Original article

Nuclear Medicine Communications

A correlation study between maximum standardized uptake values and pathology and clinical staging in nonsmall cell lung cancer

Peiou Lu, Lijuan Yu, Yingci Li and Yajuan Sun

Objective **To investigate the relationship between maximum standardized uptake value and pathological type, degree of differentiation, tumor size, and clinical staging of nonsmall cell lung cancer (NSCLC).**

Methods **This study included 135 cases with pathologically proven NSCLC. Correlations between maximum standardized uptake value (SUV_{max}) and pathological type, degree of differentiation, tumor size, and clinical staging were analyzed.**

Results **There was a significant correlation between the SUV_{max} of NSCLC and the pathological type ($r=0.391$, $P=0.000$); the SUV_{max} of squamous cell carcinoma (SCC) was higher than that of adenocarcinoma (AC) ($P=0.000$), and the SUV_{max} of AC was higher than that of bronchioloalveolar carcinoma ($P=0.004$). There was a positive correlation between the SUV_{max} of AC and the degree of differentiation ($r=0.222$, $P=0.044$); SUV_{max} was lower in well-differentiated ACs than in moderately or poorly differentiated ACs ($P=0.034$ and 0.022 respectively); however, there was no statistical difference between the moderately differentiated and poorly differentiated groups ($P=1.000$). There was no correlation between the SUV_{max} of SCC and the degree of differentiation ($r=-0.304$, $P=0.054$). A positive correlation was found between the SUV_{max} of NSCLC and tumor size ($r=0.569$, $P=0.000$). The SUV_{max} of AC had a positive correlation with clinical staging ($r=0.298$, $P=0.006$); SUV_{max} was lower in stage I than in stages II, III, and IV ($P=0.047$, 0.038 and 0.015, respectively); however, the SUV_{max} in stages II, III, and IV were not different ($P=0.708$, 0.570 and 0.528, respectively). There was no correlation between the SUV_{max} of SCC and clinical staging ($r=0.066$, $P=0.680$).**

Conclusion **There was a correlation between the SUV_{max} of NSCLC and the pathological type and tumor size. A positive correlation was found between the SUV_{max} of AC and the degree of differentiation and clinical staging. There were no correlations between the SUV_{max} of SCC and the degree of differentiation or clinical staging. *Nucl Med Commun* 31:646–651 © 2010 Wolters Kluwer Health | Lippincott Williams & Wilkins.**

Nuclear Medicine Communications 2010, **31**:646–651

Keywords: adenocarcinoma, bronchioloalveolar carcinoma, deoxyglucose, position emission tomography, squamous cell carcinoma

The Center of PET/CT, Tumor Hospital, Affiliated to Harbin Medical University, Harbin, China

Correspondence to Lijuan Yu, 150 Haping Road, Nangang District, Harbin, Heilongjiang Province 150081, China
Tel: +86 451 86298558; fax: +86 451 86663760;
e-mail: yulijuan2002@yahoo.com.cn

Received 3 January 2010 **Revised** 11 March 2010
Accepted 12 March 2010

Introduction

2-deoxy-2-^{18}F-fluoro-D-glucose (^{18}F-FDG) PET/computed tomography (CT) imaging, which is based on the different metabolic rates of glucose in different tissues, can identify malignant lesions. It has already been used for the diagnosis, preoperative staging, assessment of curative effect, prognosis, and more in lung cancer. Maximum standardized uptake value (SUV_{max}), as a semiquantitative index, is mainly used in describing and comparing the metabolic rates of FDG in different patients or in different viscera, and it is also used in the diagnosis or for the differential diagnosis of lesions as either benign or malignant. SUV_{max} may vary widely even for the same type tumor. This problem is especially prominent in PET imaging of lung cancers and it produces many difficulties in routine diagnosis. We retrospectively studied ^{18}F-FDG PET/CT images from 135 patients with pathologically proven nonsmall cell lung cancers (NSCLCs), and the pathological types, degrees of differentiation, tumor sizes, and clinical stagings of the cancers. The aim of this study was to explore the correlation between SUV_{max} and these other factors.

Materials and methods

The retrospective study had been approved by the hospital's medical ethics committees.

