FDG-PET: procedure guidelines for tumour imaging

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Aim

The aim of this document is to provide general information about [^{18}F]fluorodeoxyglucose positron emission tomography (FDG-PET) in oncology. These guidelines do not include all the existing procedures for FDG-PET but describe only the most common FDG-PET protocols used in the current clinical routine studies. For this reason, some techniques, such as dynamic tomographic studies, and some instruments, such as gamma cameras for coincidence imaging, are only touched upon. The guidelines should therefore not be taken as inclusive of all possible PET procedures or exclusive of other nuclear medicine procedures useful to obtain comparable results. It should be remembered that the resources and the facilities available for patient care may vary from one country to another and from one medical institution to another. The present guide has been prepared for nuclear medicine physicians and is intended to offer assistance in optimising the diagnostic information that can currently be obtained from FDG-PET imaging. The Guidelines of the Society of Nuclear Medicine (SNM), the Procedures Guidelines for Brain Imaging Using FGD (EANM) and the existing guidelines for PET of some European Societies have been reviewed and integrated into the present text. The same has been done with the most relevant

literature on this topic, and the final result has been discussed with a group of distinguished experts.

Background

PET is a non-invasive diagnostic tool that provides tomographic images and quantitative parameters of perfusion, cell viability, proliferation and/or metabolic activity of tissues. These images result from the use of different substances of biological interest (sugars, amino acids, metabolic precursors, hormones) labelled with positron-emitting radionuclides (PET radiopharmaceuticals).

FDG is an analogue of glucose and is taken up by living cells via the first stages of the normal glucose pathway. The rationale behind its use as a tracer for cancer diagnosis is based on the increased glycolytic activity in neoplastic cells. FDG is trapped in the cancer cells due to their high glycolytic activity and excreted from the body via the renal system, which is unable to reabsorb the tracer. A 50- to 60-min interval between FDG administration and image scan is usually enough to obtain a good tumour/background ratio of the tracer.

The cell alterations related to neoplastic transformation are associated with functional impairments that are discernible before structural alterations occur. Therefore, FDG PET can reveal the presence of a tumour when conventional morphological diagnostic modalities (i.e. X-ray, CT, MRI and ultrasound) do not yet detect any evident lesions.

FDG uptake in tumours correlates with tumour growth and viability, so the PET scan and the possible metabolic quantification may provide useful information about tumour characterisation, patient prognosis and monitoring of the response to anticancer therapy. At present there is considerable evidence that the application of FDG-PET is becoming more and more widespread for the diagnostic assessment of patients with suspected malignancies, in tumour staging and in therapy monitoring.

Clinical indications

The clinical indications of FDG-PET are:

1. Diagnosis of malignant lesions
2. Evaluation of the extent of disease (staging/restaging)
3. Study of patients with biochemical evidence of recurrence (increase in tumour marker levels) but no clinical features or evidence of disease with morphological imaging
4. Differentiation of recurrent or residual malignant disease from therapy-induced changes
5. Study of patients with metastases from unknown primary sites
6. Grading of malignant lesions
7. Determination of the most aggressive part of the tumour to plan biopsy
8. Evaluation of tumour response to chemotherapy or radiotherapy
9. Planning of radiotherapy with both therapeutic and palliative intent

Precautions

1. Pregnancy (suspected or confirmed): In the case of a diagnostic procedure in a patient who is known or suspected to be pregnant, a clinical decision is necessary to weigh the benefits against the possible harm of carrying out any procedure.
2. Breastfeeding: Breastfeeding should be discontinued until at least 6 h following FDG administration or restarted when the radioactivity in the milk will not result in a radiation dose to the child of greater than 1 mSv.
3. Diabetes: High glucose levels may interfere with tumour targeting due to competitive inhibition of FDG uptake by D-glucose. Even if diabetes does not preclude the possibility of PET imaging of cancer, there are no general guidelines for FDG-PET in cancer diagnosis in diabetic patients. Many centres have the patients fast and do not administer additional insulin despite the presence of hyperglycaemia, and obtain useful diagnostic images. However, an FDG-PET study should not be recommended when the glucose level in the blood exceeds 200 mg/dl.
4. Kidney failure: The quality of PET imaging decreases if the kidney clearance is poor, but this is not necessarily a contraindication.

