were treated with at least 3 cycles of camrelizumab; iv) an Eastern Cooperative Oncology Group Performance Status (20) score of 0-2; v) patients with complete evaluable imaging data and peripheral hematological parameters (peripheral lymphocyte count and serum ALB level) before treatment; and vi) patients at clinical stage IV, according to the eighth edition of the American Joint Committee on Cancer staging (21) manual. The exclusion criteria were as follows: i) Patients with incomplete clinicopathological data and follow-up information; ii) patients with hematological or autoimmune diseases; iii) patients with respiratory or cardiovascular diseases; iv) patients with a history of using steroid within 2 weeks of any disease; v) patients with multiple primary tumors; and vi) patients with severe dysphagia before treatment. A total of 17 patients were excluded and 158 patients were eventually enrolled. The whole enrollment process is presented in Fig. 1. The present study was approved by the Ethics Committee (protocol number: JSXHRYLL-NK-201901) of the Medical School of Yangzhou University (Xinghua, China). The last follow-up was performed on July 20, 2022.

Evaluation of efficacy and definition of PNI and BMI. A low-dose computed tomography scan and barium enema examination were performed before treatment and every 8 weeks after treatment. The Response Evaluation Criteria in Solid Tumors (RECIST version 1.1) (22) were adopted to evaluate response and efficacy. Three radiologists were asked to conduct efficacy evaluations for every patient. The primary endpoint of the study was OS time, which was defined as the time from initial treatment to death from any cause. For patients who had been lost to follow-up before death, the last follow-up time was considered as the equivalent to time of death. The secondary endpoint was PFS time, which was defined as the time from the start of treatment to disease progression or death from any cause. Immune-related adverse events (irAEs) were diagnosed using clinical practice guidelines (23).

PNI was defined as serum ALB (g/l) plus five times the total count of peripheral blood lymphocytes (10^9/l). According to the Guidelines for the Prevention and Control of Overweight and Obesity in Chinese Adults (24), BMI is defined as the weight before treatment divided by the square of the height, namely weight (kg)/height (m^2). A Beckman AU Series AU5800 instrument (Beckman Coulter, Inc.) and a Xisen Meikang XN9100 blood analysis instrument [Xisen Meikang Medical Electronics (Shanghai) Co. Ltd.] were used to perform peripheral blood testing. In order to ensure the accuracy of the ALB level and platelet count, internal quality control was performed once a day and the external quality assessment of Jiangsu Province Clinical Examination Center and the National Health Commission Clinical Inspection Center was participated in every half a year.

Statistical analysis. The optimal cut-off values for PNI and ALB were determined by receiver operating characteristic (ROC) curve. The χ^2 test was used to analyze the clinicopathological data between high and low PNI/ALB/BMI groups. Survival analyses between groups were performed using the Kaplan-Meier method and the log-rank test. Univariate and multivariate Cox proportional hazard models were used to evaluate the prognostic value of related variables. All statistical analyses were two-sided probability tests (α=0.05) and $P<0.05$ was considered to indicate a statistically significant difference. The statistical analyses were performed using IBM SPSS Statistic 26.0 (IBM Corp.).

Results

Patient characteristics. A total of 158 patients with metastatic ESCC receiving camrelizumab treatment were enrolled in this study. The median age at the time of diagnosis was 67 years (range, 52-87 years). The proportion of male patients was 63.9%. Patients with a drinking history accounted for 60.1% of all participants. A total of 50 patients (31.6%) had received first-line camrelizumab plus paclitaxel and cisplatin treatment. A total of 108 patients (68.4%) had received at least first-line treatment with paclitaxel plus cisplatin. Monotherapy was administered to 38.6% of the patients and combined chemotherapy was administered to 61.4% of the patients. The proportion of well-differentiated, moderately differentiated and poorly differentiated ESCC was 18.5, 51.3 and 32.3%, respectively. All patients were of clinical stage IV. The median PNI and ALB values before treatment were 44.3 (range, 34.5-55.4) and 39.3 g/l (range, 30.5-47.6 g/l), respectively. By July 2022, the median follow-up time was 11.1 months (range, 2.0-26.2 months).

