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The relation of body adiposity to the outcomes of thoracoscopic lobectomy for lung cancer – a single-center cohort study

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Abstract

Introduction: The outcomes of lung cancer surgery depend on the patients' nutritional status. Body fat percentage (BF%) is one of the indicators of body composition and nutritional status. Direct measurement of BF% is complicated, requires significant resources and is rarely performed. The CUN-BAE (Clínica Universidad de Navarra – Body Adiposity Estimator) index has been shown to accurately predict BF% is several clinical settings, but its relation to the outcomes of lung surgery has not been reported so far.
Aim: To determine the relation of the BF% to the outcomes of thoracoscopic lobectomy.
Material and methods: This retrospective study included 1,183 patients who underwent thoracoscopic lobectomy for non-small cell lung cancer between June 1999, and September 2019 at one department. BF% was calculated according to the Clínica Universidad de Navarra – Body Adiposity Estimator equation. The primary endpoints were postoperative complications and long-term survival.
Results: Univariate analysis showed that higher BF% was related to lower incidence of complications (p = 0.001), including prolonged air leak (p < 0.001), atelectasis (p < 0.05), psychosis (p < 0.001), reoperations (p < 0.05), and shorter chest drainage (p = 0.001) and hospitalization duration (p < 0.001). Multivariate analysis showed that higher BF% was correlated with lower risk of complications (p = 0.005; OR = 0.964; 95% CI: 0.940 to 0.989), including prolonged air leak (p < 0.001; OR = 0.923; 95% CI: 0.886 to 0.962), and shorter duration of chest drainage (p < 0.001; B = –0.046; 95% CI: –0.069 to –0.023) and hospitalization (p < 0.001; B = –0.112; 95% CI: –0.176 to –0.048). Cox proportional hazards regression analysis showed that BF% was not related to long-term survival.
Conclusions: Body fat percentage is a valuable tool that can help predict the short-term outcomes of minimally lobectomy for lung cancer.

Key words: lung cancer surgery, minimally invasive surgery, thoracoscopy/video-assisted thoracoscopic surgery, obesity, body fat.

Introduction

Video-assisted thoracoscopic surgery (VATS) lobectomy is the recommended method of surgical treatment of early-stage non-small cell lung cancer (NSCLC) [1]. Short- and long-term outcomes of NSCLC treatment are predicted on the basis of comorbidities, functional status of the patient and cancer stage [2]. Despite implementation of minimally invasive techniques, identification of various risk factors and development of complex predictive models, we are still unable to accurately predict postoperative complications and long-term outcomes.

Obesity is defined as accumulation of excess body fat, and contributes to the development of other conditions such as diabetes, cardiovascular diseases and neoplasms [3]. Although obesity increases the overall population morbidity and mortality, some studies suggested that it might be related to better outcomes of lung cancer treatment, which has been termed the "obesity paradox" [4].

Body composition, including body fat content, can be assessed most accurately using objective methods, such as bioelectrical impedance analysis (BIA) or dual-energy X-ray absorptiometry (DEXA) [5]. All these methods, however, require specialized equipment and experience and are not routinely used in clinical practice. Therefore, the nutritional status is usually assessed by body mass index (BMI). The index is easy to calculate but has significant disadvantages:

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it does not reflect differences between people resulting from age, gender or fitness, and does not allow for the assessment of body composition [6]. The Clínica Universidad de Navarra – Body Adiposity Estimator (CUN-BAE) has been invented to enable accurate estimation of body adiposity by calculation of body fat percentage (BF%). The equation was originally developed and validated on large groups of subjects of both sexes, with a wide range of ages and body adiposity [7]. It has been proven that BF% calculated with CUN-BAE correlated well with body fat measured by BIA, accurately predicted adverse cardiovascular events in obese patients and predicted complications in patients after TAVI [7–9].

Aim

The relation of BF% calculated with CUN-BAE to the short- and long-term outcomes of surgical treatment of lung cancer has been poorly studied. This study aimed to determine whether BF% calculated with CUN-BAE was related to the short- and long-term outcomes of VATS lobectomy in patients with NSCLC.

