

Physiologic ^{18}F -FDG Uptake in the Fallopian Tubes at Mid Cycle on PET/CT

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We observed bilateral pelvic foci of ^{18}F -FDG uptake (BiPF) exclusively in females—a finding not previously reported—and assessed the frequency, anatomic localization, and clinical significance of the uptake. **Methods:** On ^{18}F -FDG PET/CT and coregistered contrast-enhanced CT scans of 159 females (age, 16–81 y), the presence of BiPF and their location were evaluated. The findings were correlated with the age and menstrual history of the patient. **Results:** BiPF were seen in 14 (22%) of 63 patients up to 53 y old, predominantly at mid menstrual cycle, and were best coregistered to the fallopian tubes on contrast-enhanced CT. None of 96 patients older than 53 y showed BiPF. **Conclusion:** Fallopian ^{18}F -FDG uptake was seen predominantly in premenopausal women at mid menstrual cycle. This finding is in accordance with known cyclic changes of fallopian tubes in response to ovarian hormones and may be the first, to our knowledge, imaging evidence revealing the influence of estrogen on the fallopian tubes.

Key Words: ^{18}F -FDG; physiologic uptake; normal variant; fallopian tube; ovary; menstrual cycle

J Nucl Med 2010; 51:682–685

DOI: 10.2967/jnumed.109.074484

An accumulation of ^{18}F -FDG unrelated to malignancy is frequently seen on PET (1–5). Such uptake may be caused by normal variants or benign pathologic processes or may be physiologic. PET/CT is indispensable for proper interpretation of these benign findings for accurate staging and patient management planning in oncology. For example, without coregistered CT images, brown fat uptake of ^{18}F -FDG in atypical locations such as the retrocrural region may be mistaken for adrenal metastasis (6).

In female patients, physiologic ^{18}F -FDG uptake in the ovary has been reported by several groups of investigators. This finding is typically unilateral, focal, and discoid or spheric and has been attributed to a functional follicle, corpus luteum, or corpus luteal cyst (7–9). We recently observed bilateral pelvic foci of ^{18}F -FDG uptake (BiPF)

along the pelvic wall—1 on each side, exclusively in female patients—on PET/CT studies. A search showed no reports of this finding. Compared with the typical ovarian uptake described in the literature, the observed findings were always bilateral, often had a comma or tadpole or tubular shape, and were always adjacent to the ovaries on the coregistered PET/CT images. This retrospective study was undertaken to assess the frequency, anatomic localization, and possible clinical significance of this finding on PET/CT.

MATERIALS AND METHODS

Patients

Our institutional review board approved the protocol for this retrospective study. ^{18}F -FDG PET/CT scans of 302 consecutive patients were obtained between May 1, 2009, and May 31, 2009, and reviewed. Of these patients, the 143 male patients were excluded from this study. Of the remaining 159 female patients (mean age, 52.3 y; age range, 16–81 y), 150 patients were referred for evaluation of known malignancy and 9 patients for cancer screening.

Of the 150 patients with known malignancy, 48 had gynecologic and the remaining 102 patients had nongynecologic malignancies. For those patients who showed BiPF, detailed information on the indication for PET/CT, past medical history related to pelvic surgery, and the menstrual cycle status including the first day of the last normal menstrual period were obtained from the patients' medical records or PET/CT questionnaire.

Imaging Procedures

All patients fasted for at least 6 h before the administration of ^{18}F -FDG and rested for an hour before undergoing PET/CT. Blood glucose concentration was measured and confirmed to be less than 140 mg/dL. Approximately 5.5 MBq of ^{18}F -FDG per kilogram of body weight were injected intravenously. Imaging was performed on a Biograph TruePoint 40 (Siemens Medical System). Sixty minutes after ^{18}F -FDG injection, a low-dose CT scan was obtained for attenuation correction, with a 40-slice multidetector helical CT unit (SOMATOM Sensation; Siemens), using the following parameters: 120 kVp; 35 mA; 0.5-s rotation time; 1.2-mm slice collimation; 40.3-mm feed per rotation; 3-mm scan reconstruction, with a reconstruction index of 2 mm; 50-cm field of view; and 512×512 matrix. A PET scan was then immediately acquired from the level of the neck to the mid thigh in 3-dimensional mode at 3 min per bed position. The PET unit has

Received Dec. 29, 2009; revision accepted Feb. 2, 2010.

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an axial field of view of 21.6 cm and a spatial resolution of 4.0 mm in full width at half maximum at 1 cm from the center. PET data were reconstructed iteratively using an ordered-subset expectation maximization algorithm with the low-dose CT datasets for attenuation correction.