Determination of optimal cut-off values for PNI, ALB and BMI. As shown in Fig. 2, the area under the ROC curve for PNI and ALB was 0.811 and 0.733, respectively. The optimal cut-off values for PNI and ALB, which were calculated by ROC

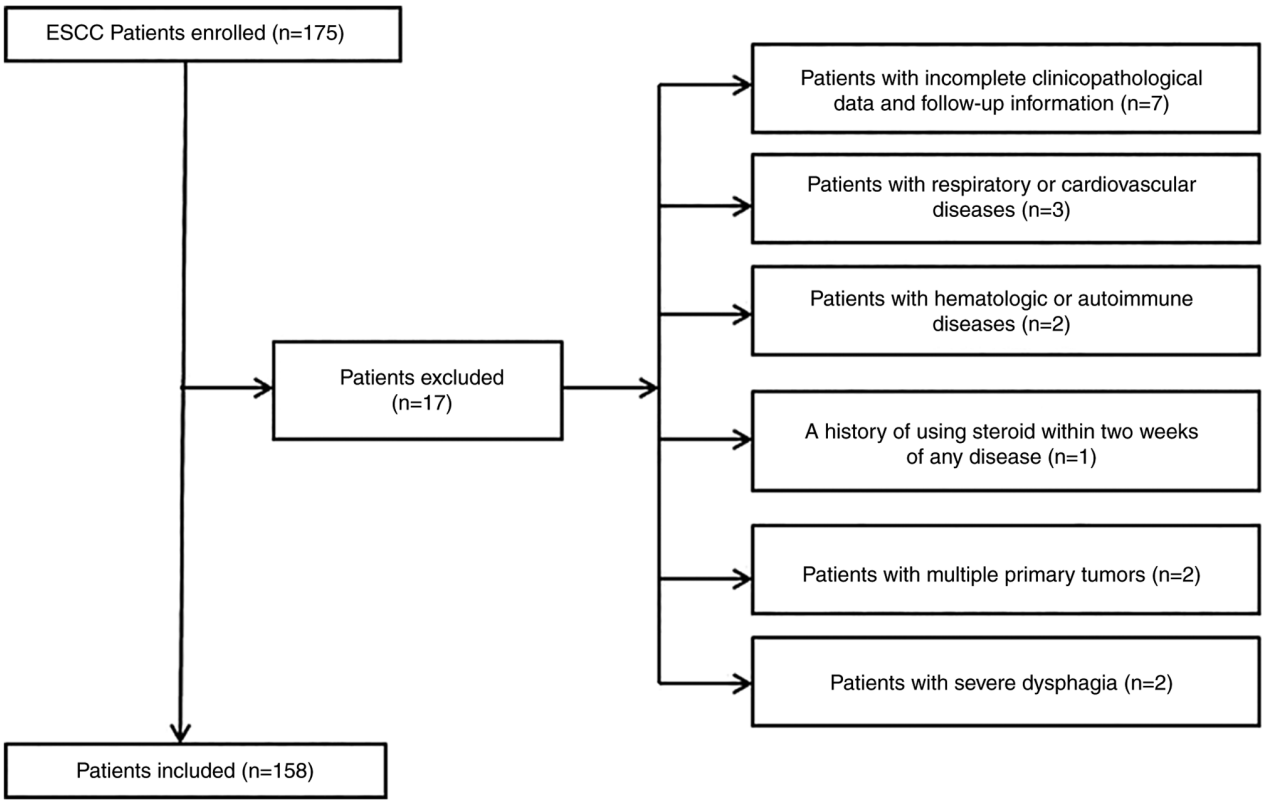

Figure 1. Flowchart of the enrollment process. ESCC, esophageal squamous cell carcinoma.