Material and methods

The Bioethics Committee of Poznan University of Medical Sciences waived the need for ethics approval and the need to obtain consent for the collection, analysis and publication of the retrospectively obtained and anonymized data for this non-interventional study.

This single-center, retrospective, cohort study analyzed records of all patients who underwent thoracoscopic anatomical resection from June 7, 1999, to August 27, 2019. The exclusion criteria were: sublobar resection (wedge resection, segmentectomy), pneumonectomy, small-cell lung cancer, metastasis, and nonneoplastic histology. Patients who underwent VATS lobectomy for NSCLC were included.

Pre-operative evaluation included history and clinical examination with body mass and height measurements, chest computed tomography scan, abdominal ultrasound, electrocardiography, pulmonary function test, and fiberoptic bronchoscopy. If indicated, echocardiography, exercise test, diffusing capacity for carbon monoxide, positron emission tomography/computed tomography, and invasive mediastinal staging were performed.

Surgery was performed under general anesthesia with single-lung ventilation. In most patients, three-portal VATS was used; starting 2014, some patients were operated on using bi-portal or uniportal VATS. The surgical procedure included lobectomy followed by dissection of mediastinal lymph nodes. One chest tube was used, which was removed after resolution of the air leak and when the fluid volume was < 250 ml for 24 h. Postoperative complications were classified according to the definitions of the European Society of Thoracic Surgeons [10]. Reoperation was defined as surgical operation for postoperative complications during hospital stay after the anatomical resection. Data on survival were obtained from the Polish National Lung Cancer Registry.

Body fat percentage was calculated according to the Clínica Universidad de Navarra – Body Adiposity Estimator (CUN-BAE) equation: $BF\% = -44.988 + (0.503 \times age) + (10.689 \times sex) + (3.172 \times BMI) - (0.026 \times BMI^2) + (0.181 \times BMI \times sex) - (0.02 \times BMI \times age) - (0.005 \times BMI^2 \times sex) + (0.00021 \times BMI^2 \times age)$; male sex was assigned “0” and female sex “1” value [7].

Primary outcome was the occurrence of postoperative complications. Secondary outcomes were duration of chest drainage, time of postoperative hospitalization, and short- and long-term survival.

Statistical analysis

The analyzed data were expressed as mean ± standard deviation, median, minimum and maximum values, range, or percentage, as appropriate. Normality of distribution was tested using the Shapiro-Wilk test, and equality of variances was checked using Levene’s test. Comparison of two unpaired groups was performed using the unpaired *t*-test for data that followed a normal distribution and had homogeneity of variances or the Mann-Whitney *U*-test. Comparison of two paired groups was performed using the paired *t*-test for data that followed a normal distribution or the Welch test. The relationship between variables was analyzed using Spearman’s rank correlation coefficient. Variables for which the BF% relationship turned out to be statistically significant were further assessed in the multivariate analysis. In the multivariate analysis, apart from BF%, we included the most important clinical factors: age, sex, the Thoracic Revised Cardiac Risk Index (ThRCRI), FEV1% and TNM stage. Multivariate analysis was carried out according to the type of dependent variable. The continuous dependent variables were analyzed using multiple linear regression, nominal variables by logistic regression, and survival by Cox proportional hazards regression analysis. All results were considered significant at $p < 0.05$. Statistical analyses were conducted using Statistica 13.0 (StatSoft, Dell, Round Rock, TX).

Results

This study included a total of 1,183 patients after VATS lobectomy for NSCLC. Baseline, surgical and histopathological characteristics are presented in Table I.

Mean BF% was 32.8 ±7.4% and mean BMI was 26.2 ±4.6 kg/m^2. We found that BF% was higher in female compared to male patients (38.9% vs. 28.1%, $p < 0.001$), and in patients with diabetes mellitus (34.1% vs. 32.1%, $p < 0.001$) and arterial hypertension (34.2% vs. 31.2%, $p < 0.001$) (Table II). There was a strong correlation between BF% and BMI ($R = 0.594$, $p < 0.001$), a weak correlation between BF% and age ($R = 0.12$, $p < 0.001$) and a very weak negative correlation between BF% and pathological stage of NSCLC ($R = -0.06$, $p = 0.029$). No association was found between BF% and T ($p = 0.503$), N ($p = 0.105$), M ($p = 0.284$) categories.

