Inner Spaces
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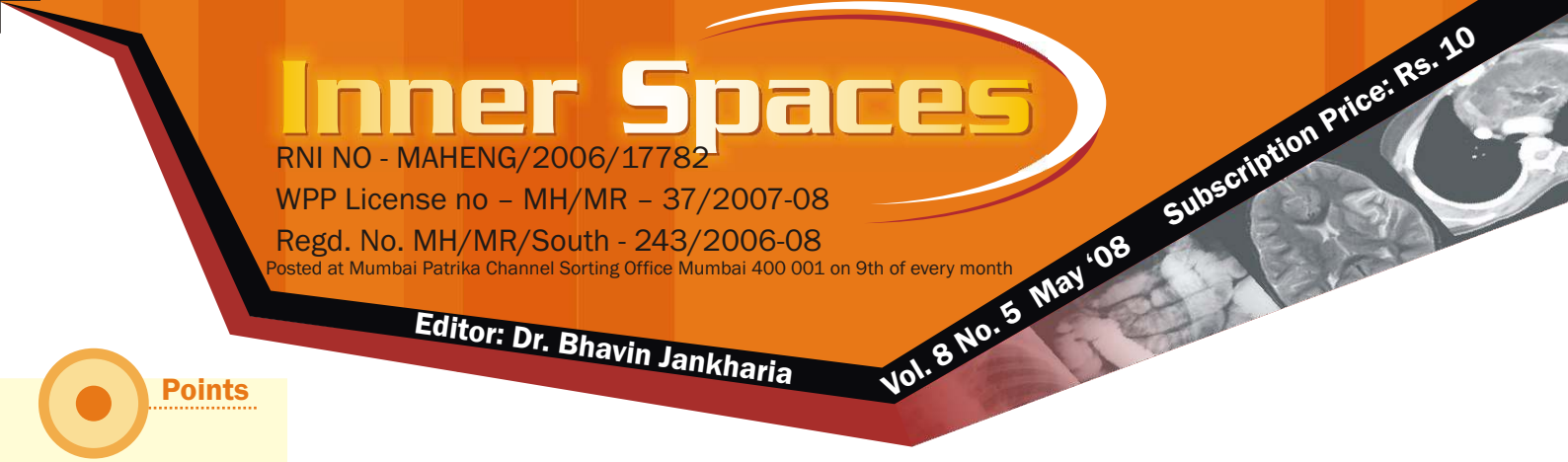

Points

- Functional and molecular imaging is as important as anatomic structural imaging
- PET using FDG is currently the most sensitive method for functional / molecular imaging in oncology
- PET/CT uses the advantages of PET and CT together to give more accurate information
- PET/CT is now useful across the entire spectrum on oncology indications; diagnosis of cancer, staging, guiding biopsies and treatment, assessing response to treatment, differentiating residual tumor from fibrosis and evaluation of recurrent tumor

PET/CT in Oncology

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Imaging plays an increasing role in the care of cancer patients. Anatomic imaging modalities, such as plain radiographs, CT scan and MRI are commonly used to detect and localize cancer, where tumors are recognized and followed based on their density, shape, size, and location. More recently, a new method called 'Positron Emission Tomography' (PET) has been established. It is a functional, biochemical, and molecular imaging method, which is complementary to anatomic imaging and is proving effective in guiding the care of cancer patients.

PET has the unique ability to assess the functional and biochemical processes of the body's tissues, which are altered in the earliest stages of virtually all diseases. PET detects these changes often before anatomical or structural changes have occurred or are evident on MRI or CT.

PET has been used extensively to study cellular metabolism in the brain, heart and malignant tumors. A PET scan is considered particularly effective in evaluating cancer. It is a useful tool for identifying if cancer is present, if it is spreading, if it is responding to treatment and if a person is cancer free after treatment.

There are several radiopharmaceuticals used in PET, but the most commonly used is 18F Fluorodeoxyglucose (FDG), which is an analogue of glucose labeled with 18F. FDG has been called the 'molecule of the millennium'. The radionuclide 18F is a cyclotron produced positron emitter with a half-life (T1/2) of approximately 110 minutes.

