Role of ^{18}F-FDG PET/CT imaging in cardiac and pericardial masses

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Background. **Considering the few reported cardiac masses, PET/CT in the imaging workup of cardiac masses is not well established. This retrospective study analyzed the role of ^{18}F-FDG PET/CT imaging in cardiac/pericardial masses.**

Methods and results. **Fifty-nine patients with newly diagnosed cardiac/pericardial masses who underwent PET/CT and transthoracic echocardiography (TTE) were recruited. Echocardiographic and PET/CT characteristics were evaluated for predictive value in differentiating malignant and non-malignant lesions using histologic confirmation as the gold standard. The McNemar test was used to test the differences in sensitivity between PET/CT and TTE. ^{18}F-FDG PET/CT had higher sensitivity in determining the malignancy of cardiac/pericardial masses compared to TTE (sensitivity, 96.6% vs 72.4%, P = .039). However, when pericardial masses were excluded from the analysis, the difference in sensitivity between the two was not statistically significant (sensitivity, 95.6% vs 78.3%, P = .219). ^{18}F-FDG PET/CT identified two malignant pericardial masses missed on TTE, changed the diagnostic orientation of TTE in 15 patients, and found seven patients with extracardiac lesions in 29 malignant patients.**

Conclusions. **PET/CT was an effective additional image modality in patients with suspected malignant cardiac mass for further confirmation and to screen for potential metastasis. (J Nucl Cardiol 2022;29:1293–303.)**

Key Words: Cardiac tumor • cardiac angiosarcoma • cardiac myxoma • ^{18}F-FDG PET/CT imaging • echocardiography

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Abbreviations	
TTE	Transthoracic echocardiography
SUVmax	Maximum standardized uptake value
TMR	Tumor-to-mediastinum tissue ratio
AUC	Area under the curve
ROC	Receiver-operating-characteristic
PET	Positron emission tomography
CT	Computed tomography
^{18}F-FDG	^{18}F-Fluorodeoxyglucose

INTRODUCTION

Cardiac tumors are rare entities with high mortality.[1,2] Surgical removal is the treatment option of most cases.[3] Complete surgical resection can cure most benign heart lesions[4] and is also an important treatment for local cardiac malignancies. Palliative surgery is only recommended to relieve rapidly progressing symptoms, in case of unresectable lesions or presence of metastases.[5,6] Hence, proper differentiation among these masses and accurate staging of malignant tumors play a vital role in the treatment option.

The two most commonly used noninvasive diagnostic modalities to evaluate suspicious cardiac masses are echocardiography and magnetic resonance imaging (MRI).[7-11] Transthoracic echocardiography (TTE) is the first diagnostic procedure, with a high sensitivity of 93.3%.[12] Cardiac MRI provides further information about morphology, location and extent of the mass. CT is recommended for assessing infiltration into the pericardium or the heart itself[13] and detecting calcifications,[14] especially for patients with contraindications for MRI. However, it is still difficult to accurately discriminate between malignant and benign tumors. Several reports show that ^{18}F-FDG PET/CT can aid noninvasive preoperative determination of malignancy[15-27] and may be helpful in detecting metastases of malignant cardiac tumors.[28-30]

However, there are limited data available on ^{18}F-FDG PET/CT imaging in cardiac/pericardial masses. The aim of this study was to evaluate the ability of ^{18}F-FDG PET/CT imaging in cardiac/pericardial masses in a relatively large sample size.

PATIENTS AND METHODS

Patients

This study was approved by the institutional review board of our hospital and informed consent was waived due to its retrospective nature of the study. We retrospectively identified 59 patients referred for ^{18}F-FDG PET/CT evaluation of newly diagnosed cardiac/pericardial masses from August 2010 to October 2019. All patients were referred to assess metabolism of the cardiac tumors and to screen for extracardiac tumor manifestations. The inclusion criteria were as follows: (1) patients underwent TTE; (2) patients did not receive any prior therapy; (3) patients had the lesion resected or biopsied for histopathologic confirmation within four weeks following ^{18}F-FDG PET/CT scans. One patient who received cardiac biopsy 25 days before ^{18}F-FDG PET/CT scan was excluded from the study. All patients had the cardiac/pericardial lesions resected (N = 57) or biopsied (N = 2) for histopathologic confirmation. Two patients underwent only biopsy owing to wide encroachment.

Transthoracic Echocardiography Examination

Two-dimensional transthoracic echocardiograms (IE33/IU22, Philips) were used in the study. Images were obtained in standard views. Contrast agents were not used. Echocardiography studies were clinically interpreted by two experienced cardiologists at our hospital. Characterizing lesions as malignant or nonmalignant was based on the image signs and parameters together.

