The Correlation between Skeletal Muscle Index of the L3 Vertebral Body and Malnutrition in Patients with Advanced Lung Cancer

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Abstract

Background: By analyzing the L3 skeletal muscle index in patients with advanced lung cancer, we determined whether this index could be an independent predictor of malnutrition in such patients and its role in nutritional assessments.

Methods: Retrospective analysis was performed on patients with advanced lung cancer who received medical treatment at the Cancer Center of The First Hospital of Jilin University from January 2017 to July 2017, and relevant data were collated and analyzed. Abdominal CT was used to analyze the L3 skeletal muscle index, and PG-SGA score, body mass index (BMI), and serological indicators were analyzed. According to PG-SGA scores, patients were divided into severe malnutrition (≥9 points), mild to moderate malnutrition (≥3 points and ≤8 points), and no malnutrition (≤2 points) groups. Pearson correlation analysis was conducted between the skeletal muscle index and PG-SGA score, BMI, and laboratory test indices. Univariate and multivariate logistic regression analyses were conducted on the factors related to malnutrition, and a forest plot was drawn to identify malnutrition risk and protection factors.

Results:

1. The age of patients in the severe malnutrition group, the mild to moderate malnutrition group, and the no malnutrition group significantly differed, with mean ages of 63.46±10.01 years, 60.42±8.76 years, and 55.03±10.40 years, respectively. Furthermore, the NLR of the severe malnutrition group was significantly higher than that of the no malnutrition group, with statistical significance. The difference between the mild to moderate malnutrition group and the no malnutrition group were not statistically significant, with NLRs of 4.07±3.34, 3.09±1.47, and 2.47±0.92, respectively. The L3 skeletal muscle mass indices of patients in the severe malnutrition and mild to moderate malnutrition groups were significantly lower than that of the patients in the no malnutrition group, with statistical significance. The L3 skeletal muscle mass index of patients in the severe malnutrition group, mild to moderate malnutrition group, and no malnutrition group were 27.40±4.25 cm^2/m^2, 38.19±6.17 cm^2/m^2, and 47.96±5.02 cm^2/m^2, respectively.

2.The multivariate analysis showed that the L3 skeletal muscle index was an independent risk factor for malnutrition (OR=0.627, p=0.000; OR=0.454, p=0.000).

3.The Pearson correlation analysis showed that the PG-SGA score positively correlated with age (r=0.296), but negatively correlated with L3 skeletal muscle mass index (r=-0.857) (P≤0.05). The L3 skeletal muscle mass index also negatively correlated with age (r=-0.240) (P≤0.05).

Conclusion

1. The differences in the L3 skeletal muscle index, age, PA, and NLR were statistically significant among patients with advanced lung cancer with different nutritional statuses.

2. In the nutritional assessment of patients with lung cancer, the L3 skeletal muscle index was consistent with the PG-SGA.

3. The L3 skeletal muscle index is an independent predictor of malnutrition in patients with advanced lung cancer.

Background

Malignant tumors are a social and public health problem worldwide. According to 2012 statistics, the incidence and mortality of malignant tumors in China exceeded the average level of that of the world [1–3]. Malignant tumor-related malnutrition has become a main cause of death in patients with cancer, with about 20% patients dying from malnutrition. Among all types of cancer, lung cancer has a high risk of malnutrition [4]. The accurate and reasonable assessment of the nutritional status of patients with advanced lung cancer is necessary to further improve survival. Metabolic disorders caused by malignant tumors result in systemic muscle loss, due to inflammatory responses and catabolism. However, abnormal nutritional in clinical practice is often associated with obesity. Therefore, the core of diagnostic malnutrition lies in the accurate identification of muscle loss in patients. CT, as an imaging examination, can accurately analyze different components of the human body, such as bone, muscle, and fat, and is widely recognized as the gold standard for human component analysis [5]. Professor Martin and others [6–11] conducted a retrospective study, in which skeletal muscle content was inferred from the lumbar and abdominal CT scan results of patients, and the skeletal muscle index (SMI) was calculated to evaluate patient nutritional status. The results of the study showed that CT images can detect hidden muscle consumption, and the skeletal muscle index had better specificity and sensitivity for assessing nutritional status and predicting patient prognosis. At present, the application value of the L3 skeletal muscle index has been recognized by researchers worldwide, and digestive system neoplasms have always been the focus of L3 skeletal muscle index research. Low L3 skeletal muscle index has a significant predictive prognostic effect in patients with liver cancer and colorectal cancers [12, 13], but whether the L3 skeletal muscle index could be a significant predictor of lung cancer needs to be further explored. This study aimed to analyze the relationship between the L3 skeletal muscle index and nutritional status of patients with advanced lung cancer, to determine whether it can be an independent predictor of malnutrition in patients with lung cancer.