Pre-examination procedures

Patient preparation

The technologist or physician should give the patient a thorough explanation of the test. The patient must fast for 6 h before a PET scan, during which time he or she should be encouraged to drink only water with no carbohydrates to ensure hydration and promote diuresis. The patient should provide the nuclear medicine physician with all the available clinical and radiological documentation related to the disease to be studied by PET.

Pre-injection

Clinical evaluation by the nuclear medicine physician

The nuclear medicine physician should take into account all the information that could facilitate the interpretation of the PET scan (CT, MRI and other previously performed diagnostic imaging).

In particular, all the following parameters should be checked:

– Fasting state
– History of diabetes

- Patient weight and height
- Recent surgery or invasive diagnostic procedures (at least a 4-week interval should be allowed) and radiation therapy (at least a 3-month interval should be allowed)
- Recent chemotherapy (bone marrow and gastrointestinal toxicity can affect the biodistribution of FDG as well as tumour uptake)
- Presence of inflammatory conditions (infections, abscesses, TBC, etc.)
- Presence of benign disease with high tissue proliferation (fibrous dysplasia, sarcoidosis, etc.)
- Hydration, administration of a diuretic (10–20 mg i.v. furosemide) and placement of a urinary catheter with subsequent bladder irrigation with physiological solution may be helpful in eliminating urinary activity, which may complicate the interpretation of FDG uptake in the pelvis or abdomen.

Blood glucose test

Blood glucose levels should be checked prior to FDG administration and should not exceed 130 mg/dl. This is necessary to evaluate the reliability of the study in diabetic patients receiving antidiabetic and/or steroid therapy.

Patient relaxation

Before FDG administration the patient has to relax in a waiting room to minimise muscular activity and thereby any physiological uptake of FDG in the muscles. Hyperventilation may cause uptake in the diaphragm and stress-induced tension may be seen in the trapezius and paraspinal muscles. Some authors have proposed the administration of benzodiazepines to obtain muscle relaxation.

In the evaluation of head and neck cancer, the patient should avoid talking or chewing immediately before and after FDG administration to minimise FDG uptake in local muscles (laryngeal and masticatory muscles).

In the evaluation of brain tumours, the patient should wait in a quiet and darkened room before (and after) FDG administration.

FDG injection, dosage, administered activity

The activity of radiopharmaceutical to be administered should be determined after taking account of the European Atomic Energy Community Treaty, and in particular article 31, which has been adopted by the Council of the European Union (Directive 97/43/EURATOM). This Directive supplements Directive 96/29/EURATOM and guarantees health protection of individuals with respect to the dangers of ionising radiation in the context of medical exposures. According to this Directive, Member States are required to bring into force such regulations as may be necessary to comply with the Directive. One of the criteria is the designation of Diagnostic Reference Levels (DRLs) for radiopharmaceuticals; these are defined as *levels of activity for groups of standard-sized patients and for broadly defined types of equipment.* It is expected that these levels will not be exceeded for standard procedures when good and normal practice regarding diagnostic and technical performance is applied. For the aforementioned reasons the following activity for FDG should be considered only as a general indication based on the data in the literature and current experience. It should be noted that in each country, nuclear medicine physicians should respect the DRL and the rules stated by the local law. Injection of activities greater than national DRLs must be justified.

The injected activity of FDG to obtain good imaging with a full-ring PET scanner with BGO crystals should be 6 MBq/kg. The activity for adults can range between 111 and 555 MBq (3–15 mCi), and that for children (5 years old), between 4 and 7 MBq (0.10–0.18 mCi). The organ which receives the largest radiation dose is the bladder (see Table 1). FDG should be administered intravenously, using a butterfly to ensure correct venous access. If the FDG extravasates into the soft tissue at the injection site, the radiopharmaceutical may accumulate in benign lymph nodes due to lymphatic re-absorption. In some superficial tumours (breast carcinoma, melanoma), FDG should be administered contralaterally to the site of disease. In some circumstances it is best to inject FDG into a vein of the foot.

If a semiquantitative or quantitative analysis of FDG uptake is to be carried out, it is necessary to record specific information including the patient's weight and height, administered FDG activity and time of injection.

It should be noted that the above recommended injected activity is valid for BGO full-ring PET cameras, and that the administered activity of the radiopharmaceutical may vary for other systems and acquisition protocols.

