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Lecture series

PET CT physics - fundamental aspects

Radiation Protection in whole body PET CT for adult and childrens

Radiopharmaceutical aspects of the PET/CT tracers

PET/CT: Technique & Normal Physiology &Pitfalls in imaging

PET/CT Quantification – SUVmax

PET CT in Head and Neck tumour

PET CT in Neuroendocrine Tumours

PET CT in GIT malignancy

PET CT in soft tissue and musculoskeletal tumours

PET/CT interpretation – normal distribution

PET-CT: Oncology – general overview

Contrast enhanced CT in PETCT

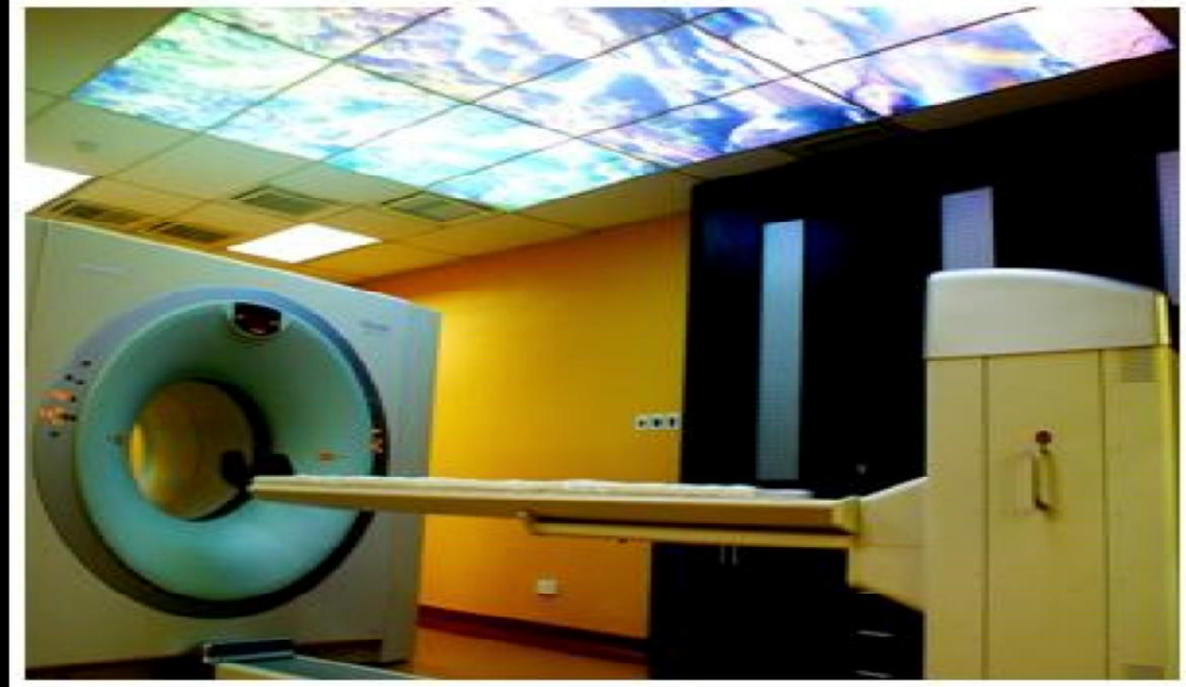
PET CT in Lymphoma and melanoma

PET CT in Lung Cancer

PET/CT: Breast carcinoma

PET-CT: in infections and Inflammation

Centre for Diagnostic Nuclear Imaging



An overview

PET-CT Training Course

SYNOPSIS OF THE LECTURES

The general aspects of PET-CT

Positron Emission Tomography/Computed Tomography (PET/CT) fusion imaging is a novel multimodality technology that allows the correlation offindings from two concurrent imaging modalities in a comprehensive examination. As altered glucose metabolism is characteristic for many malignancies, FDG-PET is mostly used in oncology for staging and therapy monitoring. It can also be seen as a physiologic activity in the bowel or muscles, in benign disease such as inflammation or post-traumatic reactive changes, or simply represent artefactual uptake from inaccurate CT attenuation correction in dense objects, often mistaken for cancer. The experienced PET/CT reader mostly manages to differentiate malignant from non-malignant FDG uptake based on accurate interpretation of the PET data by correlating with the CT anatomic information. Quantitative evaluation of FDG PET images

provides quantitative data in the form of the standardized uptake value (SUV) . This is an uptake measurement that provides a mean of comparison of FDG uptake between different lesions. Measurement of SUV requires attenuation correction to avoid the variability in FDG uptake due to the differences in tumor habitus within the body. This value normalizes the tumor FDG uptake with the FDG injected activity and the body weight . The cut-off value of 2.5 in differentiating malignant to benign is at large limited due to varied tumour histological characteristic in malignant tumor

The radiopharmaceutical aspects

Management of PET radiopharmaceuticals production covers (i) production of radioactive isotope ("radionuclide") from cyclotron, and (ii) synthesis of radionuclide labeled with a biologically active molecule and quality assurance of the PET radiopharmaceuticals injection.

As most of the PET radiopharmaceuticals are injectable solution, the raw materials and equipment used are maintained at sterile level. [^{18}F]FDG is the ubiquitous PET radiopharmaceuticals for oncology and in some applications, neurology.

