# Is combined ^{18}F-Fluorodeoxyglucose-Positron Emission Tomography/Computed Tomography superior to Positron Emission Tomography or Computed Tomography alone for diagnosis, staging and restaging of pancreatic lesions ?

Veerle Casneuf[1], Louke Delrue[2], Annemarie Kelles[3], Nancy Van Damme[1], Jacques Van Huysse[4], Frederik Berrevoet[5], Martine De Vos[1], Philippe Duyck[2], Marc Peeters

Departments of (1) Gastroenterology, (2) Radiology, (3) Nuclear Medicine, (4) Pathology, (5) Hepatobiliary Surgery, UZ Gent, Gent, Belgium.

## Abstract

*Background and study aims :* To evaluate whether combined ^{18}F-FDG PET/CT has an additive value over ^{18}F-FDG-PET or CT alone for diagnosis, staging and restaging of pancreatic lesions.

*Patients and methods :* Forty-six consecutive patients (23 women, 23 men; median age 62.5 years) underwent FDG-PET/CT. Analysis of PET, CT and fused PET/CT images was performed by 2 readers. Patients were divided in 2 groups : diagnosis and staging of primary tumours (n = 34) and restaging : screening for recurrent or progressive pancreatic cancer (n = 12). Accuracy analysis was performed lesion-by-lesion and patient-by-patient. Results were correlated with histopathology or clinical follow-up.

*Results :* Ninety-five foci were identified on PET, 140 lesions on CT and 119 on PET/CT. Thirty-four lesions were defined as 'definitely pathologic' and localised in pancreas, liver, lung or bone by all 3 techniques with equal certainty. In 11 patients malignancy was ruled out with the highest certainty by PET/CT. All 3 modalities made 2 false positive diagnoses of malignancy and missed metastases or vascular ingrowth in 7 patients. The accuracy rate of PET/CT (91.2%) for diagnosis of primary pancreatic lesions is higher compared to CT (88.2%) and PET alone (82.3%). Also for locoregional staging PET/CT has a higher accuracy rate (85.3%) compared to CT (83.8%) and PET (79.4%). When used for restaging, sensitivity (90.0%) and accuracy rate (91.6%) were highest for PET and PET/CT. CT had a lower sensitivity (80.0%).

*Conclusions :* Topographical assignment of 'spots' with high FDG uptake is superior with PET/CT compared to PET alone. Fused PET/CT has a slightly higher sensitivity and accuracy rate for diagnosis and locoregional staging of primary pancreatic lesions compared to CT alone. PET and PET/CT perform equally well in screening for recurrent or progressive pancreatic cancer, with high accuracy. Due to its unlimited access, lower radiation exposure and cost, multidetector row CT remains the imaging technique of choice for diagnosis, staging and screening for recurrent pancreatic cancer. (Acta gastroenterol. belg., **2007**, 70, **330-338**).

**Key words** : FDG PET, CT, MDCT, FDG PET/CT, pancreas, tumour, pancreatitis, staging, lymph nodes, metastases.

## Introduction

Carcinoma of the pancreas has a poor prognosis with less than 20% of affected patients alive 1 year after diagnosis (1,2). Early detection is essential, because curative resection is the only option for survival (3-5). Staging is done according to TNM classification system (6). Preoperative diagnosis of pancreatic carcinoma remains difficult despite the wide array of diagnostic modalities available such as abdominal ultrasound (US), multidetector row computed tomography (CT, MDCT), endoscopic retrograde cholangiopancreaticography, magnetic resonance imaging (MRI) and endoscopic ultrasound (EUS). These anatomical imaging modalities have formed the corner stone of diagnosis and staging until now (7-14). However, main shortcoming of CT remains the detection of small volume peritoneal surface metastases and liver metastases of less than 1 centimetre diameter (15). Other challenges still remain, which include the definitive diagnosis of small tumours (< 2 cm), differentiating benign and malignant inflammatory lesions (e.g. mass-forming chronic pancreatitis or secondary to post-treatment fibrosis). Exploratory laparoscopy or laparotomy is frequently used before definitive surgical treatment, to decide upon resectability (16-19).