1 Methods

1.1 Study Participants

A retrospective analysis was performed on 272 patients with lung cancer admitted to the Cancer Center of the First Hospital of Jilin University, from January 2017 to June 2017. Case inclusion criteria: (1) lung cancer diagnosed by pathological examination; TNM stage IV, with extensive small cell lung cancer or recurring lung cancer; (2) good heart, lung, kidney, and other vital organ function, without metabolic disease; (3) evaluated by abdominal plain scan CT; (4) no nutritional support treatment performed before the nutritional assessment and laboratory tests. Case exclusion criteria: (1) merged with other types of

tumors; (2) died within 30 days of admission; (3) did not detect relevant indicators or had incomplete indicators.

1.2 Data Collection

All patients received PG-SGA(the Patient Generated Subjective Global Assessment), abdominal CT, BMI measurement, laboratory biochemical testing, and bioelectrical impedance analysis (BIA) within 24 hours of admission (before intravenous fluids and nutritional support treatment). Patients' age, sex, height, and weight were recorded, and the patients did not eat or drink for two hours before the measurement. Before the measurement, all patients urinated and wore the same hospital gown. After completing the height and weight measurements, the body mass index was calculated (BMI = weight (kg)/ height ^{2} (m)). All patients underwent fasting aseptic venous blood hospital laboratory testing on the second morning of admission. Indicators were recorded, including albumin (ALB), prealbumin (PA), neutrophil-to-lymphocyte ratio (NLR), and platelet-to-lymphocyte ratio (PLR) in the peripheral blood. SliceOmatic 5.0 software produced by TOMOVISION Canada was used to analyze abdominal CT scans. According to the abdominal CT scans, we selected the third lumbar intervertebral disc plane image, two continuous images on the L3 plane, and the sum of the skeletal muscle cross-sectional area (including the psoas major, erector spinae, quadratus lumbar muscles, transverse abdominis, external oblique, and internal oblique). The average value was calculated, and the square of the height (cm^2/m^2) was divided to obtain the L3 skeletal muscle index (L3 SMI).

BIA was conducted while patients were lying supine on a bed or examination table, with legs apart and arms not touching the torso, by a registered dietitian using a bioelectrical impedance analyzer, Inbody(Biospace Co®). Resistance(R) and capacitance (Xc) were directly measured in ohms at 50 kHz, 800 mA using Inbody BIA. One assessment of R and Xc was made. Phase angle was calculated using the following equation: Phase Angle = Resistance/Capacitance) * (180/π).

1.3 Nutritional Status

Nutritional status was assessed according to PG-SGA scores. The higher the overall score, the worse the nutritional status. In this study, nutritional status was classified into three grades: no malnutrition, mild-to-moderate malnutrition and severe malnutrition. Definition of malnutrition: PG-SGA score ≥ 3 was defined as malnutrition. After evaluation, patients were divided into severe malnutrition group(PG-SGA ≥ 9 points, PG-SGA A group), mild-to-moderate malnutrition group(3 ≤ PG-SGA ≤ 8 points, PG-SGA B group), and no malnutrition group(PG-SGA ≤ 2 points, PG-SGA C group).