Clinical data

This study investigated 135 cases of NSCLC in patients (76 male, 59 female, mean age 62.0 ± 12.1 years, range 39–76 years) who underwent whole-body ^{18}F-FDG PET/CT examinations in our hospital from February 2005 to March 2009. We selected SUV_{max} as the index in this research, and we chose as the region of interest the area where the uptake of ^{18}F-FDG was the strongest. From this, the SUV_{max} was automatically calculated by the software.

0143-3636 © 2010 Wolters Kluwer Health | Lippincott Williams & Wilkins

DOI: 10.1097/MNM.0b013e328339bddb

Study grouping methods are shown in Table 1: (i) we surveyed and compared the SUV_{max} of the 135 lung cancer cases and their corresponding normal lung tissues. Simultaneously, we divided these cases according to their different pathological types into three groups, squamous cell carcinoma (SCC), adenocarcinoma (AC), and bronchioloalveolar carcinoma (BAC). We analyzed their relativities and compared the differences in the SUV_{max} of these different pathological types. In addition, the AC and SCC were, respectively, separated into three subgroups according to their degree of differentiation (well-differentiated, moderately differentiated, and poorly differentiated) by two pathological physicians. We then analyzed their relativities and compared the differences among the groups. (ii) We divided these cases into four groups according to the largest axial diameter (d) in the imaging of PET, which was treated as the tumor size, of the NSCLC, $d \leq 10$ mm, $10\,\text{mm} < d \leq 20$ mm, $20\,\text{mm} < d \leq 30$ mm, and $d > 30$ mm. We then analyzed the relativity and compared the differences in the SUV_{max} among the groups. Meanwhile, we used a linear regression analysis technique to analyze the SUV_{max} of these 135 cases of lung cancer together with the tumor size. Using these results, we drew the allocation plan in a scatter plot. (iii) AC and SCC were, respectively, assigned to four groups according to the 2002 version of the TNM staging system for lung cancer, which was drawn up by the American Joint Commission for Cancer and the Union Internationale Contre le Cancer. The correlation between the clinical stages and SUV_{max} was analyzed and the difference in SUV_{max} among groups was compared.

Table 1 The patient characteristics and SUV_{max}

Parameters	*n*	*d*	SUV_{max} (mean ± SD)
Normal lung tissue	135		0.48 ± 0.06
NSCLC	135		9.28 ± 4.68
Histology			
SCC	42	3.01 ± 1.56	12.19 ± 4.01
AC	84	2.12 ± 1.17	8.48 ± 4.25
BAC	9	1.41 ± 0.65	3.13 ± 1.84
AC differentiation			
Well differentiated	20	1.79 ± 1.11	6.21 ± 3.84
Moderately differentiated	28	2.30 ± 1.31	9.29 ± 4.70
Poorly differentiated	36	2.17 ± 1.07	9.12 ± 3.74
SCC differentiation			
Well differentiated	11	3.00 ± 1.23	13.46 ± 4.10
Moderately differentiated	10	3.08 ± 1.12	13.47 ± 4.89
Poorly differentiated	21	2.98 ± 1.91	10.92 ± 3.22
Tumor size			
$d \leq 10$ mm	22		4.29 ± 2.56
$10 < d \leq 20$ mm	40		6.91 ± 2.88
$20 < d \leq 30$ mm	43		10.08 ± 3.97
$d > 30$ mm	30		12.97 ± 3.80
TNM stage of AC			
Stage I	39	1.93 ± 1.07	6.88 ± 4.17
Stage II	10	2.15 ± 1.45	9.78 ± 2.03
Stage III	21	2.16 ± 1.13	9.30 ± 3.39
Stage IV	14	2.58 ± 1.27	10.79 ± 5.33
TNM stage of SCC			
Stage I	18	2.96 ± 1.16	12.46 ± 3.95
Stage II	6	2.31 ± 1.10	10.18 ± 4.87
Stage III	11	2.97 ± 1.14	13.18 ± 4.21
Stage IV	7	3.78 ± 2.90	11.68 ± 3.13

AC, adenocarcinoma; BAC, bronchioloalveolar carcinoma; *d*, the biggest axial diameter; *n*, number; NSCLC, nonsmall cell lung cancer; SCC, squamous cell carcinoma; SD, standard deviation; SUV_{max}, maximum standardized uptake value; TNM, tumor node metastasis.