Eighteen-fluoro-deoxy-glucose (^{18}F-FDG) positron emission tomography (PET) has addressed some of these limitations. Because normal pancreas has low glucose utilisation, foci of abnormal FDG uptake can easily be visualised as regions of increased activity (20-23). This allows differentiation of benign and malignant pancreatic masses with high diagnostic accuracy (24-32). More recent reports have also highlighted the limitations of FDG-PET like poor spatial resolution limiting locoregional staging (tumour, nodes) of pancreatic cancer (33,34).

Dual-modality PET/CT seems to overcome the limitations of PET and CT individually (35-37). PET/CT has been proven clinically useful in e.g. lymphoma, colorectal, lung and breast cancer (26,38-45), but is not yet widely investigated in pancreatic disease. Our study was undertaken to evaluate whether combined PET/CT, performed with intravenous contrast, has an additive value over PET and CT alone for the diagnosis, staging and restaging of pancreatic lesions.

## Patients and methods

### Population

Forty-six consecutive patients, referred between October 2004 and April 2006 for whole-body ^{18}F-FDG-PET/CT

because of suspected pancreatic disease were entered in a database. This PET/CT centre is located in a third stage referral centre at the University Hospital of Ghent, Belgium.

*Study design*

Forty-six consecutive patients were included. Patients were subsequently divided into 2 groups, based on the reason for PET/CT referral : diagnosis and staging of primary pancreatic tumours and screening for recurrent or progressive pancreatic cancer. First, PET scans were analysed separately by a blinded nuclear medicine physician (AK) and CT scans by a blinded radiologist (LD). Secondly, combined PET/CT scans were analysed 2 months later, by the same 2 readers side-by-side. All patient records were reviewed. Image findings were correlated with histological diagnoses of resected specimen or/and biopsies (VC). When no histological data were available, clinical course or/and surgical findings were used as the standard of reference. Periods of follow-up were calculated in months, starting the day PET/CT was performed until the date of death or last clinical follow-up.

Data analysis was done in accordance with the guidelines of the local ethics committee.

*PET/CT imaging protocol*

All imaging was performed with an integrated PET-CT scanner (Philips Gemini PET-CT, Philips Medical Systems, Cleveland, USA) that comprises a 16-section high-performance multi-detector row CT scanner with a row action maximum likelihood algorithm based PET scanner (46,47). After patients had fasted for at least 6 hours, blood glucose levels were determined to ascertain a level of less than 200 mg/dl. Patients received subsequently 4 MBq/kg of body weight (10 mCi) of FDG intravenously followed by 250 ml of sodium chloride and 20 mg of furosemide. For muscle relaxation 5 mg of diazepam (Valium®, Roche) was given orally. Image acquisition was started 60 minutes after injection of FDG in a relaxed supine position with the arms alongside the body. During the whole procedure (low-dose CT, PET and contrast-enhanced CT) patients were instructed to breathe normally.

First a low-dose CT was performed primarily for attenuation correction. The scan range included the cranium towards the upper thighs using a standardized low-dose protocol with following parameters : section thickness 5 mm, field of view 600 mm, effective tube current time product maximum 30 mAs and tube voltage 120 kV.

A PET scan followed the CT scan from the orbito-meatal region up to the upper thighs consisting of 8-9 bed positions of 3 minutes per table position. PET images were acquired in a three-dimensional mode. The intrinsic spatial resolution of the system is 8 mm.

Subsequent to PET, a diagnostic contrast-enhanced CT was performed after administration of 140 ml intra-

venous contrast - Iodixanol (320 mg iodine per ml (Visipaque®), Amersham Health AS, Nydalen, Oslo) injected with a dual head injector (E-Z-EM, Lake Success, NY, USA) at 2.5 ml/sec. Venous phase imaging was performed with a 100 seconds post-injection delay. Scanning extended from the cranium towards the upper thighs. Parameters were as follows : section thickness 3 mm, rotation time 0.5 sec, pitch 0.9, matrix $512 \times 512$, tube voltage 120 kV and effective tube current time product maximum 150 mAs. Images were reconstructed with 5 mm section thickness at 2 mm intervals. Both arms were positioned alongside the body during the whole imaging procedure.