1.4 Statistical Methods

SPSS 22.0 statistical software was used for data analysis. Measurement data are expressed as mean ± standard deviation. Pearson's correlation analysis was used for correlation analysis. The malnutrition factors were analyzed by univariate and multivariate logistic regression analyses, and a forest plot was drawn. We drew the ROC curve to explore the value of various indicators for malnutrition diagnoses. $P < 0.05$ indicated that the respective difference was statistically significant.

2 Results

2.1 Baseline Patients Information

A total of 110 patients with lung cancer p were included in this study, according to the inclusion and exclusion criteria. Among them, were 73 males (66.36%) and 37 females (33.64%), aged from 32 to 82 years, with an average age of 59.98 ± 9.91 years. There was 30 patients in group A, accounting for 27.3%, 54 patients in group B, accounting for 49.1% and 26 patients in group C, accounting for 23.6%. See Table 1 for details.

Table 1
Basic clinical information of the patients

Characteristics	*n*
Gender(M: F)	73(66.4%): 37□33.6%□
Age(y)	59.98 ± 9.91
PA	182.64 ± 82.77
ALB	38.65 ± 4.63
BMI	23.50 ± 3.01
PhA	5.36 ± 0.93
NLR	3.22 ± 2.11
PLR	175.85 ± 104.64
L3 SMI	37.56 ± 9.14
Nutritional status	
PG-SGA A	30(27.3%)
PG-SGA B	54(49.1%)
PG-SGA C	26(23.6%)
PA: prealbumin; ALB: albumin; BMI; Body mass index; PhA: phase angle; NLR: neutrophil-to-lymphocyte ratio; PLR: platelet-to-lymphocyte ratio; L3 SMI: L3 skeletal muscle index. Nutritional status was classified according to the PG-SGA scores: PG-SGA ≥ 9 points(PG-SGA A group); 3 ≤ PG-SGA ≤ 8 points(PG-SGA B group); PG-SGA ≤ 2 points(PG-SGA C group).	
Continuous variables presented as mean ± s.d. and categorical variables are presented as counts (%).	

2.2 Statistical Analysis Results

(1) The mean age of the severe malnutrition group was 63.46 ± 10.01 years, that of the mild-to-moderate malnutrition group was 60.42 ± 8.76 years, and that of the no malnutrition group was 55.03 ± 10.40 years. The univariate analysis showed that age significantly differed between the mild-to-moderate and severe malnutrition groups, compared with the no malnutrition group (OR = 1.062, P = 0.024; OR = 1.100, P = 0.002). See Tables 2 and 3 for details.

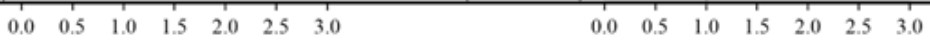
Table 2
Basic clinical information stratified by nutritional status

Factor	*PG-SGA A*	*PG-SGA B*	*PG-SGA C*	*t**	*p**	*t#*	*p#*
Age	63.46 ± 10.01	60.42 ± 8.76	55.03 ± 10.40	-2.422	0.018	-3.085	0.003
PA	145.67 ± 82.49	184.44 ± 84.80	221.53 ± 59.24	2.265	0.027	3.989	0.000
ALB	39.00 ± 2.49	39.38 ± 4.69	39.00 ± 2.49	− .0457	0.649	1.709	0.096
BMI	22.50 ± 3.33	24.04 ± 2.64	23.52 ± 3.14	-0.772	0.442	1.176	0.245
PhA	4.79 ± 0.99	5.31 ± 0.69	6.10 ± 0.78	4.572	0.000	5.417	0.000
NLR	4.07 ± 3.34	3.09 ± 1.47	2.47 ± 0.92	-1.683	0.097	-2.193	0.037
PLR	189.42 ± 118.40	182.45 ± 112.86	143.04 ± 48.72	-1.460	0.149	-1.742	0.091
L3 SMI	27.40 ± 4.25	38.19 ± 6.17	47.96 ± 5.02	7.022	0.000	16.573	0.000
* The reference category was PG-SGA Group C, and the analysis category was PG-SGA Group B							
# The reference category was PG-SGA Group C, and the analysis category was PG-SGA Group A							

