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FULL PAPER

Pulmonary mucosa-associated lymphoid tissue lymphoma: ^{18}F -FDG PET/CT and CT findings in 28 patients

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Objective: The aim of the study was to evaluate the CT and fluorine-18-fluorodeoxyglucose positron emission tomography/CT (^{18}F -FDG PET/CT) imaging findings of lung mucosa associated lymphoid tissue (MALT) lymphoma.

Methods: 28 patients with histologically confirmed pulmonary MALT lymphoma who underwent a chest CT and ^{18}F -FDG PET/CT for staging were retrospectively analysed. The CT images were evaluated to determine morphological pattern of appearance, laterality, localization, number, size, presence of thoracic lymphadenopathies and secondary/combined findings. PET images were analysed visually and semi-quantitatively by measuring the maximum standardized uptake value (SUVmax), lesion-to-liver SUVmax ratio and lesion-to-blood pool SUVmax ratio. The relationship between qualitative and semi-quantitative features at ^{18}F -FDG PET/CT and CT findings were also analysed.

Results: A total of 57 pulmonary lesions were identified by CT: 37 areas of consolidation, 4 masses, 12 nodules and 4 ground-glass opacities. Solitary and multiple lesions were detected in 10 and 18 patients, respectively; among patients with multiple lesions, 16 were bilateral and 2 unilateral. ^{18}F -FDG PET/CT revealed increased ^{18}F -FDG uptake in 47/57 lesions, in 26/28 patients. ^{18}F -FDG avidity was significantly associated only with tumour size.

Conclusions: Pulmonary MALT lymphoma is ^{18}F -FDG avid in most cases and ^{18}F -FDG avidity is correlated with tumour size. Consolidation is the most frequent morphological pattern of disease presentation.

Advances in knowledge: This study demonstrated that lung MALT lymphoma are ^{18}F -FDG avid in most cases depending on tumour size. Single or multiple areas of consolidation are the most common pattern of presentation of lung MALT lymphoma at CT.

INTRODUCTION

Primary non-Hodgkin's lymphoma (NHL) of the lung is a very rare disease accounting for only 0.4% of all malignant lymphomas.^{1–4} The most common subtype of pulmonary NHL is the mucosa-associated lymphoid tissue (MALT) type.⁵ MALT lymphoma, also called extranodal marginal zone B cell lymphoma, involves the mucosa-associated lymphoid tissue possibly arising from any mucosal site. It originates in the marginal zone of the MALT from B cells; this B cells are post-germinal-centre cells with rearranged and mutated immunoglobulin heavy and light chain genes.⁶ Besides stomach, lung is one of the most frequent organs involved. Lung MALT lymphoma is a disease that arises from bronchial-associated lymphoid tissue and it is considered to be related to long-term exposure to a variety of antigenic stimuli, like smoking, inflammatory

conditions or autoimmune diseases.^{7,8} Pulmonary MALT lymphomas have no specific morphological appearance and CT may show single or multiple areas of consolidation, masses, nodules and/or other rarer findings.^{9–13} This suggests that potentially any radiological abnormal parenchymal finding could be consistent with lung lymphoma.¹⁴ Fluorine-18-fluorodeoxyglucose positron emission tomography/CT (^{18}F -FDG PET/CT) is an imaging tool used for staging, restaging and follow-up in various tumours, including Hodgkin and non-Hodgkin lymphoma^{15–17}; so far, its real role in evaluating MALT lymphoma is still under investigation.^{18–20} In particular, it is still under debate if this rare type of lymphoma is ^{18}F -FDG avid or not^{21–23}; pulmonary localization of MALT lymphoma seems to be one of the most ^{18}F -FDG avid site, together with head and neck,²¹ liver²⁴ and breast localizations,²⁵ but specific studies about

its glucidic metabolic behaviour are rare in the literature and based upon a small number of patients. The purpose of this study is to describe the radiological/morphological and metabolic/functional characteristics of chest CT and of ^{18}F -FDG PET/CT in a series of 28 patients with histological diagnosis of pulmonary MALT lymphoma.