PET/CT equipment and scanning conditions

A GE Discovery ST PET/CT scanner (GE Healthcare, Milwaukee, USA) was used, and the ^{18}F-FDG was produced automatically by a GE MINItrace cyclotron and TracerLaboratory. The radiochemical purity was more than 90%. The patient fasted at least 4 h before the exam as the blood glucose should be controlled at a normal level (blood glucose < 7.0 mmol/l). The ^{18}F-FDG of 300–400 MBq was injected into the elbow vein in a resting state and PET/CT scanning was performed from the skull to the thighs after the patient rested for 60 min. In general, a low-dose CT scan was acquired with the following settings: 120 kV, 100–250 mAs with automatic adjustment, 0.8 s rotation, 1.25 mm collimation, and 1.5 : 1 pitch. A PET scan was acquired for six to seven bed positions, and each position lasted 2.5 min in a two-dimensional mode. After attenuation correction, the images of the patient were combined, and the images were reconstructed in the different imaging views, that is, in cross-sectional, sagittal, and coronal planes.

Statistical analysis

The SPSS.V16.0 statistical software package (SPSS company, Chicago, Illinois, USA) was used. The mean of the measurement data was expressed as mean ± standard deviation (mean ± S.D). A Student's *t*-test was used to compare the SUV_{max} between the normal lung tissue and the lung cancer tissue. When comparing the tumor size of different pathological types, differentiation degrees of tumor, and TNM stages, the one-way analysis of variance was used. Simultaneously, the Pearson correlation analysis was applied to analyze the correlation between SUV_{max} and tumor size. However, taking into account the effect of tumor size on SUV_{max}, partial correlation was used to analyze the correlation of SUV_{max} with pathological type, degree of differentiation, and clinical stage. Analysis of covariance was adopted to compare the difference among groups. A P value of less than 0.05 was considered to indicate statistical differences.

Results

The differences in the SUV_{max} among different pathological types

The result of the *t*-test showed that the SUV_{max} of the lung cancer was obviously higher than that of the normal lung tissue, and this result showed a statistically significant difference with $P = 0.000$. The size of SCC was larger than that of AC with $P = 0.006$, and the size of AC was larger than that of BAC with $P = 0.038$ (Table 2). Removing the effect of tumor size on the SUV_{max}, the result of the analysis of partial correlation showed that a clear relationship existed between the SUV_{max} and the pathological types, with $r = 0.391$ and $P = 0.000$.

The result among the groups displayed that the SUV_{max} of SCC was higher than that of AC with $P = 0.000$, and the SUV_{max} of AC was higher than that of BAC, with $P = 0.004$. Figure 1 shows that the SUV_{max} of SCC was the highest and it was mainly concentrated from 8.5 to 19.0. The SUV_{max} of AC was widely and continually distributed, and it was mainly well distributed between 1.0 and 16.6. However, the SUV_{max} of BAC was the lowest and it had a scattered distribution from 1.0 to 4.5.

There was no statistical difference in the tumor size in the well, moderately, and poorly differentiated AC and SCC, with $F = 1.148$, $P = 0.322$ and $F = 0.013$, $P = 0.987$, respectively. The result of the analysis of partial correlation showed that there was a positive correlation between the SUV_{max} of AC and the degree of differentiation ($r = 0.222$, $P = 0.044$). The result among groups showed that the SUV_{max} of well-differentiated AC was lower than that of moderately and poorly differentiated ACs, with $P = 0.034$ and 0.022, respectively. The differences between the SUV_{max} of moderately and poorly differentiated ACs had no statistical significance, with $P = 1.000$ (Table 2). There was no relationship between the SUV_{max} of SCC and the degree of differentiation ($r = -0.304$, $P = 0.054$) (Table 2).

