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# $\gamma$ -Camera $^{18}\text{F}$ -FDG PET in Diagnosis and Staging of Patients Presenting with Suspected Lung Cancer and Comparison with Dedicated PET

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It is not clear whether high-quality coincidence gamma-PET (gPET) cameras can provide clinical data comparable with data obtained with dedicated PET (dPET) cameras in the primary diagnostic work-up of patients with suspected lung cancer. This study focuses on 2 main issues: direct comparison between foci resolved with the 2 different PET scanners and the diagnostic accuracy compared with final diagnosis determined by the combined information from all other investigations and clinical follow-up. **Methods:** Eighty-six patients were recruited to this study through a routine diagnostic program. They all had changes on their chest radiographs, suggesting malignant lung tumor. In addition to the standard diagnostic program, each patient had 2 PET scans that were performed on the same day. After administration of 419 MBq (range = 305–547 MBq)  $^{18}\text{F}$ -FDG, patients were scanned in a dedicated PET scanner about 1 h after FDG administration and in a dual-head coincidence  $\gamma$ -camera about 3 h after tracer injection. Images from the 2 scans were evaluated in a blinded set-up and compared with the final outcome. **Results:** Malignant intrathoracic disease was found in 52 patients, and 47 patients had primary lung cancers. dPET detected all patients as having malignancies (sensitivity, 100%; specificity, 50%), whereas gPET missed one patient (sensitivity, 98%; specificity, 56%). For evaluating regional lymph node involvement, sensitivity and specificity rates were 78% and 84% for dPET and 61% and 90% for gPET, respectively. When comparing the 2 PET techniques with clinical tumor stage (TNM), full agreement was obtained in 64% of the patients (Cohen's  $\kappa = 0.56$ ). Comparing categorization of the patients into clinical relevant stages (no malignancy/malignancy suitable for treatment with curative intent/nontreatable malignancy), resulted in full agreement in 81% (Cohen's  $\kappa = 0.71$ ) of patients. **Conclusion:** Comparing results from a recent generation of gPET cameras obtained about 2 h later than those of dPET, there was a fairly good agreement with regard to detecting

primary lung tumors but slightly reduced sensitivity in detecting smaller malignant lesions such as lymph nodes. Depending on the population to be investigated, and if dPET is not available, gPET might provide significant diagnostic information in patients in whom lung cancer is suspected.

**Key Words:** lung cancer; PET;  $\gamma$ -camera coincidence;  $^{18}\text{F}$ -FDG  
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**I**n recent years, the use of  $^{18}\text{F}$ -FDG PET has proven a powerful diagnostic tool in detecting and staging several forms of cancer (1). The target-to-background-activity ratio is often relatively high in malignant tissue located in the lung, and  $^{18}\text{F}$ -FDG PET is now widely used in the routine diagnostic program for lung cancer (2). Several studies have demonstrated that  $^{18}\text{F}$ -FDG PET provides additional diagnostic information to conventional methods, alters patient management and treatment, and is cost effective in patients with or suspected for pulmonary malignancies (3–10). In the United States, the Centers for Medicare and Medicaid Services (<http://cms.hhs.gov>) have approved reimbursement for diagnosing, staging, and restaging of lung cancer with  $^{18}\text{F}$ -FDG PET.

Until recently, the use of PET has been restricted to use in centers equipped with expensive dedicated PET scanners (dPET). Coincidence photon scanning in modified  $\gamma$ -cameras equipped with 2 or 3 rotating heads (gPET) has been commercially available since the mid-1990s. Because of the reduced costs of gPET, an increasingly widespread use of  $^{18}\text{F}$ -FDG PET has been possible (11). However, gPET systems provide slightly lower spatial resolution, are less sensitive, and are counting-rate limited compared with dPET scanners (12). In general, studies have suggested lower sensitivity for gPET to detect small (<15 mm) malignant lesions compared with dPET (11,13).