Recently, other radiopharmaceuticals tracers such as 18F-FLT, 18F-FCH, 11C-Met and etc are developed to suit other clinical application. As the numbers of cancer patients are growing and also apply to other discipline, PET radiopharmaceuticals also expand. However, due to its moderately short half-live (i.e 18F-fluorine ~ 109.7 minutes, 11C-met ~ 20 minutes) the presence of small to medium cyclotron on site is needed. Otherwise, a lot of activity would only be wasted on road during transportation if the transportation is not very reliable. Another point to consider, due to radioactivity of PET radiopharmaceuticals produced in bulk, this will limit the completion of quality control test, namely; sterility test, pyrogen test (or also known as bacterial endotoxin test) and membrane filter integrity test. Those mentioned tests can only be performed when the level of activity is deemed safe, which normally after 24 to 36 hours of production. This mean, sterility and pyrogen are compromised when the PET radiopharmaceutical is administered to the patient. In spite of limitations that being listed, PET radiopharmaceuticals is applied mainly in the clinical areas of cardiology, neurology and oncology, with the latter accounting for about 90% of all PET. This is due to its efficiency to track the in-vivo metabolism at the receptor and molecular level for virtually any biological process.

The fundamental physics and radiation protection

Positron Emission Tomography (PET) facilitates the evaluation of metabolic and molecular characteristics of wide variety of cancers and is limited in the ability to visualize anatomical structures. Computed Tomography (CT) facilitates the evaluation of anatomical structures of cancers without the ability to visualize their metabolic and molecular aspects.

The combination of PET and CT (PET/CT) however, provide the ability to accurately register metabolic and molecular aspects of disease with anatomical findings. It will further add information to the diagnosis and staging of tumors. Since the introduction of PET/CT into the clinical arena in 2001, all commercial designs consist of a CT scanner placed in tandem with a PET scanner. The CT scanner is positioned to the front, closest to the patient couch, and the PET scanner is positioned to the rear. In some designs, the CT and PET are placed as close together as possible and a single gantry cover over both systems creates the impression of a fully integrated device. An alternative, more open design adopted intentionally keeps the two systems physically separated allowing access to the patient inside the tunnel. The combination of PET and CT is a well-established tool for adult medical imaging and has proven value for many sub-discipline including oncology, cardiology, and neurology. As the availability of these dual-modality systems increases, PET/CT is of growing importance in pediatric imaging—particularly for cancer detection, staging, therapeutic response monitoring, and outcome prediction. Whole-body PET/CT scanning is accompanied by substantial radiation dose and cancer risk. Thus, examinations should be clinically justified, and measures should be taken to reduce the dose. Adult PET/CT protocols should be appropriately modified for application to the pediatric population.

PET CT in malignancy

Positron emission tomography (PET) is being increasingly used for diagnosis, staging, and follow-up of various malignancies. It has been studied in the evaluation of various tumors including but not limited to solitary pulmonary nodules, non–small cell lung carcinoma, lymphoma, melanoma, breast cancer, and colorectal cancer. Computed tomography (CT) and magnetic resonance (MR) imaging rely on anatomic changes for diagnosis, staging, and follow-up of cancer. However, PET has the ability to demonstrate abnormal metabolic activity (at the molecular level) in organs that as yet do not show an abnormal appearance based on morphologic criteria. It aids in differentiation of malignant from benign lesions and in staging of malignancies. PET is also useful in the follow-up of patients following chemotherapy or surgical resection of tumor, most of whom have a complicating appearance at CT or MR imaging due to postoperative changes or scar tissue. In certain situations, it may be impossible to accurately localize an area of increased activity on PET images alone due to the absence of identifiable anatomic structures, particularly in the abdomen

PET imaging has emerged in recent years and is a sensitive technique in detecting clinically occult metastatic disease, retropharyngeal lymph nodes or small volume lesions of the head and neck tumour. The technique works on the premise that cancer cells are more metabolically active, have a higher rate of glucose metabolism, with concomitant increased glucose uptake. Nonetheless, the superiority of pet/ct to whole-body MRI in overall TNM staging supports the usefulness of 18F-FDG PET-CT as a possible first-line modality for whole-body tumor staging. the n stage was found to be prognostically significant even among patient groups stratified for the size and degree of fixation of the neck nodes involved .the SUV is not associated with the clinical staging of NPC, but is correlated to the t staging of NPC. though irrelevant to the n staging of NPC, the SUV is correlated to the size of the lymph nodes, and also related to the degree of differentiation of NPC.

Multimodality imaging PET- CT using FDG as biotracer is known to be more accurate than the conventional nuclear medicine technique in identifying lymphomatous and melanomatous extension. Its integration with multi detector CT further improved the accuracy of this technique in delineating lymphomatous infiltrates across the diaphragm . Image acquisition covering extended field of view avoid unnecessary additional studies

^{18}F-FDG PET has shown promising results in assessing response to therapy and tumour control and in prognosis in GIT cancer. Among these, assessment of early response to therapy has gained importance because it implies clinical consequences in the diagnostic management of patients. So far, almost all published studies on assessing therapy response in gastric cancer have been performed with ^{18}F-FDG PET. With the advent of PET/CT, which allows one to combine the structural information provided by helical CT with molecular imaging by PET, an almost simultaneous assessment of tumor morphology and metabolism over time has become possible . Moreover, PET/CT, by combining volumetric and metabolic measurements, may be even more accurate for assessing histopathologic tumour response in patients with advanced GIT cancer.

Pheochromocytomas are also referred to as adrenal paragangliomas. Paragangliomas originate from the neural crest-derived paraganglia of the autonomic nervous system. These tumors originate from catecholamine-producing chromaffin cells. The increased glucose uptake imaged with Flurodeoxyglucose Positron Emission Tomography (FDG PET) is largely dependent on the rate of glycolysis. FDG uptake and trapping occurs because of upregulation of glucose transporters (notably GLUT1 and GLUT3) and HEXOKINASES I and II . FDG PET imaging also allows quantification of glucose uptake. It is known that in many studies, poor disease prognosis is consistently correlated with increased tumour inherent increased glucose uptake in tumours