Median surgery time was 120 min (45–300 min), estimated blood loss was 100 ml (0–1800 ml), chest tube duration was 3 days (1–37 days) and postoperative hospitalization time was 6 days (2–83 days). Higher BF% was related to shorter chest tube duration ($R = -0.12$, $p < 0.001$) and

Table I. Baseline characteristics (*n* = 1183)

Variable	Results
Age [years][b]	64.5 ±7.7
Gender[a]:	
Male	697 (58.9)
Female	486 (41.1)
Comorbidities[a]:	862 (72.9)
Hypertension	500 (42.3)
Chronic obstructive pulmonary disease	287 (24.3)
Coronary arterial disease	187 (15.8)
Diabetes mellitus	167 (14.1)
Peripheral arterial disease	85 (7.2)
Cerebrovascular disease	41 (3.5)
ThRCRI class[a]:	
Class A	972 (82.2)
Class B	199 (16.8)
Class C	12 (1.0)
FEV1%[b]	85.0 ±21.1
Type of lobectomy[a]:	
Right upper	430 (36.3)
Left upper	341 (28.8)
Right lower	171 (14.5)
Left lower	177 (15.0)
Middle	52 (4.4)
Bilobectomy	12 (1.0)
Histopathology[a]:	
Adenocarcinoma	668 (56.4)
Squamous cell carcinoma	363 (30.7)
Large cell carcinoma	73 (6.2)
Other types	79 (6.7)
Pathological stage[a]:	
Stage I	742 (62.7)
Stage II	292 (24.7)
Stage III	128 (10.8)
Stage IV	21 (1.8)

BF% – body fat percentage, BMI – body mass index, FEV1% – percentage of predicted forced expiratory volume in 1 s, ThRCRI – Thoracic Revised Cardiac Risk Index. [a]Data are expressed as number (%). [b]Data are expressed as mean ± standard deviation.

shorter hospitalization time (*R* = –0.09, *p* = 0.001). No correlation was found between BF% and median surgery time (*R* = –0.04, *p* = 0.198) or between BF% and estimated blood loss (*R* = –0.03, *p* = 0.308).

Conversion to thoracotomy was done in 123 (10.4%) patients. There was no correlation between BF% and conversion (*p* = 0.516). BF% was higher in patients without complications compared to patients with complications (median 33.1% vs. 31.0%, *p* = 0.001), including prolonged air leak (32.9% vs. 30.4%, *p* < 0.001), atelectasis (32.6% vs. 28.8%, *p* = 0.048), delirium (32.6% vs. 27.7%, *p* < 0.001) and reoperations (32.6% vs. 26.9%, *p* = 0.016) (Table III). Indications for reoperation were as follows: prolonged air leak (*n* = 15, 48.4% of reoperations), bleeding (*n* = 7, 22.6%), bronchial fistula (*n* = 5, 16.1%), middle lobe torsion after right upper lobectomy (*n* = 3, 9.7%) and bronchial stenosis (*n* = 1, 3.2%).

In-hospital and 90-day mortality rates were 1.2% and 2.2%, respectively. BF% was not related to in-hospital mortality (*p* = 0.961) or 90-day mortality (*p* = 0.058) (Table IV). One-, 3- and 5-year survival was respectively 86.4%, 68.3% and 59.3%. In the univariate analysis, BF% of patients who survived was higher compared to the patients who died during 1 year (32.7% vs. 30.7%, *p* = 0.006), 3 years (32.9% vs. 29.7%, *p* < 0.001) and 5 years (32.5% vs. 30.2%, *p* = 0.019) follow-up (Table IV).