On completion of PET acquisition, a contrast-enhanced CT scan of the same imaging field was immediately obtained at 120 kVp and 200 mA, with a collimation of 1.2 mm, after the intravenous administration of 2.0 mL of contrast medium per milligram (Omnipaque 300; GE Healthcare AS) injected at a rate of 1.8–2.0 mL/s. Although low-dose CT was used for attenuation correction, PET images were coregistered with enhanced CT images obtained without moving the patient for optimal interpretation of the study.

Image Interpretation and Analysis

For visual analysis, 2 experienced specialists certified in both nuclear medicine and diagnostic radiology reviewed the PET/CT scan. The exact location of BiPF on PET was determined on coregistered enhanced CT images. For semiquantitative analysis, regions of interest were drawn over these regions, and the maximum standardized uptake value (SUVmax) of each region was recorded. Finally, the findings were assessed in correlation with menstrual status.

RESULTS

Frequency of BiPF According to Patient's Age

Of the 159 women included in this study, 14 (8.8%) showed BiPF. BiPF were seen in 1 of the 2 patients (50%) in their late teens, 2 of the 6 patients (33%) in their twenties, 4 of the 14 patients (29%) in their thirties, 5 of the 39 patients (13%) in their forties, 2 of the 55 patients (4%) in their fifties, and in none of the 43 patients older than 60. The mean and median ages of the 14 patients were 39 and 40 y, respectively. The youngest and oldest patients showing BiPF were 17 and 53 y, respectively. The mean SUVmax was 3.7 ± 0.8 (range, 2.6–5.3) on the right and 3.5 ± 0.8 (range, 2.5–4.9) on the left.

BiPF in Relation to Menstrual Status

Of the 14 patients with BiPF, 9 were regularly menstruating, 3 presented with abnormal uterine bleeding, 1 was close to menopause, and 1 did not menstruate because of previous total abdominal hysterectomy (Table 1). The 9 patients with regular menstruation were in the ovulatory or periovulatory phase, ranging from 10 to 18 d.

Anatomic Localization of BiPF on Enhanced CT

When ^{18}F -FDG PET images were coregistered with enhanced CT images, all 28 (14 bilateral) foci were localized adjacent to the ovaries. None of the 28 was associated with tumor. The appearance was usually tubular, comma-shaped, or tadpole-shaped on at least 1 of the 4 views—that is, projection and 3 orthogonal views (Figs. 1–3). The findings in 2 patients were especially noteworthy. In 1 patient, ^{18}F -FDG PET showed 3 foci of increased uptake—that is, BiPF and an additional third focus of nodular uptake just below the left one of the BiPF (Fig. 2).

TABLE 1. Menstrual History of Each Patient and SUVs and Location of BiPF Relative to Ovaries on Enhanced CT

Age (y)	Diagnosis	Indication for PET/CT	Menstruation	Menstrual cycle day	SUV		Location relative to ovary	
					Right	Left	Right	Left
29	Colon cancer	Surveillance	Regular	15	3.0	3.6	Lateral	Posterior
49	None	Cancer screening	Regular	12	2.7	2.7	Inferior	Superior medial
37	Stomach cancer	Surveillance	Regular	17	4.4	3.7	Superior medial	Posterior lateral
43	Thyroid cancer	Restaging	Regular	13	3.6	4.6	Superior medial	Superior lateral
50	None	Cancer screening	Regular	18	4.8	3.3	Superior medial	Superior medial
37	Uterine cervix cancer	Staging	Regular	12	4.6	3.4	Superior lateral	Superior medial
44	Thyroid cancer	Restaging	Regular	5	3.2	2.8	Inferior medial	Inferior medial
28	Renal cell cancer	Restaging	Regular	11	3.8	4.2	Superior	Posterior
17	Ovarian cancer	Restaging	Regular	10	3.8	4.7	Superior medial	Superior medial
49	Uterine cervix cancer	Staging	Abnormal uterine bleeding	NA	3.2	3.0	Posterior	Posterior
34	Uterine cervix cancer	Staging	Abnormal uterine bleeding	NA	3.4	2.5	Medial	Lateral
49	Breast cancer	Surveillance	Close to menopause	NA	3.0	2.6	Superior medial	Superior posterior
33	Uterine cervix cancer	Surveillance	NA*	NA	5.3	4.9	Posterior	Inferior medial
53	Endometrial cancer	Staging	Abnormal uterine bleeding	NA	2.6	2.8	Inferior lateral	Inferior lateral

*Patient had previously undergone total abdominal hysterectomy.
NA = not applicable.

