Original article

The utility of $^{18}$F-FDG PET/CT in solitary fibrous tumors of the pleura$^\dagger$

Z. Tazeler$^a$, G. Tan$^a$, A. Aslan$^{b,*}$, S. Tan$^c$

$^a$Department of Nuclear Medicine, Ataturk Chest Diseases and Thoracic Surgery Training and Research Hospital, Ankara, Turkey
$^b$Department of Radiology, Siyami Ersek Thoracic and Cardiovascular Surgery Training and Research Hospital, Istanbul, Turkey
$^c$Department of Radiology, Medical School of Kırıkkale University, Kırıkkale, Turkey

A R T I C L E   I N F O

Article history:
Received 11 August 2015
Accepted 13 October 2015
Available online 27 November 2015

Keywords:
Pleura
Solitary fibrous tumor of the pleura
$^{18}$F-FDG PET/CT
$^{18}$F-FDG PET
Computed tomography
Maximum standardized uptake value

A B S T R A C T

Objective: To demonstrate the utility of $^{18}$F-FDG PET/CT in the differentiation of benign and malignant solitary fibrous tumors of the pleura (SFTP).

Materials and methods: A retrospective review was performed on the $^{18}$F-FDG PET/CT data from 17 patients with histopathologically diagnosed benign or malignant SFTP. The size, side of SFTP, presence of necrosis, calcification, pleural effusion, hilar lymphadenopathy (LAP), density on CT images (Hounsfield unit-HU), and $^{18}$F-FDG uptake (SUVRmax) were recorded and compared in order to detect malignant SFTP. Statistical significance was set as $p<0.05$.

Results: The difference in size, presence of necrosis, and hilar LAP on CT images were statistically significant ($p=0.004$, $p<0.001$, $p=0.015$, respectively) in a comparison of benign and malignant SFTPs. The mean HU of benign SFTP was 46.16 ± 5.52 HU, and for malignant SFTP it was 35.03 ± 4.61 HU ($p=0.003$). The mean SUVRmax was 3.02 ± 1.02 for benign SFTP and 4.89 ± 2.12 for malignant SFTP ($p=0.021$). A cut-off value of ≥7 cm for size, ≤39.81 HU for density, and ≥3.47 for SUVRmax was obtained by ROC analysis for detecting malignant SFTP.

Conclusions: $^{18}$F-FDG PET/CT may have a limited role in diagnosing malignant SFTP in suspected patients.

© 2015 Elsevier España, S.L.U. and SEMNIM. All rights reserved.

Utilidad de la $^{18}$F-FDG PET/TC en tumores fibrosos solitarios de la pleura

R E S U M E N

Objetivo: Demostrar la utilidad de la $^{18}$F-FDG PET/TC en la diferenciación de benignidad o malignidad en tumores fibrosos solitarios de la pleura (TSP).

Material y métodos: Se revisaron retrospectivamente los datos de $^{18}$F-FDG PET/TC en 17 pacientes con diagnóstico histopatológico de TSP benigno o maligno. Se valoraron el tamaño, la localización del TSP, la presencia de necrosis, la calcificación, el derrame pleural, las adenopatías hiliares, la densidad de las imágenes de TC (unidades Hounsfield [HU]) y la captación de $^{18}$F-FDG (SUVRmax) para detectar TSP maligno. La significación estadística se estableció como $p<0.05$.

Resultados: La diferencia de tamaño, la presencia de necrosis y las adenopatías hiliares en imágenes de TC fueron estadísticamente significativas ($p=0.004$; $p<0.001$; $p=0.015$, respectivamente) comparando TSP benignos y malignos. La media de HU en TSP benigno fue 46.16 ± 5.52 HU y en TSP maligno fue 35.03 ± 4.61 HU ($p=0.003$). El SUVRmax medio fue 3.02 ± 1.02 para TSP benigno y 4.89 ± 2.12 para TSP maligno ($p=0.021$). Un valor de corte ≥7 cm para tamaño, ≤39.81 HU para densidad y ≥3.47 para SUVRmax se obtuvo mediante análisis ROC para la detección de TSP maligno.

Conclusiones: La $^{18}$F-FDG PET/TC tiene un papel limitado en el diagnóstico de pacientes con sospecha de TSP maligno.

© 2015 Elsevier España, S.L.U. y SEMNIM. Todos los derechos reservados.

