

Focal mass-like cardiac uptake on oncologic FDG PET/CT: Real lesion or atypical pattern of physiologic uptake?

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Background. Cardiac uptake on oncologic FDG PET/CT can be unpredictable. Focal or mass-like cardiac uptake not confined to normal pattern is a real challenge for interpretation due to great variability in physiologic uptake and rarity of either primary or metastatic cardiac neoplasms.

Methods and Results. Eight patients with suspicious mass-like cardiac uptake on oncologic FDG PET/CT were retrospectively analyzed with correlation to cardiac workups including contrast CT, echocardiography, and repeat PET/CT. Four patients had real cardiac lesions or metastases. Focal uptake was benign and might represent papillary muscle in the other four. SUV_{max} ratio between the cardiac focus and surrounding background cardiac uptake was statistically higher in the true-positive group than that in the false-positive group. In addition, the patients with true-positive cardiac uptake had more diffuse distant metastases compared to those with false-positive cardiac uptake.

Conclusions. Focal suspicious cardiac uptake on oncology FDG PET/CT warranted further evaluation. SUV_{max} ratio between the cardiac focus and surrounding background cardiac uptake and status of distant metastases might help to differentiate malignant from benign nature of the focal cardiac uptake on FDG PET/CT. Focal uptake of the right ventricle on oncologic FDG PET/CT is more likely suggestive of a neoplasm. (J Nucl Cardiol 2019;26:1205–11.)

Key Words: FDG PET/CT • cardiac uptake • cardiac metastasis • maximum standardized uptake value (SUV_{max})

Abbreviations	SUV_{max}	Maximum standardized uptake value
FDG PET/CT	¹⁸ F-fluorodeoxyglucose positron emission tomography/computed tomography	

INTRODUCTION

¹⁸F-fluorodeoxyglucose positron emission tomography/computed tomography (FDG PET/CT) is a standard care in oncologic applications, and it is well established

as an important imaging modality for tumor staging, restaging, detection of recurrence, and monitoring treatment response. FDG PET/CT documents metabolic and function abnormalities which usually precede the

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anatomic changes. Another significant advantage of PET/CT is its routine whole-body acquisition without additional radiation exposure to patients. In image interpretation, knowledge of physiologic uptake patterns and appearances in different organs beyond the region of interest is important since atypical pattern or variant of uptake may mimic a neoplasm.

On oncology FDG PET/CT, myocardium of the left ventricle may or may not demonstrate significant uptake.¹⁻⁴ Normal cardiac uptake typically is in the basal-ring pattern and confined to ventricular wall.⁵ Physiologic linear uptake of the right ventricle is occasionally seen, which is much less than that of the left ventricle. Increased cardiac uptake can be seen in inflammatory/infectious cardiac diseases including sarcoidosis. However, focally mass-like cardiac uptake not confined to normal pattern is a real challenge for interpretation due to great variability in physiologic uptake and rarity of either primary or metastatic cardiac neoplasm. In the literature, there are only a few case reports about incidentally detected cardiac metastases or neoplasms on oncology FDG PET/CT.⁶⁻¹¹

The aim of this study was to analyze the FDG PET/CT image findings with focal mass-like cardiac uptake with correlation to subsequent cardiac workups, and discuss the diagnostic pitfalls.

METHODS

Population and Study Design

This retrospective study was approved by the Institutional Review board. Relevant cases were identified through a search of a computerized database of 4,500 patients who underwent PET/CT imaging for oncology indications in the Advanced Imaging Center, at the University Hospital between January 2011 and December 2017. Eight patients were identified to have focal mass-like suspicious cardiac uptake on oncologic PET/CT and subsequent cardiac workups including contrast CT, echocardiography, and repeat PET/CT. Additional five patients with suspicious cardiac uptake but without further verification of suspicious cardiac uptake were excluded from the analysis.

FDG PET/CT

Combined PET-CT was performed using a PET-CT scanner (Discovery LS, GE Healthcare, Milwaukee, Wisconsin, USA) and standard techniques. The patients had fasted for at least 6 hours prior to examination, and their blood glucose level was less than 250 mg/dL. The patients received oral but not intravenous contrast media. Spiral low-dose CT (80 mA, 140 kV, and 4-mm section thickness) was performed with the cranio-caudal direction covering the areas from the vertex to the mid-thigh for the purpose of attenuation correction and

anatomic localization. Thereafter, emission scan was conducted in a reverse direction. PET images were reconstructed using CT for attenuation correction with the OSEM algorithm.

