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Relationship between preoperative body mass index and overall mortality in patients who have undergone lobectomy for lung cancer

Dan Su[1,2†], Xianning Wu[3†], Ting Zhang[2†] and Hong Zhang[1*]

Abstract

Aims Preoperative body mass index (BMI) has been shown to be an important prognostic factor after lobectomy in patients with lung cancer. However, few studies have investigated the relationship between preoperative BMI and overall mortality in these patients. In this study, we aimed to identify the range of BMI that heralds a favorable prognosis in patients who have undergone lobectomy for lung cancer.

Methods The association between BMI and overall survival was examined using primary data from an affiliated hospital database and fitted adjusted Cox regression models. The restricted cubic spline (RCS) method was used to report the relationship between preoperative BMI and overall mortality. Fully adjusted models were stratified by and adjusted for sex, age, disease stage, respiratory function, and adjuvant chemotherapy.

Results Of 3307 patients identified to have undergone radical resection of lung cancer between November 2009 and July 2019, 2365 underwent lobectomy and 558 died. BMI had a J-shaped association with overall mortality; we estimated that the overall mortality risk reached a nadir at BMI values of 23.2–29.4, with an inverse association below 23.2 (hazard ratio 0.104 per 5-unit decrease; 95% confidence interval 0.089–0.119), a positive association above 29.4 (hazard ratio 0.022 per 5-unit increase; 95% confidence interval 0.004–0.040), and the lowest mortality at 25.7.

Conclusion Preoperative BMI is an important prognostic factor after lobectomy in patients with lung cancer. A BMI of 23.2–29.4 has a prognostic benefit.

Keywords Body mass index, Preoperative, Lung cancer, Lobectomy, Restricted cubic spline

Introduction

The latest global cancer burden data released by the International Agency for Research on Cancer in 2020 show that the mortality rate of lung cancer is still the highest among all cancers worldwide. In China, lung cancer is the leading cause of new cancer diagnoses and cancer-related deaths [1]. Lobectomy is one of the most common procedures performed in thoracic surgery and is used in patients with peripheral lung cancer and irreversible lesions confined to the lung lobes. Because lung cancer has a low overall survival (OS) rate, the time from randomization to death from any cause and prognostic factors such as age, sex, stage, histopathology, antitumor

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treatment, and nutritional status [2, 3], are particularly important. However, improvements in the prognosis have been extremely limited for decades, possibly because most of these prognostic factors are non-modifiable. Preoperative nutritional status has been confirmed to be related to the prognosis in several types of cancer [4–6]. Therefore, optimization of preoperative nutritional status would represent a breakthrough in terms of prognostic indicators in lung cancer-related research.

The nutritional status of patients with lung cancer is associated with several clinical outcomes, including quality of life [7] and the therapeutic effect of drugs [8]. Mechanistically, nutrition may impact the progression of cancer [9], and good nutrition likely aids in both combating cancer and the ability to tolerate auxiliary or follow-up treatment. Considering that the value of nutritional status in improving OS has been demonstrated in recent studies [10, 11], we hypothesized that nutritional status could be monitored and optimized to improve clinical and survival outcomes in patients with lung cancer.

Body mass index (BMI) is an indicator of nutrition that is easy to obtain and follow up long-term. Several studies have identified BMI as a useful predictor of long-term outcomes in patients undergoing major surgery [4, 12, 13]. While BMI has been widely adopted as a pragmatic anthropometric proxy for nutritional assessment, particularly in undernourished cohorts, its clinical implications demonstrate paradoxical duality [14]. Elevated BMI independently correlates with adverse outcomes through distinct pathophysiological cascades unrelated to malnutrition [10]. Current evidence suggests that adiposity-driven metabolic perturbations, including leptin resistance, adipocytokine dysregulation, and ectopic lipid deposition, mediate restrictive ventilatory defects via visceral adiposity-induced diaphragmatic splinting coupled with chronic low-grade systemic inflammation [15]. These mechanisms collectively compromise respiratory mechanics, manifesting as reduced functional residual capacity and increased work of breathing, as quantified by respiratory inductance plethysmography [16–18]. Furthermore, the metabolically unhealthy obesity phenotype shows synergistic interactions between chronic overnutrition and cardiometabolic comorbidities that amplify the perioperative risk of thromboembolism [19]. In view of this bidirectional relationship, there is a need for detailed research on BMI as a composite biomarker of nutritional indicators and metabolic burden. However, most of the relevant studies have focused on the relationship between BMI and the risk of lung cancer [20] or not included important prognostic indicators, such as the surgical method used and whether postoperative adjuvant chemotherapy was administered [21]. Furthermore, few studies have reported on the relationship between preoperative BMI and overall mortality in patients who have undergone lobectomy for lung cancer. We have long believed that maintaining a normal BMI is sufficient, but is this really the case? What level of BMI is beneficial for the prognosis of patients with lung cancer?

The aim of this study was to determine the relationship between BMI and overall mortality in patients with lung cancer who have undergone lobectomy. We used the restricted cubic spline (RCS) function in dose–response to adjust for key individual-level characteristics in these patients.

