Incidental Diagnosis of Thrombus Within an Aneurysm on ^{18}F-FDG PET/CT: Frequency in 926 Patients

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Our objective was to evaluate the incidence of aneurysm and the frequency of thrombus within an aneurysm on unenhanced ^{18}F-FDG PET/CT studies. **Methods:** We reviewed 1,540 PET/CT scans from 926 patients. A log recorded whether each case of aneurysm had a suspected thrombus. The maximal standardized uptake value of the patent vessel was compared with the thrombus. Findings were confirmed using all available follow-up data. **Results:** Aneurysm was found incidentally in 16 (1.7%) of the 926 patients, with 15 occurring in the abdominal aorta and 1 in the internal jugular vein. Seven of these 16 patients had shown suggestions of thrombus on unenhanced PET/CT, and in all 7, thrombi were confirmed on contrast-enhanced CT. **Conclusion:** In 1.7% of patients, aneurysm was found incidentally on PET/CT, and thrombus was present in 44% of these cases.

Key Words: cardiology (clinical); PET/CT; vascular; aneurysm; thrombus

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According to the American Heart Association, the overall leading cause of death in North America continues to be atherosclerotic cardiovascular disease (*1*). The patient populations that typically undergo PET/CT—the elderly and patients receiving chemotherapy or radiation therapy—are at a greater risk of developing atherosclerotic cardiovascular disease.

Atherosclerosis is a progressive disease characterized by thickening of the artery walls. The thickening is composed of a fibrin layer incorporated with blood cells, platelets, blood proteins, and cellular debris, and the most susceptible vessels are the coronary arteries, popliteal arteries, descending thoracic aorta, carotid arteries, and vessels of the circle of Willis. The main complications of plaque formation include myocardial infarcts, thromboembolic cerebral infarcts, and aortic aneurysms and dissection (*2*). The most common type of aneurysm seen on PET/CT studies, the abdominal aortic aneurysm (AAA), is one that reaches an anteroposterior diameter of 3.0 cm. In men, the incidence of a 3.0- to 4.9-cm AAA ranges from 1.3% (at age 45–54 y) to 12.5% (at age 75–84 y), and in women, the incidence ranges from 0% to 5.2%, respectively. However, the incidence of AAA in the cancer population is not well known. The risk of rupture is greater in larger AAAs because they expand more rapidly than smaller AAAs, and a thrombus that is growing also has a greater risk of rupture. Intraluminal thrombus is present to variable degrees in approximately 75% of AAAs (*3*). Rupture of an AAA has been reported to be the tenth leading cause of death in the United States, and the mortality rate is as high as 90% (*4,5*). An AAA is usually diagnosed by physical examination, ultrasound, or CT.

Since the introduction of PET/CT, numerous studies have shown that whole-body dual-modality imaging is better than PET or CT alone for staging and restaging most cancers (*6*). The National Oncologic PET Registry was developed in 2006 to collect data on the clinical utility of PET. By the end of November 2010, this registry had evaluated more than 170,000 PET studies performed at 2,146 centers (*7*). A study using data from the registry concluded that ^{18}F-FDG PET brought about a change in management for 38% of cases (95% confidence interval, 37.6%–38.5%) across cancer types, proving that the use of PET should not be restricted to particular cancer types or testing indications (*8*). With ^{18}F-FDG, PET can be used to diagnose, stage, and restage many types of cancer with an accuracy ranging from 80% to 90% and is often better than anatomic imaging (*9*). However, as more studies are performed, many incidental PET/CT findings have proven to be clinically significant. Identifying asymptomatic patients and intervening before a major event continues to be a major concern.

On intravenous administration, ^{18}F-FDG is cleared rapidly from circulation, providing a high target-to-background ratio to detect hypermetabolic lesions such as malignant tumors, infection, or inflammation. A minimal amount of physiologic activity remains in circulation, as reflected by a uniform ^{18}F-FDG distribution within a vessel. However, when

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the normal blood flow is interrupted by the chronic presence of a nonmetabolically active material such as a thrombus within the lumen, a region of tracer void is seen on PET. Increased ^{18}F-FDG uptake in a vessel wall in early lesions is due to the accelerated localization of inflammatory and immune cells in the vessel wall, in contrast to a thrombus within the lumen (devoid of inflammatory cells). A finding of increased uptake is suggestive of plaque destabilization and creates concern about adverse events (*10*). The objective of our study was to determine the incidence of aneurysm in the cancer population and to evaluate the frequency with which thrombus is incidentally detected within an aneurysm on ^{18}F-FDG PET/CT studies, using data from PET and unenhanced CT components.