METHODS AND MATERIALS

Patients

We have retrospectively screened about 30,000 patients studied with ^{18}F -FDG PET/CT in our Nuclear Medicine centre from January 2006 to January 2017 using our institutional radiology information system (RIS). Among these patients, pulmonary MALT lymphoma was identified in 32 patients. The histopathological diagnosis was based on the World Health Organization criteria.²⁶ In all patients, immunologic phenotyping on paraffin sections was done to demonstrate heavy and light chain restriction and phenotype CD20 + CD5 – CD10 – cyclinD1 which were microscopically consistent with lung MALT lymphoma. We excluded patients who did not have an histological diagnosis available and those without a whole body ^{18}F -FDG PET/CT: two patients were excluded because of lack of histological data and two patients because of the absence of a ^{18}F -FDG PET/CT study. We reviewed the medical records and pathology reports of these 28 patients: epidemiological features (age at diagnosis, gender), tumour stage according to Ann Arbor classification, morphological/radiological pattern by thoracic CT, metabolic features by ^{18}F -FDG PET/CT, treatment modality and follow-up data were collected and analysed in all patients. 20 patients underwent chest CT and whole body ^{18}F -FDG PET/CT scans before any treatment while 8 patients underwent only ^{18}F -FDG PET/CT; in these patients the low-dose CT of the PET study was considered; the maximum interval between chest CT and PET/CT was 3 weeks. Baseline features of the patients are summarized in Table 1.

Chest CT imaging and interpretation

20 patients were scanned using a 128-detector CT scanner (Somatom Definition Flash; Siemens, Erlangen, Germany) with the following parameters: collimation, 128 × 0.6 mm; beam pitch, 1.2; rotation time, 0.5 s; tube voltage, 120 kV; and tube current, 110 mA. The acquisition, extending from lung apex to lung base, was performed in inspiratory apnoea without spirometric control of lung volume. The volume was reconstructed as 1-mm thick sections, applying a sharp reconstruction algorithm and a lung window setting (window width, 1600 HU; window level, –600 HU), and as 2-mm thick sections, applying a smooth reconstruction algorithm and mediastinal window setting (window width, 400 HU; window level, 40 HU).

As aforementioned, in those eight patients who did not performed chest CT the radiological analysis was made evaluating the low dose CT of PET/CT scan (tube voltage 120 kV; tube current 80 mA, rotation time 0.5–0.8 s). The volume was reconstructed as 3.8-mm thick slices; lung window setting: window width 1600 HU; window level –600 HU; mediastinal window setting: window width 400 HU; window level, 40 HU).

Table 1. Baseline characteristics of 28 patients

	<i>n</i> (%)
Age average (range)	60.5 (33–76)
Sex male	18 (64%)
female	10 (36%)
Tumour stage at diagnosis	
I	16 (57%)
II	6 (21%)
III	1 (4%)
IV	5 (18%)
Tumour size (mm) average (range)	35 (5–114)
Location	
Unilateral	12 (43%)
Bilateral	16 (57%)
Single lesion	10 (36%)
Multiple lesions	18 (64%)
Pleural effusion	2 (7%)
Mosaic pattern	1 (3%)
Lung cysts	4 (14%)
Thoracic lymph nodes	8 (29%)
^{18}F -FDG PET/CT pos	26 (93%)
SUVmax average (range)	5.3 (1.1–13)
lesion-to-liver SUVmax ratio average (range)	2.3 (0.4–6)
lesion-to-blood pool SUVmax ratio average (range)	2.8 (0.5–8.2)

CMT, chemotherapy; FDG, fluorodesoxyglucose; mm, millimeter; Pos, positive; RTT, radiotherapy; SUV, standardized uptake value.