(2) In patients with advanced lung cancer, the univariate analysis showed that the PAs of patients in the mild-to-moderate malnutrition and severe malnutrition groups were significantly lower than that of patients in the no malnutrition group, with statistical significance (OR = 0.991, P = 0.040; OR = 0.986, P = 0.002). The NLR of patients in the severe malnutrition group was significantly higher than that in the no malnutrition group, with statistical significance (OR = 1.657, P = 0.035); however, there was no statistically significant difference in NLRs between the mild-to-moderate malnutrition and non-malnutrition groups. The phase angle of patients in the mild-to-moderate and severe malnutrition groups was significantly lower than that in the non-malnutrition group, with statistical significance (OR = 0.241, P < 0.001; OR = 0.116, p < 0.001). The L3 skeletal muscle indices of patients in the mild-to-moderate and severe malnutrition groups were significantly lower than that of patients in the no malnutrition group, with statistical significance (OR = 0.600, P < 0.001; OR = 0.431, P < 0.001). See Table 3.

Table 3. Univariate analysis and multivariate logistic regression analysis of malnutrition related factors (Attached with forest plots)

PG-SGA grade	Relevant factors	Univariate OR (95% CI)	p	Multivariate OR (95% CI)	p
PG-SGA B	Age	1.062 (1.008~1.118)	0.024*	0.974 (0.858~1.107)	0.690
	PA	0.991 (0.983~1.000)	0.040*	1.008 (0.994~1.024)	0.270
	ALB	1.021 (0.912~1.144)	0.713		
	NLR	1.373 (0.875~2.156)	0.168	4.142 (0.970~17.689)	0.055
	L3 SMI	0.600 (0.462~0.777)	<0.001*	0.446 (0.258~0.773)	0.004*
	BMI	1.061 (0.905~1.245)	0.464		
	PhA	0.241 (0.109~0.533)	0.000*	0.296 (0.051~1.730)	0.176
PG-SGA A	Age	1.100 (1.034~1.170)	0.002*	1.020 (0.869~1.197)	0.807
	PA	0.986 (0.977~0.995)	0.002*	1.001 (0.982~1.021)	0.892
	ALB	0.911 (0.807~1.029)	0.135		
	NLR	1.657 (1.036~2.649)	0.035*	3.936 (0.886~17.490)	0.072
	L3 SMI	0.431 (0.320~0.581)	<0.001*	0.289 (0.159~0.524)	<0.001*
	BMI	0.885 (0.737~1.064)	0.194		
	PhA	0.116 (0.046~0.288)	<0.001*	0.819 (0.074~9.021)	0.871



(3) The multivariate logistic regression showed that the L3 skeletal muscle index of patients in the mild-to-moderate and severe malnutrition groups statistically differed from that of patients in the non-malnutrition group (OR = 0.446, P = 0.004; OR = 0.289, P < 0.001). Thus, the L3 skeletal muscle index an independent risk factor for malnutrition in advanced lung cancer. See Table 3 for details.

(4) The Pearson correlation analysis showed that the PG-SGA score positively correlated with age (r = 0.296), but negatively correlated with L3 skeletal muscle mass index (r=-0.857) ($P \leq 0.05$). Also, the L3 skeletal muscle mass index negatively correlated with age (r=-0.240) ($P \leq 0.05$). See Table 4 for details.

Table 4
Pearson correlation analysis

	PG-SGA		*L3 SMI*	
	r	p	r	p
PG-SGA	-	-	-0.857	0.000*
L3 SMI	-0.857	0.000*	-	-
Age	0.296	0.002*	-0.240	0.012*
ALB	-0.205	0.039*	0.216	0.029*
NLR	0.248	0.020*	-0.314	0.003*
BMI	-0.247	0.009*	0.143	0.137
*means p□0.05				

(5) With the no malnutrition group as the reference group, forest plots were drawn for the mild-to-moderate and severe malnutrition groups, respectively, and the results indicated that the L3 skeletal muscle index is an independent risk factor for malnutrition. See Table 3 for details.

