CHAPTER 225

Nuclear Medicine as a Problem Solver in Diagnosis and Therapy

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Nuclear medicine is the modality which uses radioisotopes to study the function of different organs of the body. Radiolabeled compounds which can trace metabolic pathways, enzyme functions, receptors, perfusion etc. are injected into the body and with the help of special equipment called gamma cameras the passage of tracer in the body is imaged. Important information about normal and altered physiological functions in health and disease are obtained with this technique. 2 technologies; SPECT or Single Photon Emission Computed Tomography, nowadays combined with a CT scanner (SPECT-CT) and PET-CT or Positron Emission Tomography combined with CT are routinely available. PET-CT uses very short lived isotopes of 11C, 13N, 14O,18F produced in a cyclotron and labelled with various compounds to give quantitative information about body processes. Combination of physiological information and anatomical structural information make SPECT-CT and PET-CT very powerful tools in diagnosis and management of various diseases.

Nuclear scans, both SPECT and PET-CT are invaluable in management of several diseases and many times act as problem solvers in difficult diagnostic situations. Nuclear medicine is also increasingly used in the therapeutic arena, with successful therapies with radioisotopes available for many diseases.

Tables 1, 2 & 3 summarize the diagnostic utilities of SPECT, PET-CT and Therapy respectively.

Specific examples of clinical situations helped by Nuclear medicine are also discussed later.

CASE EXAMPLES

Case 1

21 yr. old male presented with history of palpitations and weight loss. T3, T4 raised. TSH low. An isotope thyroid scan was asked for to confirm Graves' disease.

Isotope scan showing absent tracer uptake in the thyroid gland with normal uptake in the salivary glands. Diagnosis of Graves' disease was excluded and Thyroiditis was diagnosed, changing the management completely (Figure 1).

Case 2

A 35 yr. old female presented with history of irritability, nervousness, weight loss and reduced appetite. T3, T4 elevated, low TSH. Isotope scan was advised:

Isotope scan with 99mTc-pertechnetate scan showing increased intense uptake in the Thyroid gland with no uptake in the salivary glands, conforming diagnosis of Graves' disease (Figure 2).

In 10% of cases of thyrotoxicosis, what clinically appears as Graves' disease may turn out to be thyroiditis. A thyroid scan is very valuable in making the correct diagnosis and planning therapy.

Case 3

77 yr. old male patient presented with slowness in movement and imbalance since 2 months. Parkinsonism was suspected and a TRODAT scan was asked for (Figure 3). ^{99m}Tc-TRODAT scan showed normal uptake of tracer in both caudate nuclei and both putamen excluding Parkinson's disease. In Parkinson's disease there is deficiency of Dopamine in the dopaminergic neurons projecting to the caudate nuclei and putamina. There is also deficiency of the presynaptic dopamine transporter (imaged by TRODAT scan). This scan shows asymmetrical reduction in dopamine transporter in the putamen opposite to the involved limb with tremor or rigidity in Parkinson's disease and will be normal in essential tremor and drug induced parkinsonism.

Case 4

50 yr. old male on antipsychotic medication demonstrated clinical features of parkinsonism. The clinical question was whether he had Parkinson's disease or was manifesting drug effects. A TRODAT scan was asked for which clearly showed deficient uptake in the left putamen, confirming dopaminergic deficit and excluding diagnosis of drug induced parkinsonism (Figure 4).

Case 5

22 yr. old male presented with cough and weight loss. X-ray chest showed lung lesions. A PET-CT was asked for. It showed extensive lung metastases and abdominal lymph nodal metastases. A careful review of images showed a small testicular lesion which was picking up the isotope (Figure 5). A diagnosis of testicular cancer with lung and nodal metastases was made, confirmed on orchiectomy. On chemotherapy there was good response with disappearance of all metastatic lesions.

This case demonstrates the utility of FDG PET-CT in detection of occult malignancy, staging of malignancy and demonstrating response to treatment.