Introduction

Solitary fibrous tumor is a rare mesenchymal-originating slow-growing neoplasm generally located in the thoracic cavity and termed solitary fibrous tumor of pleura (SFTP). Most SFTPs are benign with different clinical presentations, but approximately 10–20% of patients may display malignant transformation with local recurrence or metastasis.$^{1,2}$

Radiological imaging findings of SFTP consist of calcification, necrosis, hemorrhage, and consequently cystic changes. Persistent enhancement on contrast enhanced computed tomography (CT) or magnetic resonance imaging (MRI) due to collagenous texture is common.$^1$ But these findings are not certain and are not helpful for differentiating and predicting the prognosis of SFTP.$^{1,4}$

Histopathological analysis of pleural fluid aspiration, trans-thoracic fine needle aspiration or Tru-Cut needle biopsy of the pleural mass

$^\dagger$ The $^{18}$F-FDG PET/CT scan was performed in Ataturk Chest Diseases and Thoracic Surgery Training and Research Hospital, Ankara, Turkey.

* Corresponding author.

E-mail address: aslahmet@gmail.com (A. Aslan).
is indeterminate and total excision of the mass by thoracotomy or video-assisted thoracoscopic surgery is required for the final diagnosis. Fluorine-18 fluorodeoxyglucose (18F-FDG) positron emission tomography/computed tomography (PET/CT) (18F-FDG PET/CT) is now widely used for the characterization of neoplasms as a robust and reliable functional imaging method. However, there are limited data on the utility of 18F-FDG PET/CT in distinguishing SFTP as benign or malignant and most of the publications are case reports. In this study, we aimed to demonstrate the diagnostic performance of 18F-FDG PET/CT in distinguishing histopathologically proven benign and malignant SFTPs.

Materials and methods

This retrospective study was approved by the institutional review board and informed and written consent from patients was waived.

Patients

The hospital information system of our institution was searched retrospectively to identify patients who had a diagnosis of SFTP between February 2011 and April 2015. Chest CT and 18F-FDG PET/CT examinations, and histopathological analysis of Tru-Cut needle or surgical specimens of patients with a diagnosis of SFTP were obtained and re-evaluated. Patients having a diagnosis of SFTP without 18F-FDG PET/CT or histopathological findings, having mesothelioma, lung cancer or other known cancers were excluded from the study. Seventeen patients with SFTP compatible with inclusion criteria were identified and included in the study.

Histopathological analysis

All patients had undergone hemithoracotomy and final diagnosis was established by histopathological examination of the masses obtained from total excision by thoracotomy and served as the reference test.

18F-FDG PET/CT imaging

All 18F-FDG PET/CT were performed before any interventional procedures for biopsy or total excision of the masses. 18F-FDG PET/CT imaging was performed (Siemens Biograph 6 – True Point PET/CT systems; Siemens, Chicago, IL, USA) for all patients 60 min after intravenous injection of 18F-FDG in the antecubital vein. Patients were requested to fast for at least 8 h and be rested for 24 h before the injection of 18F-FDG. Blood glucose level was measured before the 18F-FDG injection and injection was done when glucose levels were below 180 mg/dL. The dose of 18F-FDG was between 370 and 555 MBq (10–15 mCi). Patients were rested for 60 min for sufficient distribution of 18F-FDG to the whole body at room temperature. Unenhanced CT images were acquired for lesion localization and attenuation correction with 3 mm slice thickness with effective mAs values according to patient weight. PET acquisition was performed from the top of the skull to the upper thigh with the arms raised in bed position. Data obtained from PET scans were reconstructed with attenuation correction from CT data and an ordered subset expectation maximization algorithm. A gradient-based segmentation method was used to signify metabolically active areas after processing 18F-FDG PET/CT signals. The CT images were then fused with the PET images.