^{18}F-FDG PET/CT IMAGING

^{18}F-FDG PET/CT imaging was obtained by the following two PET/CT devices: Discovery VCT 64 (General Electric, Milwaukee, WI, USA) or uMI510 (United Imaging Healthcare, China). The patients performed a standard oncologic preparation without a high-fat/low-carbohydrate diet or heparin intervention. Patients were instructed to fast for at least 6 h, and their blood glucose levels were less than 150 mg/dL before ^{18}F-FDG injection. Whole-body acquisition from head to proximal femora was started about 60 minutes after injection of 3.7 to 4.4 MBq/kg of ^{18}F-FDG. PET scans were performed using 3D imaging mode with emission scans of two min per bed position. Images were reconstructed with the 3D iterative reconstruction method. The CT scans were obtained to match the PET scans' field of view and slice thickness. The helical CT acquisitions were performed using the following parameters: Discovery VCT 64 (140 mA; 120 kV; pitch, .516; slice thickness, 1.25 mm) or uMI 510 (140 mAs; 120 kV; pitch, 1.0625; slice thickness, 1.5 mm).

Visual and Quantitative Analysis of ^{18}F-FDG PET/CT Images

All ^{18}F-FDG PET/CT images were analyzed and interpreted by two experienced nuclear medicine physicians. They were blinded to the patients' clinical information, other conventional imaging findings, and pathology results. A consensus was reached after mutual discussion if any discrepancies between the interpreting physicians. For each cardiac/pericardial lesion identified, each reader recorded the size and graded the possibility of malignant using a five-point scoring system (0 = definitely not malignant; 1 = probably not malignant; 2 = indeterminate lesion; 3 = probably malignant; 4 = definitely malignant). The readers were informed that scoring a lesion as 3 or 4 was regarded as positive for malignant.

With the exception of physiologic distributions, all foci of cardiac/pericardial ^{18}F-FDG uptake greater than the surrounding background were assessed. The maximum standardized uptake value (SUVmax) was calculated as decay-corrected maximum activity concentration in the lesion divided by administered activity divided by body weight in kilograms. The SUVmax of the mediastinum and myocardium were measured using circular regions of interest (10 mm) placed in the lumen of the aorta ascendens and myocardial tissue next to the tumor. The tumor-to-mediastinum tissue ratio (TMR) was defined as SUVmax of the tumor divided by SUVmax of mediastinum.

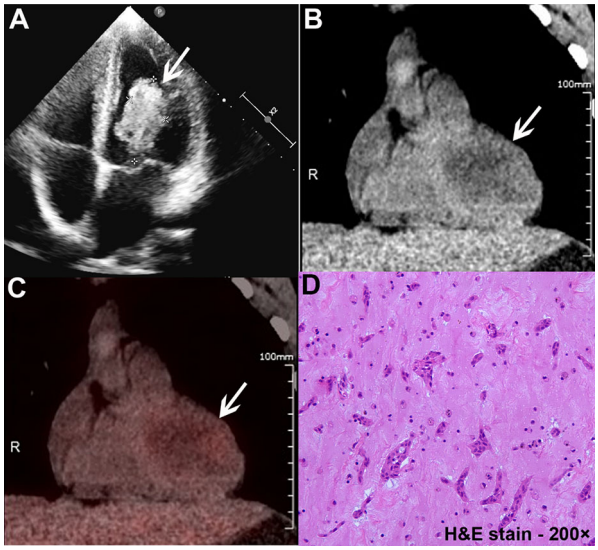

Figure 1. PET/CT scan of a 30-year-old man with cardiac mass. Transthoracic echocardiography revealed a medium echo mass in the left ventricle with irregular shape, which was indicative of malignancy (**A**, arrow). Coronal PET/CT images (arrows on CT, **B**; fusion, **C**) show no abnormal ^{18}F-FDG uptake (SUVmax, 1.7). Histologic work-up after tumor resection revealed benign primary cardiac myxoma (**D**).

Statistical Analysis

Statistical analyses were conducted using SPSS software version 23.0 (IBM Corp., New York, NY, USA; formerly SPSS Inc., Chicago, IL, USA). Receiver-operating-characteristic (ROC) curve and the predictive values were evaluated using MedCalc Statistical Software version 1.2 (MedCalc Software bvba, Ostend, Belgium). Continuous variables were presented as mean ± SD, and categorical data were summarized as frequencies and percentages. The difference between two groups was analyzed by the Chi square test or Mann–Whitney nonparametric test. ROC curve analysis was performed to evaluate the diagnostic performance. The area under curve (AUC) and the cutoff value were further determined at the point with the highest Youden index. The DeLong test was used to test for differences in AUC of the ROC. The McNemar test was used to test the differences in sensitivity and specificity between