Cancer cells require a great deal of sugar or glucose to have enough energy to grow. PET scanning utilizes the radioactive molecule FDG, which is similar to glucose. It is transported from the plasma into the cells by glucose transporters and then converted to FDG-6-phosphate, which remains metabolically trapped within the cell. This trapping phenomenon is exploited for FDG-PET imaging. The radiation emitted from the body is then detected by the specialized detectors of the PET scanner. Cancerous tissue, which uses more glucose than normal tissue, will accumulate more of the tracer and appear brighter than normal tissue on the PET images, showing metabolic "hot spots".

PET/CT offers the dual benefits of PET's metabolic information with the anatomical precision of CT. The two techniques present different types of information about the human body. Taking the two scans virtually simultaneously ensures that the patient remains in place and, therefore, that the two images form a precise computer overlay that the tumor "hot spot" on the PET scan corresponds directly to the physical mass on the CT scan. This fused image provides a more reliable alternative to the traditional side-by-side visual comparison of PET and CT images. PET/CT also eliminates the common problem of a delay between the two

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studies, during which time the patient's condition may change.

Oncologic indications for 18F-FDG-PET/CT include but are not limited to the following:

A. Differentiating benign from malignant lesions (Fig. 1)

B. Searching for an unknown primary tumor when metastatic disease is discovered as the first manifestation of cancer or when the patient presents with a paraneoplastic syndrome

C. Staging known malignancies (Fig. 2)

D. Monitoring the effect of therapy on known malignancies

E. Determining whether residual abnormalities detected on physical examination or on other imaging studies after treatment, represent tumor or post-treatment fibrosis or necrosis

F. Detecting tumor recurrence, especially in the presence of elevated levels of tumor markers (Fig. 3)

G. Selecting the region of a tumor most likely to yield diagnostic information for biopsy (Fig. 4)

H. Guiding radiation therapy planning

The US FDA has approved the use of PET in the diagnosis, staging and restaging of non-small cell lung cancer, head & neck cancer, esophageal cancer, colorectal cancer, melanoma, lymphoma; initial staging of cervical cancer; staging & restaging of breast cancer; for characterization of solitary pulmonary nodule; in thyroid cancer when iodine scan is negative and serum thymoglobulin levels are high; and for diagnosis in unknown primary cancers. PET is also being used in other cancers like brain tumor, GIST (gastro-intestinal stromal tumor), ovarian cancer, sarcoma, uterine cancer, hepatocellular cancer, pancreatic cancer, cholangiocarcinoma, testicular cancer and small cell lung cancer.

PET/CT imaging has rapidly emerged as an important imaging tool in oncology. The success of PET/CT imaging is based on several features. First, patients benefit from a comprehensive diagnostic anatomical and functional (molecular) whole-body survey in a single session. Second, PET/CT provides more-accurate diagnostic information than PET or CT alone. Third, PET/CT imaging allows radiation oncologists to use the functional information provided by PET scans for radiation treatment planning.