Image analysis

Two observers, with experience for 5 and 6 years in 18F-FDG PET/CT imaging, evaluated the PET and CT images visually and quantitatively on a workstation (Leonardo, Siemens Medical Solutions, Erlangen, Germany) without knowing the clinical data and diagnosis of the masses. On CT images, the size, side, presence of calcification, cystic or necrotic hypodense areas in the mass, pleural effusion, presence of additional thoracic masses and hilar lymphadenopathy (LAP) were noted with the consensus of both observers (Figs. 1 and 2). The mean Hounsfield unit (HU) of each mass was obtained by drawing three regions of interest (ROI) covering the mass at different locations while avoiding hemorrhagic, necrotic, cystic and calcific areas. 18F-FDG PET/CT images were interpreted on axial, sagittal and coronal planes with maximum intensity projection images. PET and fused images were considered to identify 18F-FDG positive areas that had a higher uptake of 18F-FDG than the background. With the consensus of the observers, predominant foci in the lesions were located. To quantify 18F-FDG uptake, the maximum standardized uptake value (SUVmax) was used. SUVmax was calculated using the formula below:

\[
SUV_{\text{max}} = \frac{C_{\text{max}} \times TBW}{IA}
\]

Cmax: activity concentration in the voxel of highest tumor activity (Bq/ml), TBW: total body weight (kg), IA: injected activity (kBq).

For each data set, SUVmax was measured from the predominant foci by placing the volume of interest (VOI) to include the mass. Extreme care was taken to avoid “spill-in” from neighboring tissues. Also, CT images were used for reference images to avoid necrotic, hemorrhagic and cystic areas.

Statistical analysis

SFTPs were classified as benign or malignant according to histopathological findings. 18F-FDG PET and CT findings of benign and malignant SFTPs were compared with each other. The Number Cruncher Statistical System (NCSS) 2007 and Power Analysis and Sample Size (PASS) 2008 Statistical Software (UT, USA) were used to analyze the collected data. Numeric and nominal data were expressed as mean ± SD, number (percentage), median, minimum, and maximum. Quantitative data that showed normal distribution were compared by Mann–Whitney U test. In the comparison of qualitative data, Fisher’s exact test was used. Receiver operating characteristic (ROC) analysis was performed to obtain optimal cut-off values for statistically significant numeric data for the distinction of malignant and benign SFTPs. Statistical significance was set as p < 0.05 and was bidirectional.

Results

Seventeen patients (10 men and 7 women; mean (±SD) age, 57.76 ± 10.63 years; range, 44–76 years) obtained from the hospital information system, who were diagnosed with SFTP and imaged by 18F-FDG PET/CT, were enrolled in the study. All the patients underwent thoracotomy. Eight patients were diagnosed with benign and nine patients were diagnosed with malignant SFTP on the basis of histopathological findings. From the medical records of the patients, there was no documented exposure to asbestos, intraoperative or postoperative complications due to thoracotomy, or distant metastasis.

From the pathology records of the patients, malignant SFTP diagnosis was established in 7 patients by the presence of mitotic activity higher than 4 per 10 high power areas and in 2 patients with the presence of necrosis, atypical nuclei and infiltration of the tumor. The diagnosis of benign SFTP was established by mitotic activity lower than 4 per 10 high power areas in all benign SFTPs.

There was no relation between the sex of the patients and SFTP. The mean age of the patients, size and side of the SFTP, and presence of necrosis, calcification, pleural effusion, hilar LAP on CT images,
SUV$_{\text{max}}$ of hilar LAP, attenuation value (HU) and SUV$_{\text{max}}$ of SFTPs on $^{18}$F-FDG PET/CT are summarized in Table 1. The size, presence of necrosis, hilar LAP, HU, and SUV$_{\text{max}}$ on $^{18}$F-FDG PET/CT images in the differentiation of benign and malignant SFTPs were statistically significant. There were 3 patients with pleural effusion and all had malignant SFTP. The mean SUV$_{\text{max}}$ of two malignant SFTPs were 2.77 and 2.20. In the last case, pleural effusion was too thin to calculate SUV$_{\text{max}}$ (measured 6 mm on CT images). There were no additional masses in addition to the SFTP in all patients. ROC curve analysis of mean HU, SUV$_{\text{max}}$ and size (cm), and sensitivity, specificity and accuracy values for optimal cut-off values are presented in Table 2.