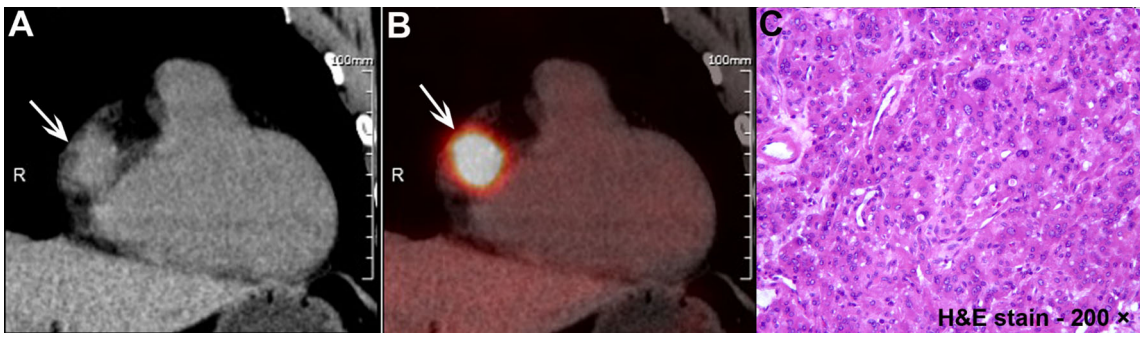

Figure 2. PET/CT scan of a 46-year-old man with pericardial mass. Coronal PET/CT images (arrows on CT, **A**; fusion, **B**) demonstrated highly increased ^{18}F-FDG uptake (SUVmax, 21.1). The lesion was missed on echocardiography. Histologic work-up demonstrated paraganglioma (**C**).

PET/CT and TTE. Significance was set at *P* less than .05 and all *P*-values reported were two-sided.

RESULTS

Patients' Characteristics, Histology and Location

Fifty-nine patients (32 men, 27 women; mean age ± SD, 50 ± 13 years) according to the inclusion criteria were retrospectively enrolled in the final analysis. Histology served as ground truth. The histologic distributions and anatomic locations are summarized in Table 1.

Of these patients, 30 (50.8%) had nonmalignant lesions (benign tumors and tumor-like lesions), 23 (39.0%) had primary malignant tumors, and six (10.2%) had secondary malignant tumors. The common histologic types were myxoma (33.9%, Figure 1) and angiosarcoma (27.1%), followed by secondary cardiac tumors (10.2%). All tumors located in the pericardium (6/6, 100.0%, Figure 2) were malignant.

Among the 59 cases, 23 (39.0%) occurred in the right atrium, 14 (23.7%) in the left atrium, 10 (16.9%) involved in more than one chamber or great vessels, six (10.2%) in the pericardium, five (8.5%) in the right ventricle and one (1.7%) in the left ventricle.

Diagnostic Performance of ^{18}F-FDG PET/CT and Transthoracic Echocardiography

The visual analysis showed that the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of ^{18}F-FDG PET/CT and TTE in