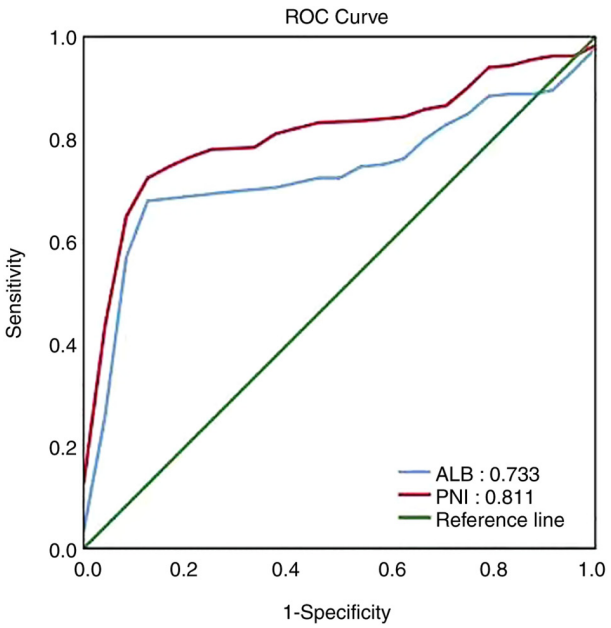

Figure 2. ROC curve analysis for the optimal cut-off values of PNI and ALB, respectively. The areas under the ROC curve of PNI and ALB are indicated. ROC, receiver operating characteristic. PNI, prognostic nutritional index; ALB, albumin.

curve, were 41.35 and 36.8 g/l, respectively. Since the normal range of recognized BMI is 18.5-23.9 kg/m^2, the cut-off value for BMI was set at the normal lower limit (18.5 kg/m^2). Patients were separately divided into high and low PNI/ALB/BMI groups based on the optimal cut-off values.

Associations between the clinicopathological parameters and PNI, ALB and BMI. The associations between the clinicopathological parameters of the patients and the PNI, ALB and BMI values are presented in Table I. PNI, ALB and BMI before treatment were significantly associated with the treatment regimen (P=0.001, P=0.002 and P=0.002, respectively). There were no significant differences with regard to the associations between PNI, ALB and BMI before treatment and age, sex, drinking history, ECOG PS, therapy line, differentiation and esophageal cancer location.

Survival analyses. Survival curves for PFS and OS were plotted using the Kaplan-Meier method, and the log-rank test was used to compare the differences between the groups. The PFS and OS times in the high PNI group before treatment were significantly longer than those in the low PNI group [median (m)PFS: 7.2 vs. 4.5 months, respectively; P<0.001; mOS: 17 vs. 8 months, respectively; P<0.001; Fig. 3A and B). The PFS and OS times in the high ALB group before treatment were significantly longer than those in the low ALB group (mPFS: 7.3 vs. 4.5 months, respectively; P<0.001; mOS: 17 vs. 8.7 months, respectively; P<0.001; Fig. 4A and B). The PFS and OS times in the high BMI group before treatment were significantly longer than those in the low BMI group (mPFS: 7.6 vs. 4.5 months, respectively; P<0.001; mOS: 17.5 vs. 8.8 months, respectively; P<0.001; Fig. 5A and B).

Univariate and multivariate analyses. The prognostic values of PNI, ALB and BMI were further evaluated by Cox proportional hazards model. The results of the univariate and multivariate analyses of PFS and OS are shown in

Table I. Associations between PNI, ALB and BMI and the clinical characteristics of the patients with metastatic esophageal squamous cell carcinoma.

		PNI			ALB, g/l			BMI, kg/m^2		
Variable	Cases, n	>41.35, n	≤41.35, n	P-value	>36.8, n	≤36.8, n	P-value	≥18.5, n	<18.5, n	P-value
Total patients	158	97	61		96	62		87	71	
Age, years				0.923			0.769			0.686
>65	94	58	36		58	36		53	41	
≤65	64	39	25		38	26		34	30	
Sex				0.306			0.643			0.229
Male	101	59	42		60	41		52	49	
Female	57	38	19		36	21		35	22	
Drinking history				0.659			0.926			0.451
Yes	95	57	38		58	37		50	45	
No	63	40	23		38	25		37	26	
ECOG PS				0.283			0.225			0.641
0	68	45	23		45	23		36	32	
1-2	90	52	38		51	39		51	39	
Therapy lines, n				0.246			0.57			0.598
1	50	34	16		32	18		26	24	
≥2	108	63	45		64	44		61	47	
Regimen				0.001			0.002			0.002
Monotherapy	61	26	35		28	33		24	37	
Combination therapy	97	71	26		68	29		63	34	
Differentiation				0.649			0.511			0.402
Well	26	14	12		14	12		13	13	
Moderate	81	50	31		48	33		42	39	
Poor	51	33	18		34	17		32	19	
Esophageal cancer location				0.349			0.109			0.515
Upper	29	16	13		14	15		18	11	
Middle	77	45	32		45	32		39	38	
Lower	52	36	16		37	15		30	22	