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Studies investigating the diagnostic value of gPET in patients with lung cancer have demonstrated supplementary information to conventional diagnostic procedures with sensitivities for detecting malignant pulmonary lesions ranging from 96% to 100%. For lymph node involvement, sensitivities were 50%–90% (14–19). A few studies have compared the diagnostic performance between gPET and dPET. In most cases, gPET was comparable with dPET, but in smaller lesions (<1.5–2.0 cm), particularly those located in lymph nodes, gPET had lower detection rates (20–23).

gPET cameras produced within the recent few years are equipped with thicker crystals, which may increase the sensitivity with only limited loss of spatial resolution (12). Most published studies comparing gPET with dPET in patients with lung cancer have used NaI (Tl) crystals with a thickness of 5/8" (20–22). In one study, including only 13 patients with lung cancer, 3/4" crystals were used (23). The development of gPET cameras has improved sensitivity and spatial resolution by modified septae, electronic components, and reconstruction algorithms. Thus, the overall performance of gPET cameras today has increased since the early reports. Phantom studies have demonstrated results showing that 3/4" crystals in gPET cameras are comparable with dPET in detecting hot spots on the basis of visual analysis, whereas semiquantitative analyses have shown that lesion-to-background ratios with gPET are inferior to dPET (24). In the present study, we investigated the diagnostic value of a gPET-camera system, equipped with 3/4" crystals, in a large, unselected group of patients with suspected pulmonary malignancy and compared the data with results from scans performed with a dPET scanner on the same patients.

## MATERIALS AND METHODS

### Patients

Patients who were consecutively admitted to the outpatient clinic of the respiratory unit at Bispebjerg Hospital because of the presence of a pulmonary lesion indicating malignancy on the radiograph were considered for this study. Only patients with a sufficient pulmonary function that potentially allowed pulmonary resection (forced expiratory volume in 1 s > 60% of expected normal value) were offered participation in the study. The clinic is a secondary referral center covering a population of 680,000 inhabitants in the Copenhagen, Denmark, area. One hundred one patients were recruited from January 1, 2000, to June 30, 2002. Results from 86 patients who had both dPET and gPET scans performed are reported. PET scans by only one modality was performed in 15 patients; the reasons for not having both scans performed were claustrophobia (3 patients), pain (1 patient), restlessness (1 patient), and technical or logistic complications (10 patients). These patients were excluded.

### Study Set-Up

All participating patients entered the routine examination program on the basis of current guidelines, including clinical examination, bronchoscopy, CT of the chest and upper abdomen, and, when needed, fine-needle aspiration biopsy (FNAB) and mediastinoscopy (25). Inclusion into the study led to an additional 2 PET

scans, in a dedicated scanner and to a  $\gamma$ -camera PET scan. CT scans were performed on a fourth-generation spiral CT scanner (Picker 5000; Philips Medical Systems) and each scan was evaluated by 2 experienced radiologists.

All investigations were performed within 4 wk from the time of the first contact to the respiratory outpatient clinic. On the basis of the results from all examinations (PET scans included), patients were admitted to evaluation and treatment at the centers of chest surgery or oncology at Rigshospitalet. All surviving patients were invited to a clinical examination and chest radiograph in October–November 2002. Clinical follow-up time in 49 patients (57%) was 13 mo (range = 4–33 mo). The remaining patients had died, had moved out of the region, or were not willing to participate further. The study was approved by the Ethical Committee for the Communities of Copenhagen and Frederiksberg, and all participated after informed consent (Journal no. 01-043/99).

### PET Scans

After 6 h of fasting, a single dose of 419 MBq (range = 305–547 MBq)  $^{18}\text{F}$ -FDG was injected intravenously. After 52  $\pm$  20 min of resting in the supine position, a PET scan was performed with the dedicated scanner at the PET Centre at Rigshospitalet. Immediately after the scan, the patient was transported to Bispebjerg Hospital (15-min transport by car) where PET in the  $\gamma$ -camera was initiated 193  $\pm$  34 min after  $^{18}\text{F}$ -FDG injection. The time delay before gPET was necessary to allow sufficient  $^{18}\text{F}$ -FDG decay to enable acceptable counting rates for gPET.

dPET was performed in an Advance full-ring dedicated scanner (General Electric Medical Systems). Reported performance for the scanner is a spatial axial and transaxial resolution of 4- to 5-mm full width at half maximum (FWHM) and a coincidence sensitivity of 6,160 kcps/MBq/cc (26). Before the emission scan, transmission scans of 10 min each were done of the chest region (the first 46 patients) and 3 min each for the area from cranial vertex to midfemur (the remaining 40 patients). Emission scans using 6 or 7 bed positions, 10 min each, over the chest and 5 min elsewhere in the first 46 patients and 5 min per body position in the next 40 patients, from the cranial vertex to the thighs, were performed immediately after transmission scans. Data were reconstructed 2-dimensionally using a filtered backprojection algorithm in the first 46 patients. A Hanning 6 filter was applied to all data. In the remaining 40 patients, an ordered-subset expectations maximization (OSEM) iterative algorithm (2 iterations, 28 subsets) was used with segmented attenuation correction (SAC). Transmission data were used for generating nonuniform attenuation maps to correct emission data.

