Received:
15 January 2013

Revised:
17 March 2013

Accepted:
29 March 2013

doi: 10.1259/bjr.20130034

Cite this article as:

Dunne RM, O'Mahony D, Wilson G, McDermott R, O'Keeffe SA. The role of the breast radiologist in evaluation of breast incidentalomas detected on 18-fludeoxyglucose positron emission tomography/CT. *Br J Radiol* 2013; 86:20130034.

The role of the breast radiologist in evaluation of breast incidentalomas detected on 18-fludeoxyglucose positron emission tomography/CT

R M DUNNE, FFR (RCSI), D O'MAHONY, FFR (RCSI), G WILSON, FRCR, R MCDERMOTT, FFR (RCSI) and S A O'KEEFFE, FFR (RCSI)

Department of Radiology, St. James's Hospital, Dublin 8, Ireland

Address correspondence to: Dr Ruth Dunne

E-mail: ruthdunne@yahoo.co.uk

Objective: To evaluate the significance of incidentally discovered breast lesions on 18-fludeoxyglucose (^{18}F -FDG) positron emission tomography (PET)/CT.

Methods: 6050 ^{18}F -FDG PET/CT studies, performed between January 2009 and February 2012, were retrospectively reviewed. 55 lesions in 50 patients were identified. Additional work-up, including mammography, ultrasound, follow-up ^{18}F -FDG PET/CT and biopsy, was available for 39 incidental breast lesions in 36 patients. All patients were female, with mean age 61.5 years (range 36–90 years). The maximum standardised uptake value (SUV_{max}), CT size and CT Breast

Imaging Reporting and Data System (BI-RADS®) scores were compared between the malignant and the benign subgroups, using the unpaired *t*-test and Fisher's exact test. Tests were two-sided and a *p*-value of <0.05 was considered to be significant.

Results: Incidental breast lesions were identified in 50 (0.8%) of 6050 ^{18}F -FDG PET/CT studies. 21 (53.8%) of the 39 breast incidentalomas were malignant on biopsy or imaging, of which 15 (38.5%) represented a second primary breast cancer. A statistically significant difference in the mean SUV_{max} between malignant and benign breast lesions was observed ($p=0.021$). Malignancy was significantly more

common in the CT BI-RADS Category 4 or greater groups (76.2%; $p=0.0105$).

Conclusion: Incidental breast lesions detected at ^{18}F -FDG PET/CT are uncommon. When detected, however, they may represent malignancy in up to 53.8% of cases.

Advances in knowledge:

1. SUV_{max} and CT findings at ^{18}F -FDG PET/CT can assist with differentiating benign and

malignant breast conditions, guiding further evaluation with dedicated breast imaging.

2. Review of ^{18}F -FDG PET/CT-detected breast lesions by a breast radiologist may be helpful in determining the need for and correlation with further breast imaging.

3. Radiologists and nuclear medicine physicians should be cognisant of breast pathology when reporting ^{18}F -FDG PET/CT image data sets.

Whole-body positron emission tomography (PET)/CT is increasingly used in the clinical setting of malignancy staging and monitoring of response to therapy. Unexpected radiological findings are frequently encountered and may suggest a second primary malignancy. In patients with a known or suspected primary malignancy, additional primary cancer has been found in 1.7–31.0% of cases [1–4].

Although the sensitivity of 18-fluorodeoxyglucose (^{18}F -FDG) PET/CT in identifying primary breast tumours varies from 25% to 80%, the specificity is more consistent from 95% to 98% [5]. However, physiological breast ^{18}F -FDG uptake may also be seen, *e.g.* in lactation, in the presence of breast implants and focally in certain benign breast lesions [6]. Previous studies have reported an incidence of malignancy of between 37.5% and 83.0% in incidental focal ^{18}F -FDG breast uptake [7–9].

The purpose of our study was to evaluate the frequency and clinical significance of incidentally discovered breast lesions on ^{18}F -FDG PET/CT at our institution.

METHODS AND MATERIALS

Patients

We performed a retrospective review of 6050 ^{18}F -FDG PET/CT studies performed at our institution from January 2009 to February 2012; of which 2719 studies were performed on female patients. The study was undertaken in accordance with the regulations of our institutional review board/ethics committee. Owing to the retrospective nature of this study, informed consent was not obtained.