All PET/CT images were qualitatively (visually) evaluated with a picture archiving and communication system diagnostic workstation (PACS 3K review station, Centricity TM, GE Medical Systems, Milwaukee, Wisconsin, USA) and with a high-resolution workstation (Syntegra, Philips Medical Systems, Cleveland, USA) by two readers.

*Image interpretation*

Visual (qualitative) PET/CT image analysis was performed in 2 phases. First, all PET images were read by a blinded nuclear medicine physician (AK) to identify regions with increased FDG uptake. All CT images were viewed by a blinded radiologist (LD) to identify lesions using soft tissue, lung and bone window levelling. Both readers were separated and blinded for each others' results. Secondly, a combined reading by the same readers was made after an interval of at least 8 weeks. This combined reading was performed to come to a consensus in defining a lesion benign or malignant on the integrated PET/CT images.

A lesion on PET was called 'positive' (suspect for malignancy) when focal FDG uptake was higher than physiologic uptake in surrounding tissues. A lesion on PET was called 'negative' (physiologic uptake or benign disease) when focal FDG uptake was similar to surrounding tissues.

A lesion on CT was called 'positive' (suspect for malignancy) when a lesion in the pancreas was enhanced less then surrounding pancreatic tissue after IV contrast injection. Lesions in liver, lungs, bone were considered 'positive' (suspect for malignancy) according to standard morphologic criteria, routinely used in daily clinical practice. Lymph nodes larger than 10mm diameter were considered 'positive' (suspect for malignancy). A lesion on CT was called 'negative' (physiologic appearance or benign disease) when no suspect morphologic signs were present.

A lesion on PET/CT was called 'negative' (benign disease or physiologic appearance) when focal FDG uptake was similar to surrounding tissues combined with normal CT findings. A lesion on PET/CT was called 'positive' (suspect for malignancy) when CT findings were aberrant or/and focal FDG uptake was higher than

surrounding tissues. PET/CT conclusions were the result of a discussion between 2 readers to come to a consensus.

Based on PET, CT and PET/CT results, a lesion-by-lesion analysis was performed by the 2 readers. Lesion localisation and characterisation was registered for PET, CT and PET/CT separately. Each lesion was counted and scored on a 3-point scale : for localisation (0 = uncertain localisation, 1 = probable localisation, 2 = certain/definite localisation) and for characterisation (0 = uncertain about benign or malignant nature, 1 = probably malignant and 2 = definitely malignant). When patients had diffuse liver metastases, a maximum of 5 lesions was included for analysis. The difference in certainty of lesion localisation and characterisation was assessed per lesion.

In a patient-by-patient analysis, accuracy of PET, CT and PET/CT was evaluated regarding the following items : diagnosis of primary pancreatic lesions, differentiation of benign and malignant disease, detection of pathologic lymph nodes, locoregional staging and diagnosis of recurrent or progressive pancreatic cancer.

### Statistics

Statistical analysis was done with SPSS for Windows (version 13.0). Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy rates for PET, CT and PET/CT were calculated per patient group. Serum glucose levels were compared between groups (One-way ANOVA) and Bonferroni correction was applied. A P-value < 0.05 was considered statistically significant.

## Results

### Patient population

Forty-six PET/CT scans from 46 consecutive patients were included in this study. There were 23 women and 23 men. Median age at the time of PET/CT was 62.5 years (range 33-79 years). Patients were divided into 2 groups, based on the reason for PET/CT referral : diagnosis and staging of primary pancreatic lesions (group 1, n = 34) and screening for recurrent or progressive pancreatic cancer (group 2, n = 12). Based on histology or/and clinical follow-up, group 1 was further

subdivided in group 1a - malignant tumours (n = 24) and group 1b - benign disease (n = 10). Clinicopathological data are summarised in table 1. Mean glycaemia at injection of FDG in the whole group (n = 46) was 114.9 mg/dl (95%CI 102.4 – 127.5 mg/dl). Glycaemias did not differ statistically significant between groups (P > 0.05). Diagnoses were confirmed by pathology (n = 31) or clinical course (n = 15) as shown in table 2. Twenty-eight of 46 patients (60.9%) were dead by the time of data analysis.