Multivariate analyses included: age, sex, BF%, ThRCRI, FEV1%, adjusted for TNM stage. In the multiple linear regression analysis, higher BF% was correlated with shorter chest drainage duration (*p* < 0.001; B = –0.046; 95% CI: –0.069 to –0.023) and shorter hospitalization time (*p* < 0.001; B = –0.112; 95% CI: –0.176 to –0.048) (Table V). In the logistic regression analysis, higher BF% was correlated with lower risk of postoperative complications (*p* = 0.005; OR = 0.964; 95% CI: 0.940 to 0.989), including prolonged air leak (*p* < 0.001; OR = 0.923; 95% CI: 0.886 to 0.962). No relation was found between the BF% and atelectasis (*p* = 0.083), delirium (*p* = 0.078) or reoperations (*p* = 0.331) (Table VI). In the Cox proportional hazards regression analysis BF% was not related to 3-year survival (*p* = 0.346) or 5-year survival (*p* = 0.629) (Table VI).

Discussion

The main findings of the study were that patients with higher BF% calculated by the CUN-BAE had lower incidence

Table II. Body fat percentage in patients with and without comorbidities

Variables	With comorbidity		Without comorbidity		*P*-value
	N (%)[a]	BF%[b]	*N* (%)[a]	BF%[b]	
DM	167 (14.1)	34.1 (10.4–54.6)	1016 (85.9)	31.1 (14.1–54.6)	< 0.001*
HTN	500 (42.3)	34.2 (15.3–54.6)	683 (57.7)	31.2 (10.4–52.3)	< 0.001*
COPD	287 (24.3)	31.4 (14.1–54.6)	896 (75.7)	32.9 (10.4–54.6)	0.075
CAD	187 (15.8)	32.1 (16.3–54.6)	996 (84.2)	32.6 (10.4–54.6)	0.813
CVD	41 (3.5)	32.4 (23.4–45.0)	1142 (96.5)	32.8 (10.4–54.6)	0.752

DM – diabetes mellitus, HTN – hypertension, COPD – chronic obstructive pulmonary disease, CAD – coronary arterial disease, CVD – cerebrovascular disease, BF% – body fat percentage. [a]Data are expressed as number (%). [b]Data are expressed as median (range). *Statistically significant (*p* < 0.05).

Table III. Body fat percentage in patients with and without postoperative complications

Variables	With complications		Without complications		*P*-value
	N (%)[a]	BF%[b]	*N* (%)[a]	BF%[b]	
Total complications	328 (27.7)	31.0 (14.1–54.6)	855 (72.3)	33.1 (10.4–53.7)	0.001*
Prolonged air leak	126 (10.7)	30.4 (14.1–54.6)	1057 (89.3)	32.9 (10.4–54.6)	< 0.001*
Residual air space	66 (5.6)	33.0 (14.3–49.9)	1117 (94.4)	32.4 (10.4–54.6)	0.748
Atelectasis	51 (4.3)	28.8 (15.3–50.8)	1132 (95.7)	32.6 (10.4–54.6)	0.048*
Pneumonia	21 (1.8)	29.2 (14.5–47.6)	1162 (98.2)	32.6 (10.4–54.6)	0.064
Delirium	35 (3.0)	27.7 (17.0–40.6)	1148 (97.0)	32.6 (10.4–54.6)	< 0.001*
Atrial arrythmia	87 (7.4)	31.5 (18.4–54.6)	1096 (92.6)	32.6 (10.4–54.6)	0.892
Reoperation	31 (2.6)	26.9 (15.9–48.0)	1152 (97.4)	32.6 (10.4–54.6)	0.016*

BF% – body fat percentage. [a]Data are expressed as number (%). [b]Data are expressed as median (range). *Statistically significant ($p < 0.05$).

Table IV. Relation of body fat percentage with short-term outcomes of thoracoscopic lobectomy for non-small cell lung cancer

Variables	Dead		Alive		*P*-value
	N (%)[a]	BF%[b]	*N* (%)[a]	BF%[b]	
At discharge	14 (1.2)	30.6 (22.6–54.6)	1169 (98.8)	32.5 (10.4–54.6)	0.961
90 days	26 (2.2)	28.6 (14.1–54.6)	1157 (97.8)	32.6 (10.4–54.6)	0.058
1 year	161 (13.6)	30.7 (10.4–54.6)	1022 (86.4)	32.7 (14.3–54.6)	0.006*
3 years	271 (31.7)	29.7 (14.1–54.6)	584 (68.3)	32.9 (14.3–54.6)	< 0.001*
5 years	212 (40.5)	30.2 (15.9–54.6)	310 (59.3)	32.5 (14.3–54.6)	0.019*

BF% – body fat percentage. [a]Data are expressed as number (%). [b]Data are expressed as median (range). *Statistically significant ($p < 0.05$).