The institutional ^{18}F -FDG PET/CT database was searched using the keyword “breast”. All ^{18}F -FDG

PET/CT studies reporting breast abnormality were included for initial review. A chart review of each patient's clinical history and the ^{18}F -FDG PET/CT showing the breast lesion was performed. All patients with a known history of breast cancer; bilateral low-grade breast ^{18}F -FDG uptake, probably physiological; and symmetrical ^{18}F -FDG breast uptake in lactating females or surrounding breast implants were excluded from this study. 50 female patients met the above inclusion criteria and represent the study group for calculating the incidence of breast incidentalomas on whole-body ^{18}F -FDG PET/CT.

Additional data obtained from the medical record of this patient cohort included the patient's age and gender, the primary cancer diagnosis and breast cancer screening history, if available. Any additional work-up of the incidentally detected breast lesion(s), including mammography, ultrasound or follow-up ^{18}F -FDG PET/CT, was recorded. Of the lesions on which biopsies were conducted, the corresponding histopathology findings were also documented. The breast work-up was performed in the referring hospital if it was a designated breast care centre with access to specialist breast radiology; otherwise, the work-up was performed at our institution's breast radiology department.

Follow-up data were available for 36 of the 50 patients. 14 patients had no further follow-up; of whom 11 patients did not require follow-up. This was because of the advanced stage of malignancy in four patients, known history of breast abscess or hidradenitis suppurativa, corresponding to the site of ^{18}F -FDG PET/CT abnormality, in two patients and a CT finding of typical benign macrocalcifications in five patients. In three patients, follow-up data were unavailable, as the referral

for PET/CT was from an external institution. These patients were excluded from further analysis. The final diagnosis of malignant or benign breast lesion was based on histological sampling in 23 patients.

In total, 39 incidental breast lesions on ^{18}F -FDG PET/CT in 36 patients were included in our study group for further assessment of the clinical significance of incidental breast findings on ^{18}F -FDG PET/CT. All patients were female, with a median age of 62.5 years (mean 61.5 years, standard deviation ± 15.26 years, range 36–90 years). Patient characteristics, including primary cancer diagnosis, are outlined in Table 1.

Imaging technique

Patients were instructed to fast for a minimum of 6 h prior to the injection of 330–370 MBq ^{18}F -FDG. Blood glucose levels were obtained prior to scanning to ensure the level was below 7 mmol l^{-1} . PET/CT scanning (Discovery VCT PET/CT; GE Healthcare, Waukesha, WI) was performed 60 min after tracer injection. The urinary bladder was not catheterised, and oral muscle relaxants were not administered. Whole-body emission

scans consisted of six to eight bed positions for 2.5 min at each position. PET data were reconstructed using ordered subset expectation maximisation techniques. Data obtained from the CT acquisition were used for attenuation correction and fusion with PET images. PET, CT and PET/CT images of the whole body were displayed in the axial, coronal and sagittal planes and were reviewed on a dedicated workstation (Advantage Workstation; GE Healthcare, Waukesha, WI). PET data were also displayed in rotating maximum intensity projection.

Imaging interpretation and analysis

For the purposes of our study, a breast incidentaloma was defined as:

- focal breast ^{18}F -FDG uptake alone
- focal breast ^{18}F -FDG uptake with corresponding mass on accompanying CT
- focal breast abnormality on CT alone.

All ^{18}F -FDG PET/CT images were analysed by three experienced nuclear medicine physicians with 5–10 years of experience. Breast ^{18}F -FDG uptake was identified as abnormal if accumulation of ^{18}F -FDG was focal and greater than in the background breast tissue. In those lesions with associated ^{18}F -FDG uptake, the maximum standardised uptake value (SUV_{max}) was calculated. The values were assessed semi-quantitatively using the standardised region-of-interest analysis and were calculated as maximum activity concentration detected in the lesion divided by the injected activity and corrected for body weight.

A breast radiologist, with at least 3 years of experience, also reviewed the accompanying CT images for focal breast abnormalities. Although the Breast Imaging Reporting and Data System (BI-RADS®) lexicon provides a standard set of interpretation descriptors for breast abnormalities on mammography, ultrasound and MRI, no CT equivalent exists [10]. Several studies have used the MRI lexicon as a reference to describe CT-detected breast lesions [7,9,11]. Each breast lesion identified on CT was analysed in terms of shape and margin as per the BI-RADS MRI lexicon [10]. The presence of a mass with circumscribed margin or that was round or oval in shape was suggestive of a BI-RADS score <4 (UK Category R3 or less). A soft-tissue mass with irregular shape or irregular or spiculated margins was suggestive of a BI-RADS score ≥ 4 (UK Category R4).