Image Analysis

An image software Mim (Mim Software Inc, Cleveland, OH) was used for image display and analysis. The whole-body maximum-pixel-intensity projection was used for visual evaluation. First, FDG PET/CT images of all included cases were reviewed again to assure the accuracy of the initial interpretation and report. Second, maximum standardized uptake values (SUV_{max}) were recorded with placements of the regions of interest over focal mass-like uptake and adjacent normal cardiac uptake, respectively. Third, the ratio of SUV_{max} of focal mass-like uptake to adjacent normal cardiac uptake was calculated.

Included patients' clinical and follow-up data after PET/CT were extracted and reviewed. FDG PET/CT findings were correlated to diagnostic CT and/or echocardiography.

RESULTS

Focal mass-like cardiac uptake was identified in 13 of 4,500 patients who had oncologic FDG PET/CT. Among eight patients who met criteria for analyses, four were positive for real cardiac lesions or metastases (true positive) and the other four were negative for cardiac abnormalities (false positive) on subsequent further cardiac workups including contrast CT, echocardiography, and repeat PET/CT. Table 1 summarizes the patients' characteristics. All patients were nondiabetic, and finger stick glucose levels were in the expected ranges. Except for the patient 6 whose images showed moderate normal cardiac uptake with basal-ring pattern, normal cardiac uptakes in the other 7 patients were only mild beyond the mass-like focus, which made focal mass-like cardiac uptake very suspicious. In patients 1 to 4, follow-up imaging indicated that mass-like cardiac uptake was related to cardiac metastases. However, for patients 5 to 8, suspicious focal cardiac uptake was either an atypical pattern of the myocardium or papillary muscle. Therefore, the positive predictive value of the suspicious cardiac uptake on FDG PET/CT was 50%.

Although the mean SUV_{max} of the mass-like foci in the true-positive group was higher than that of the false-positive (12.9 ± 4.8 vs 9.0 ± 1.8), the difference was not statistically significant ($P > 0.05$) (Table 2). The true-positive group demonstrated higher SUV_{max} ratio than the false-positive (4.5 ± 1.5 vs 2.3 ± 0.44 , $P < 0.05$). Among four confirmed cardiac lesions, two were in the interventricular septum, one was in the left myocardium and one was on the right ventricular wall. Since the physiologic uptake of the right ventricular myocardium is usually mild, focal intense mass-like right ventricular

Table 1. Patients' characteristics

Patient	Sex/ Age	PET Indication	DM/ Glucose (mg/dL)	PET findings	Cardiac finding	Normal cardiac SUV _{max}	SUV _{max} ratio (abnormal focus/normal uptake)	Verification and diagnosis
1	F/75	Lung ca	No/111	Diffuse metastases in nodes, adrenal, muscles, and bones	1.5 cm L. ventricular focus (SUV _{max} 9.0)	2.5	3.6	Contract CT: cardiac tumor
2	M/58	Sarcoma	No/135	Diffuse metastases in lungs, liver, nodes, muscles, bones, and brain	2.0 cm focus (SUV _{max} 9.5) in interventricular septum	2.5	3.8	Contrast CT: cardiac tumor
3	F/48	Sarcoma	No/96	Diffuse metastases in lungs, nodes, and bones	3.1 × 4.5 cm R. ventricular mass (SUV _{max} 21)	3.0	7.0	Echo: cardiac tumor
4	F/57	Sarcoma	No/102	Metastases in lungs, and nodes	4 × 5 cm mass (SUV _{max} 12) in interventricular septum	3.4	3.5	Echo: cardiac tumor
5	M/78	Sinus SCC	No/78	Localized lesion in R. maxillary sinus, maxilla and adjacent masseter. No metastasis	3 cm L. ventricular focus (SUV _{max} 6.0)	3.2	1.9	Echo: normal
6	M/43	Melanoma	No/84	Metastases in lungs and bones	2.5 cm L. ventricular focus (SUV _{max} 10.5)	5.2	2.0	Echo and repeat PET/CT: normal
7	F/46	Lung ca	No/97	Satellite lung lesions and mediastinal nodes. No distant metastasis.	3.5 cm focus (SUV _{max} 9.6) in interventricular septum	3.7	2.6	Echo: normal
8	M/63	Lung ca	No/93	Hilar node. No distant metastasis.	4 cm L. ventricular focus (SUV _{max} 10)	3.6	2.8	Echo: normal