(6) Taking PG-SGA ≥ 3 points as the cut-off point for diagnosing malnutrition, the receiver operating characteristic curve (ROC) was used to explore the diagnostic value of L3 skeletal muscle index and traditional indicators. The area under the curve of the L3 skeletal muscle index, PhA (phase angle), PA, BMI, PLR and NLR were 0.958, 0.821, 0.697, 0.500, 0.357 and 0.384, respectively. Thus, the L3 skeletal muscle index has good diagnostic value. See Table 5 and Fig. 1 for details.

Table 5
The AUC area of ROC curve

Factors	*AUC Area*	*95% CI of AUC Area*
L3 SMI	0.958	0.915 ~ 1.000
PA	0.697	0.569 ~ 0.826
BMI	0.500	0.340 ~ 0.659
NLR	0.384	0.242 ~ 0.525
PLR	0.357	0.217 ~ 0.497
PhA	0.821	0.706 ~ 0.935
Age	0.361	0.211 ~ 0.511

Discussion

Previous studies have confirmed that nutritional status is a factor that affects the prognosis of malignant tumors [12]. With the introduction of tumor nutrition therapy [14, 15], the importance of nutritional status of patients with tumors in clinical practice has been recognized. Researchers at home and abroad have also reached a consensus that accurate and comprehensive nutritional assessment and timely and effective nutritional intervention benefit patients for a long time. Currently, the commonly used clinical nutrition assessments are roughly grouped into three categories: anthropometry indicators, laboratory inspection indicators, and comprehensive evaluation methods. Among them, the PG-SGA is the most commonly used comprehensive evaluation method. PG-SGA is a patient-involved nutritional assessment method modified on the basis of SGA (the Subjective Global Assessment). It is considered to be a specific assessment tool for nutritional status of patients with cancer and is recommended by both the Chinese Anti-Cancer Association and the American Dietetic Association (ADA) [16, 17]. However, the PG-SGA is relatively complicated to operate, and the lack of manpower in most hospitals makes it difficult to ensure high-quality nutritional assessments. Moreover, the assessment results are easily affected by subjective factors of patients and operational deviations of medical workers, which directly lead to biased results and a lack of objective responses. The above problems have limited the application effectiveness of PG-SGA in clinical work, to a certain extent. Therefore, this study proposed the use of the L3 skeletal muscle index, a quantitative, objective, accurate, and convenient indicator, to evaluate the nutritional status of patients with cancer in the clinic.

Previous studies have shown that the sensitivity and specificity of diagnosing malnutrition are the best when PG-SGA = 3 and PG-SGA = 9 are used as cut-off values [18]. The 110 patients with advanced lung cancer in this study were grouped according to PG-SGA score results. There were 30 patients in the severe malnutrition group (group A, PG-SGA $\geq$ 9), accounting for 27.3% of the study population, and 54 cases in the mild-to-moderate malnutrition group (group B, 3 $\leq$ PG-SGA $\leq$ 8; 49.1%), and 26 cases in the no malnutrition group (group C, PG-SGA $\leq$ 2; 23.6%). The included patients were analyzed according to the groups, and patient age statistically differed in the mild-to-moderate and severe malnutrition groups compared with the no malnutrition group (P = 0.018; P = 0.003). The older the patient with advanced lung cancer, the higher the risk of malnutrition. Elderly patients with malnutrition are likely to be complicated with sarcopenia, which results in a series of subsequent health problems. Therefore, elderly patients should pay more attention to nutritional status.