Methods

Study population

A search of the lung cancer database at the First Affiliated Hospital University of Science and Technology of China identified 3869 patients who underwent radical resection of lung cancer between November 2009 and July 2019. In total, 562 patients (14.5%) were excluded because of invalid BMI measurements, lack of follow-up information, or a history of preoperative treatment (e.g., neoadjuvant chemotherapy, radiotherapy, or targeted therapy), leaving 3307 patients for inclusion in the study.

Figure 1 shows the study inclusion and exclusion criteria. Lobectomy was the most common procedure, being performed in 71.5% of cases. Patients who underwent segmentectomy usually had early-stage disease and a good prognosis, while those who underwent pneumonectomy had severe disease and a poor prognosis. Patients undergoing extensive surgery may consider BMI-targeted interventions unnecessary or ineffective and be unlikely to comply with them, so those who underwent segmentectomy or pneumonectomy were excluded. Finally, the 2365 patients who underwent lobectomy were enrolled in the study.

Study variables and definitions

Demographic, clinical, and treatment-related data, including BMI, age, sex, disease stage, single tumor, history of other tumors, FEV1%, smoking status, surgical method used, number of sentinel lymph nodes dissected, postoperative adjuvant chemotherapy, duration of follow-up, and status during follow-up, were obtained from the hospital database.

Preoperative BMI was calculated as weight (kg) divided by the square of height (m) on the day of admission before surgery. Patients were then categorized as underweight (BMI <18.5), normal weight (BMI 18.5–24.9), overweight (25.0–29.9), or obese (BMI ≥ 30.0) according to the World Health Organization BMI classification for Asians [22].

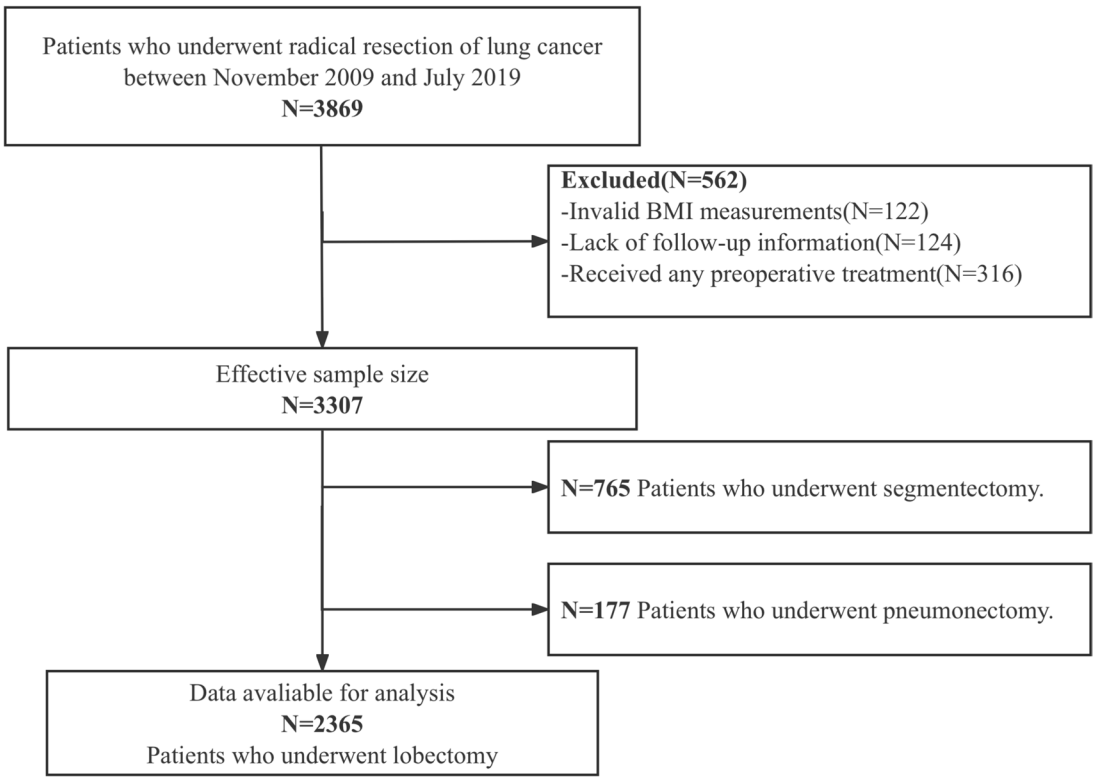

Fig. 1 Diagram showing the study inclusion and exclusion criteria (*N* = 2365)

Using the eighth edition of the International Society for Lung Cancer Research TNM staging system, the patients were categorized as having stage IA, IB, IIA, IIB, IIIA, IIIB, IIIC, or IV lung cancer. Combined with experience in clinical practice, we defined stages IA, IB, IIA, and IIB as early-stage and stages IIIA, IIIB, IIIC, and IV as late-stage [23, 24].