Table 2. Comparisons of the true- and false-positive groups

Group	Age (years)	Glucose (mg/dL)	SUV _{max} of abnormal cardiac focus	Normal cardiac SUV _{max}	SUV _{max} ratio of abnormal/normal
Positive cardiac lesion	59.5 ± 9.8	111 ± 14.8	12.9 ± 4.8	2.85 ± 0.44	4.5 ± 1.5
Negative cardiac lesion	57.5 ± 14.1	88 ± 7.4	9.0 ± 1.8	3.93 ± 0.88	2.3 ± 0.44
Statistical analysis	<i>P</i> = .40	<i>P</i> = .07	<i>P</i> = .12	<i>P</i> = 0.07	<i>P</i> = .03

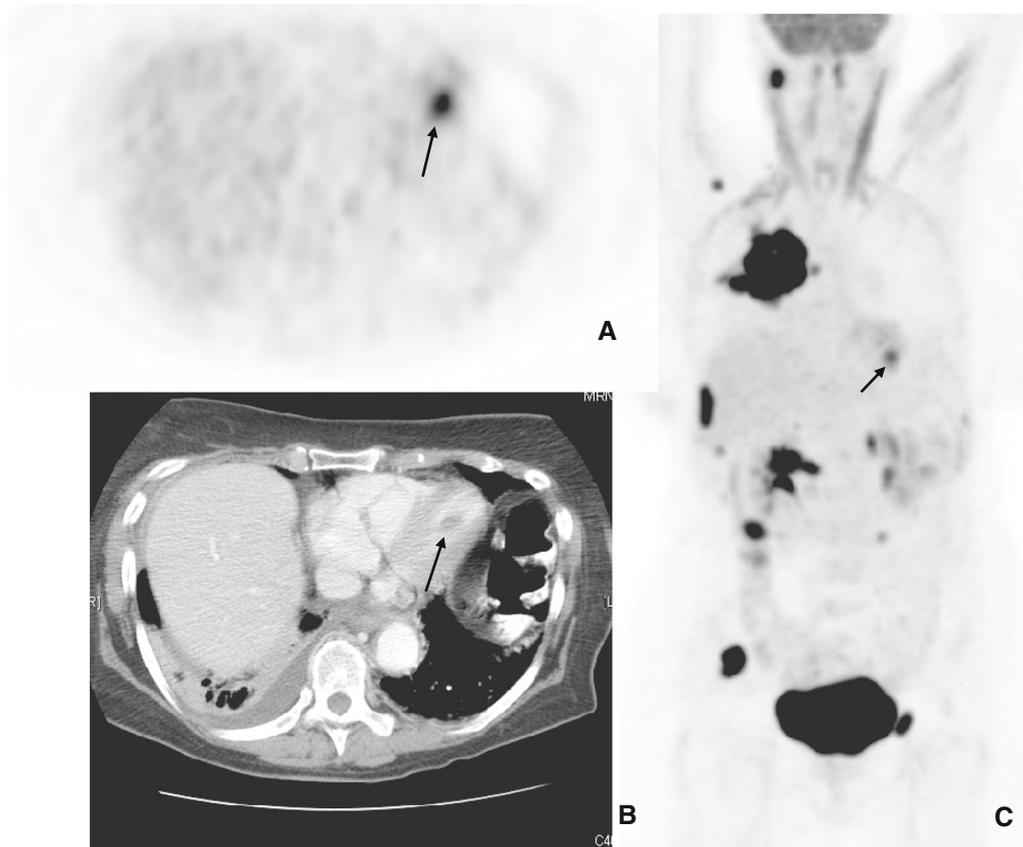


Figure 1. FDG PET (A), diagnostic CT (B) and whole-body PET MIP image (C) of the Patient 1 with lung cancer. There was a left ventricular wall focus, which corresponded to a real lesion on the diagnostic CT (arrows). There were multiple distal metastases including muscular lesions on whole-body images.