Serological examination, as one of the most widely used examinations, is an important part of the nutrition assessment of patients with cancer and has great importance in clinical work. The well-known Alb, Hb, etc., are biochemical markers that reflect nutritional status and are often used in clinical work. A considerable number of studies have confirmed the diagnostic value of these indicators. In recent years, new types of inflammation serological indicators, such as NLR and PLR, have gradually been recognized to represent the inflammation-immune state of patients. Relevant studies have shown that the tumor inflammatory response plays an important role in malnutrition and muscle loss, which in turn coordinate and jointly promote the development of cancer [19]. The nutrition, inflammation, and immune status of

patients with cancer are interrelated, and NLR has great potential for nutritional evaluation [20, 21]. In this study, we validated the role of traditional and new serological indicators in the nutritional assessment of patients with advanced lung cancer by univariate analysis. The results showed that the Alb of the malnutrition group was lower than that of the patients without malnutrition, but the difference was not statistically significant. The NLR of patients in the severe malnutrition group was significantly higher than that of the patients in the no malnutrition group.

Taking into account the invasiveness of serological examination and the complicated operation of PG-SGA scoring, clinical work is more likely to use a simpler and non-invasive means of nutritional assessment, in which case, the skeletal muscle index came into being. Compared with patient weight loss and BMI, skeletal muscle loss can more accurately and quantitatively reflect the condition of lean body tissue and nutritional status [13, 22, 23]. The core of malnutrition in patients with malignant tumors lies in the accurate identification of changes in skeletal muscle mass and strength [24]. CT examination can accurately analyze the composition of human body components. For patients with advanced tumors, without increasing the additional economic burden and radiation exposure of the patient, the CT data generated by the efficacy evaluation can be used again to evaluate the skeletal muscle content of the whole body. CT scans make it possible to accurately estimate the content of human skeletal muscle through simple operations in the clinic, and a number of studies have also shown that the results are accurate and reliable [25, 26]. At the same time, CT also has the advantages of easy operation, objectiveness, and accuracy, which minimizes the result bias and has broad applications in clinical practice.

In this study, the sliceOmatic 5.0 software was used to analyze abdominal CT of all patients and calculate the L3 skeletal muscle index. The L3 skeletal muscle index of patients in the severe, mild-to-moderate, and no malnutrition groups were statistically analyzed. In order to explore the application value of the L3 skeletal muscle index, we conducted a Pearson correlation analysis between skeletal muscle index and traditional nutrition evaluation indicators. It was showed that the L3 skeletal muscle index negatively correlated with the PG-SGA score and positively correlated with Alb and PA, which indicated that the L3 skeletal muscle index had a good correlation with the PG-SGA score and serological indicators. Taking the PG-SGA grade C group as a reference, univariate and multivariate logistic regression analyses were performed with patients in the PG-SGA A and PG-SGA B groups, respectively. The L3 skeletal muscle indices in the severe and mild-to-moderate malnutrition groups were significantly lower than that in the no malnutrition group, with statistical significance. In addition, we compared the data of patients in PG-SGA Groups A and B with those in PG-SGA Group C to draw forest plots. From the plots, it can be seen that the upper and lower limits of the 95% CI of L3 skeletal muscle index were less than 1, which means that the L3 skeletal muscle index of the malnutrition group was lower than that of the no malnutrition group. It could be considered that low L3 skeletal muscle index is a risk factor for malnutrition in patients with advanced lung cancer. At the same time, we also observed that Alb, NLR, and age differed between the malnutrition and non-malnutrition groups, and their OR values were all greater than 1. Although this difference was not statistically significant, it could also reflect, to a certain extent,

that there were indeed changes in metabolism and inflammation in patients in the malnutrition group, which was consistent with the results of previous studies. We further used PG-SGA ≥ 3 points as the cut-off point for diagnosing malnutrition and drew an ROC curve to compare the L3 skeletal muscle index with serological indicators. The results showed that the L3 skeletal muscle index had a good diagnostic effect on malnutrition in patients with advanced lung cancer, and the diagnostic efficacy was even better than the serological index. These results suggest that the L3 skeletal muscle index is consistent with the serological index and PG-SGA, which largely confirmed its application value in nutritional assessment of patients with advanced lung cancer.