Comparison of the SUV_{max} of different size lung cancers

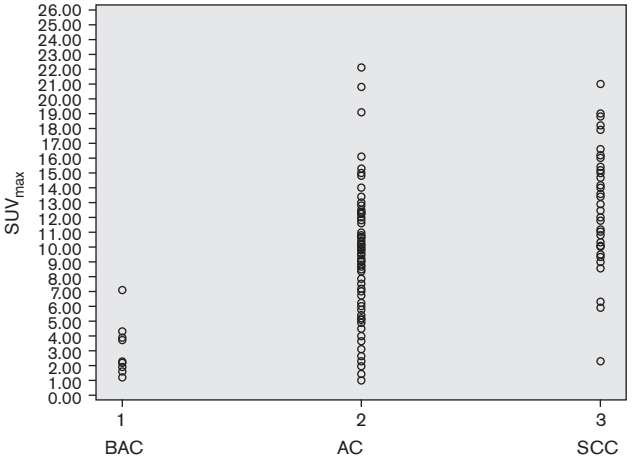
The result of the Pearson's correlation analysis showed that there was a positive correlation between the SUV_{max} of NSCLC and the tumor size, with a correlation coefficient, $r = 0.569$, $P = 0.000$. At the same time, the result of the linear regression analysis displayed that a linear relationship existed between the SUV_{max} of NSCLC and the tumor size, with $R^2 = 0.324$ (Fig. 2). The result of the analysis of variance showed that the SUV_{max} was the highest for those lung cancers with $d > 30$ mm, next was those with $20\,\text{mm} < d \leq 30\,\text{mm}$, $10 < d \leq 20$ mm, and $d \leq 10$ mm, with $P = 0.005$, 0.000 and 0.000, respectively (Table 2).

Table 2 The differences in the SUV_{max} among different pathological types, differentiation degrees, and tumor size

Parameter	*P* (*d*)	*P* (SUV_{max})
Normal lung tissue		0.000
NSCLC		
Histology		
SCC		
AC	0.006[a]	0.000[b]
BAC	0.038[a]	0.004[b]
AC differentiation		
Well differentiated	0.144[a]/0.244[a]	0.034[b]/0.022[b]
Moderately/poorly differentiated		
Moderately differentiated	0.679[a]	1.000[b]
Poorly differentiated		
SCC differentiation		
Well differentiated	0.909[a]/0.975[a]	1.000[b]/0.342[b]
Moderately/poorly differentiated		
Moderately differentiated	0.873[a]	0.356[b]
Poorly differentiated		
Tumor size		
$d \leq 10$ mm		0.005[a]
$10 < d \leq 20$ mm		0.000[a]
$20 < d \leq 30$ mm		
$d > 30$ mm		0.000[a]

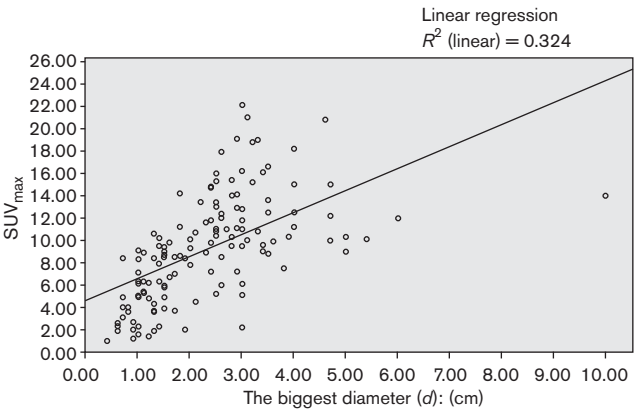
AC, adenocarcinoma; BAC, bronchioloalveolar carcinoma; *d*, the biggest axial diameter; *n*, number; NSCLC, nonsmall cell lung cancer; SCC, squamous cell carcinoma; SUV_{max}, maximum standardized uptake value.
[a]Results of analysis of variance.
[b]Results of covariance analysis.

Fig. 1



The profile of the maximum standardized uptake value (SUV_{max}) of bronchioloalveolar carcinoma (BAC), adenocarcinoma (AC), and squamous cell carcinoma (SCC).

Fig. 2



The relationship between the maximum standardized uptake value (SUV_{max}) of nonsmall cell lung cancer and the tumor size in these 135 cases.

Comparison between the SUV_{max} of AC and SCC and the clinical staging

The result of partial correlation analysis displayed that there was a significant relationship between the SUV_{max} of AC and the clinical stage ($r = 0.298$, $P = 0.006$). The result of the analysis of covariance showed that the

SUV_{max} of AC in stage I was lower than that in stages II, III, and IV, with $P = 0.047$, 0.038 and 0.015, respectively. The differences between the SUV_{max} of AC in stages II, III, and IV had no statistical significance, with $P = 0.708$, 0.570 and 0.528, respectively (Table 3). There was no relationship between the SUV_{max} of SCC and the clinical staging ($r = 0.066$, $P = 0.680$).