Table 1. Patient characteristics of 36 female patients with incidentally detected focal breast abnormality on ^{18}F -fluorodeoxyglucose positron emission tomography/CT

Parameter	Value
Number of patients	36
Age, mean $\pm$ SD (years)	61.5 $\pm$ 15.26
Underlying malignancy (number of patients)	
Lung cancer	11
Cervical cancer	8
Head and neck cancer	3
Unknown primary	3
Melanoma	2
Lymphoma	3
Oesophageal cancer	1
Retroperitoneal adenocarcinoma	1
Uterine sarcoma	1
Gastric cancer	1
Colorectal cancer	1
Renal cancer	1

SD, standard deviation.

[7,9–12]. The size and site of each abnormality was also recorded.

Statistical analysis

Statistical analysis was performed using a statistical software package (GraphPad Software; GraphPad Software, Inc., La Jolla, CA). The previously described PET and CT parameters, notably SUV_{max} and CT size, were identified and recorded for each patient and compared for statistical significance using the unpaired *t*-test between subgroups defined by the final diagnosis. Fisher's exact test was used to analyse the differences in CT BI-RADS scores between the groups. The same analysis was also performed in the subgroup of 23 patients, with the final diagnosis obtained by histopathology. Tests were two-sided, and a *p*-value of <0.05 was considered to be significant.

RESULTS

Incidence

Of 6050 patients who underwent ^{18}F -FDG PET/CT for the staging or surveillance of malignancy, 55 incidental breast lesions were identified in 50 female patients resulting in an overall incidence of 0.8%. 33 incidental breast lesions in 32 patients demonstrated focal ^{18}F -FDG uptake giving an incidence of 0.53%.

Imaging findings and further work-up

Focal ^{18}F -FDG breast uptake alone was seen in 9 (23.1%) of 39 incidental breast lesions, focal ^{18}F -FDG breast uptake with mass on accompanying CT in 19 (48.7%) of 39 lesions and a focal CT abnormality without ^{18}F -FDG uptake in 11 (28.2%) of 39 lesions. Further work-up of the incidental breast lesions is summarised in Figure 1.

17 (43.6%) of the 39 incidental breast lesions were malignant on biopsy, of which 15 (38.5%) represented a second primary breast cancer (Table 2). Histopathological examination of the specimens demonstrated invasive ductal carcinoma in eight patients, ductal carcinoma *in situ* (DCIS) in two patients and one case each of mixed mucinous and ductal carcinoma, invasive lobular carcinoma, papillary carcinoma, papillary lesion with atypia, metaplastic breast cancer, metastatic melanoma and metastatic non-small cell lung cancer (Figure 2). The incidence of PET/CT-detected primary breast cancer was 0.2% (15/6050) for all patients (male and female) and 0.6% (15/2719) for female patients during the study period.

Figure 1. Schematic representation of additional work-up of focal breast abnormalities identified on ^{18}F -fluorodeoxyglucose (FDG) positron emission tomography (PET)/CT including follow-up PET/CT, dedicated breast imaging and biopsy.

17 (43.6%) of the 39 incidental breast lesions were confirmed as benign on subsequent imaging and/or biopsy. Six lesions in six patients had a histopathological diagnosis, which showed fibroadenoma in four patients, fibrocystic change in one patient and stromal fibrosis in one patient (Figure 3). Eight lesions in seven patients had benign findings on breast imaging (BI-RADS Category 2), including cysts and an intramammary node. One patient had a normal mammogram (UK Category R1). Two patients did not undergo further breast imaging evaluation after the ^{18}F -FDG PET/CT owing to documented stable breast findings on previous ^{18}F -FDG PET/CT studies over a 4-year period, presumed BI-RADS Category 2. Four patients, with 5 of the 39 incidentalomas (4 focal ^{18}F -FDG breast uptake alone with no mass and 1 focal ^{18}F -FDG breast uptake with a mass), had follow-up ^{18}F -FDG PET/CT performed within 4 months of the initial study. All four patients had resolution of the initial breast abnormality on subsequent imaging. Three of these patients had lymphoma and one patient had oesophageal cancer, and all four underwent systemic chemotherapy in the interval between the two ^{18}F -FDG PET/CT studies. In the patients with lymphoma, the focal areas of breast ^{18}F -FDG uptake resolved in addition to all other sites of ^{18}F -FDG-avid disease seen on the initial staging study, and the combined clinical and radiological opinion was that of lymphomatous involvement of the breast.