A dual-head coincidence detection  $\gamma$ -camera (Axis; Marconi Medical Systems), equipped with 1.9-cm (0.75-in.) thick NaI (Tl) crystals, was used for acquiring gPET data. Reconstructed spatial resolution for the camera is 5-mm FWHM and the coincidence sensitivity is 1,350 kcps/MBq/cc (manufacturer's specifications). Acquisition from the midfemur to the cranial vertex (the first 49 patients) or to the basis of the skull (the remaining 37 patients) was done in 2 or 3 bed positions. The 2 detectors, with axial filters installed, were rotated 180°, each with 60 steps at 26–30 s per step. Data were single-slice rebinned into a 128  $\times$  128 matrix using only photopeak–photopeak events (511 keV  $\pm$  30%). All datasets were iteratively reconstructed and postfiltered (OSEM, 4 iterations; low-pass filter cutoff, 0.39; order 2). Uniform attenuation correction (AC) was applied, using a modified Chang algorithm and taking into account the constant calculated attenuation factors

**TABLE 1**  
Clinical Characteristics

Characteristic	Number
Male/female	58/28*
Age (y)	59 ± 12
Height (cm)	175 ± 10
Weight (kg)	74 ± 14
FEV <sub>1</sub> (L) <sup>†</sup>	2.6 ± 0.6
Tumor size (mm)	
All lesions	33 (5–200)
Malignant lesions <sup>‡</sup>	48 (10–200)

\*No. of patients.  
<sup>†</sup>FEV<sub>1</sub>: forced expiratory volume in 1 s.  
<sup>‡</sup>Three lesions were <20 mm.  
*n* = 86.

along all lines of response. After the first 54 patients had been included, external <sup>133</sup>Ba sources (Beacon; Marconi Medical Systems) were installed on the scanner. Transmission scans of the chest region were performed in the remaining 32 patients allowing nonuniform AC to be done.

#### Data Analysis

Images with slice thicknesses of 4.25 mm (dPET) and 4.7 mm (gPET), both AC and nonattenuation corrected (NAC) and in coronal, sagittal, and transversal planes, were studied on a computer screen. An initial blinded readout was done immediately after the PET imaging acquisitions, resulting in a first-stage assessment that was based on only the PET images. The scan result was reported to the clinicians to use for further planning. After all data were gathered, a second session of image evaluation was done. Two experienced nuclear medicine physicians evaluated the PET scans from gPET and dPET in separate sessions. The goal was to establish consensus with regard to TNM classification and location of lesions in each scan. The investigators were unaware of all information except for the report of the initial chest radiograph (available in 75 [87%] of the patients). A linear gray scale was used on all images, and focally increased FDG activity above physiologic levels (i.e., low, homogeneous activity in the lung fields and a higher but still homogenous mediastinal activity pattern) was considered abnormal and demonstrative of potential malignancy.

Number and location of foci were registered and a classification of each patient was made using the tumor, node, metastasis (TNM) classification system for lung tumors (27). Staging of each patient from stage 0 (no signs of malignant disease) to stage 4 (metastatic disease) was calculated from the combined TNM score.

Results from the gPET scans were compared with dPET, and both PET scans were compared with the gold standard, which was defined as the final outcome of each patient, on the basis of results from all other examinations, including invasive procedures, histology, and clinical follow-up. If no pathologic diagnosis was obtained, a lesion was considered benign if the patient was alive at the time of clinical follow-up and radiologic examination showed regression or no progression of the lesion.

Final outcome was also categorized according to the TNM system (f-TNM). Full f-TNM score was obtained in 45 (52%) patients, f-TN (primary lesion and regional lymph nodes status)

score was obtained in 22 (26%) patients, and f-T (primary lesion alone) was assessed in 17 (20%) patients.

Pathologic diagnosis was obtained in 81 (94%) of the patients. In addition to bronchoscopy, FNAB was performed in 30 patients, mediastinoscopy in 17, and open-chest surgery in 34 patients. Lesion size was determined in 76 (88%) of the patients, from pathologic evaluation after surgery (21 patients) or from the CT scans (55 patients). It was not possible to assess pathologic diagnosis or relevant follow-up data in 2 (2.3%) patients. These patients were omitted from data analysis regarding sensitivity and specificity against f-TNM but included for comparison between the 2 PET techniques. Data are expressed as mean ± SD or median (range). For comparing diagnostic rates of the 2 PET modalities, the McNemar test for correlated proportions was used.