Table V. Relation of body fat percentage and other factors with the short-term outcomes of thoracoscopic lobectomy for non-small cell lung cancer – multiple linear regression analysis

Variable	*B* value	*P*-value adjusted for TNM stage	*P*-value unadjusted for TNM stage
Duration of chest drainage:			
FEV1%	–0.008	0.007*	0.007*
ThRCRI	–0.119	0.26	0.247
Sex	0.308	0.106	0.098
Age	0.03	< 0.001*	< 0.001*
BF%	–0.046	< 0.001*	< 0.001*
Duration of in-hospital stay:			
BF%	–0.11	< 0.001*	< 0.001*
Sex	0.935	0.081	0.069
Age	0.048	0.032*	0.045*
FEV1%	–0.025	0.004*	0.004*
ThRCRI	0.535	0.054	0.061

FEV1% – forced expiratory volume in the 1st s, ThRCRI – Thoracic Revised Cardiac Risk Index, BF% – body fat percentage. *Statistically significant ($p < 0.05$).

of postoperative complications, including prolonged air leak, and shorter chest drainage and hospital stay duration. The initial results indicated that long term outcomes were better in patients with higher BF%; however, the multivariate analysis did not confirm these findings.

The relationship between the nutritional status of patients and the results of the surgical treatment for lung cancer has been extensively studied, but the results are ambiguous. Most of the studies on nutritional status in patients with NSCLC have used BMI as a proxy of the fat content. Fernandez *et al.* examined a group of 27,844 patients from the STS National Database who were operated on for lung cancer and found that lower BMI was a risk factor for in-hospital and 30-day mortality [11]. Thomas *et al.* analyzed the data of 19,635 patients after NSCLC surgery from the French Epithor database and found that overweight and obesity protected against postoperative mortality and complications. Interestingly, the authors considered the use of BMI as a proxy of the fat content to be the main limitation of their study [12]. On the other hand, a significant number of studies did not show any relationship between BMI and treatment outcomes, which could

Table VI. Relation of body fat percentage and other factors with complications and long-term survival of thoracoscopic lobectomy for non-small cell lung cancer – logistic regression analysis

Variable	Odds ratio[1]	95% confidence interval	*P*-value adjusted for TNM stage	*P*-value unadjusted for TNM stage
Complication rate:				
BF%	0.965	0.94–0.99	0.005*	0.006*
Sex	1.148	0.767–1.719	0.532	0.502
Age	1.026	1.007–1.046	0.006*	0.008*
FEV1%	0.99	0.984–0.997	0.003*	0.003*
ThRCRI	1.215	0.986–1.497	0.06	0.068
Prolonged air leak:				
BF%	0.924	0.887–0.962	< 0.001*	< 0.001*
Sex	1.827	0.973–3.43	0.065	0.061
Age	1.04	1.009–1.071	0.007*	0.01*
FEV1%	0.999	0.989–1.009	0.824	0.829
ThRCRI	0.65	0.426–0.993	0.051	0.047*
Atelectasis:				
BF%	0.951	0.897–1.007	0.083	0.086
Sex	1.204	0.474–3.061	0.703	0.696
Age	1.061	1.013–1.110	0.011*	0.011*
FEV1%	0.97	0.956–0.984	< 0.001*	< 0.001*
ThRCRI	1.253	0.833–1.884	0.273	0.279
Postoperative psychosis:				
BF%	0.932	0.865–1.005	0.078	0.068
Sex	0.118	0.14–1.022	0.051	0.052
Age	1.099	1.039–1.163	0.001*	0.001*
FEV1%	0.989	0.972–1.006	0.222	0.218
ThRCRI	2.025	1.333–3.074	< 0.001*	< 0.001*
Reoperation:				
BF%	1.045	0.891–1.039	0.326	0.331
Sex	0.95	0.273–3.308	0.935	0.95
Age	0.981	0.928–1.036	0.487	0.466
FEV1%	0.992	0.972–1.012	0.415	0.415
ThRCRI	0.96	0.479–1.924	0.908	0.897
1-year survival:				
BF%	0.985	0.958–1.012	0.308	0.27
Sex	0.887	0.572–1.376	0.746	0.593
Age	1.019	0.998–1.041	0.107	0.073
FEV1%	0.986	0.979–0.993	< 0.001*	< 0.001*
ThRCRI	0.94	0.742–1.19	0.513	0.606
3-year survival:				
BF%	0.992	0.997–1.007	0.346	0.292
Sex	0.97	0.758–1.240	0.89	0.805
Age	1.017	1.005–1.029	0.013*	0.005*
FEV1%	0.987	0.983–0.991	< 0.001*	< 0.001*
ThRCRI	0.936	0.818–1.071	0.226	0.339
5-year survival:				
BF%	0.996	0.983–1.009	0.629	0.559
Sex	0.964	0.79–1.176	0.951	0.718
Age	1.009	1.0–1.019	0.119	0.059
FEV1%	0.992	0.988–0.995	< 0.001*	< 0.001*
ThRCRI	0.979	0.879–1.091	0.509	0.702