Table 2. Patient characteristics and imaging features of the histologically confirmed lesions

Parameter	Age (years)	Focal ^{18}F -FDG uptake	SUV _{max}	CT abnormality	CT size (mm)	CT BI-RADS score	Pathology
Benign, n=6	40	Yes	1.9	No	NA	1	Stromal fibrosis
	42	Yes	2.3	Yes	16	4	Fibroadenoma
	67	Yes	1.3	Yes	17	4	Fibroadenoma
	38	Yes	1.9	Yes	22	3	Fibroadenoma
	47	No	NA	Yes	12	3	Fibroadenoma
	54	No	NA	Yes	15	3	Fibrocystic change
Malignant, n=17	45	Yes	3.1	No	NA	1	Invasive ductal carcinoma
	61	Yes	2.8	No	NA	1	Invasive mixed mucinous and ductal carcinoma
	85	Yes	2.0	Yes	17	4	Papillary carcinoma
	65	Yes	2.7	Yes	16	4	DCIS
	76	Yes	2.6	Yes	10	4	Invasive ductal carcinoma
	72	Yes	9.4	Yes	6	4	Metastasis
	68	Yes	4.3	Yes	9	4	Invasive ductal carcinoma
	81	Yes	3.5	Yes	11	4	Invasive ductal carcinoma
	69	Yes	1.2	Yes	11	4	Invasive ductal carcinoma
	84	Yes	3.3	Yes	17	4	Invasive ductal carcinoma
	55	Yes	4.9	Yes	22	4	Invasive ductal carcinoma
	36	Yes	3.2	Yes	10	4	Metastasis
	76	Yes	5.4	Yes	30	4	Invasive lobular carcinoma
	90	Yes	3.4	Yes	11	4	Metaplastic breast cancer
	62	Yes	1.8	Yes	13	4	Papillary lesion with atypia
	62	No	NA	Yes	39	5	Invasive ductal carcinoma
	79	No	NA	Yes	22	4	DCIS

BI-RADS, Breast Imaging Reporting and Data System; DCIS, ductal carcinoma *in situ*; ^{18}F -FDG, 18-fluorodeoxyglucose; NA, not applicable; SUV_{max}, maximum standardised uptake value.

The fourth patient with oesophageal cancer had residual ^{18}F -FDG uptake in the primary tumour on follow-up ^{18}F -FDG PET/CT without breast finding and, on review, the initial focal breast uptake was felt to represent a spurious finding.

The overall imaging features and the imaging features of histologically confirmed incidental breast lesions detected in our patient cohort are summarised in Table 3. The mean SUV_{max} measured in the 19 (90.5%) of 21 malignant lesions with focal ^{18}F -FDG uptake was 6.495

Figure 2. Positron emission tomography (PET)/CT in a 55-year-old female for initial staging of lung cancer. (a) 18-fludeoxyglucose (^{18}F -FDG) PET/CT revealed a focal area of ^{18}F -FDG uptake in the lower outer quadrant of the right breast (arrow), with a maximum standardised uptake value of 4.9. (b) The CT portion of the examination demonstrated a 2.2-cm spiculated mass [arrow; CT Breast Imaging Reporting and Data System (BI-RADS) Category 4]. The patient subsequently underwent ultrasonic and mammographic evaluation of the abnormality. (c, d) Mammographic and ultrasonic appearances were consistent with an 18-mm BI-RADS R5 lesion (arrow). Core biopsy was performed. Diagnosis: oestrogen receptor-positive Grade 3 invasive ductal carcinoma.

Figure 3. Positron emission tomography (PET)/CT in a 42-year-old female for initial staging of cervical cancer. (a) 18-fludeoxyglucose (^{18}F -FDG) PET/CT revealed a focal area of ^{18}F -FDG uptake (arrow) in the upper outer quadrant of the left breast, with a maximum standardised uptake value of 2.3. (b) The CT portion of the examination demonstrated a 1.6-cm well-circumscribed mass (arrow). The patient subsequently underwent ultrasonic and mammographic evaluation of the abnormality. (c) Mammogram demonstrated a well-circumscribed mass with smooth margins. (d) Ultrasound demonstrated an oval hypoechoic mass with smooth margins and macrolobulation in keeping with a fibroadenoma.