Post-injection

After administration of FDG the patient is requested to remain in a waiting room until the start of PET scanning.

A 60-min interval between FDG injection and acquisition of the emission images is usually enough to obtain adequate FDG biodistribution for patient evaluation. During this time the patient should drink up to 1 litre of water or receive this amount via the i.v. route to promote diuresis. Hydration and voiding is advised to limit radiation to the urinary tract.

Patients should void immediately before image acquisition is started.

Physiological FDG distribution

FDG is an analogue of glucose; it is taken up by cells to the same extent as glucose but is not metabolised. Evident accumulation of FDG can be seen in vivo, especially in the brain, heart, kidneys and urinary tract at 60 min after injection. To be able to interpret FDG images the nuclear medicine physician must be familiar with the physiological distribution of FDG. The cerebral cortex has a high uptake of FDG as it uses glucose as a substrate. The myocardium in a typical fasting state primarily uses free fatty acids, but after a glucose load it uses glucose. The FDG uptake in the myocardium is highly dependent on the dietary status, and myocardial uptake is enhanced in the presence of high blood glucose levels. In the fasting state, FDG uptake in cardiac muscle should be absent; however, this is variable. Unlike glucose, FDG is excreted by the kidneys into the urine. Accumulation of FDG in the renal collecting system is a typical finding in FDG-PET. There is some degree of FDG accumulation in the muscular system, and this is increased by exercise. The uptake in the gastrointestinal tract varies from patient to patient. Uptake is common in the lymphoid tissue of Waldeyer's ring and in the lymphoid tissue of the caecum. The wall of the stomach is usually faintly visible. Physiological thymic uptake may be present in children, in young adults and in patients with regenerating haemopoietic tissues.

Radiation dosimetry

The estimated absorbed radiation dose to various organs in healthy subjects following administration of FDG is given in Table 1. The data are quoted from ICRP 80.

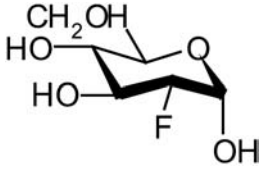
Table 1. Absorbed radiation dose per unit activity administered (mGy/MBq), for various organs in healthy subjects following the administration of FDG

Organ	Adults	15 year olds	5 year olds
Adrenals	0.012	0.015	0.038
Bladder	0.16	0.21	0.32
Bone surfaces	0.011	0.014	0.035
Brain	0.028	0.028	0.034
Breast	0.0086	0.011	0.029
Colon	0.013	0.017	0.040
Gallbladder	0.012	0.015	0.035
Heart	0.062	0.081	0.020
Kidneys	0.021	0.025	0.054
Liver	0.011	0.014	0.037
Lungs	0.010	0.014	0.034
Muscles	0.011	0.014	0.034
Oesophagus	0.011	0.015	0.035
Ovaries	0.015	0.020	0.044
Pancreas	0.012	0.016	0.040
Red marrow	0.011	0.014	0.032
Skin	0.0083	0.010	0.027
Small intestine	0.013	0.017	0.041
Spleen	0.011	0.014	0.036
Stomach	0.011	0.014	0.036
Testes	0.012	0.016	0.038
Thymus	0.011	0.015	0.035
Thyroid	0.010	0.013	0.035
Uterus	0.021	0.026	0.055
Remaining organs	0.011	0.014	0.034
Effective dose (mSv/MBq)	0.019	0.025	0.050

Radiopharmaceutical: 2-[^{18}F]fluoro-2-deoxy-D-glucose (FDG)

Description

FDG is a metabolically stable analogue of glucose (Scheme 1). It is supplied as a sterile solution for injection.



Scheme 1.

Preparation

FDG is normally prepared in a centralised PET radiopharmacy by phase transfer catalysed nucleophilic substitution of 1,3,4,6-tetra-*O*-acetyl-2-*O*-trifluoromethanesulphonyl-β-D-mannopyranose with [^{18}F]fluoride. FDG may be distributed to other sufficiently nearby centres at which no additional preparation is required.

Quality control

Good quality control is critical in the routine production of FDG as this product is synthesised daily and procedures are sometimes specific to the individual institution.