In accordance with the GOLD guidelines and consensus statements from multiple respiratory disease societies, we chose FEV1% for evaluation of respiratory function. A value of ≥ 80% was considered normal respiratory function and a value of < 80% was considered abnormal.

For the purposes of this study, a single tumor refers to the presence of only one tumor in the lungs rather than multiple tumors.

The outcome variable was OS time. The date of death was extracted from the database, and OS time was defined as the interval between the date of pathological diagnosis to the date of death or the most-recent follow-up.

Statistical analyses

First, continuous variables were summarized as the mean ± standard deviation or median (range) and categorical variables as the frequency (percentage). The Shapiro–Wilk test was used to assess the normality of the data. Differences between groups were examined using the Kruskal–Wallis test, the chi-squared test, or Fisher's exact test. Second, the OS rate was quantified using Kaplan–Meier curve analysis, and the curves for probability of survival were compared using the log-rank test. Cox regression analysis was used to identify prognostic factors for OS. Multicollinearity of the independent variables was assessed using the variance inflation factor (VIF). An RCS with 4 knots was used to simulate the relationship between BMI and overall mortality in patients with lung cancer who have undergone lobectomy. Fully adjusted models were stratified by and adjusted for sex, age, disease stage, single tumor, respiratory function, history of other tumors, and postoperative adjuvant chemotherapy. All statistical analyses were performed using R version 4.1.0 (R Foundation for Statistical Computing, Vienna, Austria) with the *survival, survminer, rms, psych, mice, car, Hmisc, patchwork, MatchIt* and *cowplot* packages. A p-value < 0.05 was considered statistically significant.

Results

Background characteristics

All 2365 individuals in our prospectively maintained database who had undergone lobectomy for lung cancer and had their BMI measured on admission were included in the study. The median follow-up duration was 28.6 months (range 3–60). The 30-day operative mortality rate was 0.13% (3/2365), with one death from pulmonary embolism in the obese group and two deaths from COVID-19-associated pneumonia (one in the underweight group and one in the normal weight group).

One hundred and eight patients (4.6%) were underweight, 1680 (71.0%) were of normal weight, 519 (21.9%) were overweight, and 58 (2.5%) were obese. The median BMI was 17.75 (range 14.15–18.49) in the underweight group, 22.67 (18.51–24.99) in the normal weight group, 26.37 (25.00–29.97) in the overweight group, and 30.90 (30.00–41.01) in the obese group. The 5-year mortality rate was 30.6% (33/108) in the underweight group, 24.6% (414/1680) in the normal weight group, 19.7% (102/519) in the overweight group, and 15.5% (9/58) in the obese group.

Table 1 shows the patient demographics and clinical and surgical details according to weight. There were no statistically significant differences in disease stage, single tumor, smoking status, or number of sentinel lymph nodes dissected among the four groups ($p > 0.05$). However, there were significant differences in patient age, sex, FEV1%, postoperative adjuvant chemotherapy and history of other tumors among the groups ($p < 0.05$).

Relationship between BMI and overall survival

Kaplan–Meier curve analysis revealed statistically significant differences in the cumulative OS rate between the four groups ($p = 0.0002$) (Fig. 2-1). The cumulative OS rate was significantly higher in the obese group than in the underweight group ($p = 0.0104$, log-rank test). The cumulative survival rate was significantly higher in the overweight group than in the underweight group ($p = 0.0002$, log-rank test) and significantly higher in the normal weight group than in the underweight group ($p = 0.0060$, log-rank test). The cumulative survival rate was also significantly higher in the overweight group than in the normal weight group ($p = 0.0463$, log-rank test). However, there was no significant difference in the cumulative survival rate between the obese group and the normal weight group ($p = 0.0951$, log-rank test) or between the obese group and the overweight group ($p = 0.3284$, log-rank test).

To avoid the possible confounding effect of a correlation between BMI and advancing age, we divided the four BMI groups into two cohorts by combining the low body weight and normal weight groups into a low BMI group and the overweight and obese groups into a high BMI group. We then performed propensity score matching for age using 1:1 nearest neighbor matching (caliper value = 0.02). Kaplan–Meier curve analysis