Transaxial (left and middle column) and MIP (right column) images of whole body PET-CT with ^{18}F-FDG. Upper row shows fused PET-CT images, lower row CT images.

Table 1: Utility of SPECT, SPECT-CT

Radiopharmaceutical	Clinical situation	Information obtained
	Nervous system	
^{99m}Tc-ECD	Memory loss	Presence of Alzheimer's disease vs Fronto temporal degeneration
	Temporal lobe epilepsy	Localization of seizure focus
^{99m}Tc-TRODAT	Parkinsonism	Diagnosis of dopaminergic deficit. Differentiate Parkinson's disease from essential tremor and drug induced Parkinsonism
	Thyroid and parathyroid	
^{99m}Tc-pertechnetate	Thyrotoxicosis	Differentiate between Graves' disease and thyroiditis. Diagnose autonomous toxic nodule
^{99m}Tc-MIBI	Hyperparathyroidism	Localize parathyroid adenoma
	Heart	
^{99m}Tc-Tetrofosmin/MIBI	Ischemic heart disease	Diagnose myocardial ischemia, extent and severity Physiological significance of angiographic coronary stenosis Gatekeeper function to decide medical management vs intervention (angioplasty/bypass surgery)
	Lung	
^{99m}Tc-MAA	Pulmonary embolism	Exclude pulmonary embolism in dyspneic patient
	Gastrointestinal system	
^{99m}Tc-Sulfur colloid	Gastroparesis	Measurement of gastric emptying times in patients with bloated sensation, diabetics
	Gastro esophageal reflux (GER)	Document presence of GER And response to therapy
^{99m}Tc-labelled RBCs	Occult GI bleeding	Identify site of gastrointestinal bleeding
	Kidneys	
^{99m}Tc-EC/DTPA/DMSA	Hydronephrosis/hydroureter	Diagnose /exclude obstructive uropathy
	Renal failure	Document accurate GFR Renal donor evaluation
	Transplant	Diagnose Acute tubular necrosis, rejection, urinoma, lymphocele
	Urinary infection	Diagnose cortical scarring
	Hypertension	Diagnose physiologically significant renal artery stenosis
	Musculoskeletal system	
^{99m}Tc-MDP	Bone pain	Diagnose stress fracture, metastases, metabolic bone disease, osteomyelitis
	Joint pains	Diagnose joint inflammation
	Lymphatic system	
^{99m}Tc-sulfur colloid	Lymphedema	Confirm lymphatic obstruction as cause for limb edema
	Sentinel node in breast cancer	Identify sentinel node in stage 1 breast cancer
	Hepatobiliary system	
^{99m}Tc-Mebrofenin	Upper abdominal pain	Gall bladder ejection fraction, sphincter of oddi dysfunction, acute cholecystitis, biliary atresia Document predicted
	Future remnant liver function	remnant liver function in planned hepatic resections for tumors and transplants

Table 2: Utility of PET-CT

Radiopharmaceutical	Clinical situation	Information obtained
	Oncology	
^{18}F-FDG	Occult malignancy	Detect occult cancer
^{18}F-FLT	Staging of cancer	Map out extent of cancer
^{18}F-FET	Detection of recurrence	Detect relapse/recurrence
	Response to therapy	PERCIST criteria for metabolic response to chemotherapy
	Recurrence vs necrosis/edema	Differentiate recurrence from response to therapy
^{68}Ga-DOTATATE	Neuroendocrine tumors	Gold standard scan for diagnosing neuroendocrine tumors (carcinoids, pheochromocytomas, insulinomas, gastrinomas etc.) Response to therapy, recurrence
^{68}Ga-PSMA	Prostate cancer	Diagnosis of prostate cancer in patients with elevated PSA Staging of prostate cancer Detection of recurrence Response to therapy
	Neurology	
^{18}F-FDG	Dementia	Differentiate Alzheimer's disease from other dementias Parkinson's plus syndromes (Progressive Supranuclear Palsy, Multi System Atrophy, Cortico Basal Degeneration)
	Paraneoplastic syndromes	Detection of occult malignancy as cause of paraneoplastic syndromes
^{18}F-FET (Fluoro Ethyl Tyrosine)	Tumors	Detection of recurrence of brain tumors after therapy
	Cardiology	
^{13}N-Ammonia ^{82}Rubidium	Ischemic heart disease	Absolute myocardial flow quantification Coronary flow reserve estimation
^{18}F-FDG	Myocardial viability	Detecting viable myocardium in patients with low LEVF post myocardial infarction
	Myocardial sarcoidosis	Detection of active myocardial sarcoidosis
	Fever of Unknown Origin	
^{18}F-FDG	Investigation of choice in prolonged fevers	Focus of occult infection, infection or neoplasm