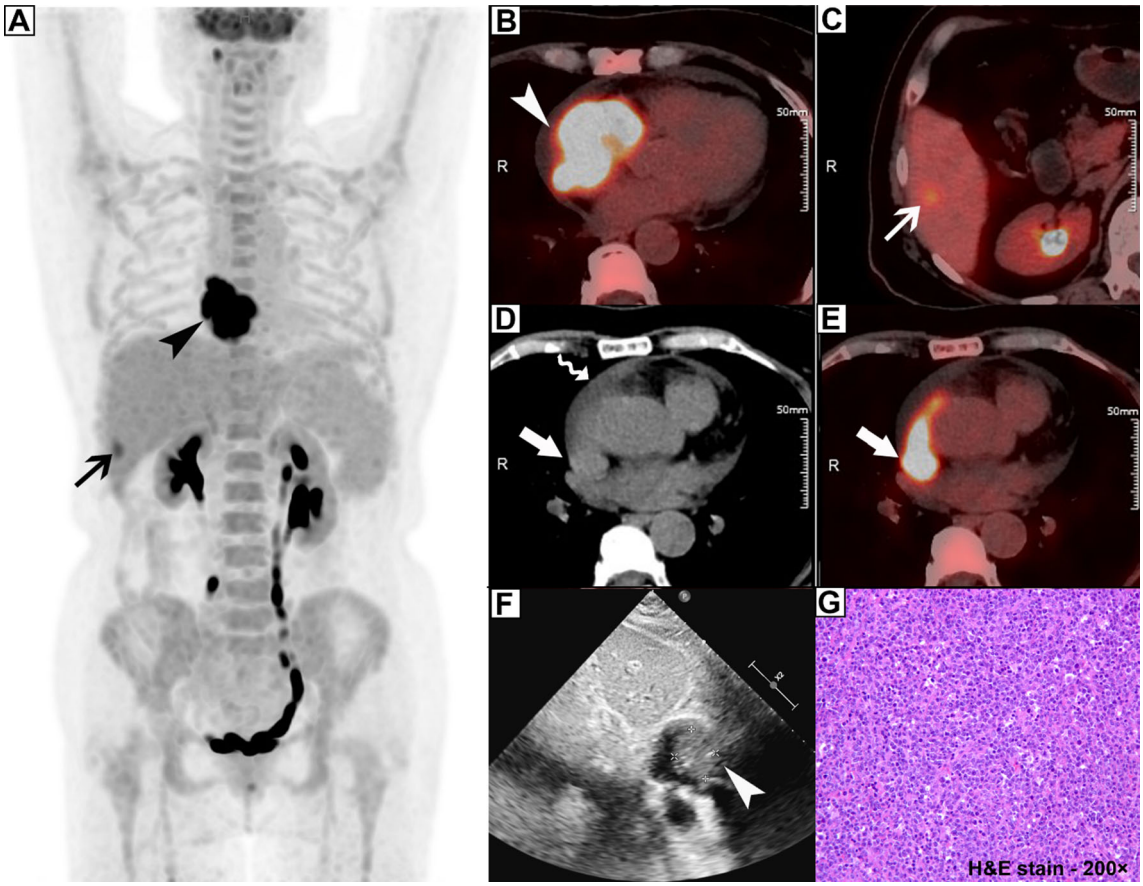

Figure 3. PET/CT scan of a 67-year-old woman with cardiac mass. ^{18}F-FDG PET/CT showed a right atrial mass with intense ^{18}F-FDG uptake (SUVmax, 25.4; arrowheads on MIP, **A**; axial CT, **B**) and a liver lesion with mildely uptake (SUVmax, 6.2; small arrows on MIP, **A**; axial CT, **C**). On axial images (**D**, CT; **E**, fusion), the right atrial mass extended to cava superior (large arrows) with pericardial effusion (curved arrow). Transthoracic echocardiography showed a solid mass in the outer wall of right atrium and at the entrance of the superior vena cava (**F**, arrowhead). Resection cardiac specimen confirmed diffuse large B-cell lymphoma (**G**).

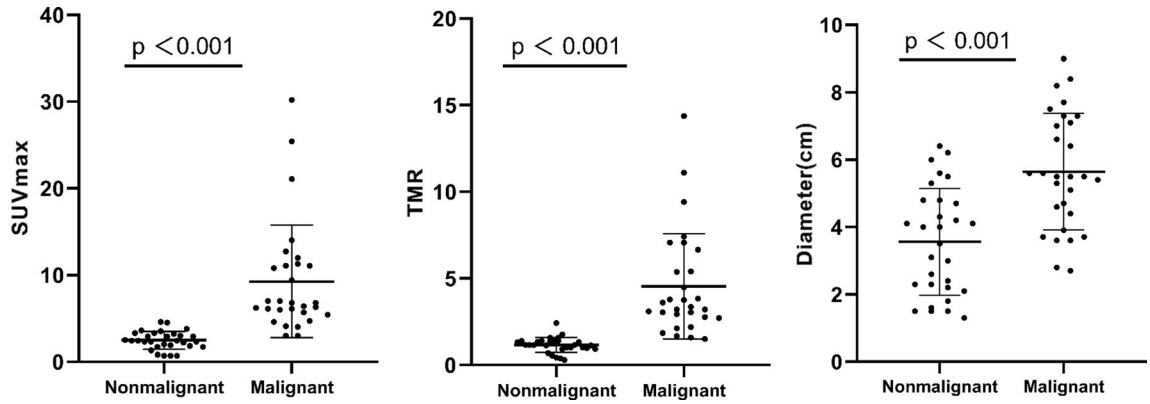

Figure 4. The SUVmax, tumor-to-mediastinum tissue ratio (TMR), and lesion size in malignant lesions were significantly higher than that of nonmalignant lesions.

determination of cardiac and pericardial malignancy were 96.6% (28/29) vs 72.4% (21/29), 86.7% (26/30) vs 76.7% (23/30), 87.5% (28/32) vs 75.0% (21/28), and 96.3% (26/27) vs 74.2% (23/31), respectively (Table 2). The sensitivity and specificity of ^{18}F-FDG PET/CT were higher than that of TTE, and there was a significant statistical difference in sensitivity between the two imaging methods (P = .039) but no statistical difference in specificity (P = .549).