Table 1 Characteristics of 2365 patients who underwent lobectomy for lung cancer

Variables		Underweight ($n = 108$)	Normal weight ($n = 1680$)	Overweight ($n = 519$)	Obese ($n = 58$)	p-value
BMI		17.58 ± 0.83	22.31 ± 1.62	26.62 ± 1.23	31.51 ± 1.82	< 0.0001
Age		63.72 ± 11.58	61.50 ± 10.00	61.19 ± 9.30	59.62 ± 9.52	0.0192
FEV1%		87.48 ± 20.05	92.74 ± 18.56	94.26 ± 18.17	92.93 ± 16.00	0.0008
Sex	Male	73(67.6%)	1060(63.1%)	305(58.7%)	29(50.0%)	0.0432
	Female	35(32.4%)	620(36.9%)	214(41.3%)	29(50.0%)	
Staging	Early	66(61.1%)	1147(68.3%)	357(68.8%)	35(60.3%)	0.2515
	Late	42(38.9%)	533(31.7%)	162(31.2%)	23(39.7%)	
SLND		3.96 ± 1.89	4.01 ± 2.03	3.92 ± 1.98	4.00 ± 1.90	0.8911
PAC	Presence	6(5.6%)	139(8.3%)	15(2.9%)	2(3.4%)	< 0.0001
	Absence	102(94.4%)	1541(91.7%)	504(97.1%)	56(96.6%)	
Single tumor	Single	105(97.2%)	1641(97.7%)	508(97.9%)	57(98.3%)	0.9428
	Multiple	3(2.8%)	39(2.3%)	11(2.1%)	1(1.7%)	
History of other tumor	No	99(92.4%)	1577(93.8%)	465(90.1%)	54(93.7%)	0.0120
	Yes	9(7.6%)	103(6.2%)	54(9.9%)	4(6.3%)	
Smoking	Never	79(73.2%)	1261(75.1%)	407(78.4%)	48(82.7%)	0.1573
	Before	9(8.3%)	115(6.8%)	43(8.3%)	3(5.2%)	
	Now	20(18.5%)	304(18.1%)	69(13.3%)	7(12.1%)	

Notes Values are expressed as the mean ± standard deviation or as the number (percentage) as appropriate. Stages IA, IB, IIA, and IIB as early-stage and stages IIIA, IIIB, IIIC, and IV as late-stage. *Abbreviations*: *BMI* body mass index, *SLND* sentinel lymph nodes dissected, *PAC* Postoperative adjuvant chemotherapy

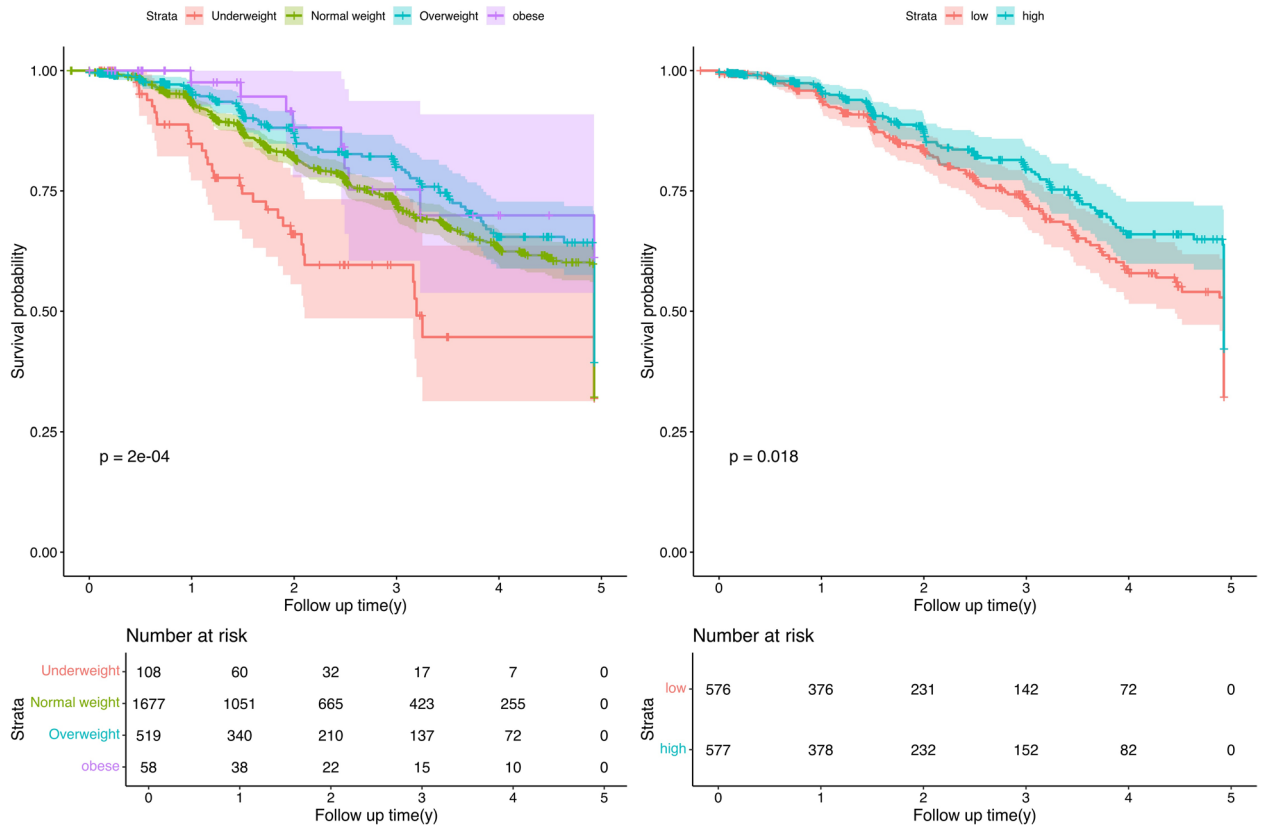

Fig. 2 Kaplan–Meier curves showing the effect of body mass index on mortality in patients with lung cancer who had undergone lobectomy according to Balance Check Before (2–1), and After Matching (2–2). Cumulative survival rates were significantly and consistently higher for patients with higher body mass index. Differences in survival rates among groups were more significant at later follow-up time points

revealed statistically significant differences in the cumulative OS rate between the four groups ($p = 0.018$) (Fig. 2-2).The OS rate was then compared between the two groups. Finally, multivariate Cox regression analysis showed that BMI, age, sex, disease stage, FEV1%, and postoperative adjuvant chemotherapy were independent predictors of the prognosis. All the VIF values for the independent variables were < 5, indicating that there was no multicollinearity problem (Table 2).