Table 3. Imaging features in the 39 incidentally detected breast abnormalities on 18-fludeoxyglucose (^{18}F -FDG) positron emission tomography (PET)/CT

Parameter	Benign	Malignant	<i>p</i> -value
Total number of lesions	18	21	
Focal ^{18}F -FDG uptake (number of lesions)	9 (50)	19 (90.5)	0.0107 ^a
PET/CT SUV _{max} (mean±standard deviation; range)	1.064±0.61; 1.3–3.1	6.495±7.64; 1.2–30.0	0.021 ^a
Number of CT abnormalities (number of lesions)	4 (22.2)	5 (23.8)	1.0
Focal CT abnormalities (number of lesions)	14 (77.8)	16 (76.2)	1.0
CT size (mm) (mean±standard deviation; range)	19.8±10.3; 8–51	15.8±8.8; 9–39	0.270
CT BI-RADS <4 (number of lesions)	12 (66.7)	5 (23.8)	0.0105 ^a
CT BI-RADS ≥4 (number of lesions)	6 (33.3)	16 (76.2)	0.0105 ^a
Histologically proven lesions (number of lesions)	6	17	
Focal ^{18}F -FDG uptake (number of lesions)	4 (66.7)	15 (88.2)	0.2705
PET/CT SUV _{max} (mean±standard deviation; range)	1.85 ± 0.412; 1.3–2.3	3.57 ± 1.957; 1.2–9.4	0.0057 ^a
No CT abnormality (number of lesions)	1 (16.7)	2 (11.8)	1.0
Focal CT abnormality (number of lesions)	4 (83.3)	15 (88.2)	1.0
CT size (mm)	16.6±4.11, 12–22	16.2±8.88, 6–39	0.962
CT BI-RADS <4 (number of lesions)	4 (66.7)	2 (11.8)	0.0212 ^a
CT BI-RADS ≥4 (number of lesions)	2 (33.3)	15 (88.2)	0.0212 ^a

BI-RADS, Breast Imaging Reporting and Data System; SUV_{max}, maximum standardised uptake value.

^aDenotes statistical significance, $p > 0.05$.

(range 1.2–30.0). However, if only the histologically proven malignant foci are included with exclusion of the cases of probable lymphomatous infiltration, 15 (88.2%) of 17 malignant lesions demonstrated focal ^{18}F -FDG uptake with a mean SUV_{max} of 3.57 (range 1.2–9.4). CT showed a focal abnormality in 15 (88.2%) of the 17 histologically proven malignancies with a mean size of 16.2 mm (range 6–39 mm). All the lesions had a CT BI-RADS score ≥4, *i.e.* suggestive of malignancy.

The mean SUV_{max} measured in 9 (50%) of the 18 benign lesions with focal ^{18}F -FDG uptake was 1.064 (range 1.3–3.1). In four (66.7%) of the six histologically proven benign lesions with focal ^{18}F -FDG uptake, the mean SUV_{max} was 1.85 (range 1.3–2.3). CT showed a focal abnormality in 14 (77.8%) of 18 benign lesions with a mean size of 19.8 mm (range 8–51 mm). CT BI-RADS score of <4 was observed in 12 (66.7%) of 18 lesions.

A statistically significant difference in SUV_{max} between malignant and benign breast lesions ($p=0.021$) was

observed. A similar significant difference was observed on comparison of the histologically confirmed malignant and benign lesions ($p=0.0057$). No significant difference in CT lesion size was observed between the overall or histologically proven malignant and benign cohorts. Malignancy was more common in the CT BI-RADS Category ≥4 group (76.2%) than in the group with BI-RADS Category <4 at CT (23.8%), and this difference was statistically significant ($p=0.0105$). A similar trend was also seen in patients with histologically confirmed malignancy ($p=0.0212$).

Screening history

The mammography screening history for 18 (50%) of the 36 patients was not available from the medical records. Our institution is the national tertiary referral centre for PET/CT, and the subsequent work-up of breast incidentalomas was frequently performed at the referring hospital. Mammography, ultrasound and histology reports were provided for this study but not the screening history. 10 patients had their first mammogram during

evaluation of an incidental breast lesion discovered on ^{18}F -FDG PET/CT (age range 42–84). 1 of these 10 women would have been called for screening as part of the national screening programme performed for all females aged 50–65 years, which commenced in Ireland in 2000. Eight patients had undergone previous mammography but none in the previous 2 years. Two of these women were called for screening and did not attend.