The visual analysis showed that the sensitivity, specificity, PPV, and NPV of ^{18}F-FDG PET/CT and TTE in determination of cardiac malignancy (no pericardial masses) were 95.6% (22/23) vs 78.3% (18/23), 86.7% (26/30) vs 76.7% (23/30), 84.6% (22/26) vs 72.0% (18/25), and 96.3% (26/27) vs 82.1% (23/28), respectively. The sensitivity and specificity of ^{18}F-FDG PET/CT were higher than that of TTE, but there was no statistical difference in sensitivity (P = .219) and specificity (P = .549) between the two imaging methods.

^{18}F-FDG PET/CT identified two malignant pericardial masses missed on TTE (Figure 2), and changed the diagnostic orientation of TTE in 15 patients, including seven benign tumors and eight malignant tumors. Among the 29 malignant patients, ^{18}F-FDG PET/CT imaging found seven patients with extracardiac lesions (24.0%), including gluteus maximus, lung, thymus and liver (Figure 3).

Echocardiography Features of Cardiac Masses

Diameter in malignant lesions (Table 3) was greater than that of nonmalignant lesions (5.6 ± 1.6 cm vs 4.7 ± 1.9 cm, P = .042). Significant differences were found between nonmalignant and malignant

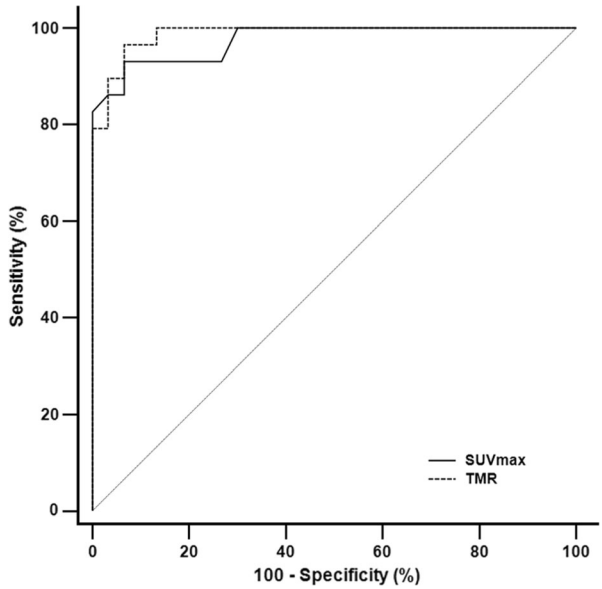

Figure 5. Receiver-operating-characteristic curves of SUVmax and tumor-to-mediastinum tissue ratio (TMR) in differentiating malignant tumor from nonmalignant lesions. The study applied the SUVmax cutoff of 3.8 to yield 93.1% sensitivity and 93.3% specificity in determining tumor malignancy.

lesions in terms of pericardial effusion (P = .001), non-mobility (P = .011), irregular margin (P < .001), and myocardial invasion (P = .011). In contrast, there were no significant differences between nonmalignant and malignant lesions in terms of gender (P = .637), age (P = .666), location in the right atrium (P = .069), involvement more than one chamber or great vessels (P = .065), and pendicle (P = .217).

PET/CT Features of Cardiac/Pericardial Masses

The ^{18}F-FDG SUVmax and TMR in malignant lesions (Figure 4, Table 4) were significantly higher than that of nonmalignant lesions (SUVmax, 9.3 ± 6.5 vs 2.5 ± 1.0, $P < .001$; TMR, 4.5 ± 3.0 vs 1.2 ± .4, $P < .001$; respectively). In addition, diameter in malignant lesions was greater than that of nonmalignant lesions (5.6 ± 1.7 cm vs 3.6 ± 1.6 cm, $P < .001$).

Moreover, the incidence of pericardium in malignant lesions (Figure 2) was significantly higher than that of nonmalignant lesions (6/29, 20.7% vs 0/30, 0%; $P = .028$). Although the involvement of more than one chamber or great vessels was more prevalent in patients with malignancies than that with nonmalignant lesions, the difference did not reach statistical significance (7/29, 24.1% vs 3/30, 10.0%; $P = .271$). Likewise, pericardial effusion was more frequent in patients with malignancies than that with nonmalignant lesions (22/29, 75.9% vs 8/30, 26.7%; $P < .001$). In contrast, no significant differences were found between nonmalignant and malignant lesions in terms of gender ($P = .506$), age ($P = .744$), the SUVmax of the mediastinum ($P = .648$), the SUVmax of myocardium ($P = .622$), and location in the right atrium ($P = .519$).