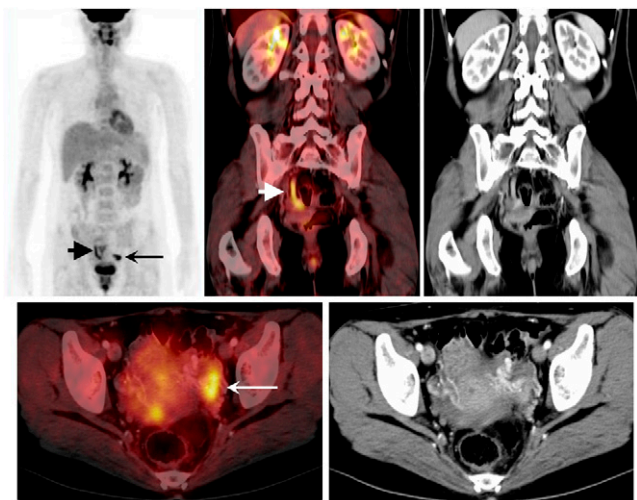


FIGURE 1. Case example showing typical appearance of BiPF on PET, which are best localized to fallopian tubes on coregistered enhanced CT scan. Projection images of PET/CT show curvilinear, increased ^{18}F -FDG uptake in right pelvis (short arrow) and comma- or tadpole-shaped focus on left (long arrow). Left focus appears more tubular on axial coregistered image.

On the enhanced CT scan, the BiPF were best coregistered to the bilateral fallopian tubes, and the third focus corresponded to a corpus luteum of the left ovary. The other patient previously had a left oophorectomy because of a benign mucinous ovarian tumor. BiPF were also seen in

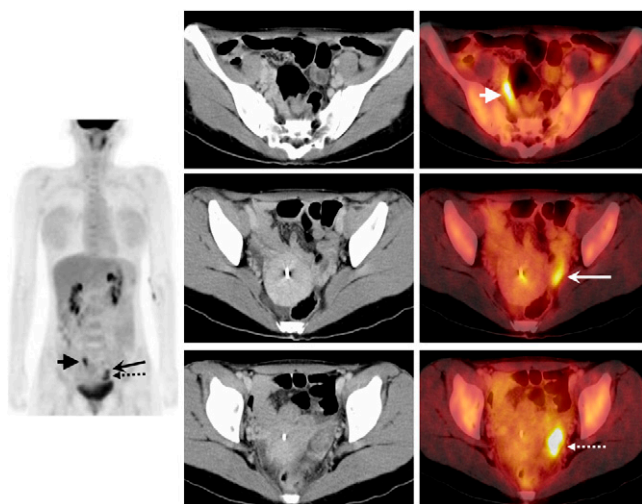


FIGURE 2. Patient with corpus luteum. Projection images show 3 foci of nodular uptake, 1 on right and 2 on left. On coregistered PET/CT images, shape of left lower focus is still oval (long dotted arrow) and corresponds to corpus luteum of left ovary. However, right focus (short arrow) and left focus (long solid arrow) just above left ovary are tubular and correspond to right and left fallopian tubes, respectively, on each side of pelvic wall.

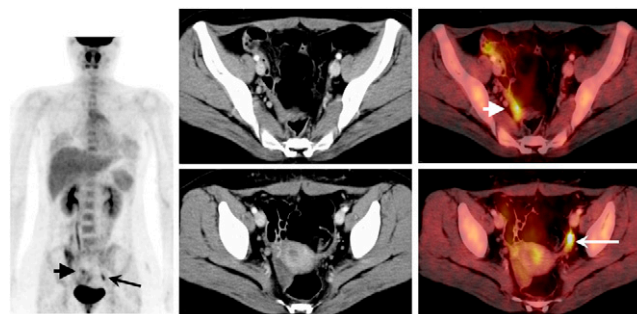


FIGURE 3. Patient with history of left oophorectomy. In addition to increased uptake in right fallopian tube (short arrow), increased tubular ^{18}F -FDG uptake corresponding to left fallopian tube (long arrow) along left pelvic side wall is clearly evident.

this patient (Fig. 3). The findings in these 2 patients exclude the possibility of bilateral ovarian ^{18}F -FDG uptake.

Of the 14 patients with BiPF, 6 were evaluated for nongynecologic malignancy, 6 for gynecologic malignancy (4 uterine cervix cancer, 1 endometrial cancer, and 1 ovarian cancer), and 2 for cancer screening. Of the 6 patients with gynecologic malignancy, 4 were operated on for the management of their malignancy, and no pathologic condition was found in the fallopian tubes.