Table 2 Results of multivariate analysis of potential prognostic factors for survival in a Cox proportional hazards model ($N = 2365$)

Factors	exp(coef)	exp(-coef)	lower 0.95	upper 0.95	*p-value*	VIF
Age	1.3419	0.7452	1.0227	1.7608	0.0339	1.0258
Sex	0.5817	1.7191	0.4234	0.7993	0.0008	1.2898
Single tumor	1.7407	0.5745	0.6945	4.3631	0.2371	1.2674
History of other tumors	1.3065	0.7654	0.6925	2.4652	0.4091	1.3045
Smoking	0.9302	1.0750	0.7898	1.0956	0.3863	1.2111
Staging	1.9348	0.5169	1.4955	2.5030	< 0.0001	1.0190
SLND	0.9959	1.0041	0.9235	1.0741	0.9159	1.0291
PAC	2.1227	0.4711	1.4296	3.1517	0.0002	1.0268
FEV1%	0.9918	1.0083	0.9854	0.9982	0.0127	1.0516

Notes The multivariable Cox model was adjusted for age, sex, single tumor, history of other tumors, smoking status, staging, surgical method used, and postoperative adjuvant chemotherapy. All the VIF values for the independent variables are shown in the far right column. *Abbreviations*: *SLND* sentinel lymph nodes dissected, *PAC* postoperative adjuvant chemotherapy, *VIF* variation inflation factor

Relationship between BMI and overall mortality after lobectomy for lung cancer

Analysis of variance showed that there was a significant nonlinear association between BMI and overall mortality ($P_{nonlinear} = 0.0042$). We conducted modeling experiments using 3–5 knots each. The results were as follows: $R^2 = 0.224$ and Dxy = 0.351 for 3 knots; $R^2 = 0.224$ and Dxy = 0.352 for 4 knots:; and $R^2 = 0.223$ and Dxy = 0.352 for 5 knots. The larger the R^2 and Dxy values, the better the fitted model. Therefore, we used an RCS with 4 knots to simulate the relationship between BMI and overall mortality in patients with lung cancer who underwent lobectomy. The RCS model after adjustment for sex, age, disease stage, single tumor, respiratory function, a history of other tumors, and postoperative adjuvant chemotherapy is shown in Fig. 3. The associations between BMI and overall mortality were J-shaped. Figure 3 shows the result for the 2365 patients who had undergone lobectomy. We used the Predict function to find the boundary between a hazard ratio (HR) >1 and an HR <1 and obtained the BMI when the HR was 1 so that we could distinguish which BMI range was a protective factor and which was a risk factor. Finally, we found that a change in the HR from 1.007 to 0.999 corresponded to a BMI of approximately 23.2 and that a change in the HR from 0.998 to 1.002 corresponded to a BMI of approximately 29.4. When BMI is approximately 25.7, the HR reached its lowest value of 0.889. Therefore, we can add a vertical line at the positions where BMI is 23.2 and 29.4 to distinguish the range in which BMI serves as a protective factor. We estimated that the overall mortality risk reached a nadir at BMIs in the range of 23.2–29.4, with inverse associations below 23.2 (HR 0.104 per 5-unit decrease; 95% confidence interval 0.089–0.119), positive associations above 29.4 (HR 0.022 per 5-unit increase; 95% confidence interval 0.004–0.040).

Further grouping analysis is shown in Fig. 4. We estimated that the overall mortality risk in the entire group of patients reached a nadir at a BMI in the range of 23.3–29.4, with inverse associations below, positive associations above, and the lowest mortality at 25.7. In men aged over 60 years with early-stage disease, the factors that protected against mortality from any cause were normal respiratory function, no postoperative adjuvant