All chest CT scans were retrospectively reviewed by two experienced radiologists with more than 10 years of experience, to describe the morphological features of MALT lymphomas: laterality, localization, number, size, presence of enlarged thoracic lymph nodes, pleural effusion, mosaic pattern and pulmonary cyst. Based on the predominant radiologic abnormalities the lung MALT lymphomas were categorized into four major patterns: (1) consolidation; (2) mass; (3) nodule and (4) ground glass opacity (GGO). Area of consolidation was defined as homogeneous increase in pulmonary parenchymal attenuation obscuring the vessels margins and airways walls²⁷; mass was defined as rounded well-defined or moderately well-defined opacity greater than 3 cm in maximum diameter²⁷; nodule was defined as rounded well-defined or moderately well-defined opacity equal to or less than 3 cm in maximum diameter²⁷; GGO was defined as a hazy increased attenuation of lung with preservation of bronchial and vascular margins.²⁷ For every lung lesion was described the presence of secondary associated features as air bronchogram, bronchiectasis, calcification and cavitation. Other CT findings, including thoracic lymphadenopathy, pleural effusion, pulmonary cysts and mosaic pattern, were also recorded. Mosaic pattern was a condition in which there was a patchwork of regions of different lung attenuation on thin-section CT. For

every lung lesion the presence of secondary associated features like air bronchogram, bronchiectasis, calcification and cavitation was described.

¹⁸F-FDG PET/CT imaging and interpretation

All patients underwent disease staging ¹⁸F-FDG PET/CT before treatment (local surgery, chemotherapy, radiotherapy and/or combination); it was performed after at least 6 h fasting with glucose level lower than 150 mg dl⁻¹. An activity of 3.5–4.5 MBq Kg⁻¹ of ¹⁸F-FDG was administered intravenously; images were acquired 60 min after injection from the skull basis to the mid-thigh on a Discovery 690 tomograph or Discovery ST PET/CT tomograph (General Electric Company—GE®—Milwaukee, WI) with standard parameters (CT: 80 mA, 120 Kv without contrast; 2.5–4 min per bed-PET-step of 15 cm) and the reconstruction was performed in a 128 × 128 or 256 × 256 matrix and 60 cm field of view. Patients were instructed to void before imaging scan, no oral or intravenous contrast agents were administered or bowel preparation used for any patient. All ¹⁸F-FDG PET/CT scans were retrospectively reviewed by two experienced nuclear medicine physicians with more than 10 years of experience. PET images were analysed both visually and semi-quantitatively. Readers had knowledge of clinical history, and every focal tracer uptake deviating from physiological distribution and background was regarded as suggestive of MALT; it was defined as discrete ¹⁸F-FDG activity higher than the surrounding tissue on visual analysis. Semi-quantitative analysis was made by measuring the maximum standardized uptake value (SUVmax), lesion-to-liver SUVmax ratio and lesion-to-blood pool SUVmax ratio for each pulmonary lesion. We measured the SUV of detectable lesions by drawing a region of interest (ROI) over the area of maximum activity and the SUVmax was calculated as the highest SUV of the pixels within the ROI. SUVmax of the blood-pool was calculated at the aortic arch by use of transaxial PET images with a round-shape 10 mm ROI not involving the wall of the vessel; SUVmax of the liver was calculated at the VIII hepatic segment of transaxial PET images using a round-shape 10 mm ROI.

Statistical analysis

All statistical analysis was carried out using Statistical Package for Social Science (SPSS) version 23.0 for Windows (IBM, Chicago, IL) and MedCalc Software version 17.1 for Windows (Ostend, Belgium). The descriptive analysis of categorical variables comprised the calculation of simple and relative frequencies. The numeric variables were described as mean, standard deviation, minimum and maximum.

Univariate logistic regression analysis was performed to assess the relationship between qualitative ¹⁸F-FDG PET/CT (FDG avidity) and the other clinical, pathological and radiological parameters. Variables with $p < 0.05$ in the univariate analysis were further analysed using multivariate logistic regression analysis to determinate which variables were independently associated.