MATERIALS AND METHODS

Patient Selection

We reviewed 1,540 consecutive ^{18}F-FDG PET/CT studies of 926 patients who were scanned because of known or suspected cancer.

PET/CT

An intravenous 5.18 MBq (0.14 mCi)/kg injection of ^{18}F-FDG was administered after the patient had fasted for at least 4 h. The patient sat in a quiet injection room without talking during the subsequent 60-min ^{18}F-FDG uptake phase and was allowed to breathe normally during image acquisition. All scans were acquired using a Gemini PET/CT scanner (Philips).

CT

The CT component of the Gemini consisted of a 16-slice helical scanner with a gantry port of 70 cm. Images were acquired at 12–13 bed positions, using the following parameters: 120–140 kV and 33–100 mAs (based on body mass index), 0.5 s per CT rotation, a pitch of 0.9, and a 512 × 512 matrix. The CT acquisition was performed before the emission acquisition. CT data were used for image fusion and for generation of the CT transmission map. The arms were placed above the patient's head for CT acquisitions, except for patients with head and neck cancer, who placed their arms at their sides. Per our protocol, the CT images were obtained without oral or intravenous contrast material.

PET Scanning and Image Processing

The PET component of the Gemini is composed of gadolinium oxyorthosilicate–based crystals. Emission data were acquired for 12–13 bed positions, at 3 min per bed position. The field of view was from the top of the head to the bottom of the feet. The 3-dimensional acquisition parameters consisted of a 128 × 128 matrix and an 18-cm field of view with a 50% overlap. The images were processed using a 3-dimensional row-action maximum-likelihood algorithm. Total scanning time per patient was 36–39 min.

Image Analysis

The PET/CT images were retrospectively evaluated on a Gemini TF Extended Brilliance Workspace (Philips) by 2 board-certified nuclear medicine physicians. A log recorded whether each case of aneurysm had a thrombus suspected on the basis of PET and unenhanced CT. When a thrombus was suspected, the maximal standardized uptake value of the patent vessel at the site of the aneurysm was compared with that at the site of the suspected thrombus. Findings were subsequently confirmed after a thorough review of the medical records, including all clinical notes and radiology reports.

RESULTS

An aneurysm was found incidentally on ^{18}F-FDG PET/CT scans in 16 (1.7%) of the 926 patients (12 men and 4 women; mean age, 72.6 y; 95% confidence interval, 1.7 ± 0.8). The aneurysm was in the internal jugular vein in 1 patient and in the abdominal aorta in the remaining 15. Table 1 summarizes the characteristics of these patients.

TABLE 1
Characteristics of Patients with Thrombus

Patient no	Age (y)	Sex	Type of cancer	Site of aneurysm	Size of aneurysm (cm)	SUVmax of vessel	SUVmax of thrombus
1	76	F	Lymphoma	Abdominal aortic	6.7	1.8	0.3
2	73	M	Lung cancer	Abdominal aortic	3.7	1.9	0.8
3	63	M	Head/neck cancer	Abdominal aortic	4.4	2.2	0.5
4	79	M	Lung cancer	Abdominal aortic	7.6	1.5	0.5
5	58	F	Melanoma	Internal jugular	1.4	Occluded*	1.6
6	88	M	Rectal cancer	Abdominal aortic	3.9	2.1	1.2
7	66	M	Lung cancer	Abdominal aortic	4.0	1.6	0.8
8	73	M	Head/neck cancer	Abdominal aortic	5.5	2.5	
9	82	M	Lung cancer	Abdominal aortic	5.3	2.0	
10	74	M	Lung cancer	Abdominal aortic	3.2	1.7	
11	71	M	Lung cancer	Abdominal aortic	5.4	1.7	
12	74	M	Lung cancer	Abdominal aortic	6.7	1.9	
13	72	M	Lung cancer	Abdominal aortic	5.6	1.8	
14	66	M	Lung cancer	Abdominal aortic	4.0	1.7	
15	66	M	No malignancy	Abdominal aortic	4.0	1.8	
16	85	F	Lung cancer	Abdominal aortic	4.3	4.9	

*Previously unknown finding requiring emergent treatment.
SUVmax = maximal standardized uptake value.