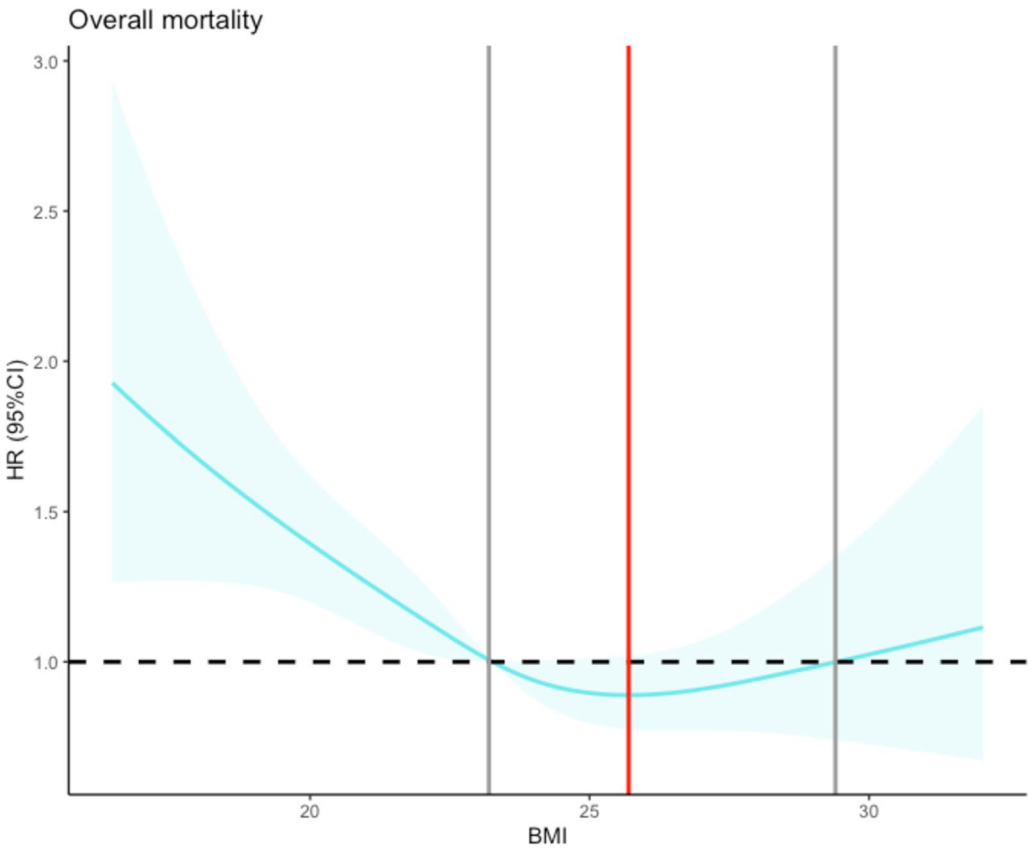

Fig. 3 Association between body mass index and overall mortality. Patients with a body mass index of 25.7 had the lowest mortality (red line). Body mass index was a protective factor for overall mortality in the range of 23.2–29.4 (gray line). Abbreviations: BMI, body mass index; CI, confidence interval; HR, hazard ratio