The relationship between semi-quantitatively features (SUVmax, lesion-to-liver SUVmax ratio and lesion-to-blood pool SUVmax ratio) and the morphological parameters were calculated using Anova test and independent t test.

The Pearson correlation coefficient was applied to find correlation between the semiquantitative features (SUVmax, lesion-to-liver SUVmax ratio and lesion-to-blood pool SUVmax ratio) and the tumour size. We applied these test because the SUVmax, lesion-to-liver SUVmax ratio, lesion-to-blood pool SUVmax ratio and the tumour size were normally distributed. A p -value < 0.05 was considered statistically significant.

Duration of follow-up was calculated from the date of diagnosis to the last control or date of death.

RESULTS

Patient's features

We evaluated 28 patients with lung MALT lymphoma histological proven, 18 (64%) were male and 10 (36%) female; mean age was 60.5 ± 12.5 years (range 33–76 years). Patients were staged according to the Ann Arbor system as follows: stage I ($n = 16$), stage II ($n = 6$), stage III ($n = 1$) and stage IV ($n = 5$). Among patients with stage IV MALT lymphoma, all had extrapulmonary disease histological proven: three in stomach, one in kidney and one in liver (Table 1). All patients had no history or concomitant oncological disease different from MALT lymphoma. Four patients had associated conditions as follows: two patients systemic lupus erythematosus and two patients Sjogren syndrome. Patients were treated according to the stage and location of the disease: 5 patients underwent surgical resection (in three cases single lobectomy, in the other two cases wedge resection); 17 received chemotherapy (CMT), 2 underwent surgery plus CMT, 1 patient underwent radiotherapy and 3 patients didn't undergo any therapy (1 patient was lost at follow-up before starting treatment and the other 2 patients did not received therapy due to the early stage of disease and asymptomatic condition). CMT regimen consisted of R-CVP (rituximab-cyclophosphamide, vincristine and prednisolone) or R-CHOP (rituximab-cyclophosphamide, doxorubicin, vincristine and prednisolone). The average duration of follow-up was 62 months (9–125 months).

CT findings

57 pulmonary lesions were identified in 28 patients: 37 (65%) presenting as areas of consolidation, 12 (21%) as nodules, 4 (7%) as masses and 4 (7%) as GGOs (Figure 1).

Solitary lesion was observed in 10 of 28 patients (36%), multiple lesions in the remaining 18 (64%) patients. Among 18 patients with multiple lesions, 2 demonstrated unilateral pulmonary MALT lymphoma and the remaining 16 had bilateral disease. 32 (56%) lesions were in the right lung: 15 in the upper lobe, 9 in the middle lobe and 8 in the lower lobe. 25 (44%) lesions were distributed in the left lung: 18 in the upper lobe and 7 in the lower lobe (Table 2).

Lesion size, considering diameter maximum of the tumour, was $35 \text{ mm} \pm 26 \text{ mm}$ (range 5–114 mm).

In consolidation areas average diameter maximum was $38.7 \pm 21 \text{ mm}$ (range 5–114 mm), in masses $65 \pm 38 \text{ mm}$ (range 35–89 mm), in nodules $13.6 \pm 6 \text{ mm}$ (range 6–28 mm) and in GGO $29 \pm 13 \text{ mm}$ (range 20–45 mm). The commonest secondary

Figure 1. Example of the main four morphological pattern of presentation of lung lesion at chest CT. (a) Axial CT scan revealing two areas of consolidation in both upper lobes (black arrows) in a 71-year-old female. (b) Axial CT scan showing a nodule of 18 mm of diameter in the upper lobe of left lung (white arrow) in a 58-year-old male. (c) Axial CT scan revealing a big mass of 74 mm of diameter in the lower lobe of right lung (black arrow) in a 58-year-old male (d) Axial CT scan showing a part solid GGO in the left lung (white arrow) in a 72-year-old male.