Discussion

SFTPs, originating from submesothelial fibroblasts, have a slow grow rate and are generally asymptomatic in clinical practice.\cite{7,8} But the size and location of the tumor may cause different clinical presentations, such as cough, chest pain, dyspnea, feeling of a moving mass in the hemithorax, and hemoptysis.\cite{1,5} In some cases, slow-growing SFTP may show malignant transformation, which has a poor prognosis. Unfortunately, histological findings cannot forewarn malignancy in the initial histopathological examination and total excision of the lesion is required for final diagnosis and treatment.\cite{9,11,2} Many diagnostic approaches have been adopted to predict the malignant course of SFTP; however, they have failed.\cite{2} CT is the preferred imaging method for pleural diseases, but is proposed to have limited capacity in SFTP. $^{18}$F-FDG PET/CT may provide additional data for diagnosing, staging and predicting the prognosis of SFTP, since it is a functional and morphological imaging modality.\cite{3} This study mainly focused on the utility of $^{18}$F-FDG PET/CT for the differentiation of benign and malignant SFTPs. Both benign and malignant SFTPs showed low $^{18}$F-FDG uptake, but malignant SFTP showed a higher $^{18}$F-FDG uptake with a significant difference. Additionally, the mean HU of malignant tumors was significantly lower than for benign SFTP.

SFTP is generally seen in the right hemithorax with a visceral pleura base and occurs in patients of all ages, with a predominance in patients over 50 years old.\cite{1,2,8} In our study, 64.7% of all SFTPs were in the right hemithorax and, interestingly, malignant SFTP had a predilection for the right hemithorax ($n = 7, 87.5\%$). The youngest case in our study was 44 years old and the mean age of patients with
benign and malignant SFTP was over 50 years, consistent with the literature.\(^1\) We did not find a relationship with age or sex, but found a strong relation with size for malignancy. SFTP size over 10 cm is generally related to malignancy.\(^2\) We found a sensitivity value of 100% for a size equal or greater than 7 cm. However, Schmidt et al.\(^2\) found no relation between size and malignancy in SFTP in their study evaluating the clinicopathologic features of SFTPs, contrary to previous data. Interestingly, the mean size of benign SFTP was higher than malignant SFTP (12 vs. 7.9 cm) in their study.

Preoperative prediction of malignancy in SFTP can help clinicians to manage the preoperative treatment and predict the prognosis of the disease. Chest X-ray is the first tool for the diagnosis of SFTP and can depict oval or round smooth pleural masses, but thorax CT can provide more data.\(^8,13,14\) Location, contours, necrosis, hemorrhage and calcification in SFTP, presence of pleural effusion and hilar LAP can be precisely shown by thorax CT.\(^1\) Encapsulated and lobulated appearance with calcifications in a homogeneous mass is accepted for benign SFTP while necrosis and hemorrhage are peculiar to malignant SFTP on CT images.\(^1,12,15\) In the analysis of CT images of \(^{18}\)F-FDG PET/CTs in our study, we found no relation between calcification and benign SFTP but necrosis was present in all malignant SFTPs (\(p < 0.001\)). Calcification was present in 3 malignant SFTPs, while there was none in benign SFTP. From our data, based on visual inspection of CT images, we did not find a correlation between the presence of calcification, necrosis, or hemorrhage with histopathologic findings. Therefore, there might be misdiagnosis with calcification, necrosis, or hemorrhage in patients with benign SFTP. Schmidt et al.\(^2\) found a higher number of cases with necrosis and hemorrhage in benign SFTP compared to malignant SFTP in their study with histopathological findings of SFTP. The final diagnosis of SFTP requires complete resection of the mass, but Schmidt et al.\(^2\) established the histopathological diagnosis by complete resection of mass only in 2 patients out of 25 patients. Hence, a new study comparing imaging findings with histopathology could explain whether these findings are related accurately to benign or malignant SFTP. Pleural effusion is generally associated with pleural malignancy and was present in 3 patients with malignant SFTP.\(^1,8\) Although the difference was not significant, we measured a slight \(^{18}\)F-FDG uptake in pleural effusion (mean \(\text{SUV}_{\text{max}}\) = 2.51). Hilar LAP on CT images is generally related to malignancy and we detected hilar LAP in 7 malignant SFTPs, which was significant. Therefore, the presence of necrosis and hilar LAP are common CT findings in malignant SFTP. Both pleural malignant and benign masses can be seen as a pleural thickening or nodularity without necrosis, calcification or LAP on CT images. The attenuation of SFTP on CT images is generally at soft tissue values and affected by the content of the mass.\(^10\) All SFTPs displayed moderate density on CT images and the mean \(\text{HU}\) of malignant SFTP