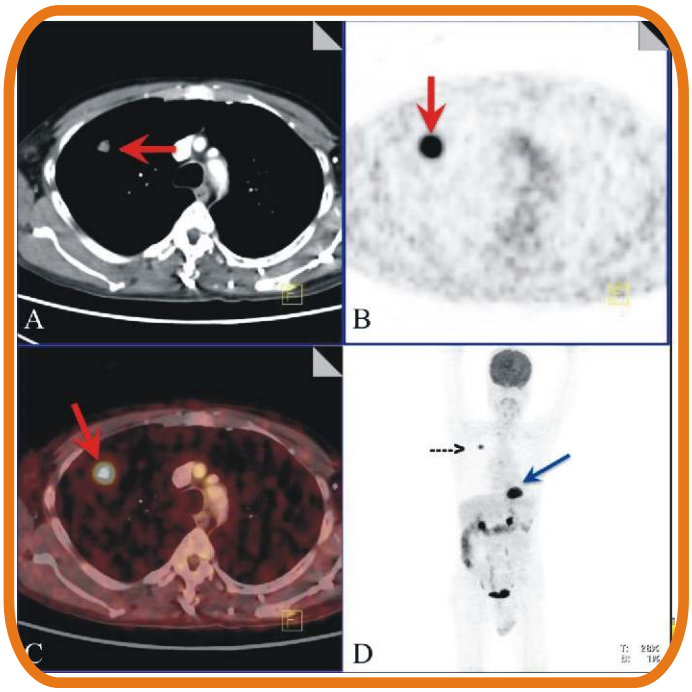

Fig. 1

Fig. 1: Metastasis from bronchogenic carcinoma. This patient has a proven large cell carcinoma of the left lower lobe (blue arrow in D). An earlier contrast-enhanced CT scan had shown a mildly enhancing nodule in the right upper lobe (red arrow) and it was not clear whether this was benign or malignant. The PET and PET/CT images clearly show markedly increased activity (SUV 10.4), clearly suggestive of a malignant tumor (red arrows in B and C), most likely representing metastasis from the left lower lobe mass.

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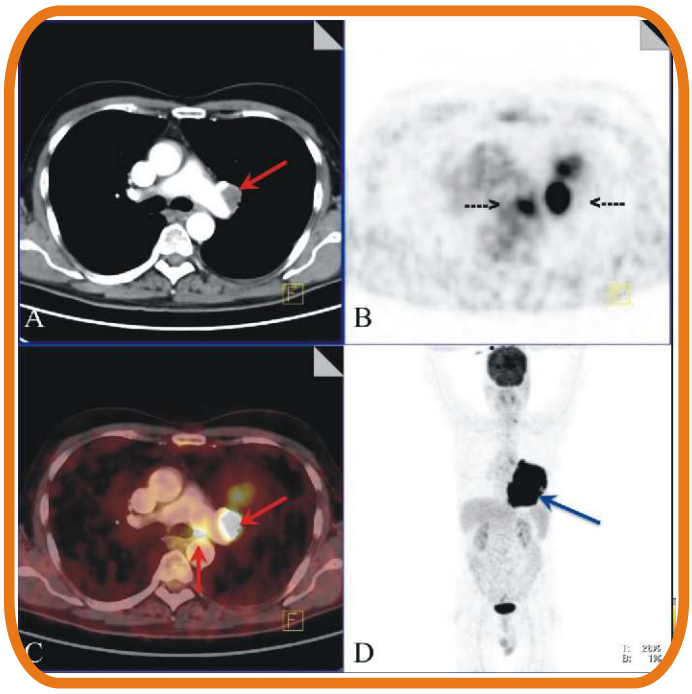

Fig. 2

Fig. 2: Staging of lung cancer. A large squamous cell carcinoma is seen in the left lower lobe (blue arrow in D). This patient has ipsilateral left hilar lymphadenopathy (red arrows in A & C and black arrows in B) showing significant uptake (SUV 8), suggestive of metastatic disease. Since this qualifies as N1 disease, this patient may be a candidate for surgery. There is no other evidence of abnormal uptake throughout the body.

Fig. 3: Recurrent buccal carcinoma. This patient had a history of buccal carcinoma, for which a hemi-mandibulectomy was performed. The patient came with an ulcer in the flap, which shows marked uptake (red arrows in B & C), in an ulcerated soft tissue lesion (red arrow in A). The coronal MP shows that there is no uptake in the lymph nodes and the CT scan also did not show lymphadenopathy.