PNI, prognostic nutritional index; ALB, albumin; BMI, body mass index; ECOG PS, Eastern Cooperative Oncology Group Performance Status.

Tables II and III, respectively. Univariate analyses indicated that the high PNI, ALB and BMI groups before treatment were associated with longer PFS and OS times (all P<0.001). To avoid the multicollinearity among PNI, ALB and BMI, in the multivariate analyses, three independent Cox models were separately constructed. Each model included only one of the three variables. The multivariate analyses indicated that PNI, ALB and BMI were independent prognostic factors (all P<0.001) for survival outcomes in patients with metastatic ESCC treated with camrelizumab.

Analyses of immune-related adverse events. irAEs occurred in 141 participants (89.2%). Categories and grades of irAEs for the different treatment regimens are displayed in Table IV. Reactive cutaneous capillary endothelial proliferation was one of the most common irAEs. Grade 3-4 irAEs were rare in the camrelizumab group, while in the camrelizumab plus chemotherapy group, grade 3-4 adverse events such as fatigue, thrombocytopenia, anemia and leukopenia were markedly increased, which is likely related to the chemotherapy. Most of the irAEs were mild and controllable in the two groups. There were no irAEs leading to treatment termination or death.

Discussion

Previously, the main treatments for patients with esophageal cancer such as surgery, chemoradiotherapy and molecular targeted therapy failed to significantly prolong survival time (25). Recently, immunotherapy has achieved marked efficacy in such patients and has become one of the standard treatments for esophageal cancer. Some studies have demonstrated the sustained response and long-term survival benefits of immunotherapy in advanced oesophageal cancer, metastatic non-small-cell lung cancer

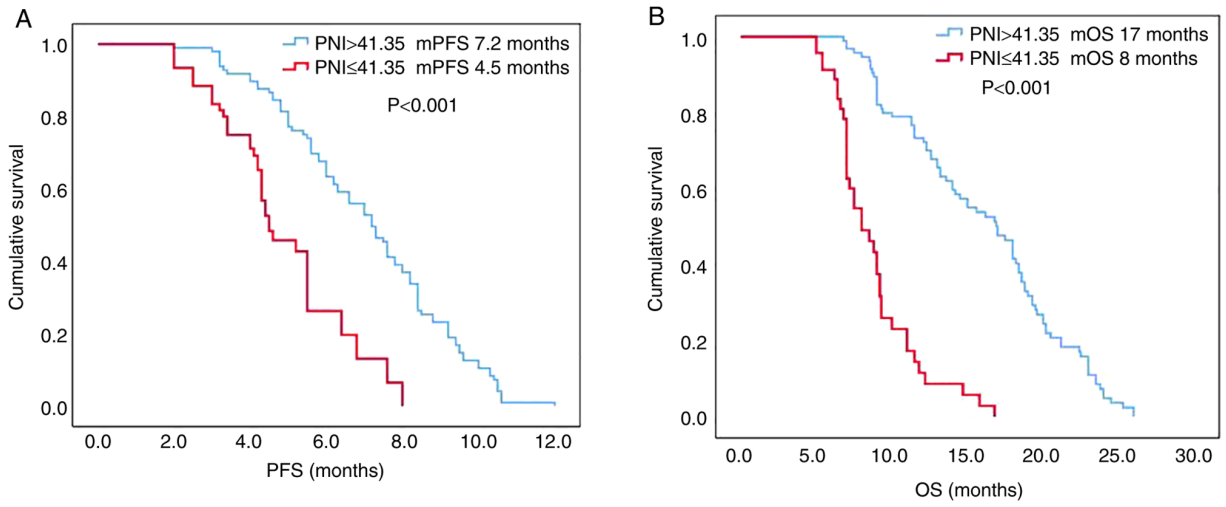

Figure 3. Kaplan-Meier analyses of PFS and OS according to PNI at baseline. Kaplan-Meier survival curves showing the differences in (A) PFS and (B) OS between the high and low PNI groups. mPFS, median progression-free survival; mOS, median overall survival; PNI, prognostic nutritional index.