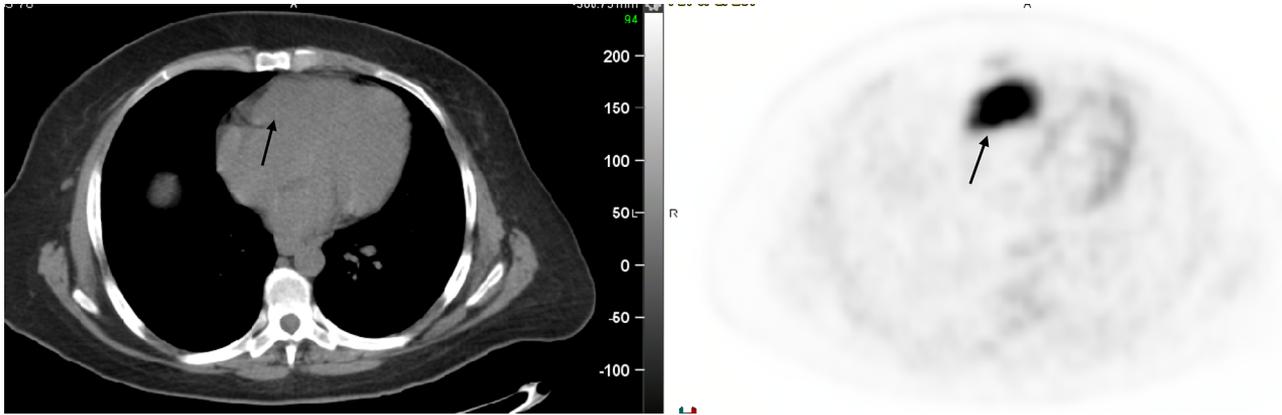


Figure 2. FDG PET/CT image of the Patient 3 with the extremity sarcoma. Intensely FDG avid mass was seen on the right ventricular wall (arrow) which was confirmed by echocardiography. There was the highest uptake ratio of 7.0 between the abnormal focus and normal background cardiac uptake.

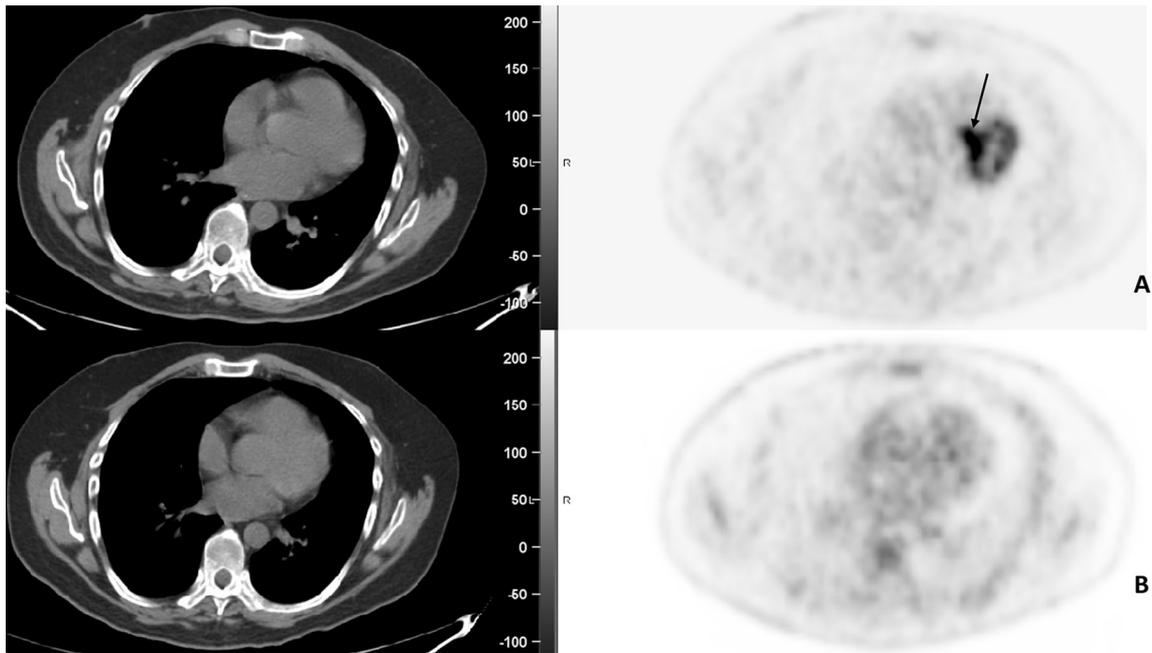


Figure 3. FDG PET/CT images of the Patient 6 with melanoma (A). There was focal increased uptake on the anteroseptal wall of the left ventricle (arrow) beyond the diffuse normal cardiac uptake. Echocardiography was negative. Repeated PET/CT images showed normal pattern of the cardiac uptake without previously noted focus (B).

uptake on an oncologic FDG PET/CT is very suspicious for a metastatic lesion.

Although no patient had pathological verification of the focal cardiac uptake obviously due to patients' advanced disease status, we assumed that the lesions of the true-positive group were most likely metastases considering the image findings. It was noted that all true-

positive patients had more distant metastatic disease than the false-positive. Two of them had muscular metastases. In comparison, only one of four patients of the false-positive group had distant metastasis and the other three had localized lesions only on PET/CT images. Therefore, the status of distant metastasis might be another pitfall in interpretation of focal suspicious cardiac uptake.