## RESULTS

Basic patient characteristics are shown in Table 1.

### Detection of Pulmonary Tumors

Final outcome was obtained in 84 (98%) of the patients. Of the remaining 2 patients, one died 2 d after the PET scans from respiratory problems. One patient was not capable of further invasive investigations and died after 10 mo from cardiac failure. Autopsy was not performed in these patients.

A malignant diagnosis of a primary lung lesion (and enlarged mediastinum in one patient) was found in 52 (prevalence 52/84 = 62%) of the patients. Types of malignancy are listed in Table 2. f-TNM outcome for patients with primary lung cancer is shown in Table 3. In 32 patients, absence of malignant disease was concluded from final outcome. Benign inflammatory lesions were demonstrated in 15 of these patients.

dPET correctly detected the pulmonary lesions in all 52 patients with proven malignant disease (sensitivity 100%), whereas one patient was missed by gPET (sensitivity 98%). Diagnostic rates are shown in Table 3. When we compared sensitivity, specificity, accuracy, and predictive values between dPET and gPET we found no statistical significance. The single false-negative case by gPET was a primary lung

**TABLE 2**  
Histologic Results of Patients with Malignant Tumors

Result	No. of patients
Non-small cell lung cancer (type not specified)	4
Adenocarcinoma	25
Squamous cell carcinoma	11
Large cell carcinoma	3
Bronchoalveolar carcinoma	1
Carcinoid tumor	1
Small cell lung cancer	2
Malignant lymphoma	3
Metastasis from renal cell carcinoma	1
Metastasis from colon cancer	1

*n* = 52.

**TABLE 3**  
Diagnostic Rates for Detection of Malignant Lung Lesions and Regional Lymph Nodes

Cancer type	Prevalence	Sensitivity	Specificity	Accuracy	PPV	NPV
Primary lung lesion ( <i>n</i> = 84)*	62					
gPET		98 (90–100)	56 (38–74)	82	78	95
dPET		100 (93–100)	50 (32–68)	81	76	100
Regional lymph nodes ( <i>n</i> = 67)*	27					
gPET		61 (36–83)	90 (78–97)	82	69	86
dPET		78 (52–94)	84 (70–93)	82	64	91

\*No. of evaluable patients. No statistically significant differences were found between the 2 PET modalities (McNemar test).  
PPV = positive predictive value; NPV = negative predictive value.  
Values are % (95% confidence intervals).

adenocarcinoma that was 10 mm, with no signs of dissemination; Figure 1 illustrates this patient.

Sixteen patients without malignant thoracic disease had false-positive results (with regard to the presence of malignancy) with dPET; 14 of these patients also had false-positive gPET scans, resulting in specificity rates of 50% and 56%, respectively. Pathologic examination showed inflammation or infection (one patient had sarcoidosis) in 10 (63%; dPET) and 9 (64%; gPET) of these patients. An additional 5 patients had pathologically proven inflammatory or infectious disease but without increased <sup>18</sup>F-FDG accumulation.

#### Evaluation of Lymph Node Involvement

Of the 67 patients who could be evaluated regarding regional lymph node involvement, 18 had pathologically proven lymph nodes metastases. dPET detected lymph node