### Table 1
Clinical, radiologic and PET/CT results in patients with solitary fibrous tumor.

<table>
<thead>
<tr>
<th></th>
<th>Total (n = 17)</th>
<th>Diagnosis of SFTP</th>
<th>(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Malign (n = 9)</td>
<td>Benign (n = 8)</td>
<td></td>
</tr>
<tr>
<td>Age (year)</td>
<td>Mean ± SD</td>
<td>57.76 ± 10.63</td>
<td>60.33 ± 11.07</td>
</tr>
<tr>
<td>Sex; n (%)</td>
<td>Female 7(41.2)</td>
<td>3(33.3)</td>
<td>4(50.0)</td>
</tr>
<tr>
<td></td>
<td>Male 10(58.8)</td>
<td>6(66.7)</td>
<td>4(50.0)</td>
</tr>
<tr>
<td>Size (cm)</td>
<td>Range (median)</td>
<td>2.1–22.5(9)</td>
<td>7.8–22.5(11.2)</td>
</tr>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>9.99 ± 6.37</td>
<td>13.67 ± 2.27</td>
</tr>
<tr>
<td>Side of lesion; n (%)</td>
<td>Left 6(35.3)</td>
<td>5(55.6)</td>
<td>1(12.5)</td>
</tr>
<tr>
<td></td>
<td>Right 11(64.7)</td>
<td>4(44.4)</td>
<td>7(87.5)</td>
</tr>
<tr>
<td>Necrosis; n (%)</td>
<td>Presence 9(53%)</td>
<td>9(100%)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>None 7(47%)</td>
<td>0</td>
<td>8(100%)</td>
</tr>
<tr>
<td>Calcification; n (%)</td>
<td>Presence 3(17.6)</td>
<td>3(33.3)</td>
<td>0(0)</td>
</tr>
<tr>
<td></td>
<td>None 14(82.4)</td>
<td>6(66.7)</td>
<td>8(100)</td>
</tr>
<tr>
<td>Pleural effusion; n (%)</td>
<td>Presence 3(17.6)</td>
<td>3(33.3)</td>
<td>0(0)</td>
</tr>
<tr>
<td></td>
<td>None 14(82.4)</td>
<td>6(66.7)</td>
<td>8(100)</td>
</tr>
<tr>
<td>Hilar LAP; n (%)</td>
<td>Presence 8(47.1)</td>
<td>7(77.8)</td>
<td>1(12.5)</td>
</tr>
<tr>
<td></td>
<td>None 9(52.9)</td>
<td>2(22.2)</td>
<td>7(87.5)</td>
</tr>
<tr>
<td>SUV(_{\text{max}}) of Hilar LAP</td>
<td>Range (median)</td>
<td>1.6–7.06(3.29)</td>
<td>1.6–7.06(3.52)</td>
</tr>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>3.81 ± 1.74</td>
<td>3.92 ± 1.85</td>
</tr>
<tr>
<td>Mass attenuation on CT (HU)</td>
<td>Range (median)</td>
<td>27–53.3(38.6)</td>
<td>27–38.7(37.1)</td>
</tr>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>40.59 ± 7.56</td>
<td>35.03 ± 4.61</td>
</tr>
<tr>
<td>SUV(_{\text{max}}) of mass</td>
<td>Range (median)</td>
<td>1.6–9.8(3.8)</td>
<td>2.4–9.8(4.9)</td>
</tr>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>4.01 ± 1.90</td>
<td>4.89 ± 2.12</td>
</tr>
</tbody>
</table>

\(a\) \(p < 0.05\).
\(b\) \(p < 0.01\).
\(c\) Mann Whitney \(U\) test.
\(d\) Fisher’s exact test.

**Abbreviations:** SFTP, solitary fibrous tumor of pleura; HU; Hounsfeld unit; \(^{18}\)F-FDG; Fluorine-18 fluorodeoxyglucose, \(\text{SUV}_{\text{max}}\); maximum standardized uptake value; \(n\); number; SD; standard deviation.

### Table 2
ROC curve analysis of density on CT (HU), \(^{18}\)F-FDG uptake (\(\text{SUV}_{\text{max}}\)) and size of benign and malignant SFTPs.