Discussion

Our research showed that the SUV_{max} of the lung cancer tissue was higher than that of the normal lung tissue. In these 135 cases of lung cancer, the average of the SUV_{max} was 9.28 ± 4.68, but for the normal lung tissue, the average was only 0.48 ± 0.06. Compared with the normal lung tissue, the lung cancer tissue grew actively, the cellular proliferation was abnormal, and the energy requirements were six times greater than the normal lung tissue, which made the glycolysis rate of tumor cells show a marked increase [1]. The concentration of ^{18}F-FDG in the cells and the intracellular glucose metabolism level were positively correlated, so the SUV_{max} of the lung cancer tissue was higher than that of the normal lung tissue.

There was a relationship between the SUV_{max} of lung cancer and its pathological type. The results of the study showed that in NSCLC, the SUV_{max} of SCC was higher than that of AC, the SUV_{max} of AC was higher than that of BAC, and such results were consistent with earlier reports by Kim *et al.* [2]. Many studies from both Chinese and foreign scientists showed that there was a relationship between the SUV_{max} of lung cancer and its biological character, and between the uptake of ^{18}F-FDG and the activity of glucose transporter (Glut) and hexokinase (HK). Glut-1 can be located both in the cytoplasm and the cell membranes, but those in the cell membrane are more important in the uptake process of FDG [3–5]. The tumor's histology can affect the way and the degree of overexpression of Glut-1 in lung cancers. In SCC the degree of Glut-1 expression and its distribution scope was higher than in AC. The Glut-1 of SCC mainly existed in cell membranes, but the Glut-1 of AC mainly existed in the cytoplasm, with only a small amount in the cell membranes [6]. This can explain why the SUV_{max} of SCC was higher than that of AC. The degree of Glut-1 expression in BAC was lower than that of non-BAC, but was still higher than that of normal lung tissues [7], and the SUV_{max} of BAC was lower than that of SCC and AC, but it was still higher than that of normal lung tissues. In addition, the uptake of FDG by SCC was higher than that of AC; maybe this result was also related to the rapid proliferation and the short doubling times. Some studies showed that glucose metabolism measured by FDG-PET correlated with the doubling time of malignant pulmonary lesions. Thus, high levels of glucose metabolism were associated with shorter tumor doubling times and faster tumor growth [8]. It is known that the doubling time of SCC is about 92 days, which is shorter than that of AC with 168 days.

Table 3 The differences in the SUV_{max} of AC and the clinical staging

	P values		
TNM stage of AC	Stage II	Stage III	Stage IV
Stage I	0.047[a]	0.038[a]	0.015[a]
Stage II		0.708[a]	0.570[a]
Stage III			0.528[a]

AC, adenocarcinoma; SUV_{max}, maximum standardized uptake value; TNM, tumor node metastasis.
[a]Results of analysis of covariance.

There was a relationship between the SUV_{max} of AC and its differentiation, and the SUV_{max} of well-differentiated AC was lower than that of moderately and poorly differentiated ACs. Mamede's [5] studies showed that the uptake degree of FDG of AC was related to its degree of differentiation. The SUV_{max} of well-differentiated tumor was lower than that of poorly differentiated tumor, and they also considered that the degree of Glut-1 and HK-II expression by AC and its degree of differentiation could be correlated to one another. The low FDG uptake of well-differentiated ACs was mainly decided by the low degree of Glut-1 and HK-II expression. The SUV_{max} of most lung cancers was higher than 2.5, but there were some lung cancers whose SUV_{max} was not obviously elevated. Some well-differentiated ACs and most BACs can seem false negative. The SUV_{max} of AC was lower than 2.5 in six cases of this group, which represented 7.1%. These six patients were made up of four cases of well-differentiated tumors, one case of moderately differentiated tumor, and one case of poorly differentiated tumor. Most of the BACs were peripheral lung carcinomas, they were all well differentiated and had a lower degree of malignancy. Their speed of growth was very slow and the doubling times were long. The potential for proliferation and the glucose metabolism rate were lower than those of non-BACs [9], so the SUV_{max} was lower and always seemed false negative [10]. The SUV_{max} of BACs was less than 2.5 in five cases of this group, which represented 55%. In CT imaging, they displayed mixed focal ground-glass opacity. Therefore, for these foci whose SUV_{max} was less than 2.5, and especially for those nodes showing malignant signs such as spiculation and lobules in CT imaging, we cannot easily diagnose it as benign, and we suggest the patient seek regular check-up or biopsy. There was no relationship between SUV_{max} and the degree of differentiation in SCC, which pointed out that we should not predict the degree of differentiation in SCC only by the value of SUV_{max}.