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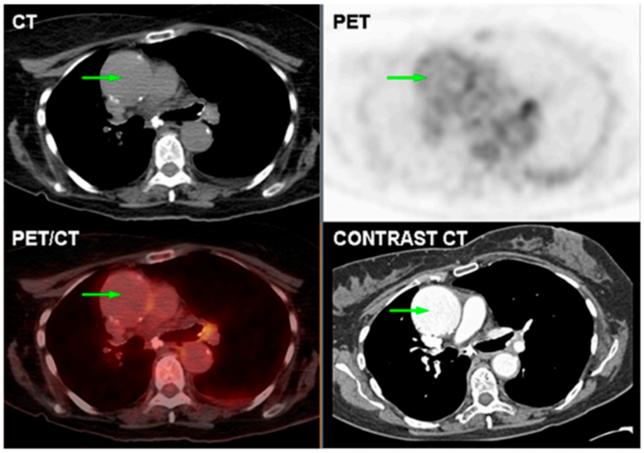

FIGURE 1. Large ascending AAA in 82-y-old woman with history of lung cancer. Unenhanced CT shows uniformly dense aortic aneurysm. Uniform physiologic ^{18}F-FDG uptake is seen within lumen of aortic aneurysm on PET.

Seven (44%) of the 16 patients had ^{18}F-FDG PET/CT findings suggestive of thrombus, and the presence of a thrombus was subsequently confirmed on contrast-enhanced CT (95% confidence interval, 44 ± 24). The mean diameter of aneurysms was 4.85 cm (range, 1.7–7.6 cm), the mean maximal standardized uptake value of patent vessels with thrombi was 1.9 (range, 1.5–2.2), and the mean maximal standardized uptake value of thrombi was 0.8 (range, 0.3–1.6) ($P < 0.01$).

Figure 1 shows a 5.5-cm ascending AAA in an 82-y-old woman with a history of lung cancer. PET/CT shows uniform vascular uptake without evidence of thrombus. Contrast-enhanced CT confirmed these findings. Figure 2 shows a 7.2-cm AAA in a 78-y-old man with a history of lung cancer. PET/CT shows a tracer void in the lateral and posterior aspects of the vessel, suggestive of thrombus. Contrast-enhanced CT confirmed these findings, and the patient received an intravascular stent graft the following week. Figure 3 shows a previously unknown complete thrombosis of the left internal jugular vein in a 57-y-old woman with a history of melanoma. Contrast-enhanced CT confirmed the findings, and the patient was emergently admitted and treated with anticoagulation therapy. However, the presentation of this patient was different from the others. The occluded vessel showed reduced uptake in the lumen but increased uptake in the walls. Of the remaining 5 patients with findings suggestive of thrombus formation, 2 died shortly after PET/CT was performed, 1 received a stent. and 2 began anticoagulation therapy.

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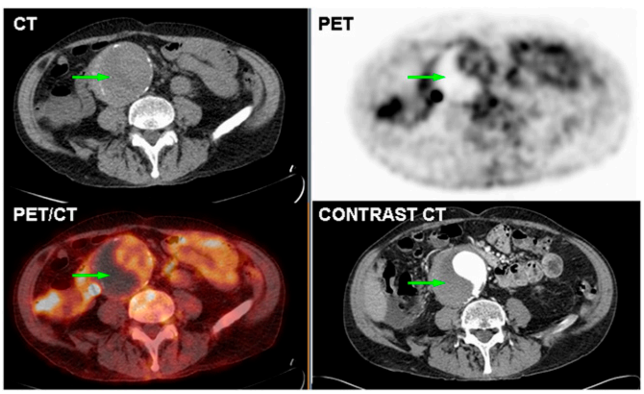

FIGURE 2. Large AAA in 78-y-old man with history of lung cancer. Unenhanced CT shows uniformly dense aortic aneurysm. PET shows region of tracer void in lateral aspect of aneurysm, suggestive of thrombus, and physiologic blood-pool activity medially giving ying-yang pattern. Suspected thrombus was confirmed with contrast-enhanced CT.

DISCUSSION

The use of ^{18}F-FDG PET has been gaining momentum in the diagnosis, staging, and restaging of many cancers and is often better than anatomic imaging alone (*6*). According to the Academy of Molecular Imaging, there are more than 5,000 PET/CT systems installed worldwide, making PET/CT one of the fastest-growing imaging modalities (*11*). The fusion of functional and anatomic imaging continues to evolve and provide valuable clinical information. PET/CT provides information additional to that of either modality alone and has become the first-line modality for staging and restaging tumors and for evaluating the response of various types of cancer to therapy (*12*). Currently, the CT component of PET/CT in many centers continues to be a low-dose, unenhanced study used mainly for image fusion and attenuation correction. A recent study demonstrated that 73% of sites worldwide use a dedicated low-dose CT acquisition for PET/CT images (*13*). However, even in the absence of contrast enhancement, useful information can be gained by a skilled reader for ^{18}F-FDG-avid or non–^{18}F-FDG-avid abnormalities.