In the radiopharmacy preparing the FDG, it is important to check:

- Chemical purity; (using HPLC with ultraviolet or conductivity detection), to ensure the absence of any compounds other than FDG which could be toxic or pharmacologically active.
- Radiochemical purity (usually determined using HPLC with radiation detection).
- Radionuclidic purity (by measurements of energy spectra and physical half-life, or indirectly using HPLC and gas chromatography techniques).
- Sterility and apyrogenicity: Although these microbiological tests are too time consuming to be carried out before patient administration, they should be per-

formed retrospectively on a regular basis to ensure the pharmaceutical quality of the preparation process.

Departments receiving FDG from another centre (when it is allowed by the local law) should assay the radioactive concentration by measurement in a calibrated ionisation chamber. Radiochemical purity may be confirmed using a TLC method. (Solid-phase Merck silica gel plate 60 F_{254}. Mobile phase 95% acetonitrile in water. Rf ^{18}F-FDG 0.45, ^{18}F fluoride 0.0, partially acetylated 2-[^{18}F]fluoro-2-deoxy-D-glucose derivatives 0.8–0.95.

Special precautions

The preparation may be diluted with sterile physiological saline if required.

PET scanner quality control

Clinical scanning should be accompanied by a strict quality control programme consisting in calibration and performance tests. Calibration may include:

- Normalisation procedure: to ensure the existence of an adequate correction of the changes in efficiency among the crystals of the detectors. This procedure takes several hours and can be performed every month, providing that there are no detector failures.
- Setup scan: to ensure that all detectors are working properly. The setup scan changes the detect gains to modify any possible drifts. This takes about 2 h and can be done weekly.
- Blank scan: to ensure that the detectors have not drifted since the last normalisation. The blank scan also serves for attenuation correction. This test takes a short time (30 min) and can be performed daily.

Performance tests can usually be carried out according to the international recommendations: the American guidelines are published by NEMA (National Electrical Manufacturer Association), and the European guidelines are published by IEC (International Electrotechnical Committee).

Image acquisition

Instrumentation

Scanners

- State-of-the-art dedicated PET scanner: A state-of-the art PET scanner consists of several full-ring detectors—BGO (bismuth germanate orthosilicate) or LSO (lutetium orthosilicate) or GSO (gadolinium orthosilicate). Variations on this basic design include the partial ring BGO dedicated PET scanner and the dedicated PET scanner with six position-sensitive sodium iodide detectors.
- Alternatives to dedicated PET scanners include the gamma camera with 511-keV collimators and the dual-head gamma camera for coincidence imaging (no collimators).
- CT-PET scanner: In this system a CT scanner is combined with the PET components of a full-ring BGO/LSO/GSO scanner. This allows correction of PET images by CT attenuation data and concomitant co-registration of functional images from PET and morphological images from CT. Extensive clinical evaluation of this system is still ongoing; however, the high level of integration of anatomical and functional imaging that can be attained improves the role of PET not only in the diagnosis and staging of cancer, but also in the design and monitoring of appropriate therapies.

Comparison of scanners

Comparison of scanners is beyond the scope of this document. However, it is worth mentioning that manufacturers are going to develop different PET systems for performing clinical PET studies with FDG. The performance of the coincidence scanner systems has been the subject of debate, especially with regard to their costs and diagnostic accuracy compared with those of the available PET scanners. In this respect, coincidence imaging gamma cameras show several practical advantages (low cost and high physical resolution) but also many limitations (in respect of sensitivity, count rate and activity outside the field of view). At present the general opinion is that their clinical reliability is lower than that of full-ring BGO/LSO/GSO scanners. Their potential role in oncological routine seems to be limited to a few oncological indications in some specific anatomical regions. In fact, there is general agreement within the international nuclear medicine community today that the standard for PET is the *dedicated scanner with a full ring of BGO/LSO/GSO detectors*; this view is based on its excellent physical and clinical performance and the extensive clinical experience in its application in oncology worldwide. For these reasons, the present procedure guidelines relate to this system.

Acquisition modality

Limited-field tomographic images
(with or without attenuation correction)

Whole-body scan should be considered the standard procedure in cancer patients today (see following section). Limited-field tomographic images may be restricted to

particular locoregional studies (e.g. brain, head and neck cancer, axillary staging, evaluation of response to treatment) on the basis of specific diagnostic questions.