### Lesion-by-lesion analysis : Localisation - Characterisation certainty

Spots of increased FDG-uptake that were observed on PET, clearly appearing like physiologic activity, such as normal ureter or bowel functioning were not taken into account. Only relevant CT findings, i.e. non-physiologic or suspicious for malignancy were withheld for analysis. Thus, PET identified 95 foci of abnormal (i.e. non-physiologic or malignant) high FDG-uptake. CT identified 140 lesions, of which 99 were evident suspect for malignancy (primary tumours or metastases).

### PET = CT = PET/CT

Thirty-four lesions were defined as 'definitely pathologic' and localised in pancreas, liver, lung or bone by PET, CT and PET/CT with equal certainty.

Eleven lesions were defined as 'benign' disease by all 3 modalities : pancreatic cyst (n = 1), pancreatic cystadenoma (n = 2), chronic pancreatitis (n = 6), focal nodular hyperplasia in the liver (n = 1) and para-aortic lymph nodes (diameter 1.0 cm, n = 1). In these 11 patients pancreatic malignancy, liver metastasis and local recurrence were correctly ruled out with the highest certainty by combined PET/CT, compared to PET or CT alone.

All 3 techniques made 1 false positive diagnosis of liver metastasis (1.3*1.9 cm on CT, haemochromatose on biopsy) and 1 chronic pancreatitis was erroneously taken for an adenocarinoma ('tumour' lesion on CT 1.8 cm diameter). In contrast, all 3 modalities missed 1 local recurrent cancer (malignant tissue in resection region) and 1 neuro-endocrine carcinoma (3.0*3.5 cm on EUS) with diffuse liver and peritoneal metastases (all +-1.0 cm diameter). In 6 other patients vascular ingrowth or/and metastases (< 1.0 cm diameter) in the liver, peritoneum or omentum were missed.

Table 1. — **Clinicopathological data**

|  | | Group 1a | Group 1b | Group 2 |
|---|---|---|---|---|
| Number of patients | | 25 | 9 | 12 |
| M/F ratio | | 13/12 | 5/4 | 5/7 |
| Median age (yr) | | 63.0 | 58.0 | 66.5 |
| Mean glycemia (mg/dl) | | 122.2 | 95.9 | 114.3 |
| | (95%CI) | (102.4-141.9) | (85.2-106.6) | (87.5-141.1) |
| DM | *Yes* | 7 | 3 | 1 |
| | *Not known* | | | 1 |

(M/F ratio = male/female ratio, yr = years, 95%CI = 95% Confidence Interval, DM = Diabetes mellitus).

Table 2. — **Confirmation of diagnosis**

|  | Histology | Clinical follow-up |
|---|---|---|
| Group 1a : Primary malignant tumours 22/25 histology 3/25 follow-up | 18 adenocarcinomas : – resection (n = 8) – biopsy tumour (n = 4) – biopsy metastasis (n = 6) | 1st patient : 3*negative biopsy of primary tumour, liver metastasis after 2 months, died after 6 months |
|  | 4 neuro-endocrine tumours : – resection (n = 3) – biopsy metastasis (n = 1) | 2nd patient : 3 negative biopsies of pancreas, intra-operative findings suspect, liver metastasis after 3 months, died after 8 months |
|  |  | 3rd patient : negative brushing cytology, lung metastasis after 14 months, died after 16 months |
| Group 1b : Benign lesions 9/9 histology | Chronic pancreatitis (6/9) : – resection (n = 4) – biopsy (n = 2) Cystadenoma (3/9) – biopsy (n = 3) |  |
| Group 2 : Restaging 12/12 : follow-up |  | Recurrence positive (10/12) : Median follow-up 4.3 months (range 1.0-11.0 months) |
|  |  | Recurrence negative (2/12) – 10.0 months follow-up – 15.0 months follow-up |

(n = number of patients).