DISCUSSION

Focal, nonmalignant ^{18}F -FDG uptake noted within the female pelvis includes physiologic uptake in the bowel, endometrium, and ovary. The CT portion of the PET/CT study can be useful in localizing and characterizing foci of increased ^{18}F -FDG accumulation within the bowel (5). Endometrial ^{18}F -FDG uptake seems to be dependent on the menstrual cycle (7). In premenopausal women, increased ^{18}F -FDG uptake was seen during the ovulatory and menstrual phases in the normal cyclic endometrium. In addition to the endometrium, the ovary is known to show physiologic ^{18}F -FDG uptake around the ovulatory and early luteal phases in premenopausal women (7–9). Increased ^{18}F -FDG uptake in the corpus luteal cyst is also well known (10). Other than the endometrium and ovary, no female reproductive organs have been reported in the literature to show physiologically increased ^{18}F -FDG uptake that is high enough to be of concern. We identified increased ^{18}F -FDG uptake in the fallopian tubes on PET/CT with intravenous contrast in a considerable proportion of female patients (14/159 [8.8%]).

Although integrated PET/CT has significantly reduced false-positive results related to physiologic or other benign uptake, the precise localization of an ^{18}F -FDG-avid focus on CT without intravenous contrast is still challenging in the interfaces of complex soft-tissue structures with similar CT attenuation coefficients such as the female pelvis. In the present study, the use of contrast enhancement facilitated

the identification of the ovary, thus helping us with accurate localization of BiPF in relation to the ovaries on PET/CT. BiPF in all 14 patients were found adjacent to but clearly not in the ovaries.

In addition to anatomic localization on the coregistered enhanced CT images, there are several other reasons and other evidence supporting the theory that BiPF do not represent ovarian uptake. Ovarian uptake of ^{18}F -FDG was attributed previously to the dominant follicle or corpus luteum or corpus luteal cyst (7–9). Naturally, the ovarian uptake should be unilateral. In contrast, our finding is bilateral. Moreover, this finding was noted in a patient whose left ovary was surgically removed. In another patient with a corpus luteum of the left ovary, BiPF were seen in addition to the nodular ^{18}F -FDG uptake corresponding to the corpus luteum. Although CT is somewhat limited in defining the precise structures of the fallopian tube in some patients, the findings in these 2 patients together with other factors mentioned—that is, location on the enhanced CT scan and bilateral nature in all 14 patients—effectively exclude the ovary as a possible cause of BiPF.

As with endometrial and ovarian uptake, ^{18}F -FDG uptake in the fallopian tubes was also seen mostly in patients of active reproductive age, and the oldest patient showing this finding was 53 y old. Of the 14 patients with BiPF, 9 were regularly menstruating, with their menstrual cycles being in the ovulatory or periovulatory phase. Menstrual cycle day could not be accurately determined in 4 of the 14 patients: 3 patients had abnormal uterine bleeding and 1 was close to menopause. The remaining one 33-y-old patient had undergone total abdominal hysterectomy without oophorectomy because of early uterine cervix cancer. The correlation of BiPF with menstrual cycle history raises the possibility of a relationship between ovarian hormones and BiPF in women with intact ovarian function.

The fallopian tubes undergo cyclic changes under the influence of ovarian hormones (11). Cells in the fallopian tubes increase in height during the proliferative phase and reach maximal height in the ovulatory or periovulatory period. Of the ovarian hormones, the maximal level of estrogen at mid cycle stimulates cellular hypertrophy, secretion, and ciliogenesis, whereas a high level of progesterone is associated with cellular atrophy and deciliation (12). It seems quite likely that BiPF identified in this study represents the physiologic metabolic response of the fallopian tubes to the high level of estrogen at mid cycle.

It is conceivable that ^{18}F -FDG PET may have a role in the functional assessment of the fallopian tubes.

CONCLUSION

We identified physiologic ^{18}F -FDG uptake in the fallopian tubes. The finding was seen predominantly in premenopausal women at mid menstrual cycle. This is certainly in accordance with known cyclic changes of fallopian tubes in response to ovarian hormones and may be the first imaging evidence revealing the influence of estrogen on the fallopian tubes.

ACKNOWLEDGMENTS

This work was partially supported by Korea Science and Engineering Foundation (KOSEF) grants funded by the Korean government (MEST) (M20702010003-08N0201-00314 and 7-2007-0023).

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