This static scan consists of an emission scan and a transmission scan (facultative). Correction for attenuation is essential if one wishes to calculate the standardised uptake values from the images. The sequence of the two scans (scanning protocols) and the techniques for performing transmission scans vary according to the tomographic system available.

Exact positioning of the body region to be studied can be obtained by means of external markers that should be accurately placed on the patient. Patient cooperation is important (ability to lie still for 60–90 min, ability to put the arms above the head). If necessary, tools to aid immobilisation (e.g. head or body elastic bands) may be used.

The number of static acquisition scans should be chosen according to the axial field of view of the PET scanner. Translation of the bed between scans can be manually run or it can be automatically set through the software.

Emission scan. The emission acquisition lasts between 5 and 15 min depending on the injected activity, the size of the patient and the type of acquisition protocol used (2D or 3D).

Transmission scan. The transmission acquisition uses rotating rod sources of ^{68}Ge and serves to correct the emission scan images from the photon attenuation. Correction factors are obtained by measuring the ratio between a blank scan (performed when the scanner is empty) and a transmission scan (performed with an external source when the patient is in position). The transmission scan can be done either before or after the emission scan, depending on the scanning protocol. If repositioning of the patient is necessary, great care should be taken to minimise artefacts in subsequent PET images due to incorrect repositioning. Such transmission acquisition (using ^{68}Ge rod sources) has to last approximately 10 min; for shorter acquisition times either segmentation algorithms or high-energy single-photon sources are required (in accordance with manufacturers' guidelines). In brain scans, attenuation correction can be obtained using analytical methods instead of performing the transmission acquisition scan. In CT-PET systems such photon attenuation correction is obtained by means of a CT scan.

Whole-body tomographic images (with or without attenuation correction)

Since the axial field of view of PET scanners is limited to 15–20 cm, the whole-body study is a linear tomographic scan that acquires sequential static images by moving the patient bed through the gantry. This static scan is carried out in a series of steps, the length of each step being slightly smaller than the field of view. The whole-body scan enables good evaluation of the extent of disease throughout the principal parts of the body (brain, thorax, abdomen, pelvis, arms and legs). The correct definition of the whole-body scan is PET imaging from head to toe; this is what should be done in oncology. Several centres, however, consider that a scan from the head to the pelvic floor, excluding the legs, also represents a whole-body scan. There is general consensus that the brain should always be included.

Whole-body PET consists of an emission acquisition scan and a transmission acquisition scan. Whole-body studies are usually carried out without attenuation correction as the total scanning time would otherwise become very long. The sequence of transmission and emission scans and the modality of performing the transmission scan vary according to the tomographic systems and scanning protocols. New techniques for performing and processing whole-body transmission scans are under development.

The margins of a whole-body scan have to be marked out for each study; they are usually constituted by the intertrochanteric femoral line and the vertex of the patient. The patient's cooperation is important (ability to lie still for 60–120 min, ability to put the arms above the head). If necessary, tools to aid immobilisation (e.g. head or body elastic bands) may be used.

Emission scan. In a standard patient, using PET with an axial field of view of 15 cm, the number of acquisitions is six or seven. Standard acquisition times vary from 5 to 10 min for 2D acquisition and from 2 to 8 min for 3D acquisition, according to the injected dose and the size of the patient.

Transmission scan. The transmission acquisition scan uses rotating sources of ^{68}Ge (facultative) and serves to correct the emission scan images for photon attenuation. Such transmission acquisition does not last as long as the emission acquisition and consists of acquiring for 2–3 min a scan of the same body region as is imaged by the emission scans. Transmission acquisition scans can be performed immediately following each emission acquisition scan or at the end of all emission acquisition scans, depending on the scanning protocol. In CT-PET systems, photon attenuation correction is obtained by means of a CT scan of the same body regions as are studied by PET scans.

Dynamic studies

The acquisition modalities for dynamic studies are only briefly mentioned here because they are not commonly used in clinical routine. This type of acquisition is used to quantitate the regional metabolic rates of FDG. Dynamic tomographic imaging consists of a sequence of serial images in a limited field, starting at the time of FDG administration and continuing for 60–90 min. This re-

quires the determination of arterial input function and measurements of FDG and glucose plasma levels and body surface area. A calibration factor between the scanner events and in vitro activity is needed and can be obtained by means of adequate imaging of a phantom.