<table>
<thead>
<tr>
<th></th>
<th>Size (cm)</th>
<th>Density (HU)</th>
<th>(^{18})F-FDG uptake ((\text{SUV}_{\text{max}}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUC</td>
<td>0.917</td>
<td>0.944</td>
<td>0.833</td>
</tr>
<tr>
<td>Optimal cut-off</td>
<td>(\geq 7)</td>
<td>(\leq 39.81)</td>
<td>(\geq 3.47)</td>
</tr>
<tr>
<td>Sensitivity (%)(^a)</td>
<td>100(95–100)</td>
<td>87.5 (79–93)</td>
<td>77.8 (68–85)</td>
</tr>
<tr>
<td>Specificity (%)(^a)</td>
<td>87.5 (79–93)</td>
<td>100(95–100)</td>
<td>75 (65–83)</td>
</tr>
<tr>
<td>Positive predictive value (%)(^a)</td>
<td>88.8 (81–94)</td>
<td>100(95–100)</td>
<td>75.7 (66–83)</td>
</tr>
<tr>
<td>Negative predictive value (%)(^a)</td>
<td>100(95–100)</td>
<td>88.8 (81–94)</td>
<td>77.1 (67–85)</td>
</tr>
<tr>
<td>Accuracy (%)</td>
<td>93.75</td>
<td>93.75</td>
<td>76.4</td>
</tr>
</tbody>
</table>

\(a\) Values in parentheses are 95% CI.

**Abbreviations:** AUC; area under curve; HU; Hounsfeld unit; \(\text{SUV}_{\text{max}}\); maximum standardized uptake value.
were significantly lower than benign SFTP. This may be due to the presence of necrosis in all malignant SFTPs. Also, the size of the SFTP has an effect on the CT appearance. Small tumors can be detected as a soft tissue mass with uniform margins while larger SFTPs exhibit a heterogeneous mass. \(^1\) Former studies gave no suggestion of HU values for malignancy in SFTP. We found a specificity value of 100\% for a cut-off value of \(<39.81\) HU on CT images. Only one benign SFTP had an attenuation value of 36.75\% on CT images. But in this patient, there was no demonstrable necrosis, calcification, pleural effusion or mediastinal LAP on CT images and the \(SU_{\text{max}}\) value was 3.14.

For optimal therapy management, determination of malignancy is required for SFTPs. In reported cases, there were overlaps or imaging findings incompatible with histopathological specimens.\(^{11,14}\) Fine needle aspiration biopsy of a SFTP can diagnose a fibrous tumor originating from the pleura, but can fail in the final diagnosis due to sampling different portions of the mass. Hence, total excision of the SFTP is required for diagnosing malignant SFTP. \(^{18}\) \(^{18}\) F-FDG PET/CT, a functional imaging method with morphologic data, seems to be an accurate imaging method for diagnosing malignant pleural diseases with a sensitivity of 86\% and a specificity of 80\% in a meta-analysis.\(^{13}\) In malignant SFTP, \(^{18}\) F-FDG uptake is expected to be higher than for benign SFTP and can be used as a problem solver method.\(^{1,4,6}\) Additionally, \(^{18}\) F-FDG PET/CT can display metastatic or local recurrence of malignant SFTP.\(^{11}\) On \(^{18}\) F-FDG PET/CT images, early changes in malignant SFTP can be detectable in the pleura while morphological abnormalities are not present.\(^{13}\)