Primary tumors of the patients of the true-positive groups were high grade sarcoma (3 patients) and lung cancer (1 patient). Sarcoma was a dominant primary with cardiac metastasis in the current cohort, which was inconsistent with the reports in the literatures possibly due to small sample size.

Figures 1 and 2 illustrate the case examples of the true-positive mass-like cardiac uptake, and Figure 3 a case of false-positive cardiac uptake.

DISCUSSION

Although it is very rare, cardiac metastasis is more frequent than primary cardiac tumor. Lung cancer, nonsolid primary such as leukemia and lymphoma, breast cancer, and esophageal cancer are the most common primary malignancies for cardiac metastasis.¹² Metastasis may spread to the heart via hematogenous or lymphatic routes, or direct extension. Cardiac metastasis is often asymptomatic. Cardiac gadolinium-enhanced MRI and/or echocardiography are considered a standard image modalities for cardiac neoplasm.

Maurer et al. described four common patterns of FDG cardiac distribution on oncologic PET/CT: absent, diffusely increased (with or without some heterogeneity), focally increased (papillary muscles), or regionally increased.⁵ Nonuniform FDG cardiac uptake is often seen with relatively decreased uptake of the septum and anterior wall, and predominant uptake of the base.⁵ Similarly, Nose et al. categorized physiologic cardiac uptake of FDG PET image in patients without heart disease into four patterns: none, diffuse, focal, and focal on diffuse.¹³ In general, the focal and focally increased or regionally increased uptake represent heterogeneous uptake. Diffuse cardiac uptake, either homogeneous or heterogeneous, is typically in the basal-ring pattern and considered physiologic. Yi et al. reported echocardiographic findings of seven cases of unusual myocardial uptake on oncology FDG PET/CT, which included pericardial effusion, regional wall motion abnormality and increased myocardial wall thickness but no cardiac tumors.¹⁴ Therefore, most of focal cardiac uptake seems normal or benign.

In the current cohort, the patients with mass-like focal cardiac uptake beyond mild cardiac background uptake or moderate basal-ring pattern uptake were enrolled for analyses, and the pattern of the abnormal cardiac uptake was different from previously described heterogeneous uptake. All cases were interpreted as suspicious for cardiac metastasis. Four patients had real cardiac lesions verified on subsequent diagnostic CT and echocardiography. However, the other four had no cardiac abnormality on subsequent workups. Therefore, mass-like focal uptake in these four false-positive cases

most likely represented the papillary muscle. Focal papillary muscle uptake may be isolated without adjacent myocardial uptake, especially in the posterior muscle which sometimes demonstrates a globular shape.¹⁵ Other possibilities include variable benign uptake, brown adipose tissue or interatrial lipomatous hypertrophy, or even rest ischemia.¹⁶ Although there was a high false-positive rate in this small case series, suspicious cardiac uptake on oncology FDG PET/CT warranted further evaluation.¹⁷

The only parameter with statistical difference between the true- and false-positive groups was SUV_{max} ratio between the focus and surrounding normal background cardiac uptake, which was higher in the true-positive cases. Increased FDG accumulation within the tumor relatively resulted in decrease of surrounding normal myocardium. The ratio might be helpful in image interpretation, but its significance was too preliminary. Another finding was that all true-positive patients had diffuse distant metastases in multiple organs and tissue including muscle in two cases. When the images only showed localized disease, cardiac metastasis or true cardiac lesion was less likely.

A major limitation of the current study is small sample size because of rarity of cardiac metastasis. In addition, no patient of the cohort had pathological verification of cardiac pathology, obviously due to invasive nature of the procedure and known late-stage status of malignant and metastatic disease.

CONCLUSION

In the current cohort of eight patients with mass-like focal cardiac uptake on oncologic FDG PET/CT, four had real lesions or metastases, and the focal uptake was benign and might represent papillary muscle in the other four.

NEW KNOWLEDGE GAINED

- Focal cardiac uptake on oncologic FDG PET/CT may represent either real lesion/metastasis or atypical physiologic/papillary muscle uptake.
- Focal suspicious cardiac uptake on oncologic FDG PET/CT warrants further evaluation.
- SUV_{max} ratio between the cardiac focus and surrounding background cardiac uptake and status of distant metastases might help to differentiate malignant from benign nature of the focal cardiac uptake on FDG PET/CT.
- Focal intense uptake of the right ventricle on oncologic FDG PET/CT is more suspicious for a neoplasm.

Disclosure

The author declares no conflicts of interest related to this article.

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