FEV1% – forced expiratory volume in the 1st s, ThRCRI – Thoracic Revised Cardiac Risk Index, BF% – body fat percentage. *Statistically significant ($p < 0.05$). [1]Ratio of the chances of occurrence of a specific complication in relation to no complication, or ratio of chances of 1-, 3- or 5-year survival to the chance of death during the respective time since surgery.

be related to the limitations of BMI, as discussed in the introduction [13]. Using BF% instead of BMI could presumably allow for a more accurate prediction of the outcomes in patients with NSCLC.

This study demonstrated that patients with an uncomplicated course after lung cancer surgery had a higher BF%. On the other hand, patients with complications, especially prolonged air leak, had lower BF%. The direct cause of this relationship is unknown, but it could probably be explained by changes in the mechanics of the lungs and chest wall related to higher body adiposity. In the case of android-type obesity, which is most common in patients operated on for NSCLC, visceral fat is accumulated mainly in the abdominal cavity, mediastinum and chest wall [14]. As a result, intraabdominal pressure increases, the diaphragm moves cranially towards the chest and the intrapleural pressure becomes slightly less negative. Transpulmonary pressure – the difference between intrapleural pressure and intraalveolar pressure – decreases [15]. Since transpulmonary pressure is the main driving force of postoperative air leak, its reduction in patients with higher BF% could result in a lower incidence of prolonged air leak. In addition to the purely mechanistic hypothesis, there may be other plausible explanations for the relationship between BF% and postoperative air leakage. In some patients operated on for lung cancer, low BF% may be an indicator of malnutrition. Research demonstrated that in patients with signs of malnutrition, prolonged air leakage may be associated with poorer lung parenchyma quality and impaired tissue healing processes [16]. In these patients, greater susceptibility of the lung parenchyma to intraoperative damage and slower healing could result in longer postoperative air leakage. Whatever the cause, reduction in prolonged air leak incidence in patients with higher BF% would lead to a lower reoperation rate, and shorter chest drainage and hospitalization duration.

The relationship between a poor nutritional status and a higher incidence of postoperative delirium has not been reported so far. However, other factors, such as abnormal levels of sodium, potassium and glucose, older age, cerebrovascular disease history and higher ASA score, have been linked to delirium [17]. In the present study, the relation found in univariate analysis was not confirmed in the multivariate analysis and probably resulted from the coexistence of lower BF and delirium in patients with numerous comorbidities and in a worse general condition. The existence of a direct cause-and-effect relationship between both factors seems unlikely.