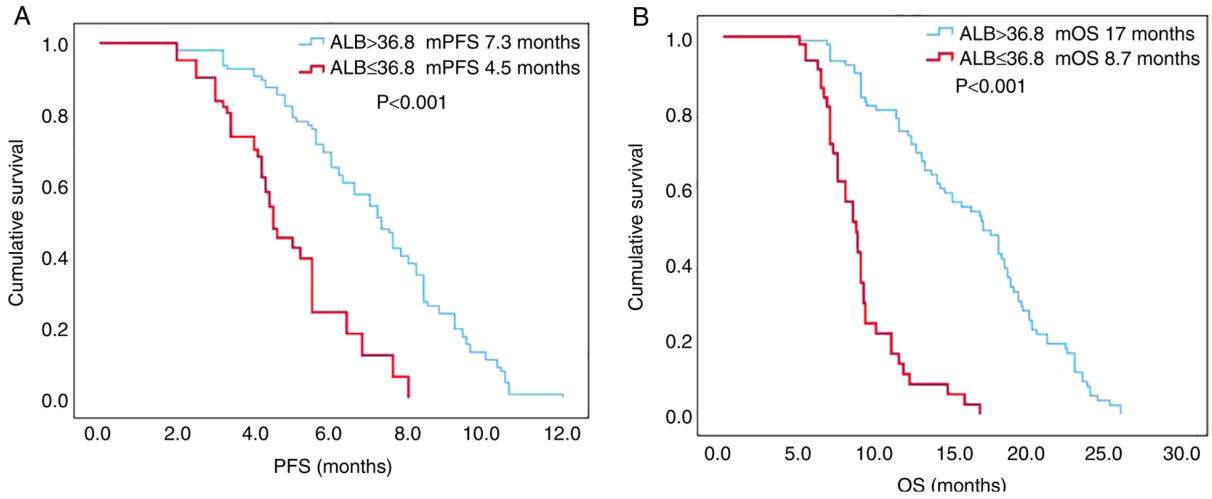

Figure 4. Kaplan-Meier analyses of PFS and OS according to ALB at baseline. Kaplan-Meier survival curves showing the differences in (A) PFS and (B) OS between the high and low ALB groups. mPFS, median progression-free survival; mOS, median overall survival; ALB, albumin.

and microsatellite-instability-high advanced colorectal cancer (6,11,12). However, only a small proportion of patients benefit from this treatment, and knowing how to identify the populations that would receive the greatest benefit is still an urgent problem to be solved. Therefore, it is of great clinical importance to explore biomarkers that predict the best efficacy of immunotherapy. In addition, more than half of all malignant tumor patients exhibit nutritional risk at the time of diagnosis and subsequent treatment (26). Pan *et al* (26) reported that malnutrition and nutritional risk were common problems affecting the efficacy of treatment for patients with cancer in China during hospitalization. A retrospective analysis of 158 patients with metastatic ESCC treated with camrelizumab was conducted in the present study. It was found that low PNI, ALB and BMI values were independent risk factors for survival outcomes in patients with metastatic ESCC who underwent treatment with camrelizumab.