associated features of the pulmonary lesions were the presence of an air bronchogram: a total of 33 air bronchogram findings were detected in 31 consolidation areas and in 2 GGOs. Bronchiectasis was present in 17 lesions, all presenting as areas of consolidation. Whereas we recorded only one case of cavitation and one case of calcification in a consolidation lesion (Table 2). Evaluating

Table 2. CT features of 57 lung lesions

Radiologic features	n (%)
Localization	
Right lung	32 (56%)
RUL:RML:RLL	15:9:8 (26%:16%:14%)
Left lung	25 (44%)
LUL:LLL	18:7 (32%:12%)
Morphological pattern	
Consolidation	37 (65%)
Nodule	12 (21%)
Mass	4 (7%)
GGO	4 (7%)
Secondary associated features	
Air bronchogram	33 (58%)
Bronchiectasis	17 (30%)
Cavitation	1 (2%)
Calcification	1 (2%)

GGO, ground glass opacity; LLL, left lower lobe; LUL, left upper lobe; RLL, right lower lobe; RML, right middle lobe; RUL, right upper lobe.

Figure 2. Comparison between FDG negative and positive lung MALT lymphoma. Axial CT (a), axial PET (b) and axial fused PET/CT images (c) in a 74-year-old male with a 12-mm nodule in the upper lobe of right lung showing no pathological FDG uptake corresponding to the pulmonary lesion. Axial CT (d), axial PET (e) and (f) axial PET/CT images in a 72-year-old male showing an intense FDG uptake in a big area of consolidation in lower lobe of left lung with a SUVmax of 11.9 lesion-to-liver SUVmax ratio of 3.2 and lesion-to-blood pool SUVmax ratio of 4.4.

other CT findings, 2 patients had pleural effusion, 4 presences of pulmonary cystic lesions and 1 mosaic pattern presentation. Thoracic lymph nodes were identified in 8 of 28 patients (29%) (Table 1).

¹⁸F-FDG PET/CT findings

Among 28 patients, 26 (93%) were ¹⁸F-FDG-avid showing the presence of a hypermetabolic lesion corresponding to the lesion histological demonstrated as MALT lymphoma; while two patients (7%) had negative ¹⁸F-FDG PET/CT (Table 1). The patients with negative ¹⁸F-FDG PET/CT were a 74-year-old male with an isolated nodule of 12 mm of diameter in the right middle lobe (Figure 2) and a 64-year-old female with a GGO in the left upper lobe without other lung lesions. On a per-lesion based analysis, considering all 57 pulmonary lesions, ¹⁸F-FDG PET/CT showed avid lesions in 47/57 (82%) cases: 34/37 (92%) among areas of consolidation, 4/4 (100%) among masses; 6/12 (50%) considering nodules and 3/4 (75%) evaluating GGOs.

¹⁸F-FDG PET/CT positive lung lesions had larger average maximum diameter than those not ¹⁸F-FDG avid (average diameter maximum 40 vs 11 mm, $p = 0.002$), this correlation was also confirmed in the multivariate regression analysis ($p = 0.005$) (Table 3). Considering an arbitrarily maximum diameter threshold of 2 cm, recognized as a value which widely overcomes the limits

Table 3. Comparison between qualitative, semiquantitative features at ^{18}F -FDG PET/CT and clinical-morphological characteristics