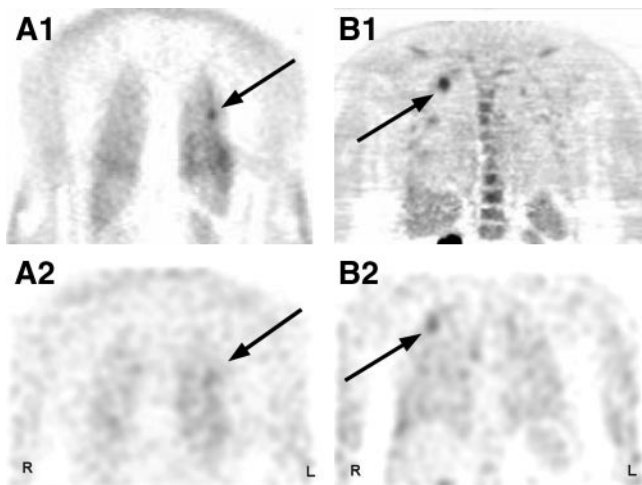
involvement in 14 (sensitivity 78%) and gPET in 11 (sensitivity 61%) of these patients. See Table 3 for diagnostic rates. There was no statistical significance between results from the 2 PET techniques. Scans of ipsilateral hilar nodes (N1) in 2 patients (colon cancer metastasis and adenocarcinoma), squamous cell carcinoma in ipsilateral mediastinal nodes (N2) in one patient, and small cell lung cancer in contralateral mediastinal nodes (N3) in one patient were false-negative with both dPET and gPET. Scan results for an additional 3 patients (N1 adenocarcinoma, N2 malignant lymphoma, and squamous cell carcinoma) were false-negative with gPET. When including only patients with verified primary malignant lung tumors, sensitivities were 80% and 67% for dPET and gPET, respectively.

#### Distant Metastases

Among the 47 patients with verified primary lung cancer, the presence or absence of distant metastases was identified in 17 patients. Three of these had metastases to the brain, liver, adrenal glands, or spine. These were all correctly detected by both PET technologies. There was one false-positive result of distant metastasis that was described with dPET (unspecific FDG uptake in the maxillary bone).

#### Comparison of gPET and dPET

TNM stages for both PET modalities for all 86 patients are shown in Table 4. Full agreement among the 3 TNM parameters between the 2 PET techniques was found in 55 (64%) patients: Cohen's  $\kappa = 0.57$ , indicating a moderate level of agreement. In Table 5, PET TNM stages are grouped into 3 categories: no signs of malignant disease (stage 0), malignant lung disease with limited dissemination where surgery or radiotherapy with curative intention may be possible (stages 1a–3a), or disseminated malignant lung disease where curative therapy is not possible (stages 3b–4). Agreement was present in 70 (81%) of the patients, resulting in a  $\kappa$  value of 0.71. Although this  $\kappa$  score is acceptable, Table 5 also shows that disagreement would have clearly resulted in different management plans in 19% of cases if the data from one or other PET study were used, with dPET apparently being more sensitive than gPET. Final outcomes for the 16 discordant results are shown in



**FIGURE 1.** Images of 10-mm adenocarcinoma in posterior of upper lobe in left lung of 55-y-old man. Coronal views of NAC data from dedicated PET (A1) and  $\gamma$ -camera PET (A2). Images of inflammatory lung disease verified by bronchoscopy and fine-needle biopsy in 70-y-old man. NAC images from dedicated PET (B1) and  $\gamma$ -camera PET (B2). For both patients, arrows show areas with focally increased <sup>18</sup>F-FDG activity, interpreted as malignant with dedicated PET but normal physiologic with  $\gamma$ -camera PET.

**TABLE 4**  
TNM Staging and Comparison Between  
gPET and dPET

TNM stage by gPET	TNM stage by dPET (no. of patients)						
	0	1a	1b	2	3a	3b	4
4					1		12
3b						5	4
3a					2	2	
2			1			1	2
1b		3	14	2	2	1	3
1a		7		3			2
0	15	2					2

Filled areas indicate full agreement (64%; Cohen's  $\kappa = 0.56$ ).

Table 6. These stage disagreements were not always due to the inaccuracy of gPET. Four patients were without malignant disease according to gPET, whereas dPET suggested variable degree of malignant disease. Of these, 2 patients were eventually classified as being without malignant disease; one patient represented the single false-negative (by gPET) result with a 10-mm adenocarcinoma (Fig. 1). No final outcome was obtained from the last patient, who died from cardiac failure before a conclusion could be drawn.

## DISCUSSION

dPET succeeded in detecting all 52 patients with malignant thoracic lesions, whereas gPET detected 51 of the cases. These high sensitivity rates are in accordance with previously reported data for both PET techniques in lung cancer patients (4). The patient with the one false-negative result by gPET had a solitary adenocarcinoma with a diameter of 10 mm, and the patient was included in the initial part of study when nonuniform attenuation correction was not yet possible with the gPET system. Reported false-negative malignant lung tumors by gPET have all been small (<10–17 mm) (15–17,19,22) or of the bronchoalveolar carcinoma type (15,16). The use of thicker crystals in the  $\gamma$ -camera ( $3/4$ " in contrast to  $5/8$ " used in most early studies) might have increased sensitivity for detecting smaller lesions. Our study, in accordance with others (23), demonstrated a lower sensitivity of gPET for smaller lesions compared with dPET, despite the use of newer technology. In the present study only 3 pulmonary lesions in 52 patients with malignant tumors were smaller than 20 mm. This might explain why gPET in our population resulted in a high sensitivity (98%) and a high negative predictive value (95%) comparable with what was obtained by dPET.