DISCUSSION

^{18}F -FDG PET/CT is increasingly used in the evaluation of most types of malignancy and has a significant impact on patient management [1,2]. The whole-body imaging capabilities and co-registration of PET images with images from CT allow combined anatomical and functional imaging, increasing the accuracy of ^{18}F -FDG PET/CT for diagnosis of previously unknown cancer foci compared with conventional imaging modalities [2,3]. In addition to detection of previously unknown sites of metastatic disease, incidentally detected additional malignancies have been reported with a prevalence of between 1.1% and 1.7% [3,4,13,14], with gastrointestinal tract, thyroid, lung, ovary and larynx the commonest sites.

In the present series, the incidence of incidental breast lesions was 0.8%, with an incidence of focal breast ^{18}F -FDG uptake of 0.45% in keeping with the previously reported rates of incidental ^{18}F -FDG-avid foci in the breast ranging between 0.36% and 1.1% [7–9]. The frequency of malignancy in incidental breast lesions was 53.8% (21 of 39 lesions), 71.4% of these representing a primary breast tumour and 28.6% representing metastatic disease. 67.8% of breast lesions with focal ^{18}F -FDG uptake were malignant. This correlates with previous studies that reported rates of malignancy of incidental ^{18}F -FDG-avid breast foci of 37.5%, 57% and 83% [7–9].

The national uptake of breast screening in Ireland for females between 50 and 65 years is almost 74%, but, given the low number of patients for whom the screening mammography history was available in our cohort, it is not possible to ascertain whether the majority of our patient subgroup underwent regular mammography screening if available when they were 50–65 years of age. While some studies suggest an increased incidence of screening mammography following an initial diagnosis of colorectal cancer [15], normal referral and

screening processes may be disrupted during cancer diagnosis and treatment.

The overall incidence of ^{18}F -FDG PET/CT-detected primary breast cancers was 0.2% in all patients and 0.6% in all female patients undergoing ^{18}F -FDG PET/CT during the study period. This is the first study of this kind performed in a country with a national breast screening programme, and the incidence is similar to the background incidence of breast cancer on subsequent mammography screening rounds [16]. The incidence of ^{18}F -FDG PET/CT-detected breast cancer was higher than in previous studies and this may be because routine screening mammography is not offered to patients in Ireland outside the 50–65 years age bracket.

The positive predictive value for malignancy in CT-detected breast lesions has been reported to be 30%, highlighting the importance of dedicated review of all CT abnormalities by a breast radiologist [17]. In our institution, all ^{18}F -FDG PET/CT breast findings are reviewed by a breast radiologist. Mammography and ultrasound performed for further evaluation of an ^{18}F -FDG PET/CT-detected lesion are carefully correlated with the PET images, CT images and fused images for mapping of the position and size of the lesion. This is to ensure that a mammographically occult lesion detected on ^{18}F -FDG PET/CT is not overlooked. Breast radiologists may have to become familiar with the review of ^{18}F -FDG PET/CT image data sets in the same way that they review CT studies, as the use of this imaging modality increases.

SUV has been shown to provide a quantitative measure of ^{18}F -FDG uptake that can distinguish between benign and malignant lesions [18–20]. In our study, there was a statistically significant difference in the mean SUV_{max} between the benign and the malignant lesions both in the overall group, 1.064 vs 6.495 ($p=0.021$), and in the histologically confirmed group, 1.85 vs 3.57 ($p=0.0057$), correlating with previously reported studies [7,9]. Litmanovich et al [7] demonstrated a statistically significant difference between the SUV_{max} of malignant breast lesions (3.13 ± 2.25) and that of benign breast lesions (1.85 ± 1.18). Kang et al [9] also demonstrated a statistically significant difference between the rate of malignancy in breast lesions with an $\text{SUV}_{\text{max}} \geq 2$ (66.7%) and the rate of malignancy in breast lesions with an $\text{SUV}_{\text{max}} < 2$ (24.2%). However, other studies have not shown a correlation of SUV values with the

incidence of breast malignancy [21]. One possible reason for variation in results within the literature may relate to variation in SUV values of breast malignancy based on tumour size and histological diagnosis. For example, small malignant breast tumours and subtypes of breast cancer such as DCIS, lobular carcinoma and tubular carcinoma can be false-negative findings on ^{18}F -FDG PET/CT [5,13]. In this study, the statistically significant association between mean SUV_{max} and breast malignancy may relate to the high number of invasive ductal carcinomas detected; therefore, mean SUV_{max} alone may not be useful to predict malignancy in incidentally detected ^{18}F -FDG PET/CT breast lesions.