	PET/CT pos n 47	PET/CT neg n 10	<i>p</i> value	Av SUVmax	<i>p</i> value	Av L-to-L SUVmax ratio	<i>p</i> value	Av L-t-BP SUVmax ratio	<i>p</i> value
Pattern			0.778		0.839		0.667		0.713
Consolidation	34	3		5.1		2.1		2.7	
Mass	4	0		7.8		2.8		3.8	
Nodule	6	6		3.8		1.8		2.2	
GGO	3	1		5.7		2.5		3.1	
Laterality			0.820		0.498		0.392		0.622
Unilateral	10	2		5.7		2.5		2.9	
Bilateral	37	8		5		2.1		2.7	
Air bronchogram			0.051		0.986		0.453		0.648
Positive	30	3		5.2		2.3		2.8	
Negative	17	7		5.2		2		2.6	
Bronchiectasis			0.136		0.541		0.578		0.877
Positive	17	1		4.8		2.3		2.8	
Negative	30	9		5.4		2.1		2.7	

av, average; L-t-L, lesion to liver; L-t-BP, lesion to blood pool: neg, negative; Pos, positive.
Between paranthesis *p* value of multivariate analysis.

related to PET/CT resolution power and breathing variation, 8/17 (47%) lesions with a diameter less than 2 cm were ^{18}F -FDG avid, whereas 38/38 (100%) lesions with diameter > 2 cm were ^{18}F -FDG avid. Evaluating every specific radiological pattern of appearance, in the six ^{18}F -FDG not avid nodular lesions average maximum diameter was significantly lower compared to ^{18}F -FDG positive nodular lesions (9.8 vs 18.2 mm, $p = 0.025$); a similar evidence was present also in consolidation pattern (13.3 vs 41 mm, $p = 0.049$). Comparing the metabolic and morphological pattern of presentation, laterality, presence of bronchiectasis and air bronchogram there were no significant differences between positive and negative ^{18}F -FDG PET/CT (Table 3).

All thoracic lymph nodes detected by chest CT were ^{18}F -FDG-avid; not further thoracic lymphadenopathies were discovered by ^{18}F -FDG PET/CT. In three patients ^{18}F -FDG PET/CT showed additional pathological uptakes corresponding to extrapulmonary localizations of MALT lymphoma: in two cases detecting gastric ^{18}F -FDG avid lesions (Figure 3; confirmed to be a MALT lymphoma by histological examination after biopsy) and in one patient detecting kidney involvement. Thus ^{18}F -FDG PET/CT changed tumour stage in these three cases identifying new pathological uptakes related to MALT lymphoma and upstaging to stage IV from stage I in two cases and from stage II in one. The other two cases of extrapulmonary MALT localizations (gastric and hepatic involvement) were already known before ^{18}F -FDG PET/CT and it simply confirmed pathological findings.

In patients with positive ^{18}F -FDG PET/CT, average SUVmax of the lesions was 5.3 ± 2.9 (range 1.1–13); lesion-to-liver SUVmax ratio was 2.3 ± 1.3 (range 0.4–6) and lesion-to-blood pool SUVmax ratio 2.8 ± 1.7 (range 0.5–8.2) (Table 1). SUVmax,

lesion-to-liver SUVmax ratio and lesion-to-blood pool SUVmax ratio in consolidation areas were 5.1 ± 2.9 (range 1.1–13), 2.1 ± 1.3 (0.4–6), 2.7 ± 1.6 (0.5–8.2), respectively; in masses were 7.8 ± 2.5 (4.9–10.6), 2.8 ± 1.5 (1.3–4.8), 3.8 ± 2 (1.8–6.6), respectively; in nodules were 3.8 ± 1.9 (2.3–7), 1.8 ± 0.9 (0.9–3.2), 2.2 ± 1.2 (1.1–3.9), respectively and in GGO were 5.7 ± 3.2 (2.8–9.2), 2.5 ± 1.5 (1.1–4.2), 3.1 ± 1.9 (1.3–5.1), respectively. SUVmax, lesion-to-liver SUVmax ratio and lesion-to-blood pool SUVmax ratio were not correlated with morphological pattern of disease, laterality and secondary radiological findings (Table 3). Only SUVmax was correlated significantly with tumour size (Figure 4).