There was a dependency between the SUV_{max} of lung cancers and the tumor size [11]. SUV_{max} had a tendency to increase as the tumor's size increased. We divided these 135 cases into four groups, according to the tumor's largest axial diameters. In this research we found larger tumors with greater average SUV_{max} values, which were

4.29 ± 2.56, 6.91 ± 2.88, 10.08 ± 3.97, and 12.97 ± 3.80, respectively. The linear regression analysis found a coefficient of determination of 0.324, which means that 32.4% of the variation in SUV_{max} can be explained by the differences in the tumor size. Some biological specificity existed in the lung cancer tissue, such as the rapid proliferation of cells, the increase of Glut in the cell membranes, and the high activities of phosphorylase in the cells. These specificities made the metabolism of glucose increase obviously and the number and the ratio of these active tumor cells increase along with the tumor's size. The cell oxygen requirements of the tumor increased, the metabolism of glucose became faster, and the blood supplies can easily be insufficient, relatively, so the tighter the supply of oxygen and glucose, higher the rate of Glut-1 overexpression. Greater amounts of FDG entering the tumor correlated with higher SUV_{max} values, according to semiquantitative analysis, and some research has shown that a correlation exists between the rate of Glut expression and tumor size [12]. Brown *et al.* [6] suggested that Glut-1 overexpression at the cellular level determined the rate of FDG uptake, and at the whole tumor level, the size affected the uptake of FDG. No contradiction existed between these two findings. However, the influence of partial volume effects because of the limited resolution of PET imaging and patient respiratory motion during examination are not neglected. This can be a considerable underestimation of the true activity concentration within lesions with a diameter of less than twice the resolution of the PET scanner at full-width at half-maximum. The actual spatial resolution is worse considering the respiratory motion, scatter, and noise. Partial volume effects strongly depend on the size of the tumor. The smaller the tumor, the greater the underestimation of the SUV [13].

This study also found a correlation between the SUV_{max} of AC and its TNM stage. The SUV_{max} of AC in stage I was lower than that in stages II, III, and IV. Maybe this result can be attributed to the invasiveness of stages II, III, and IV, which is higher than that of stage I. In theory, with higher levels of invasiveness, the uptake of glucose is greater and SUV_{max} is higher. Although the small tumor size in stage-I patients may be another influencing factor, statistical analysis indicated that tumor size among stage-I, II, III, and IV groups had no difference in this study.

There was no relationship between the SUV_{max} of SCC and its clinical stage. These were all consistent with Yen's reports [14].

There were some limitations in this study. First, the number of SCC and BAC cases was small, in particular there were only nine cases of BAC, and therefore, a study using a larger sample size with SCC and BAC would be desirable. Second, in our study we concluded that SUV_{max} was correlated with tumor size; however, we did not recommend a potentially accurate method to correct the SUV for partial volume effects. Hickeson *et al.* [15] reported that, for a small lesion equal to or less than 2.0 cm in maximal diameter on CT scan, there was a substantial increase in the calculated SUV with the use of the corrected SUV (corSUV) method as compared with the value obtained using the SUV_{max} method. Therefore, a systemic research should be carried out for the relationship between corSUV and tumor size.

All in all, the semiquantitative index (SUV_{max}) is regarded as an index for diagnosing lung cancers by PET/CT, and it can be affected by many factors such as the pathological type, degree of differentiation, tumor size, and clinical staging. The SUV_{max} of SCC was higher than that of AC and BAC, and the SUV_{max} of BAC was the lowest. In AC, the SUV_{max} of moderately and poorly differentiated AC were higher than that of well-differentiated AC, and no relationship existed between the SUV_{max} of SCC and its degree of differentiation. A positive correlation existed between the SUV_{max} of NSCLC and the tumor size, with bigger tumor sizes correlating with higher SUV_{max} values. For 32.4% of NSCLC, the differences in SUV_{max} can be explained by the differences in tumor sizes. In the clinical stages of AC, the SUV_{max} of stage I was lower than that of stages II, III, and IV. However, for SCC no relationship existed between SUV_{max} and clinical stage.