The decrease in skeletal muscle index was obvious in patients with advanced lung cancer who developed malnutrition, but not in patients without malnutrition. We believe that this is because changes in skeletal muscle mass and function occur over a long-term accumulative process, which is affected by the side effects of anti-tumor therapy, tumor biological characteristics, nutrition consumption, abnormal energy metabolism, and other factors. Malnutrition in patients with malignant tumors is affected by tumor type, stage, location, treatment method, and other factors [27, 28]. Compared to patients with digestive system neoplasms, most of which cause malnutrition by tumor space effects and digestive tract dysfunction, malnutrition in patients with advanced lung cancer is often caused by a combination of systemic factors [4, 29, 30]. Long-term anti-tumor treatment and chronic consumption from tumors can lead to changes in body composition. The reduction of skeletal muscle and lean body tissue directly leads to treatment-related adverse reactions and worse subsequent treatment efficacy. On the other hand, continuous skeletal muscle consumption increases the patient's tolerance to treatment drop and increases the risk of malnutrition. Malignant tumors can also secrete pro-inflammatory factors that increase fat and protein catabolism and weight loss. This reflects the interaction of inflammation, immunity, and nutrition in patients with advanced lung cancer [31–33]. Long-term changes in the above factors eventually lead to significant skeletal muscle reduction and weakening of strength in patients with malnutrition.

To our knowledge, this study is the first to apply the L3 skeletal muscle index to nutritional assessment in patients with advanced lung cancer. The results of this study provide a strong verification for promoting the application of skeletal muscle index in nutritional status assessments of patients with cancer. The L3 skeletal muscle index reflects the state of the patient’s skeletal muscle by medical imaging. The decrease in skeletal muscle mass is related to patient immune function and inflammation state [34, 35], which means that, to a certain extent, the skeletal muscle index reflects the immune-inflammatory state of the body and represents changes in body nutritional metabolism and composition. In summary, the L3 skeletal muscle index provides a quantitative index for the nutritional assessment of patients with advanced lung cancer. There were deficiencies in the experiment, and further exploration is needed in the future. First, a larger sample size verification experiment is needed. Second, in terms of the research objects, we look forward to more detailed subgroup that construct L3 skeletal muscle index group cut-off values, which are suitable for different populations according to sex or cancer type.

In summary, a low L3 skeletal muscle index is an independent risk factor for malnutrition in patients with advanced lung cancer. We believe that the L3 skeletal muscle index has excellent sensitivity and

specificity for the nutritional assessment of patients with advanced lung cancer, which is consistent with the PG-SGA and has good efficacy in diagnosing malnutrition. The L3 skeletal muscle index obtained by CT analysis, as a new nutritional evaluation index, has the advantages of being non-invasive, objective, and accurate and will have value as a quantitative evaluation index in the future.

Conclusion

In summary, the correlation between the L3 skeletal muscle index and malnutrition was investigated. We chose the Asian population as the research object, first observed that the L3 skeletal muscle index statistically differed among patients with advanced lung cancer with different nutritional statuses. The regression model suggested the L3 skeletal muscle index was an independent risk factor for malnutrition. And we further confirmed the applicability of the L3 skeletal muscle index in advanced lung cancer patients. The L3 skeletal muscle index has good diagnostic value in nutritional assessment.

Abbreviations

SMI
skeletal muscle index
the L3
the third lumbar vertebra
BMI
body mass index
ALB
albumin
PA
prealbumin
NLR
neutrophil to lymphocyte ratio
PLR
platelet to lymphocyte ratio
PG-SGA
the Patient-Generated Subjective Global Assessment
SGA
the Subjective Global Assessment
BIA
bioelectrical impedance analysis
ROC
the Receiver Operating Characteristic Curve
PhA
phase angle

ADA
the American Dietetic Association

Declarations

Ethics approval and consent to participate The study was approved by the Ethics Committee of the first affiliated hospital of Jilin University (2017-362), and all the patient data in this research was approved by this committee. All study participants have filled out written informed consent for participation.