Figure 3. (a) MIP, showing the presence of bilateral hypermetabolic lung lesions and an increased diffuse FDG uptake in the stomach. Axial PET (b) and axial PET/CT (c) scan revealing an increased FDG uptake corresponding to the gastric thickening wall.

Figure 4. (a) Relationship between tumour size in millimeter and SUVmax value ($r = 0.477$; $p = 0.002$). (b) Relationship between tumour size in millimeter and lesion to blood pool SUVmax ratio ($r = 0.283$, $p = 0.061$). (c) Relationship between tumour size in millimeter and lesion to liver SUVmax ratio ($r = 0.221$; $p = 0.136$). SUV, standardized uptake value.

DISCUSSION

Lung MALT lymphoma is a rare extranodal low-grade B-cell lymphoma and it is considered to originate from MALT of the bronchus. It is the most common subtype of NHL of the lungs, accounting for up to 90% of all primary pulmonary lymphoma.^{1–6} The CT imaging findings of pulmonary MALT lymphoma are various and include solitary or multifocal, round or segmental lesions that may be located centrally or peripherally with no lobular predilection²⁸; the most frequent imaging findings are consolidations, followed by nodules and masses. Other rarer appearances include GGO and interstitial change. The most common concomitant findings are air bronchogram and bronchiectasis.^{29–32} Cavitation, calcification, pulmonary cystic lesions and pleural effusion are less common. Also in our study, we demonstrated that consolidation (65%) is the most frequent morphological pattern of disease presentation, followed by nodule (21%), mass (7%) and GGO (7%). Air bronchogram was detected in more than half of the patients and bronchiectasis was present in about a third, frequently present with areas of consolidation. Lung MALT lymphoma is often observed as multiple and bilateral disease^{31–33}; this result was confirmed also in our work with a rate of multiple lesions of 64% and bilaterality of 57%. Similar patterns on CT scans can be seen in many other entities, both neoplastic and non neoplastic disease like eosinophilic pneumonia, sarcoidosis, adenocarcinoma, and other lung lymphoproliferative disorders; thus differential diagnosis can be very difficult.

There are conflicting reports about ¹⁸F-FDG uptake in MALT lymphoma and also in lung MALT lymphoma. Hoffmann et al^{34,35} firstly described lung MALT lymphoma as not ¹⁸F-FDG avid tumours and did not recommend ¹⁸F-FDG PET. However in those two works, only a small number of patients

were included and patients were scanned without whole-body CT attenuation correction resulting in lower imaging quality. Besides, PET scans were performed 40 min following the injection of ¹⁸F-FDG, probably too early. Subsequently, other authors^{36–43} investigated the metabolic behaviour of pulmonary MALT achieving a high detection rate (Table 4). In 2005 Beal et al³³ reported 11 cases of pulmonary MALT lymphoma avid of ¹⁸F-FDG. Moreover, other authors³⁸ demonstrated that ¹⁸F-FDG uptake differences in MALT may be due to different histological features, showing that MALT lymphoma with plasmacytic differentiation had more frequently ¹⁸F-FDG avid lesions. This result was controverted by Albano et al in a larger sample of patients studied.²³

In a recent work²³ focused on the role of ¹⁸F-FDG-PET/CT, Ki-67 score and plasmacytic differentiation in extragastric MALT lymphoma, we demonstrated a per-patient detection rate of 100% in 24 patient with pulmonary MALT lymphoma; in the present study we have increased the number of pulmonary MALT lymphoma adding four patients with histological diagnosis and showing a slightly reduction of detection rate (93%).