**PET ⊖, CT ⊕, PET/CT ⊕**

CT and PET/CT could identify lesions that did not show increased FDG uptake on PET : 2 primary pancreatic tumours (3.5 cm and 2.7 cm diameter), 1 of these was a mucinous adenocarcinoma. In 5 patients CT and PET/CT detected additional liver metastases (+-1.0 cm diameter, n = 4) or lung metastases (maximum 1.0 cm diameter, n = 1). In another patient CT and PET/CT made a false positive diagnosis of liver metastasis (0.9 cm diameter, sclerosing cholangitis on biopsy). Other 'definitely malignant' findings, only identified on CT and PET/CT, were ascites (n = 2) and pleural effusion (n = 1). The following 'uncertain benign/malignant' lesions were identified on CT, also without FDG uptake : renal cyst (3.0 cm, n = 1), suprarenal incidentaloma (1.2 cm, n = 1) and prostate hypertrophy (n = 1).

**PET ⊕, CT ⊖, PET/CT ⊕**

PET and PET/CT detected a pancreatic tumour in 1 patient (2.3 cm on histology of resection specimen) and metastases in the bone (Th12, Th7, Th4) and liver (diffuse, +-1.0 cm diameter) in another patient, whereas CT missed these diagnoses.

**PET ⊕, CT ⊖, PET/CT ⊖**

Six lesions were misinterpreted as 'probably malignant' on PET : 3 probable liver metastases, 1 probable bone metastasis at L3, 1 sigmoidal focus and 1 suprapubic focus. CT and PET/CT could exclude malignancy in these 6 lesions and identify respectively cholecystitis (n = 2), inflammation around a biliary stent, degenerative bone disease at L3, sigmoid diverticulosis and

prostate adenoma. Thus, PET was false positive in these 6 cases.

Two foci of high FDG-uptake on PET were registered as 'probably malignant' : 1 suprapubic and 1 at the upper arm, but no anatomic correlation could be identified on CT. All the more, combined PET/CT could not state a firm conclusion either. After further investigation, following diagnoses were made : 1 tubular adenoma with low-grade dysplasia in the colon and 1 thrombophlebitis at the upper arm.

*Patient-by-patient analysis* : *Accuracy analysis*

Group 1/ Diagnosis of primary pancreatic lesions (n = 34) (Table 3)

*Diagnosis of primary pancreatic lesions – T-status (Table 3a)*

Of 34 patients, 24 had a primary malignant tumour [adenocarcinoma (n = 20), neuro-endocrine carcinoma (n = 4)] and 10 had benign disease of the pancreas [chronic pancreatitis (n = 7), pancreatic pseudocyst (n = 1), serous (n = 1) or mucinous (n = 1) cystadenoma]. In the group of malignant tumours, group 1a (n = 24), PET detected 19/24 primary tumours, CT 21/24 and PET/CT 22/24.

All 3 modalities detected 9/10 benign tumours and falsely considered 1 patient with chronic pancreatitis as an adenocarcinoma. In 4 of these 10 patients surgery was performed because of raised CA 19.9, icterus or positive FNA. Definitive histology showed chronic pancreatitis in all 4. Six others did not undergo resection.

Table 3. — **PET, CT and PET/CT in group 1 : Primary pancreatic lesions**

Table 3a : Diagnosis

|  | PET | CT | PET/CT |
|---|---|---|---|
| Sensitivity | 84.0% | 92.0% | 84.0% |
| Specificity | 88.8% | 88.8% | 88.8% |
| PPV | 95.4% | 95.8% | 95.4% |
| NPV | 66.6% | 80.0% | 66.6% |

(PPV = positive predictive value, NPV = negative predictive value).

Table 3b : Locoregional Staging

|  | PET | CT | PET/CT |
|---|---|---|---|
| Sensitivity | 56.5% | 60.0% | 56.5% |
| Specificity | 72.7% | 72.7% | 72.7% |
| PPV | 81.2% | 83.3% | 81.2% |
| NPV | 44.4% | 50.0% | 44.4% |
| Accuracy | 61.8% | 67.6% | 61.8% |

(PPV = positive predictive value, NPV = negative predictive value).