Selection criteria for patients in the present study were a standard chest radiograph that suggested possible lung tumor. This naturally also led to the inclusion of patients with nonmalignant diseases characterized by tissues that potentially could show increased FDG uptake (i.e., inflammation and infection), which could result in several false-positive

PET scans. Accordingly, we found lower specificities for both gPET and dPET (56% and 50%, respectively) compared with previous studies (50%–100%) (28). Sixty-four percent of the patients with false-positive PET scans in our study had pathologically proven inflammation or infection. Therefore, we expected lower positive predictive values (76%–78% in the present study) in an unselected population with a prevalence of malignancy being 62%. However, the way the patients were chosen for inclusion in this prospective study was part of the daily clinical scenario. In the routine clinical situation, patients with possible malignant lung lesions have to undergo several relevant diagnostic procedures within a very short time. In Denmark, all diagnostic procedures have to be performed within 6–8 d and offer relevant treatment for lung cancer within 10 calendar days (decree by the Danish Ministry of Health). In this study, these time limits were met in most patients.

Sensitivities for detecting malignancy in regional lymph nodes were lower than for the detection of primary pulmonary lesions for both PET techniques. This study confirms previous reports that have demonstrated the difficulties for FDG PET to detect malignant lymph nodes in hilar and mediastinal regions and that gPET seems inferior to dPET in that respect (4,21,22).

Three patients had proven metastatic lung cancer and were correctly staged by both PET modalities. The advantage of whole-body FDG PET for detecting previously unknown distant metastases is well known (17). In our study, the metastatic lesions were all seen with other imaging modalities.

Four previously published studies have compared dPET with gPET in patients with lung cancer (20–23). Only 2 studies included more than 20 patients, and those studies focused on lung lesions in a highly selected patient group (malignancy prevalence of 100%) (21,22). As also demonstrated in our study, gPET provided results comparable with dPET regarding detection of primary pulmonary malignant lesion, whereas for investigation of lymph node involvement, gPET seemed inferior to dPET. dPET was more efficient in detecting smaller (<20 mm) lesions.

We compared the TNM stage from the 2 PET scans. Full agreement was only seen in 64% of the patients (Table 4). Assessing precise T, N, and M stage is often difficult with

**TABLE 5**  
TNM Staging by Clinical Significance

TNM stage by gPET	TNM stage by dPET (no. of patients)		
	0	1a–3a	3b–4
3b–4		1	21
1a–3a		34	11
0	15	2	2

Filled areas indicate full agreement (81%; Cohen's  $\kappa = 0.71$ ).

**TABLE 6**  
Final Stage for Patients with Discordant PET Staging

TNM stage by PET*		Final TNM stage	Most correct PET result†	Clinical follow-up (mo)‡	Survival time after PET scans (mo)	Other diagnostic data, data from hospital records, clinical follow-up
gPET	dPET					
0	1a-3a	0	gPET	22	>25	Regression of lesion, histology: inflammation
0	1a-3a	1a-3a or 3b-4	dPET	NA	<1	Adenocarcinoma
0	3b-4	0	gPET	27	>30	Regression of lesion
0	3b-4	?	?	NA	10	No invasive procedures; died from cardiac disease
1a-3a	3b-4	0	gPET	6	>8	Regression of lesion, benign histology
1a-3a	3b-4	0	gPET	5	>7	Regression of lesion, histology: inflammation
1a-3a	3b-4	1a-3a	gPET	6	>8	Adenocarcinoma, no lymph node metastases
1a-3a	3b-4	3b-4	dPET	NA	14	Metastases to contralateral lymph nodes
1a-3a	3b-4	3b-4	dPET	8	>11	T4 tumor, chest wall, and mediastinal invasion
1a-3a	3b-4	1a-3a or 3b-4	(gPET)	NA	>32	Squamous cell carcinoma, no clinical follow-up; CT: no metastases
1a-3a	3b-4	1a-3a or 3b-4	?	NA	11	Biopsy: adenocarcinoma; refused operation
1a-3a	3b-4	1a-3a or 3b-4	(dPET)	23	>27	Adenocarcinoma; recurrence in contralateral lung after 8 mo
1a-3a	3b-4	1a-3a or 3b-4	(dPET)	23	>27	Malignant lymphoma
1a-3a	3b-4	1a-3a or 3b-4	(gPET)	NA	>26	Squamous cell carcinoma, no clinical follow-up; CT: no metastases
1a-3a	3b-4	1a-3a or 3b-4	?	6	>9	Adenocarcinoma; operation not performed
3b-4	1a-3a	1a-3a or 3b-4	?	NA	11	Small cell lung cancer; no surgery or clinical follow-up