Focal breast abnormalities were detected in 30 of 39 incidental breast lesions in the CT portion of ^{18}F -FDG PET/CT. No significant difference was detected between the mean size in the overall benign and malignant groups. This result correlates with a previous study by Litmanovich et al [7], which showed no statistically significant difference in the CT size or CT tissue density between benign and malignant breast lesions. Of the malignant lesions that demonstrated a focal CT abnormality, all lesions were CT BI-RADS Category 4 or higher. Malignant disease was statistically significantly more common in the Category ≥ 4 CT BI-RADS group in both the overall and histologically confirmed lesions, 76.2% and 88.2%, than in the overall and histologically confirmed benign lesions, 66.7% and 33.3% ($p=0.105$ and $p=0.0202$, respectively). Although a previous study by Kang et al [9] did not show a statistically significant difference in the malignancy rates in breast lesions with a BI-RADS Category <4 (30.2%) and those with a BI-RADS Category ≥ 4 (100%), the incidence of malignancy in breast lesions with a BI-RADS Category ≥ 4 was 100%. The results of our and other studies suggest that, in incidentally discovered breast lesions, size is not a useful

predictor of malignancy, and all lesions with a CT BI-RADS score of ≥ 4 require further work-up regardless of the ^{18}F -FDG uptake.

The limitations of our study include small sample size and the retrospective design. In addition, not all breast abnormalities detected on ^{18}F -FDG PET/CT had histopathological correlation. In the majority of patients, this was because of benign appearances on breast imaging (BI-RADS 2) not requiring biopsy, but, in some cases, the advanced stage of the primary malignancy took precedence over the breast lesion regardless of histological diagnosis. To overcome this limitation, we only included cases with follow-up breast and/or ^{18}F -FDG PET/CT imaging. We also compared the results and analysis between the overall and histopathologically confirmed benign and malignant lesions to ensure that the results were comparable.

CONCLUSION

Incidental breast lesions detected at ^{18}F -FDG PET/CT are uncommon and identified in 1.8% of examinations in female patients. When detected, however, they may represent malignancy in up to 53.8% of cases. Both the SUV_{max} and CT findings on ^{18}F -FDG PET/CT can independently assist in differentiating the benign and malignant conditions. This is particularly useful in patients with focal breast ^{18}F -FDG uptake alone and CT-detected breast lesions without focal ^{18}F -FDG uptake. Further evaluation with dedicated breast imaging and/or biopsy can be performed based on these parameters. Breast radiologists may have to become familiar with reviewing ^{18}F -FDG PET/CT image data sets to evaluate the detected breast lesions. Similarly, PET/CT-trained radiologists and nuclear medicine physicians should be cognisant of breast pathology when reporting ^{18}F -FDG PET/CT image data sets.

REFERENCES

1. Kluetz PG, Meltzer CC, Villemagne VL, Kinahan PE, Chander S, Martinelli MA, et al. Combined PET/CT imaging in oncology: impact on patient management. *Clin Positron Imaging* 2000;3:223–30.
2. Israel O, Mor M, Guralnik L, Hermoni N, Gaitini D, Bar-Shalom R, et al. Is ^{18}F -FDG PET/CT useful for imaging and management of patients with suspected occult recurrence of cancer? *J Nucl Med* 2004;45:2045–51.
3. Bohuslavizki KH, Klutmann S, Kröger S, Sonnemann U, Buchert R, Werner JA, et al. FDG PET detection of unknown primary tumors. *J Nucl Med* 2000;41:816–22.
4. Agress H, Cooper BZ. Detection of clinically unexpected malignant