Median follow-up time after PET/CT of these patients is 18.0 months (range 16-33 months).

Overall, PET/CT had a higher accuracy rate (91.2%) as a diagnostic tool, compared to CT (88.2%) and PET (82.3%) alone.

*Diagnosis of pathologic lymph nodes – N-status*

In group 1a, CT detected pathologically enlarged (> 1.0 cm diameter) lymph nodes in more patients compared to PET and PET/CT. Because histology yields as the gold standard, only 15 patients in whom pathological confirmation of lymph nodes was available were withheld for analysis. In group 1a, 7 patients had no pathologic lymph nodes on CT (< 1.0 cm) and PET (no increased FDG uptake). In 6 of them histology was indeed negative. In 2 others enlarged lymph nodes were found on CT (> 1.0 cm) combined with high FDG uptake on PET, but histology confirmed this in only 1. In group 1b, 6 patients had no pathologic lymph nodes on PET and CT, which was also confirmed by negative histology.

*Locoregional staging - TNM status (Table 3b)*

All 3 imaging techniques understaged 7 patients, since unexpected omental or peritoneal metastases or/and vascular ingrowth were found during surgery. Specificity was the same for all 3 modalities (90.9%). Overall accuracy for locoregional staging for PET, CT and PET/CT was 79.4%, 83.8% and 85.3% respectively.

Group 2/ Restaging : Screening for recurrent or progressive malignant disease (n = 12) (Table 4)

PET, and PET/CT performed equally well in this patient population. Both imaging techniques identified 9 of 10 recurrent or progressive pancreatic cancers, whereas CT missed one progressive disease (bone and liver metastases). All 3 modalities correctly excluded pro-

Table 4. — **PET, CT and PET/CT in group 2 : Screening for recurrent or progressive pancreatic cancer**

|  | PET | CT | PET/CT |
|---|---|---|---|
| Sensitivity | 90.0% | 90.0% | 90.0% |
| Specificity | 100.0% | 100.0% | 100.0% |
| PPV | 100.0% | 100.0% | 100.0% |
| NPV | 66.6% | 66.6% | 66.6% |
| Accuracy | 91.6% | 91.6% | 91.6% |

(PPV = positive predictive value, NPV = negative predictive value).

gression in 2 others. Consequently, sensitivity (90.0%), specificity (100.0%) and accuracy rate (91.6%) were identical for PET and PET/CT. As for CT, sensitivity was slightly lower (80.0%). Negative predictive value was rather low for PET and PET/CT (66.6%) and even lower for CT (50.0%), possibly because only 2 true negative patients were included in our series.

## Discussion

Differentiation of pancreatic tumours remains a challenge for the clinician. Ninety percent of malignant lesions are ductal adenocarcinomas, mostly detected in an advanced disease state. Because surgery is the only curative option, early diagnosis and accurate staging play a fundamental role. In some cases however, the preoperative diagnosis of pancreatic carcinoma remains difficult even with the wide array of anatomical imaging techniques available today. FDG-PET allows differentiation of pancreatic masses with high diagnostic accuracy (25-30). Reported sensitivities and specificities are between 71-100% and 64-100%, respectively (31,32, 48). The strength of biological imaging lies in its ability to detect pathology irrespective of lesion morphology. Combining anatomical and biological data is of particular advantage in imaging the abdomen because a number of intra-abdominal organs (such as the bowel) exhibit non-specific FDG uptake. This can result in diagnostic uncertainty and false positive results.

Data about the accuracy of combined PET/CT in pancreatic disease are scarce. Lemke et al performed a retrospective image fusion of PET and CT, showing increased sensitivity of both imaging modalities (49). Another study evaluated combined PET/CT, performed without intravenous contrast, for staging of pancreatic cancer in 59 patients. Sensitivity and specificity for the detection of pancreatic cancer were 91 and 69% respectively. Four patients with chronic pancreatitis were false-positively diagnosed as cancer. PET/CT was false negative in 5 patients with proven adenocarcinoma. However, in 16% of patients, PET/CT detected additional distant metastases in the lung, liver and abdominal wall. This changed the management in these patients, who were deemed resectable after routine staging (50).