Consent for publication Not applicable

Availability of data and material Materials described in the manuscript, including all relevant raw data, will be freely available to any scientist wishing to use them for non-commercial purposes, without breaching participant confidentiality. Any investigator interested in viewing raw data may contact us by email ds9291@qq.com.

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Author	contributions
XL	Subject determination, document collation, paper writing and revision
WJ	Subject determination, document collation, paper writing and revision
KZ	Document collation, paper writing and revision
JL	Document collation, paper writing and revision
LL	Document collation, paper writing and revision
JC	Determine the theme, guide the writing of the paper, review the paper
WL	Determine the theme, guide the writing of the paper, review the paper

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Figures

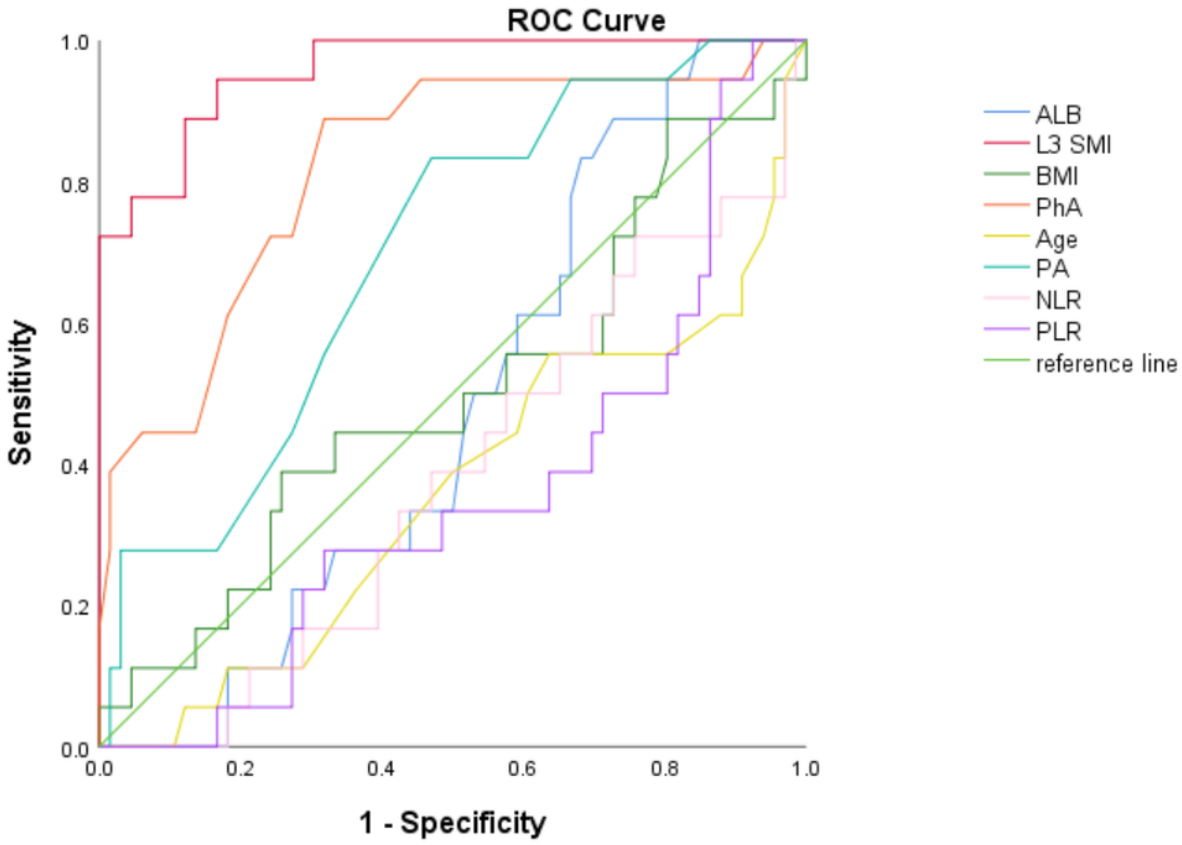

Figure 1

The ROC curve