Although the tumor microenvironment is crucial in the selection of immunotherapy biomarkers, other factors of the host, especially nutrition and immune status, cannot be ignored. The level of serum ALB is a common biomarker to evaluate the nutritional status of a patient (27). Low ALB level reflects the poor nutritional status of the body, weakens the body's cellular immunity, humoral immunity and other defense mechanisms, and is associated with a poor prognosis in patients with tumors (28). ALB is produced by hepatocytes and regulated by various pro-inflammatory cytokines such as interleukin-1 (IL-1), IL-6 and tumor necrosis factor-α (29,30). ALB has been demonstrated to protect the host against tumorigenesis by stabilizing cell growth and DNA replication, buffering changes in various biochemical reactions, such as catalytic chemical reactions, binding and dissolving various compounds, and maintaining sex hormone homeostasis (31). Therefore, in a sense, ALB can reflect the immune and inflammatory status of the host. A small sample study (32) showed that ALB level was an independent predictor of early mortality in patients with esophageal cancer, and could be combined with other biomarkers to provide prognostic information and

Table II. Univariate and multivariate analyses of progression-free survival in patients with metastatic esophageal squamous cell carcinoma treated with camrelizumab.

	Univariate analysis		Multivariate analysis	
Variable	HR (95% CI)	P-value	HR (95% CI)	P-value
Age (>65 vs. ≤65 years)	0.975 (0.690-1.376)	0.884		
Sex (male vs. female)	1.067 (0.747-1.522)	0.722		
Drinking history (yes vs. no)	1.107 (0.778-1.575)	0.572		
ECOG PS (0 vs. 1-2)	0.925 (0.653-1.311)	0.663		
Therapy lines (1 vs. ≥2)	0.997 (0.697-1.426)	0.988		
Regimen (monotherapy vs. combination therapy)	0.839 (0.585-1.204)	0.342		
Differentiation (well vs. moderate vs. poor)	1.026 (0.788-1.335)	0.850		
Tumor location (upper vs. middle vs. lower)	1.044 (0.819-1.331)	0.725		
PNI (>41.35 vs. ≤41.35)	3.294 (2.114-5.133)	<0.001	3.599 (2.233-5.800)	<0.001
ALB (>36.8 vs. ≤36.8)	3.615 (2.323-5.627)	<0.001	4.148 (2.564-6.711)	<0.001
BMI (≥18.5 vs. <18.5)	4.564 (2.938-7.088)	<0.001	5.623 (3.419-9.249)	<0.001

PNI, prognostic nutritional index; ALB, albumin; BMI, body mass index; ECOG PS, Eastern Cooperative Oncology Group Performance Status; HR, hazard ratio; CI, confidence interval.