Conclusion

There was a correlation between the SUV_{max} of NSCLC and the pathological type and tumor size. A positive correlation was found between the SUV_{max} of AC and the degree of differentiation and clinical staging. There were no correlations between the SUV_{max} of SCC and the degree of differentiation or clinical staging.

Acknowledgements

The study was supported by the science and technology project of The Education Department of Heilongjiang Province, Item number (11521175).

References

1 Nolop KB, Rhodes CG, Brudin LH, Beaney RP, Krausz T, Jones T, *et al.* Glucose utilization in vivo by human pulmonary neoplasms. *Cancer* 1987; **60**:2682–2689.
2 Kim BT, Kim Y, Lee KS, Yoon SB, Cheon EM, Kwon OJ, *et al.* Localized form of bronchioloalveolar carcinoma: FDG PET findings. *AJR Am J Roentgenol* 1998; **170**:935–939.
3 Haberkorn U, Ziegler SI, Oberdorfer F, Trojan H, Haag D, Peschke P, *et al.* FDG uptake, tumor proliferation and expression of glycolysis associated genes in animal tumor models. *Nucl Med Biol* 1994; **21**:827–834.
4 Golshani-Hebroni SG, Bessman SP. Hexokinase binding to mitochondria: a basis for proliferative energy metabolism. *J Bioenerg Biomembr* 1997; **29**:331–338.
5 Mamede M, Higashi T, Kitaichi M, Ishizu K, Ishimori T, Nakamoto Y, *et al.* [^{18}F]FDG uptake and PCNA, Glut-1, and hexokinase-II expressions in cancers and inflammatory lesions of the lung. *Neoplasia* 2005; **7**:369–379.
6 Brown RS, Leung JY, Kison PV, Zasadny KR, Flint A, Wahl RL. Glucose transporters and FDG uptake in untreated primary human non-small cell lung cancer. *J Nucl Med* 1999; **40**:556–565.
7 Higashi K, Ueda Y, Sakurai A, Wang XM, Xu L, Murakami M, *et al.* Correlation of Glut-1 glucose transporter expression with [^{18}F] FDG uptake in non-small cell lung cancer. *Eur J Nucl Med* 2000; **27**:1778–1785.

8 Duhaylongsod FG, Lowe VJ, Patz EF Jr, Vaughn AL, Coleman RE, Wolfe WG. Lung tumor growth correlates with glucose metabolism measured by fluoride-18 fluorodeoxyglucose positron emission tomography. *Ann Thorac Surg* 1995; **60**:1348–1352.
9 Higashi K, Ueda Y, Yagishita M, Arisaka Y, Sakurai A, Oguchi M, *et al.* FDG PET measurement of the proliferative potential of non-small cell lung cancer. *J Nucl Med* 2000; **41**:85–92.
10 Marom EM, Sarvis S, Herndon JE II, Patz EF Jr. T1 lung cancers: sensitivity of diagnosis with fluorodeoxyglucose PET. *Radiology* 2002; **223**:453–459.
11 Khalaf M, Abdel-Nabi H, Baker J, Shao Y, Lamonica D, Gona J. Relation between nodule size and ^{18}F-FDG-PET SUV for malignant and benign pulmonary nodules. *J Hematol Oncol* 2008; **1**:13.
12 Ogawa J, Inoue H, Koide S. Glucose-transporter-type-I-gene amplification correlates with sialyl-Lewis-X synthesis and proliferation in lung cancer. *Int J Cancer* 1997; **74**:189–192.
13 Soret M, Bacharach SL, Buvat I. Partial-volume effect in PET tumor imaging. *J Nucl Med* 2007; **48**:932–945.
14 Yen TC, See LC, Lai CH, Yah-Huei CW, Ng KK, Ma SY, *et al.* ^{18}F-FDG uptake in squamous cell carcinoma of the cervix is correlated with glucose transporter 1 expression. *J Nucl Med* 2004; **45**:22–29.
15 Hickeson M, Yun M, Matthies A, Zhuang H, Adam LE, Lacorte L, *et al.* Use of a corrected standardized uptake value based on the lesion size on CT permits accurate characterization of lung nodules on FDG-PET. *Eur J Nucl Med Mol Imaging* 2002; **29**:1639–1647.