A study assessed the incidental non–^{18}F-FDG-avid findings in 250 PET/CT scans of various types of cancers. It revealed clinically significant incidental findings in 3% of patients (*14*). In our study, 16 (1.7%) of 1,540 PET/CT scans (926 patients) revealed an incidental finding of aneurysm. Of these 16 scans, 7 (44%) had an incidental finding of thrombus, each of which was confirmed on contrast-enhanced CT.

Treatment of thrombus is usually altered after the detection of venous thrombosis. However, treatment of an arterial thrombus is based on the presence or absence of embolism while taking into account the risk of bleeding from aneurysmal rupture. In the rare occurrence of patients with cancer and acute arterial thrombus, anticoagulation has been successfully used. Overall, the prognosis for any cancer may be worsened by concurrent thrombosis (*15,16*).

To the best of our knowledge, this study is the first to determine the incidence of aneurysm in a population of cancer patients who underwent PET/CT. Also, despite a handful of case reports, this could be the first study associating an intravessel region of PET tracer void with

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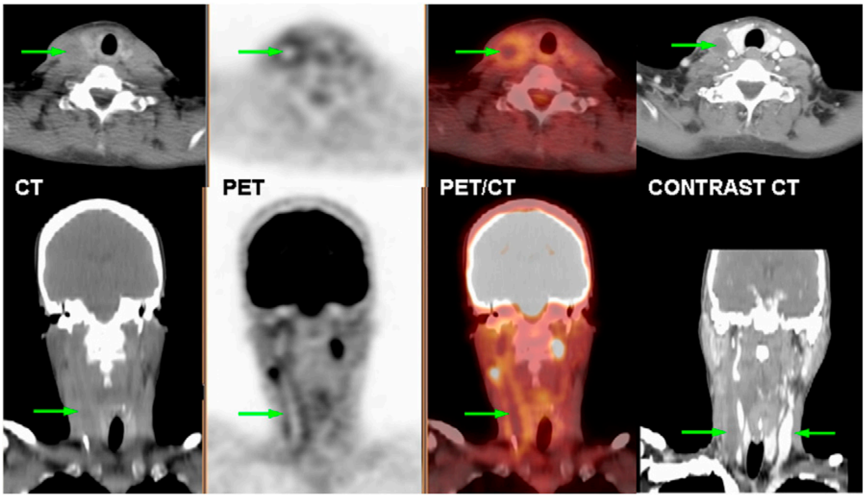

FIGURE 3. Fully occluded left internal jugular vein in 57-y-old woman with history of melanoma. Unenhanced CT shows subtly hypodense left internal jugular vein. PET shows increased ^{18}F-FDG uptake along course of vessel walls, with relative photopenia throughout lumen. Findings suggest acute process with accumulation of inflammatory and immune cells in vessel wall, with fully occluded lumen. Contrast-enhanced CT confirmed findings, showing no enhancement of left internal jugular vein, as compared with right.

a suggestion of thrombus formation. Thinner thrombi can be difficult to detect because of the limited spatial resolution of PET and artifacts associated with aortic pulsation and patient motion.

Our study is not without limitations. The CT component of the PET/CT study was done without contrast enhancement and using a lower-dose technique. Given that thrombus formation is best visualized with contrast material, it is likely that the current study may have underestimated the frequency of thrombus formation within an aneurysm. Nevertheless, unenhanced CT, when combined with PET, has been proven to show some findings that are infrequent but significant.

CONCLUSION

Our data suggest that 1 of every 50 oncologic PET/CT studies will show an aneurysm, and about half of these will contain a thrombus. We believe an incidental finding of ^{18}F-FDG uptake within an aneurysm with a relatively cold area within the vessel is highly suggestive of a thrombus and requires further evaluation. These findings usually alter the prognosis and treatment of venous thrombosis and may do so for arterial aneurysmal thrombosis as well.

DISCLOSURE STATEMENT

The costs of publication of this article were defrayed in part by the payment of page charges. Therefore, and solely to indicate this fact, this article is hereby marked “advertisement” in accordance with 18 USC section 1734.

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