Table 1. Histologic types and lesion locations of the enrolled 59 patients with cardiac/pericardial masses

Histology type	N (%)*	Site†	Method of diagnosis
Nonmalignant	30 (50.8%)		
Myxoma	20 (33.9%)	LA (10), RA (8), LV (1), RA+RV(1)	Surgery (20)
Thrombus	3 (5.1%)	RA (2), LA (1)	Surgery (3)
Intravenous leiomyoma	2 (3.4%)	RA + RV + pulmonary artery (1), RA + cava inferior (1)	Surgery (2)
Inflammatory myofibroblastic tumor	1 (1.7%)	LA (1)	Surgery (1)
Cyst	1 (1.7%)	RA (1)	Surgery (1)
Hamartoma	1 (1.7%)	RV (1)	Surgery (1)
Hemangioma	1 (1.7%)	RV (1)	Surgery (1)
Lipomyoma	1 (1.7%)	RA (1)	Surgery (1)
Malignant	29 (49.2%)		
Primary	23 (39.0%)		
Angiosarcoma	16 (27.1%)	RA (10), Pericardium (4), RV (2)	Surgery (15), biopsy (1)
Malignant tumor (not further specified)	2 (3.4%)	Pericardium (1), LA (1)	Surgery (1), biopsy (1)
Composite hemangioendothelioma	1 (1.7%)	RV (1)	Surgery (1)
Epithelioid sarcoma-like hemangioendothelioma	1 (1.7%)	LA + RA (1)	Surgery (1)
Intimal sarcoma	1 (1.7%)	LA + right superior pulmonary vein (1)	Surgery (1)
Paraganglioma	1 (1.7%)	Pericardium (1)	Surgery (1)
Pleomorphic leiomyosarcoma	1 (1.7%)	LA (1)	Surgery (1)
Secondary	6 (10.2%)		
Lymphoma	2 (3.4%)	RA + cava inferior (2)	Surgery (2)
Type B3 thymoma	2 (3.4%)	RA + cava superior (2)	Surgery (2)
Lung adenocarcinoma metastasis	1 (1.7%)	LA + Right inferior pulmonary vein (1)	Surgery (1)
Metastatic cardiac tumor of unknown	1 (1.7%)	RA (1)	Surgery (1)

*Values are n/N (%)
LA, left atrium; *LV*, left ventricle; *RA*, right atrium; *RV*, right ventricle

Table 2. Performance of PET/CT and echocardiography in determination of malignancy

Analysis	Cutoff value	AUC	Sen (%)	Spe (%)	PPV (%)	NPV (%)
Visual analysis						
^{18}F-FDG PET/CT			96.6	86.7	87.5	96.3
Echocardiography			72.4	76.7	75.0	74.2
ROC analysis						
SUVmax	> 3.8	.975	93.1	93.3		
TMR	> 1.6	.987	96.6	93.3		

AUC, area under curve; Sen, sensitivity; *Spe*, Specificity; *PPV*, positive predictive value; *NPV*, negative predictive value; *ROC*, receiver-operating-characteristic; *SUVmax*, maximum standardized uptake value; *TMR*, tumor-to-mediastinum tissue ratio

Table 3. Echocardiography features of cardiac masses (no pericardial masses)

Characteristic	Nonmalignant (30)	Malignant (23)	*P* value
Gender	M, 15; F, 15	M, 13; F, 10	.637
Age, years	51 ± 15	50 ± 12	.666
Diameter, cm	4.7± 1.9	5.6 ± 1.6	.042
Pericardial effusion	6	15	.001
Location in the right atrium	18	8	.069
Involvement more than one chamber or great vessels	6	10	.065
Non-mobility	9	15	.011
Pendicle	5	1	.217
Irregular margin	6	17	< .001
Myocardial invasion	2	9	.011

ROC Analysis of SUVmax and TMR in Differentiating Malignancy from Nonmalignant Lesions

The ROC curve is shown in Figure 5, and the corresponding statistics are shown in Table 2. Although the AUC value of TMR was higher than that of SUVmax, there is no statistical difference (.987 vs .975, P = .301). The cutoff values with a maximum Youden index of the SUVmax and TMR were 3.8 and 1.6, resulting in a sensitivity of 93.1% vs 96.6% and a specificity of 93.3% vs 93.3%, respectively.

DISCUSSION

There are several important findings in this study. First, we identified echocardiographic and PET/CT characteristics that were predictive of cardiac/pericardial malignancy, and especially PET/CT in a large sample size. Second, we demonstrated that ^{18}F-FDG PET/CT was an effective additional image modality in patients with suspected malignant cardiac mass for further confirmation and to screen for potential metastasis, especially for pericardial masses.