Studies in cardiac surgery and general surgery, also cited by the authors of studies on lung cancer, indicated other possible causes of the relationship between nutritional status and complications, such as larger vasculature size, younger age and more complex and aggressive pharmacological treatment of obese patients [18]. However, these factors are unlikely to be associated with the obesity paradox in patients after VATS lobectomy. First, the most commonly occurring complications of lung cancer surgery (prolonged air leak, atelectasis, pneumonia) are unrelated to the total vasculature size [11]. Second, there is no evidence to support the hypothesis that obesity was more common in younger lung cancer patients; in our study there was weak positive correlation of higher BF% and BMI with age. Finally, aggressive treatment of obesity-related comorbidities, such as diabetes mellitus, arterial hypertension or coronary heart disease, has not been proven to influence the outcome of lung cancer treatment [19].

The relationship between higher BF% and long-term outcomes of lung cancer surgery is unclear. In our study, although the univariate analysis suggested a relationship between BF% and long-term survival, the multivariate analysis did not confirm it. Numerous studies have demonstrated an association between the nutritional status and the results of surgical treatment of lung cancer and discussed the probable underlying mechanisms. First, the most important role of the adipose tissue is to store triglycerides and free fatty acids and ensure their availability in the event of increased demand, such as cancer and its treatment. The greater amount of adipose tissue could help endure surgery, and could improve postoperative rehabilitation and compliance with adjuvant treatment [20]. Secondly, adipose tissue fulfills an important endocrine function by secretion of adipokines – adiponectin, leptin and others [21]. *In vitro* studies revealed that adiponectin may decrease migration, viability and invasiveness and increase the epithelial cell apoptosis rate [22], and leptin levels have been correlated with overall survival in lung cancer [23]. Thirdly, the occurrence of complications after lung cancer surgery is a known predictor of worse long-term outcomes [24], and a lower postoperative complication rate in patients with better nutritional status could improve survival. The relationship between the nutritional status and the results of surgical treatment of lung cancer is not well researched and requires further studies, especially in the areas of pathophysiological mechanisms and potential therapeutic interventions aimed at improving the nutrition of patients.

Limitations of the study

The main limitation of the study was its retrospective design, with the numerous shortcomings that it entailed, such as the risk of misclassification bias and information bias, and the inability to determine causation. Although the most important data collected in the hospital databases (weight and height, data regarding surgery, postoperative stay, histology and follow-up) were reliable and of high quality, some data were incomplete. This concerned especially data on smoking. As reported by Nagata *et al*., preoperative low BMI and elevated CRP were predictive factors for poor prognosis in smokers, but not in non-smokers [25]. The assessment of the relationship between BF% and smoking, especially in the immediate preoperative period, could presumably provide some additional information and give new insights into the mechanisms of BF% influence on outcomes of NSCLC treatment. The other data not included in the database concerned the reason of death (cancer- or non-cancer-related). Secondly, CUN-BAE has not been validated in patients with NSCLC. A prospective study would be needed to compare the accuracy of the equation in the assessment of BF% to objective methods (BIA, DEXA). It would also be interesting to compare the calculated BF% with the body fat content assessed on the basis of other tests such as computed tomography, and to assess the role of adipose tissue distribution between subcutaneous and visceral fat. Unfortunately, due to the retrospective nature and the long time period covered by the study, CT scans were available in only a small proportion of patients. We are planning further prospective studies in which the calculated BF% will be compared with BF% measured using objective methods, and analyzed in relation to radiological examinations such as CT. Thirdly, some authors consider CUN-BAE to be too complicated to apply for routine clinical and scientific use and proposed simpler models that accurately calculated BF% [8]. Currently, most calculations are carried out using spreadsheets; hence the degree of complexity is of secondary importance. Future research conducted on the subject of the relationship between the nutritional status of patients and the results of lung cancer treatment should also take into account the use of various models predicting body fat content.

Conclusions

The study showed that body fat percentage estimated with the CUN-BAE is a valuable tool that can help predict the outcomes of minimally invasive surgical treatment of non-small cell lung cancer. The relation of body composition to the pathogenesis, treatment and prognosis of lung cancer is still poorly understood and more research is needed.

Disclosure

The authors report no conflict of interest.

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