The dynamic images may be combined with the standard procedures that are used in cancer patients for studies in the whole-body area.

Corrections

Attenuation correction should be obtained from correction emission photon attenuation by one of the following methods:

- Transmission imaging (corresponding images acquired with an external source)
- Mathematical attenuation correction (estimated attenuation correction based on the emission data)
- Hybrid attenuation correction (attenuation map calculated from a transmission measurement followed by a segmentation image)
- CT-based attenuation correction (measuring an attenuation correction map using a CT scanner in line with PET, transforming the CT map into a 511-keV attenuation map by segmentation and absorption correction and forward projection of the data for use as attenuation correction data)
- Scatter correction can be obtained by removal of non-coincidence from the emission data.

Image processing

If no attenuation correction is performed, axial images are reconstructed with a filtered backprojection method using a 128×128 matrix and selecting an appropriate filter and an appropriate cut-off (e.g. Hanning filter and 8.5 mm cut-off per pixel).

If attenuation correction is performed, the following applies: in 2D limited-field static studies, axial images are reconstructed with a filtered backprojected method, using the previously described parameters. The images are automatically corrected on the basis of the data from the transmission acquisition scans. In 2D whole-body studies, axial images are elaborated with segmentation and an iterative reconstruction method (OSEM), using a 128×128 matrix and selecting an appropriate number of iterations and projections/subset. Standard values for iterative reconstruction using the OSEM algorithm are 16 subsets and 2 iterations, but each centre should optimise the protocol to suit its requirements (qualitative or quantitative imaging, type of workstation used, remote workstation for post-processing of the data). In CT-PET studies, the attenuation correction procedure relies on the attenuation map from the CT scan images. In this case a 512×512 matrix should be used to elaborate PET images.

All axial reconstructed images are then re-oriented according to the coronal and sagittal axes, the number and thickness of which are appropriately related to the clinical and diagnostic circumstances.

Image analysis

Qualitative analysis

PET images are visually analysed by looking for local differences in FDG uptake in the regions imaged. PET evaluation should, whenever possible, be compared with morphological studies to better localise the lesion. However, in the event of a negative PET scan outside the brain, morphological imaging may not be required.

Semiquantitative analysis

Semiquantitative estimation of tumour metabolism involves a comparison of absolute or relative regions of interest. Normalised semiquantitative analysis includes correction for the administered activity. The most widely used semiquantitative index in PET studies is the standardised uptake value (SUV). This can be calculated as the ratio between the FDG uptake (MBq/ml) in a small region of interest (placed over the tumour in an attenuation-corrected image) and the administered activity related to the weight (kg) or body surface (m^2) of the patient. A calibration factor is required to convert the value measured from the image into MBq/ml. SUVs should be calculated in the hottest part of the lesion because cancer tissues have a very heterogeneous distribution of FDG uptake.

Other corrections may take into account the fact that FDG does not accumulate in the adipose tissue, so patient weight may be substituted by the lean body mass. The SUV should also be corrected for blood glucose concentration since its value is underestimated if the patient has elevated blood glucose concentrations. Calculation of the SUV requires all available data on patient characteristics (weight, height, blood glucose levels) and injected radiopharmaceutical (injected activity of FDG, preparation time and administration time). In clinical PET, the SUV may guide the differential diagnosis between a benign lesion and a malignancy; however, this value seems to be more reliable in the evaluation of tumour response to treatment.

Quantitative analysis

A quantitative analysis can be performed when it is possible to calculate the curve of the arterial FDG concentration against time (arterial input function). In this way physiological parameters can be measured in absolute units (e.g. glucose metabolic rate in mol min^{-1} g^{-1} or

blood flow in ml min^{-1} g^{-1}). Such absolute quantification is usually not performed in the clinical routine. It requires direct sampling of arterial blood (serial measurements) and dynamic acquisition. Some non-invasive alternatives have been studied: the input function can be retrieved from the PET images using the aorta, volumes of interest and partial volume correction.