In our study, we compared the accuracy of PET, CT and PET/CT in different pancreatic diseases. As demonstrated by our lesion-by-lesion analysis, CT remains the

imaging technique with the best spatial resolution. Although, the clinical significance of small lesions (< 1.0 cm) is not always clear. Major impact of PET/CT in the evaluation of pancreatic disease is that topographical assignment of foci of FDG accumulation is superior over PET alone. 'Probably malignant' foci on PET, suspect for e.g. liver metastases were correctly assigned to inflammation by CT. This is a substantial advantage leading to fewer equivocal lesions and increased diagnostic certainty.

CT and PET/CT detected 2 primary malignant pancreatic tumours that were missed on PET. One of these 2 was a mucinous tumour. It is well known that mucinous and neuro-endocrine tumours are non-FDG avid, which is a clear disadvantage for PET (51-53). Nevertheless, 3 of 4 neuro-endocrine tumours included in our series showed increased FDG uptake. We found a higher overall diagnostic sensitivity for PET/CT (91,6%) and CT (87,5%) for primary pancreatic lesions than for PET alone (79,1%). This sensitivity might be even more favourable for CT when a 3 phase scanning protocol would be performed. A MDCT for evaluation of the pancreas is scanned with sustained breath hold in 3 phases : unenhanced, arterial and portal phase. In our PET/CT centre, an unenhanced low-dose CT scan is performed before PET scan, mainly for attenuation correction. After the PET scan, a CT scan is performed with contrast injection, but in venous phase. Both arms are positioned alongside the body and patients are instructed to breathe normally during the whole procedure. Both factors can cause artefacts on CT images. It is possible that this lead to an underestimation of CT in our study. To address this question, we need a prospective study comparing dedicated state of the art MDCT scan of the pancreas with PET/CT of the pancreas.

The evidence so far suggests that both PET and CT are poor at nodal staging of pancreatic disease (54-57). Possible reasons for this low sensitivity are micrometastatic involvement and close proximity of peripancreatic lymph nodes to the primary tumour, which can obscure their detection.

In the past, major impact of PET has been its ability to identify distant metastases. However, main shortcoming of PET and CT remains subcentimetric metastases (58-61). In our staging group, all 3 modalities missed omental and peritoneal metastases and vascular ingrowth in 7 patients. On the other hand, CT and PET/CT identified additional lung and liver metastases, without FDG uptake. Although it was not the case in our patient group, this shows that PET/CT provides, with fused CT data, additional diagnostic information that could alter the staging process in some patients. We found an overall staging accuracy for PET/CT of 85.3% compared to CT (83.8%) or PET (79,4%).

In our series, PET/CT was also used for restaging, to screen for recurrent or progressive pancreatic cancer. PET and PET/CT correctly identified 9 of 10 recurrent or progressive cancers whereas CT missed 1 progressive

disease. All 3 modalities confirmed absence of progression in 2 patients. The large number of positive patients might be the result of a selection bias, since some of them were sent to PET/CT because conventional imaging was inconclusive. Combining anatomical with functional data, PET/CT has a theoretical advantage over PET or CT alone e.g. in differentiating fibrosis from recurrent disease. Indeed, both readers confirmed that their diagnostic certainty about relapse or progression was higher for the combined reading of PET/CT than for PET or CT individually.

In conclusion, we think that the major impact of PET/CT in the evaluation of pancreatic disease is that topographical assignment of PET foci is superior over PET alone. PET/CT is more expensive, causes higher radiation exposure and is less accessible than MDCT. Therefore PET/CT has an additive value in diagnostic and staging algorithms only in these particular cases where MDCT alone is inconclusive. PET/CT is an excellent 'all-in-one' tool for the early detection of recurrent or progressive pancreatic cancer. Since recent papers suggest a benefit in survival after palliative surgical resections, it might become of clinical importance to detect recurrences as soon as possible (62-64).

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