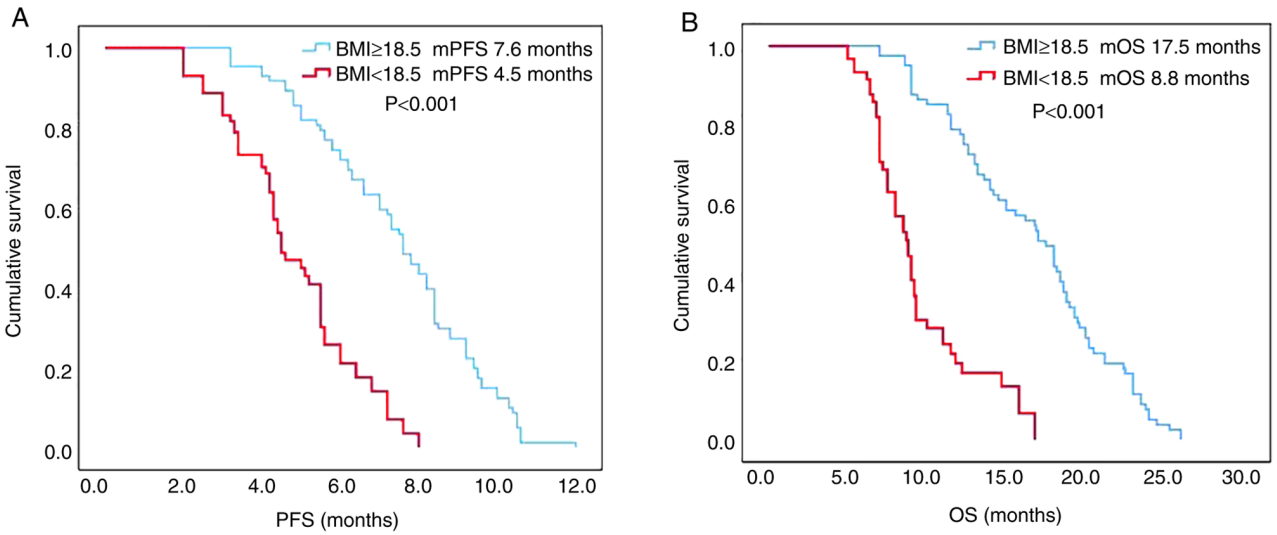

Figure 5. Kaplan-Meier analyses of PFS and OS according to BMI at baseline. Kaplan-Meier survival curves showing the differences in (A) PFS and (B) OS between the high and low BMI groups. mPFS, median progression-free survival; mOS, median overall survival; BMI, body mass index.

guide treatment. The present study demonstrated that ALB was associated with the prognosis of immunotherapy in patients with metastatic ESCC. In a retrospective study, Qi *et al* (33) found that preoperative ALB is significantly associated with OS upon univariate analysis, but not upon multivariate analysis, implying that ALB is associated with prognosis, but is not an independent prognostic factor. In the present study, ALB was an independent risk factor for survival outcome in patients with metastatic ESCC treated with camrelizumab. The differences between these findings may be related to the differences in cut-off values, treatment methods and baseline characteristics of the patients.

Lymphocytes, one of the basic components of cellular immunity, inhibit the proliferation and invasion of tumor cells by cytokine-mediated cytotoxicity (34). The decrease in lymphocytes before treatment is a factor indicating a poor prognosis for patients with cancer, which may be associated with the immunosuppressive microenvironment of the host (35). A previous study (34) showed that lymphopenia is an independent prognostic factor for survival outcomes in metastatic breast cancer, advanced soft-tissue sarcoma and non-Hodgkin's lymphoma. PNI, which is calculated from serum ALB and peripheral blood lymphocyte levels, is a comprehensive index reflecting the nutritional and immune status of the host (36). This suggests that it has a potential predictive value for immunotherapy in patients with cancer. A retrospective analysis of 123 patients with advanced non-small cell lung cancer treated with PD-1 inhibitors found that PNI was an independent predictor for early progression and survival outcomes (37). The results of two other studies (33,38)

Table III. Univariate and multivariate analyses of overall survival in patients with metastatic esophageal squamous cell carcinoma treated with camrelizumab.

	Univariate analysis		Multivariate analysis	
Variable	HR (95% CI)	P-value	HR (95% CI)	P-value
Age (>65 vs. ≤65 years)	1.209 (0.842-1.735)	0.304		
Sex (male vs. female)	1.278 (0.885-1.845)	0.192		
Drinking history (yes vs. no)	1.285 (0.890-1.854)	0.180		
ECOG PS (0 vs. 1-2)	0.999 (0.695-1.438)	0.998		
Therapy lines (1 vs. ≥2)	1.258 (0.853-1.854)	0.247		
Regimen (monotherapy vs. combination therapy)	0.821 (0.562-1.199)	0.307		
Differentiation (well vs. moderate vs. poor)	1.091 (0.831-1.434)	0.530		
Tumor location (upper vs. middle vs. lower)	0.957 (0.739-1.239)	0.739		
PNI (>41.35 vs. ≤41.35)	6.168 (3.862-9.848)	<0.001	7.605 (4.460-12.969)	<0.001
ALB (>36.8 vs. ≤36.8)	6.406 (3.996-10.271)	<0.001	7.852 (4.616-13.358)	<0.001
BMI (≥18.5 vs. <18.5)	5.499 (3.438-8.797)	<0.001	7.915 (4.597-13.626)	<0.001

PNI, prognostic nutritional index; ALB, albumin; BMI, body mass index; ECOG PS, Eastern Cooperative Oncology Group Performance Status; HR, hazard ratio; CI, confidence interval.

Table IV. Summary of immune-related adverse events (n=158).