This is because \(^{18}\) F-FDG PET/CT is a functional imaging modality and a functional abnormality can be detected before the structural deformity takes shape.\(^{13}\) Nevertheless, \(^{18}\) F-FDG PET/CT characteristics of SFTP are not well established. Besides, there are also conflicting data on \(^{18}\) F-FDG uptake in benign and malignant SFTPs in the medical literature. In previously published reports, \(^{18}\) F-FDG PET/CT findings of benign SFTP showed mild or no FDG uptake.\(^{1,4}\) Enon et al.\(^{1,2}\) observed no \(^{18}\) F-FDG uptake in benign SFTP and a mean \(SU_{\text{max}}\) of 4.5 in three malignant SFTPs. But Lococo et al.\(^{11}\) reported a case of malignant SFTP with a \(SU_{\text{max}}\) value of 2.2 while Dong et al.\(^{14}\) reported a case of histopathologically benign SFTP with malignant behavior in bilateral lungs with a \(SU_{\text{max}}\) value of 21.8. We observed slightly higher \(^{18}\) F-FDG uptake in both groups in our study and all benign SFTPs had a lower \(SU_{\text{max}}\) value, below 5. Malignant SFTP displayed higher \(SU_{\text{max}}\) of \(^{18}\) F-FDG uptake than benign SFTP and a value of 3.48 had a sensitivity of 78\% and a specificity of 75\%. However, the mean \(SU_{\text{max}}\) of malignant SFTP (4.89 \(\pm\) 2.12) was not remarkable and still low when compared to other malignant masses, which may limit the utility of the method for differentiation of a malignancy in SFTP. Also, the \(SU_{\text{max}}\) of hilar LAP were lower than expected (mean \(SU_{\text{max}}\) = \(3.92 \pm 1.85\)). On \(^{18}\) F-FDG PET/CT images, high cellular areas expected to have high \(^{18}\) F-FDG uptake are used as a criterion for malignancy. But in clinical practice, small neoplasia with low metabolic activity, like bronchioloalveolar, mucinous or carcinoid tumors, can give false-negative \(^{18}\) F-FDG PET/CT results with normal or moderate \(SU_{\text{max}}\).\(^{15}\) Also, pleural infections, inflammatory diseases, or talc pleurodesis can cause false-positive findings for malignant pleural lesions on \(^{18}\) F-FDG PET/CT.\(^{11}\) In our study group, no patient had a history of pleural infection or pleurodesis or any malignant tumor history. Low \(SU_{\text{max}}\) of malignant SFTP might be related to their low metabolic activity and slow growth rate. Also, a heterogeneous cellular structure consisting of hypo/hypercellular areas due to ischemia, necrosis, hemorrhage, and calcification may explain low \(SU_{\text{max}}\) values in malignant SFTP.\(^{11}\)

In the current study, although HU and \(SU_{\text{max}}\) were significant and objective, mean values were close to each other and both values were similar to other benign lesions in the thoracic cavity. Hence, it is hard to judge malignancy in a SFTP just by HU and \(SU_{\text{max}}\) values. Additionally, in clinical practice, the cytologic diagnosis of malignant SFTP has challenges due to the heterogeneous texture of the tumor, and in some cases, cytological analysis of fine needle aspiration biopsies may not reflect the nature of the SFTP. In our study, there were two false-positive and two false-negative patients. Both the false-negative patients had a size of SFTP over 7 cm (10 cm and 18 cm) and a HU value lower than 39.81 HU (36.6 and 37.5 HU) while the two false-positive patients had a size of SFTP of 4.5 cm and 7.5 cm, and a HU value of 53.3 HU and 42.4 HU. Also, necrosis was only present in false-negative patients. Therefore, a combination of CT findings, such as size, necrosis and hilar LAP, with measurement of density and \(^{18}\) F-FDG uptake of the SFTP on \(^{18}\) F-FDG PET/CT images can be helpful in the preoperative diagnosis and can help to predict the prognosis of the disease. \(^{18}\) F-FDG PET/CT may be used alone for the guidance of the fine needle aspiration or excisional biopsy to sample the metabolically active areas of the SFTP to reach the correct diagnosis.

Our study had some limitations. Since SFTP is a rare disease, our study group was relatively small. Secondly, we did not perform volume parameters (tumor lesion glycolysis or total glycolytic volume), which can provide more reliable semi-quantitative analysis on \(^{18}\) F-FDG PET/CT images. Thirdly, the presence of necrosis, calcification or hemorrhage was evaluated by visual inspection and was not confirmed by histopathological findings. Finally, \(^{18}\) F-FDG PET/CT could not detect small malignant foci in the mass that cannot be seen due to the low resolution of the method.

In conclusion, \(^{18}\) F-FDG PET/CT may provide information on the aggressive behavior of SFTP by giving both functional and morphologic imaging data in the preoperative period, but low \(SU_{\text{max}}\) of malignant SFTP limits its utility if used alone. The interpretation of CT images and \(^{18}\) F-FDG PET/CT findings together may be helpful in managing individualized treatment in suspected patients. Further studies with higher numbers of patients will help to solidify our results.

**Conflicts of interest**

The authors declare that they have no conflicts of interest.

**Ethical approval**

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study (retrospective study), formal consent is not required.

This article does not contain any studies with animals performed by any of the authors.

**References**