- and premalignant tumors with whole-body FDG PET: histopathologic comparison. *Radiology* 2004; 230:417–22. doi: [10.1148/radiol.2302021685](https://doi.org/10.1148/radiol.2302021685).
5. Ishimori T, Patel PV, Wahl RL. Detection of unexpected additional primary malignancies with PET/CT. *J Nucl Med* 2005;46: 752–7.
 6. Israel O, Yefremov N, Bar-Shalom R, Kagana O, Frenkel A, Keidar Z, et al. PET/CT detection of unexpected gastrointestinal foci of ^{18}F -FDG uptake: incidence, localization patterns, and clinical significance. *J Nucl Med* 2005;46:758–62.
 7. Litmanovich D, Gourevich K, Israel O, Gallimidi Z. Unexpected foci of (18)F-FDG uptake in the breast detected by PET/CT: incidence and clinical significance. *Eur J Nucl Med Mol Imaging* 2009;36:1558–64. doi: [10.1007/s00259-009-1147-4](https://doi.org/10.1007/s00259-009-1147-4).
 8. Korn RL, Yost AM, May CC, Kovalsky ER, Orth KM, Layton TA, et al. Unexpected focal hypermetabolic activity in the breast: significance in patients undergoing ^{18}F -FDG PET/CT. *AJR Am J Roentgenol* 2006;187:81–5. doi: [10.2214/AJR.05.0548](https://doi.org/10.2214/AJR.05.0548).
 9. Kang BJ, Lee JH, Yoo IR, Kim SH, Choi JJ, Jeong SH, et al. Clinical significance of incidental finding of focal activity in the breast at ^{18}F -FDG PET/CT. *AJR Am J Roentgenol* 2011;197:341–7. doi: [10.2214/AJR.10.6126](https://doi.org/10.2214/AJR.10.6126).
 10. D'Orsi CJ, Bassett LW, Berg WA. Breast Imaging Reporting and Data System: ACR BI-RADS breast imaging atlas. Reston, VA: American College of Radiology; 2003.
 11. Inoue M, Sano T, Watai R, Ashikaga R, Ueda K, Watatani M, et al. Dynamic multidetector CT of breast tumors: diagnostic features and comparison with conventional techniques. *AJR Am J Roentgenol* 2003;181:679–86. doi: [10.2214/ajr.181.3.1810679](https://doi.org/10.2214/ajr.181.3.1810679).
 12. Taylor K, Britton P, O'Keeffe S, Wallis MG. Quantification of the UK 5-point breast imaging classification and mapping to BI-RADS to facilitate comparison with international literature. *Br J Radiol* 2011; 84:1005–10. doi: [10.1259/bjr/48490964](https://doi.org/10.1259/bjr/48490964).
 13. Yasuda S, Ide M. PET and cancer screening. *Ann Nucl Med* 2005;19: 167–77.
 14. Kim TY, Kim WB, Ryu JS, Gong G, Hong SJ, Shong YK. ^{18}F -fluorodeoxyglucose uptake in thyroid from positron emission tomogram (PET) for evaluation in cancer patients: high prevalence of malignancy in thyroid PET incidentaloma. *Laryngoscope* 2005;115: 1074–8. doi: [10.1097/01.MLG.0000163098.01398.79](https://doi.org/10.1097/01.MLG.0000163098.01398.79).
 15. McBean AM, Yu X, Virnig BA. Screening mammography rate and predictors following treatment for colorectal cancer. *J Cancer Surviv* 2009;3:12–20.
 16. Breastcheck Report 2009–2010. Available from: http://www.breast-check.ie/sites/default/files/bcheck/documents/programme_report_2010.pdf
 17. Moyle P, Sonoda L, Britton P, Sinnatamby R. Incidental breast lesions detected on CT: what is their significance? *Br J Radiol* 2010;83:233–40. doi: [10.1259/bjr/58729988](https://doi.org/10.1259/bjr/58729988).
 18. Avril N, Dose J, Jänicke F, Bense S, Ziegler S, Laubenbacher C, et al. Metabolic characterization of breast tumors with positron emission tomography using F-18 fluorodeoxyglucose. *J Clin Oncol* 1996;14: 1848–57.
 19. Adler LP, Crowe JP, al-Kaisi NK, Sunshine JL. Evaluation of breast masses and axillary lymph nodes with [F-18] 2-deoxy-2-fluoro-D-glucose PET. *Radiology* 1993;187:743–50.
 20. Avril N, Bense S, Ziegler SI, Dose J, Weber W, Laubenbacher C, et al. Breast imaging with fluorine-18-FDG PET: quantitative image analysis. *J Nucl Med* 1997;38: 1186–91.
 21. Chung A, Schoder H, Sampson M, Morrow M, Port E. Incidental breast lesions identified by ^{18}F -fluorodeoxyglucose-positron emission tomography. *Ann Surg Oncol* 2010;17:2119–25. doi: [10.1245/s10434-010-0950-2](https://doi.org/10.1245/s10434-010-0950-2).