	Camrelizumab + chemotherapy (n=97)		Camrelizumab (n=61)	
irAE category	Any grade	Grade 3-4	Any grade	Grade 3-4
RCCEP	80 (82.5)	10 (10.3)	51 (83.6)	3 (4.9)
ALT increase	32 (33.0)	4 (4.1)	9 (14.8)	0 (0.0)
AST increase	33 (34.0)	6 (6.2)	8 (13.1)	0 (0.0)
Increased blood bilirubin	12 (12.4)	2 (2.1)	3 (4.9)	0 (0.0)
Hypothyroidism	11 (11.3)	0 (0.0)	7 (11.5)	0 (0.0)
Fatigue	31 (32.0)	0 (0.0)	5 (8.2)	0 (0.0)
Anemia	69 (71.1)	18 (18.6)	8 (13.1)	0 (0.0)
Proteinuria	6 (6.2)	0 (0.0)	2 (3.3)	0 (0.0)
Leukopenia	73 (75.3)	35 (36.1)	6 (9.8)	0 (0.0)
Thrombocytopenia	31 (32.0)	17 (17.5)	0 (0.0)	0 (0.0)
Rash	13 (13.4)	3 (3.1)	4 (6.6)	0 (0.0)

irAE, immune-related adverse event; RCCEP, reactive cutaneouscapillary endothelial proliferation; ALT, alanine aminotransferase; AST, aspartate aminotransferase.

revealed that preoperative PNI was an independent prognostic factor for OS in patients with ESCC after surgery and that it could be used as a biomarker to predict survival outcomes. This association was also observed in the present study.

BMI is one of the common standards used to measure the degree of obesity and health, which can reflect the nutritional status of the body. Research in China has revealed that a decrease in preoperative BMI is significantly associated with poor postoperative survival outcomes in patients with gastric cancer or adenocarcinoma of the gastroesophageal junction (39). In another cohort study of 615 patients with ESCC who underwent esophagectomy or chemoradiotherapy, a high BMI before treatment was found to be an independent prognostic factor for long-term survival (40), which was similar to the present results.

To the best of our knowledge, the association between nutritional indicators and the efficacy and prognosis of patients metastatic ESCC treated with immunotherapy is still largely unknown. To the best of our knowledge, this association was first observed in the present study. A previous study demonstrated that some specific nutrients may be related to the etiology or severity of cervical cancer (41), which implied that the type of nutrition may affect the progression of disease or treatment efficacy. In addition, ALB, BMI and PNI can reflect the nutritional and immune status of the body, and it is easy to conduct quality control for them in studies. Furthermore, compared with

the common biomarkers for predicting immunotherapy, such as PDL-1, MMR and TMB, the nutritional indicators used in this study were cost-effective and are easily available in clinical practice. Since the specific nutrients were not taken into account in this study, it may be an aim of future research. However, there are also some limitations in the present study. Firstly, selection bias is inevitable in the present study as it is a single-center, small-sample, retrospective analysis. Therefore, further validation of the findings is required in large-sample, multicenter, prospective studies. Secondly, although the results are similar to those of previous studies, due to the lack of a unified cut-off value in various studies, it may be difficult to repeat the conclusions in other experiments. Consequently, consistent cut-off values need to be explored in subsequent studies.

In summary, the present study revealed that PNI, ALB and BMI are effective predictors to evaluate the survival outcomes in patients with metastatic ESCC treated with camrelizumab. Furthermore, PNI, ALB and BMI may be independent prognostic factors in these patients.

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Availability of data and material

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

JL and DL were responsible for study conception and design. Administrative support and the χ^2 test and Cox proportional hazard models were conducted by GH and CZ. WX, JX, WZ and PJ enrolled the study subjects and performed survival analyses and the follow-up for all patients. JW collected and assembled the data, and performed ROC curve analysis. Data analysis and interpretation was performed by JL. The manuscript was written by JL. JL, GH, CZ, JW, WX, JX, WZ, PJ and DL confirm the authenticity of all the raw data. All authors have read and approved the final manuscript.

Ethics approval and consent to participate

This study involving human participants was reviewed and approved by the Ethics Committee of the Medical School of Yangzhou University (Xinghua, China). As it is a non-interventional retrospective study, the requirement for informed consent was waived. Privacy was maintained and identifiable information of all patients was kept confidential and used in compliance with the Declaration of Helsinki.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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