Interpretation criteria

To evaluate PET images, the following items should be taken into consideration:

- The clinical issue raised in the request for PET imaging
- The clinical history of the patient
- Scanning protocol (attenuation correction or not)
- The physiological distribution of FDG
- Anatomical localisation of the abnormal uptake according to other imaging data
- Intensity of FDG uptake
- Semiquantitative (or quantitative) values (if available)
- Clinical correlation with any other data from previous clinical, biochemical and morphological examinations
- Causes of false negative results (size of the lesion, low metabolic rate, concomitant drug use interfering with the uptake, physiological uptake masking cancer lesions)
- Causes of false positive results [artefacts; sites of physiological uptake: muscular activity, myocardial uptake, uptake in the stomach and intestine; post-therapy uptake: bone marrow and spleen (after G-CSF), thymus (in young patients)]

Reporting

The nuclear medicine physician should record all information regarding the patient, type of examination, date, radiopharmaceutical (administered activity and route), any other drugs given to the patient (diuretics, benzodiazepines, etc.), concise patient history and reason for requesting the PET study.

The report for the referring physician should describe:

1. The procedure (scanning protocol, PET scanner used, image acquisition, area imaged, patient preparation, glucose levels and possible treatment such as hydration, furosemide etc.).
2. Findings [anatomical location of the lesion(s), uptake intensity, semiquantitative (or quantitative) values].
3. Comparative data (the findings should be correlated with previous information or results from other clinical or instrumental studies).
4. Interpretation: a clear diagnosis of benign/malignant lesion should be given if possible, accompanied by a differential diagnosis when appropriate. Comments on factors that may limit the accuracy of the PET examination are sometimes important (scanner resolution, size of the lesions, false positives, etc). If an additional diagnostic examination or adequate follow-up is required in order to reach a conclusive impression, this must be recommended.

Some sources of error

- Small size of the lesion
- Low metabolic rate of the tumour
- Local uptake masking cancer lesions
- Interfering cytostatic treatments that may decrease the tumour uptake of FDG
- Interfering medical treatment that increases the physiological uptake of FDG (GCSF stimulates bone marrow uptake)
- Artefacts, in particular if images are not corrected for photon attenuation
- Physiological uptake of FDG by the brain, myocardium and other muscles, kidney and urinary system, gastrointestinal tract and thymus (in young patients)
- Infectious/inflammatory processes (e.g. abscesses, TBC, sarcoidosis, active granulomatosis, thyroiditis)
- Post-surgery uptake (healing surgical wounds up to 8 weeks, scars, stoma, tube placement, etc.)
- Post-chemotherapy uptake (bone marrow or intestine)
- Post-radiotherapy uptake (active fibrosis, radiation pneumonitis)

Issues requiring further clarification

The clinical use of dual-head gamma cameras for coincidence detection is a matter of debate. The critical issues to be addressed include indications, limits and reliability in oncological diagnostics. The main question is: Can gamma cameras for coincidence detection be considered a reliable alternative to dedicated PET with full-ring BGO/LSO/GSO detectors? And if so, for which indications? The data from the literature show that the clinical and diagnostic efficacy of a dedicated PET scanner is superior to that of dual-head gamma cameras for coincidence, except for some limited regions/indications that still need to be extensively validated. This is the reason why in the USA it was decided no longer to reimburse scans made with such cameras.

Another point to be clarified is the position of PET scanning in the diagnostic work-up of cancer patients in comparison with the conventional diagnostic modalities (X-rays, CT, MRI, etc.). So far PET has been considered a second-choice examination to resolve diagnostic doubts arising from other information. In this respect the discussion should focus on the following question: Are there any indications in which PET scanning should precede the conventional morphological radiological examinations? There is a multitude of literature suggesting

that this answer will be yes, based on the superiority of PET over CT. The progressive use of the PET-CT systems in the diagnostic work-up will solve this problem, as both forms of information (functional and morphological) will be provided by the same hybrid machine.

Disclaimer

The European Association has written and approved guidelines to promote the use of nuclear medicine procedures with high quality. These general recommendations cannot be applied to all patients in all practice settings. The guidelines should not be deemed inclusive of all proper procedures and exclusive of other procedures reasonably directed to obtaining the same results. The spectrum of patients seen in a specialised practice setting may be different than the spectrum usually seen in a more general setting. The appropriateness of a procedure will depend in part on the prevalence of disease in the patient population. In addition, resources available for patient care may vary greatly from one European country or one medical facility to another. For these reasons, guidelines cannot be rigidly applied.

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