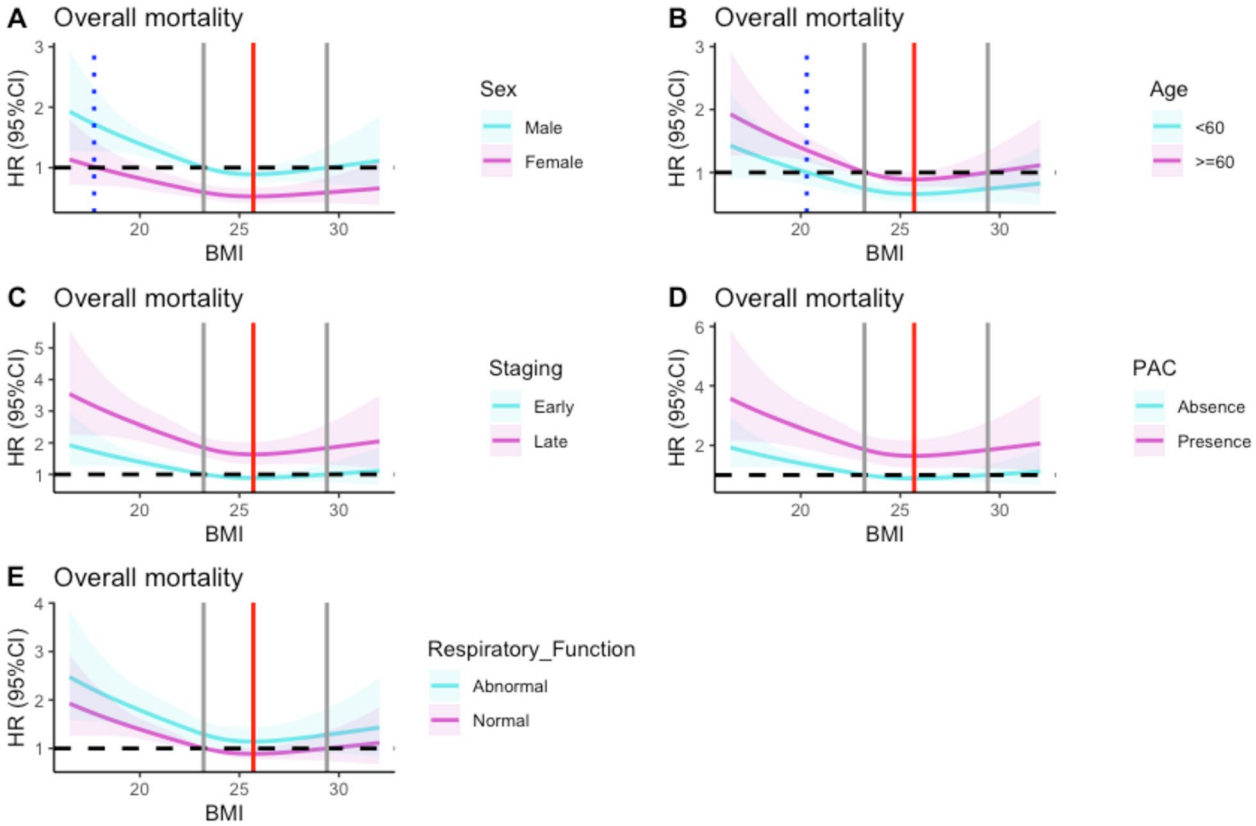

Fig. 4 Association between BMI and overall mortality in patients with lung cancer who had undergone lobectomy according to sex (**A**), age (**B**), disease stage (**C**), PAC (**D**), and respiratory function (**E**). Patients with a BMI of 25.7 had the lowest mortality (gray line). (**A**) BMI was a protective factor in the range of 23.2–29.4 in men (gray line) and when > 17.7 in women (blue dashed line). (**B**) In the group aged over 60 years, BMI of 23.2–29.4 (gray line) was a protective factor; in the group aged younger than 60 years, BMI of > 20.3 was a protective factor (blue dashed line). (**C**) In the group with early-stage disease, BMI of 23.2–29.4 was a protective factor (gray line). (**D**) In the group that did not receive postoperative adjuvant chemotherapy, BMI of 23.2–29.4 (gray line) was a protective factor. (**E**) In the group with normal respiratory function, BMI of 23.2–29.4 was a protective factor (gray line). Abbreviations: BMI, body mass index; CI, confidence interval; HR, hazard ratio; PAC, postoperative adjuvant chemotherapy

chemotherapy, and a BMI in the range of 23.3–29.4. In women, a BMI > 17.7 (indicated by a blue dashed line in Fig. 4) protected against death from any cause. In the group aged ≤ 60 years, BMI > 20.3 was a protective factor in terms of all-cause mortality.

Discussion

Nutritional status has been found to be associated with both disease recurrence and the prognosis in patients with lung cancer [25]. Previous studies have reported an association between preoperative nutritional status and the prognosis of patients with lung cancer who have undergone surgery [26, 27]. Given that most reported prognostic indicators are difficult to follow up, we performed this study to determine the association between preoperative BMI and postoperative OS in patients with lung cancer. We found that the mortality rate was highest in the underweight group, followed by the normal weight group and then the overweight/obese group. The results of our survival analyses also confirmed that preoperative BMI was a significant independent risk factor for postoperative lung cancer patients. This finding is similar to that of previous research in patients with non-small-cell lung cancer [28], in whom lower BMI and significant weight loss before surgery had a negative impact on surgical outcomes [29].

Malnutrition has been associated with a poor response to therapy and identified as a major contributor to increased mortality [30, 31]. This finding is consistent with the "obesity paradox," the pathophysiology of which remains to be elucidated. One possible explanation is that fat storage in overweight/obese patients may protect the balance of muscle protein catabolism in chronic wasting diseases [32] because protein is crucial for survival, maintaining cell function and supporting cell architecture [33]. Another possible explanation

is that a high inflammatory state related to sarcopenia in underweight patients may lead to increased mortality [34]. However, some studies in patients with thyroid cancer suggest that a higher BMI confers a greater risk of malignancy [35, 36]. Therefore, fat stores may factor differently in other types of tumors. Nevertheless, preoperative nutritional status remains an important predictor [37], particularly in our lung cancer cohort, and may be useful for surgeons and oncologists when making decisions regarding treatment.

Our finding of a significant association between higher BMI and improved survival outcomes may have been influenced to some extent by cancer-related cachexia, namely, weight loss in the later stages of the disease. Nevertheless, our results are consistent with the "obesity paradox" previously observed in a cardiology cohort [38], and BMI should not be interpreted as a treatment target. On the contrary, it is a substitute marker for nutritional reserve and metabolic recovery during cancer treatment. However, in cancer patients, BMI alone may not be sufficient to distinguish between protective obesity and muscle atrophy. Future research should include dual assessment of baseline BMI and pre-diagnostic BMI to reduce the interference of disease progression with weight or integrate body composition indicators (such as the CT-derived skeletal muscle index) to elucidate the complex interactions between adipose tissue, muscle mass, and survival.

Treatments are challenging for patients with lung cancer, and the prognosis should be considered early in the preoperative phase. The surgical methods used most often for patients with lung cancer are segmentectomy, lobectomy, and pneumonectomy. Analysis of our preliminary results suggested that far fewer patients undergo segmentectomy and pneumonectomy and that the prognosis of these patients is related more closely to the timing of the disease than BMI. Therefore, in this study, we focused on the patient group that underwent lobectomy.

Our multivariate Cox regression analysis identified six variables, namely, BMI, age, sex, disease stage, respiratory function, and postoperative adjuvant chemotherapy, to be independent predictors of the prognosis in patients with lung cancer who have undergone lobectomy. These variables were used to plot the RCS.