\*TNM stages: 0, no malignancy; 1a-3a, malignancy suitable for treatment with curative intent; 3b-4, nontreatable malignancy.

†Data in parentheses indicate that conclusion is based on limited end-point data.

‡NA: patient died before or did not attend follow-up.

? = Data not conclusive for final staging.

n = 16.



FDG PET because the low resolution (compared with CT) and lack of anatomic details cannot provide exact information on size, anatomic location, or invasion into adjacent structures. When using a more clinically relevant staging (i.e., no malignancy, malignancy suitable for treatment with curative intent, or nontreatable malignancy), a higher degree of agreement was seen (81%) (Table 5). This comparison, however, only reveals how well the 2 types of PET scanners depicted the same lesions; it does not allow conclusions regarding which method is more accurate. Though follow-up data from the 16 patients with discordant PET results are not complete (Table 6), they suggest similar degrees of accuracy for the 2 methods in these patients. It is interesting, that although the gPET performed with a slightly lower sensitivity, gPET showed a slightly higher specificity than dPET (Table 3) because of a higher rate of false-positive foci. When comparing findings from the 2 scanners with the final outcome accuracy, positive and negative predictive values were not very different (Table 3). In the clinical setting, the FDG PET scans would never stand alone but should be supplemented with other imaging modalities for obtaining better anatomic information because an accurate T classification is important for the further investigation and treatment strategy.

The use of a single <sup>18</sup>F-FDG dose for both PET scans in our study resulted in a longer period of time from injection

to scan for gPET (193 min) compared with dPET (52 min). This set-up was optimal with regard to counting-rate statistics for each of the individual systems because the standard optimal FDG dose could be used for dPET and the radioactivity was below the counting-rate limit for the system at the time when gPET data acquisition was initiated. However, it has been suggested that delayed FDG PET imaging is beneficial in oncologic PET, because the contrast between malignant and benign tissue seems to increase with longer time between injection and scan (29). This may have favored gPET compared with dPET in the present study, but the importance of this issue for gPET requires further investigation. Both the dedicated PET scanner and the  $\gamma$ -camera were upgraded halfway through the study period, but subgroup analyses did not suggest an influence on the comparative results.

In summary, this study, in an unselected population of 86 patients with suspected lung cancer, demonstrated very high degrees of sensitivity for both gPET and dPET for detecting primary malignant lung disease. For lymph node staging, gPET seemed less sensitive than dPET. Despite the use of newer generation  $\gamma$ -cameras with theoretically higher sensitivity, gPET is still slightly less sensitive than dPET for detection of smaller lesions, including lymph nodes. However, depending on the population to be investigated and the availability of dPET, gPET may provide significant diag-

nostic information in the evaluation of patients suspected for malignant lung disease.

Since this study was conducted, the gPET scanners have been further developed in favor of improved sensitivity and spatial resolution; for example, our 2-head gPET was upgraded to a 3-head version (Irix; Marconi/Philips). Other gPET camera manufacturers have also improved their cameras (e.g., by improving the onboard CT facility). Important reasons for choosing dPET for  $^{18}\text{F}$ -FDG PET scans in the future might be determined by other factors such as the considerably shorter scan time that is less demanding for the patient and that allows higher productivity. Furthermore, the anatomic localization of  $^{18}\text{F}$ -FDG foci by way of coregistration with morphologic CT and MR scans, or even (almost) simultaneously acquired CT scans (PET/CT scanner), is without doubt more favorable when using a dPET scanner.

## CONCLUSION

This study, which compared  $^{18}\text{F}$ -FDG PET using a  $\gamma$ -camera with a dedicated PET scanner, demonstrated fairly good agreement with regard to detecting primary lung tumors but slightly reduced sensitivity with regard to detecting smaller malignant lesions such as lymph nodes.

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