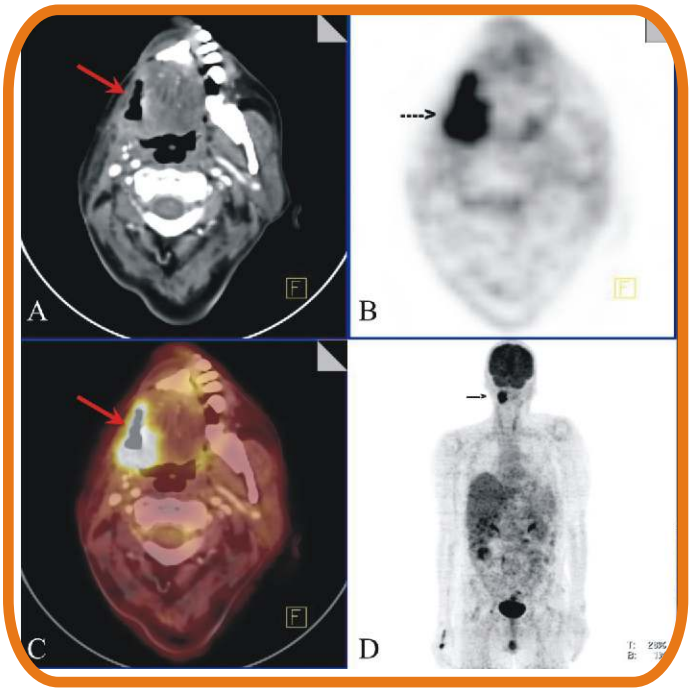

Fig. 3

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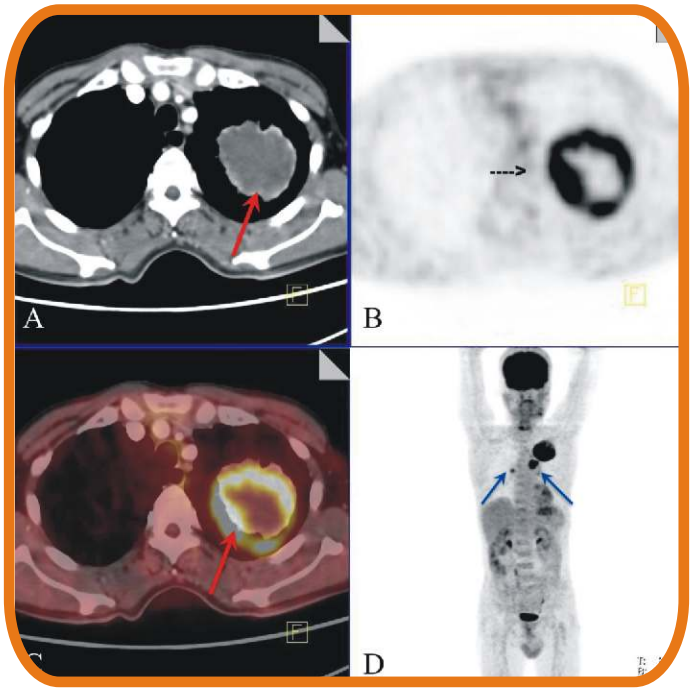

Fig. 4: Necrotic malignancy for biopsy. A large necrotic mass is seen in the left upper lobe (red arrow in A). This shows uptake only in the periphery (black arrow in B, red arrow in C). A biopsy was therefore performed only from the periphery to ensure that diagnostic material was obtained. The diagnosis was squamous cell carcinoma. Ipsilateral and contralateral metastatic lymph nodes are seen (blue arrows in D).

Fig. 4

Numerous studies have evaluated the use of FDG-PET for monitoring tumor response to chemotherapy and radiotherapy. These studies have shown that residual FDG uptake after completion of therapy is a strong predictor of patient survival in malignant lymphomas and several solid tumors. Studies have also indicated that in responding tumors, FDG uptake decreases markedly within the first chemotherapy cycle (i.e. 34 weeks after the start of therapy). Conversely, the absence of a measurable decrease in tumor FDG uptake after the first chemotherapy cycle has been found to predict lack of tumor shrinkage and poor patient survival. This result suggests that FDG-PET could be used to identify nonresponsive tumors early in the course of therapy, and to adjust treatment regimens according to the individual chemosensitivity and radiosensitivity of the tumor tissue.

Traditionally, treatment planning in radiation oncology has been based on the results of CT and MRI. PET has the potential to delineate gross tumor volume (GTV) with a higher accuracy with reduced interobserver variability.

PET/CT provides multiple exciting new opportunities to integrate functional and morphological information for tumor staging, radiation treatment planning and monitoring of tumor response to therapy. Most importantly, however, PET/CT imaging greatly facilitates the integration of PET in clinical practice and medical research.

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