We observed a J-shaped association between BMI and overall mortality, with nadirs at 23.2–29.4 and the lowest mortality at 25.7. This finding is somewhat different from that of a similar study in the UK [39]. An interesting finding was that before this stable interval, the HR decreased with an increase in BMI (HR 0.104 per 5-unit decrease), and after this interval, the HR increased with an increase in BMI (HR 0.022 per 5-unit increase). This suggests that before this BMI interval (23.2–29.4), the patient's BMI should be as high as possible, but after this interval, the patient's BMI should be as low as possible.

The J-shaped relationship between BMI and clinical outcomes observed in this study aligns with the emerging concept of the obesity paradox in populations with chronic disease, wherein moderate adiposity confers survival advantages over both underweight and severe obesity. Our findings suggest that maintaining BMI within the range of 23.2–29.4 may represent an optimal equilibrium between metabolic resilience and catabolic protection, with distinct clinical implications for patients outside this interval. Although our research findings confirm that low BMI is associated with a poor prognosis. serum albumin levels and lymphocyte ratios can better reflect systemic inflammation and protein calorie malnutrition. It is insufficient to evaluate nutritional status based solely on BMI or to focus solely on weight gain in underweight patients (BMI <23.2). Albumin levels should be included in the nutritional triage for early intervention, such as supplementing branched chain amino acids to reverse protein catabolism, rather than focusing on changes in weight alone. Aggressive nutritional rehabilitation should prioritize a hypercaloric diet (35–40 kcal/kg/day) with ≥ 1.5 g/kg/day protein to replenish lean mass. Resistance training, rather than excessive aerobic exercise, is critical to avoid counterproductive energy expenditure. Future trials should validate composite nutritional indices (e.g., the albumin-adjusted skeletal muscle index) to optimize patient selection for targeted nutritional support. For patients who are overweight or obese (BMI >29.4), weight loss regimens must balance caloric restriction with muscle preservation.

The gender-age-physiology index has been reported to be useful for predicting mortality in patients with lung disease [40], which is consistent with our findings that male patients and older people had a worse prognosis; their HR has a stronger association with different levels of BMI, likely related to lifestyle and physical deterioration. If BMI can be maintained within the range of 23.2–29.4 in these patients, with a BMI of ≥ 17.7 for women and ≥ 20.3 for those up to the age of 60 years, it will be beneficial for their prognosis.

We also found that clinical staging was an independent risk factor for a poor prognosis after lobectomy in patients with lung cancer, which is consistent with previous reports [41]. Furthermore, we found that patients with normal respiratory function had a better outcome, and we suggest that the patient's BMI should be maintained between 23.2 and 29.4 for a better prognosis. This study also found that patients who did not receive postoperative adjuvant chemotherapy had a better outcome. The efficacy of postoperative adjuvant chemotherapy has been demonstrated in several studies

[42–44]. However, patients undergoing postoperative chemotherapy are often more severely ill and have poorer quality of life, which may be the reason for the poorer prognosis of patients undergoing postoperative chemotherapy in this study.

These findings provide a new direction for prognostic intervention after surgery for lung cancer. By maintaining their preoperative BMI in the range of 23.2–29.4, patients can improve their postoperative prognosis.

This study had some limitations. First, no information was available on comorbidities, and future research should analyze data from databases that include information on concomitant illnesses. Second, we did not monitor dynamic changes in BMI during follow-up, which are important in the light of data showing that changes in body weight after treatment for lung cancer influence lean mass [45]. Third, the limitations of follow-up by telephone meant that we cannot guarantee that the causes of death reported by family members were accurate. Although all-cause mortality was selected as the outcome measure, reporting cancer-related mortality is also important, and future studies should include exact causes of death in these patients. Fourth, all the study participants were recruited from the same university hospital, which raises the possibility of sampling bias. Finally, nutritional status was assessed preoperatively but not postoperatively.

Overall, our study contributes several meaningful findings concerning the postoperative prognosis of patients with lung cancer. We have confirmed that preoperative BMI plays an essential role in the prognosis after lobectomy in these patients. Furthermore, our RCS model has identified a precise BMI interval that is beneficial for the prognosis, which will provide a rationale for further research designed to improve the prognosis by nutritional intervention before initiation of treatment.

Abbreviations

BMI	Body mass index
CI	Confidence interval
HR	Hazard ratio
OS	Overall survival
PAC	Postoperative adjuvant chemotherapy
RCS	Restricted cubic spline
SLND	Sentinel lymph nodes dissected
VIF	Variance inflation factor

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Authors' contributions
D. S. and T. Z. wrote the original draft, XN. W. guided the investigation, and H. Z. guided writing—review & editing. All the authors listed have approved the final version of the manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
The study was approved by the Ethics Committee of the First Affiliated Hospital of USTC (approval number 2022KY268) and conducted in accordance with the principles of the 1975 Declaration of Helsinki. The need for informed consent was waived in view of the retrospective nature of the research.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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