In our study, per-patient lung MALT lymphomas detection rate of ¹⁸F-FDG PET/CT was anyway very high and similar to that of all the other studies available^{33,36–43} (Table 4); only two patients had not ¹⁸F-FDG avid lung MALT lymphoma. From a per-lesion detection ¹⁸F-FDG avidity was present in 82% of cases. A possible limit of previous works was that the presence of a per-patient analysis only, not considering the frequent bilaterality and multiplicity of lung MALT lymphoma and the heterogeneous morphological and metabolic features of this disease. In our analysis the only variable significantly

Table 4. Summary of main studies in literature including patients with lung MALT lymphoma and ^{18}F -FDG PET/CT

Authors	Year	Device	^{18}F -FDG avidity per patient (%)	Mean SUVmax (range)
Beal et al ³³	2005	PET/CT	11/11 (100%)	6.8 (2.6–26)
Alinari et al ³⁷	2006	PET	8/8 (100%)	7.5 (3–18)
Hoffmann et al ³⁸	2006	PET	2/4 (50%)	na
Perry et al ³⁹	2007	PET/CT	5/5 (100%)	na
Enomoto et al ⁴⁰	2008	PET	2/2 (100%)	3.8 (3.2–4.5)
Bae et al ³⁶	2008	PET/CT	6/6 (100%)	4.2 (2.2–6.3)
Zhang et al ²⁸	2011	PET/CT	8/8 (100%)	4.9 (2.8–9.4)
Zinzani et al ⁴¹	2013	PET	11/11 (100%)	3.6 (2.8–6)
Yoon et al ⁴²	2013	PET/CT	4/5 (80%)	3.3 (2.3–5.7)
Park et al ⁴³	2015	PET/CT	7/7 (100%)	4.4 (2.4–6.3) ^a
Albano et al ²³	2017	PET/CT	24/24 (100%)	na
Present study	2017	PET/CT	26/28 (93%)	5.3 (1.1–13)

FDG, fluorodesoxyglucose; na, not available; MALT, mucosa associated lymphoid tissue; PET, positron emission tomography; SUV, standardized uptake value.

^aSULmax, standardized uptake lean body mass.

correlated with ^{18}F -FDG PET/CT positivity was the maximum diameter of the lesion; lung MALT lymphoma with small size lesions were less ^{18}F -FDG avid compared to larger lesion. This evidence could be related with resolution power and partial volume effect. The crucial role of tumour size is confirmed also in the analysis of each type of morphological pattern of disease. On the other hand, no correlations were demonstrated between semi-quantitative ^{18}F -FDG PET/CT characteristics (SUVmax, lesion to liver SUVmax ratio and lesion to blood pool SUVmax ratio) and tumour size. Morphological pattern and other radiological features didn't seem to influence ^{18}F -FDG avidity.

In the literature average SUVmax of lung MALT lymphoma ranges from 3.3 to 7.5 (Table 4); in our study, we had a mean SUVmax of 5.3 very similar to those aforementioned.²⁸ So far, in the literature no articles considering the other semiquantitative parameters (lesion-to-liver SUVmax ratio and lesion-to-blood pool SUVmax ratio) are available as well as works with a number of patients like us.

In three patients ^{18}F -FDG PET/CT detected more lesions than CT upstaging the patient and contributing to a better clinical

management. This point is in agreement with the results of Carrillo-Cruz et al,⁴⁴ who demonstrated a high sensitivity of ^{18}F -FDG PET/CT in staging 17 marginal zone B cell lymphoma.

About this topic, more and larger studies are desirable and needed to confirm our evidences being aware that one important advantage of ^{18}F -FDG PET-CT is that it is a whole body technique allowing a the whole body in a single scan.

Our present study shows several limitations: the retrospective type of analysis, the small sample of patients analysed (due to the rarity of this disease) and the heterogeneous features of our sample (for example not all patients have made the same imaging scans).

In conclusion, lung MALT lymphoma can manifest diverse patterns of lung abnormality at CT, but single or multiple bilateral areas of consolidation or nodules are the main patterns. Our data confirm that lung MALT lymphomas are ^{18}F -FDG avid in most cases, indicating that ^{18}F -FDG PET/CT should be part of the diagnostic process of this particular disease. Maximum diameter of the lesion is the only factor which influences ^{18}F -FDG avidity.

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