Primary tumors of the heart are extremely rare, and their prevalence in autopsies is approximately .001% to .03%.[31,32] Seventy-five percent of primary cardiac neoplasms are benign and 25% are malignant.[3] In malignant tumors, secondary cardiac malignancies are 20 to 30 times more common than primary tumors of the heart.[2] In this study, the incidence of malignant lesions was similar to that of nonmalignant lesions, and the incidence of primary malignant lesions was higher than that of secondary ones. The reason might be that all patients were clinically suspected of having a malignant tendency, and PET/CT was employed to assist diagnosis and staging. Additionally, surgical therapy of metastatic cardiac tumor is generally contraindicated in the presence of widely disseminated neoplastic disease,[33,34] and

Table 4. PET/CT features of cardiac /pericardial masses

Characteristic	Nonmalignant (30)	Malignant (29)	*P* value
Gender	M, 15; F, 15	M, 17; F, 12	.506
Age, years	51 ± 15	50 ± 12	.744
SUVmax of mediastinum	2.1 ± .4	2.1 ± .5	.648
SUVmax of myocardium	2.3 ± .9	2.4 ± .8	.622
SUVmax of lesion	2.5 ± 1.0	9.3 ± 6.5	< .001
TMR	1.2 ± .4	4.5 ± 3.0	< .001
Diameter, cm	3.6 ± 1.6	5.6 ± 1.7	< .001
Pericardial effusion	8	22	< .001
Location in the right atrium	13	15	.519
Location in the pericardium	0	6	.028
Involvement more than one chamber or great vessels	3	7	.271

SUVmax, maximum standardized uptake value; *TMR*, tumor-to-mediastinum tissue ratio

therefore, conservatively managed metastatic masses were not included.

Echocardiography is the preferred initial imaging method to assess cardiac mass. Echocardiographic characteristics are predictive of malignant cardiac/pericardial neoplasm, including pericardial effusion, nonmobility, irregular margin, and myocardial invasion, which confirmed the findings of the previous study.[35] Moreover, contrast agents would have improved the accuracy of TTE in differentiating cardiac masses.[36] Parameters cannot associate with malignancy included pendicle, location in the right atrium, involvement of more than one chamber or great vessels.

^{18}F-FDG uptake reflects the metabolic rate of glycolysis in tumors, so quantification of ^{18}F-FDG uptake can support the noninvasive differentiation between benign and malignant cardiac tumors. The present study showed that malignant cardiac tumors usually exhibited a high ^{18}F-FDG uptake, whereas benign ones were expected to show only slight ^{18}F-FDG uptake. In current study, ^{18}F-FDG PET/CT had higher sensitivity in determining the malignancy of cardiac/pericardial masses compared to TTE. However, when pericardial masses were excluded from the analysis, the difference in sensitivity between the two was not statistically significant. Moreover, ^{18}F-FDG PET/CT identified two malignant pericardial masses missed on TTE, and changed the diagnostic orientation of TTE in 15 patients. The reason might be that operator dependence, limited windows with narrow field of view, and poor acoustic windows. In contrast, whole-body PET/CT scan provides a combination of morphologic tumor characterization and visualization of tumor metabolism, which is relatively objective and may be helpful to distinguish malignant from nonmalignant lesions. Furthermore, ^{18}F-FDG PET/CT detected extracardiac lesions in malignant cases. Therefore, whole body ^{18}F-FDG PET/CT imaging has the unique advantage in comprehensive staging of malignant tumors.

Cardiac MRI has proven to be particularly helpful in the diagnosis workup of cardiac tumors with its superior tissue characterization, high spatial resolution and multi-planar imaging. Patel[35] et al. showed that cardiac MRI provided more correct histopathologic diagnosis than echocardiography (77% vs 43%, $P <$ .0001). Recently, it has been shown that ^{18}F-FDG PET/CT can provide incremental diagnostic information in determination of cardiac malignancy and metastases.[18,25,29] In the study by Rahbar et al.,[25] ^{18}F-FDG PET/CT imaging of cardiac tumors with 24 patients (7 patients of simultaneous contrast-enhanced CT on the PET/CT scanner, 17 patients of a separately acquired contrast-enhanced CT scan) was retrospectively analyzed. Malignancy was determined with 100% sensitivity and 86% specificity at the SUVmax cutoff of 3.5. Morphologic imaging of contrast enhanced CT reached 82% sensitivity and 86% specificity. However, biopsy before or after PET/CT scan is ambiguous. An ^{18}F-FDG PET/MR study by Nensa et al. in 20 patients with cardiac masses showed that PET/MR imaging can improve the noninvasive diagnosis in the planning of surgical intervention in patients with complex cardiac infiltration and recurrence monitoring during the follow-up examination after intervention. [26]

Our results of 59 patients confirm the findings of the few previous studies that had been conducted.[18,25,26] But the cutoff value of SUVmax in our study was lower than the recent study by Qin et al. (92.11% sensitivity and

88.89% specificity with the SUVmax cutoff of 6.75).[29] The reason might be that the number of secondary cardiac tumors in our study was relatively small (6/59, 10.2%), which might have high ^{18}F-FDG uptake. Considering the tumor-to-background ratio of SUVmax can homogenize the individual differences from radiotracer uptake of background, the present study further confirmed that TMR was not better than SUVmax in determining tumor malignancy. Although the AUC value of TMR was slightly higher than that of SUVmax, there was no statistical difference between the two indices. When the SUVmax of the cardiac/pericardial lesion was higher than its cutoff value of 3.8, we regarded it as malignancy with 93.1% sensitivity and 93.3% specificity.

In our research, all tumors located in the pericardium were malignant, indicating that malignant tumors occurred more often in the pericardium than nonmalignant lesions. Furthermore, when the tumor involved more than one chamber or great vessels (Figure 3), most of them (7/10, 70.0%) were malignant. Pericardial effusion was more frequent in patients with malignancies (22/29, 75.9%) than that with nonmalignant lesions. Therefore, malignant tumors should be considered when a single tumor is found in the pericardium or in the heart that involves more than one chamber or great vessels, or with pericardial effusion.

It is well-known that ^{18}F-FDG uptake in the heart is highly heterogeneous. Uptake may range from almost non-existent to a highly significant one that can lead us to misdiagnosis of tumoral activity.[37] Normally glucose enhancement is only homogenously identified in the left ventricle.[37] Normally glucose enhancement is only homogenously identified in the left ventricle.[37] However, it is extremely rare in the atrium.[37] A minimum of six hours fasting before ^{18}F-FDG PET is recommended to decrease normal myo-cardial uptake of ^{18}F-FDG.[38,39] Meanwhile, we found that more lesions occurred in the atrium than ventricle in current study. There were six cases occurred in the ventricle and only one case in the left ventricle, in which there was low ^{18}F-FDG uptake (Figure 1). Additionally, the SUVmax of mediastinum and myocardium were measured to rule out artificial activity contribution by spillover of myocardial or blood ^{18}F-FDG uptake into the tumor region. Although regional physiologic uptake in the myocardium was observed, the vicinity of the tumors showed a mean myocardial uptake of as low as 2.3 ± .9. Therefore, normally glucose enhancement in the left ventricle might have a small impact on our study.

Our study had several limitations. First, we only evaluated pathologically confirmed masses with ^{18}F-FDG PET/CT, and therefore, a great number of nonmalignant masses without ^{18}F-FDG PET/CT were not included. Our data do not represent the true incidence of nonmalignant cardiac tumors. Second, based on its retrospective nature, special patient preparation for detecting cardiac malignancy was not undertaken, such as a high-fat/low-carbohydrate diet or heparin intervention. Third, the fact that there is no standard diagnostic approach for patients with cardiac tumors results in heterogeneous data on the availability of contrast enhanced CT and MRI. Therefore, the results are valid only for standard oncologic preparation with suspected tumors in the heart and pericardium. Future studies are eagerly awaited to better define and validate this role on prospective study with a specific and accurate preparation to suppress physiologic glucose uptake in the myocardium.

CONCLUSIONS

In conclusion, PET/CT was used to further delineate characteristics and metastasis for patients with echocardiography suspected malignancy or in more complicated cases. ^{18}F-FDG PET/CT can improve the diagnostic workup of cardiac/pericardial masses in determining tumor malignancy. ^{18}F-FDG PET/CT characteristics are predictive of malignant cardiac/pericardial neoplasm, including SUVmax, size, location in the pericardium, and pericardial effusion. Futhermore, ^{18}F-FDG PET/CT imaging provides the unique advantage in identifying pericardial masses and staging of malignancy.

New Knowledge Gained

We demonstrated that ^{18}F-FDG PET/CT can play an important role in the differentiation and staging of malignant cardiac/pericardial masses,especially for patients with echocardiography suspected malignancy or in more complicated cases. When the SUVmax of the cardiac/pericardial lesion was higher than its cutoff value of 3.8, we regarded it as malignancy with 93.1% sensitivity and 93.3% specificity.

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Disclosure

Hongyan Yin, Wujian Mao, Hui Tan, Na Zhu, Quan Wan, Jing Shi, Lin Qiu, Yan Xiu, Rongkui Luo, Haojun Yu, Hongcheng Shi have nothing to declare. The authors of this manuscript declare no relationships with any companies, whose products or services may be related to the subject

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