There are extensive metastatic lesions in the lungs along with metastatic abdominal lymphadenopathy. A small focus of neoplasm is seen in the right testicle.

Pre and post orchiectomy and chemotherapy MIP images showing complete resolution of metastatic disease indicating successful therapy (Figure 6).

Case 6

A 55 yr. old male with hypertension, dyslipidemia and strong family history of ischemic heart disease suffered myocardial infarct in January 2011. He underwent coronary bypass surgery post infarction with arterial revascularization (LIMA to LAD, radial to OM-PDA). He presented in a year post bypass with angina and dyspnea. A myocardial perfusion scan with ^{99m}Tc-Tetrofosmin was performed (Figure 7).

Myocardial perfusion images in short axis (upper 4 rows from apex to base of heart. Upper row: stress images,

Table 3: Utility in therapy

Radiopharmaceutical	Clinical situation	Utility
^{131}Iodine	Thyrotoxicosis (Graves' disease, Autonomous Functioning Toxic Nodule)	Effective ablation of toxic thyroid gland. High cure rate
	Thyroid cancer	Post thyroidectomy remnant ablation, metastatic disease ablation
^{177}Lu- DOTATATE	Metastatic neuroendocrine cancer	Effective arrest or regression of disease in 80% of patients
^{177}Lu-PSMA	Metastatic prostate cancer	Powerful potential therapy in castrate and chemotherapy resistant metastatic disease
^{153}Samarium, ^{89}Strontium	Painful skeletal metastases	Effective, lasting relief of metastatic bone pain
^{90}Yttrium-theraspheres/sirspheres	Metastatic hepatic disease	Effective reduction in tumor burden in hepatic metastases
^{131}Iodine-Lipiodol, ^{188}Rhenium Lipiodol	Metastatic hepatic disease	Effective reduction in tumor burden in hepatic metastases
^{90}Yttrium,^{188}Rhenium,^{169}Erbium, ^{166}Holmium	Painful joints	Effective radio synovectomy with pain relief

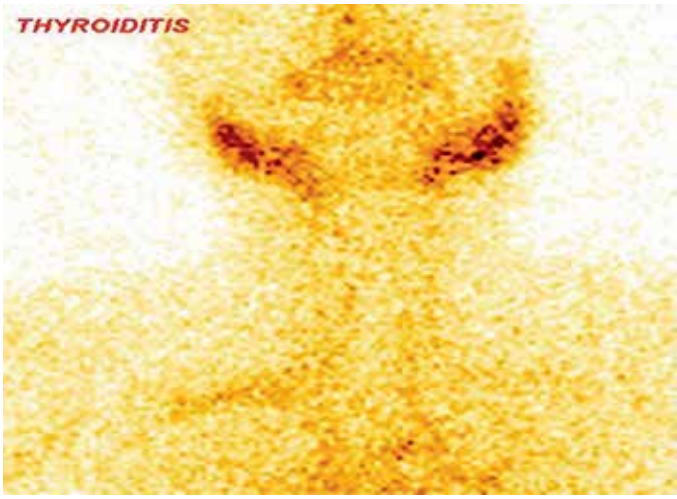

Fig. 1

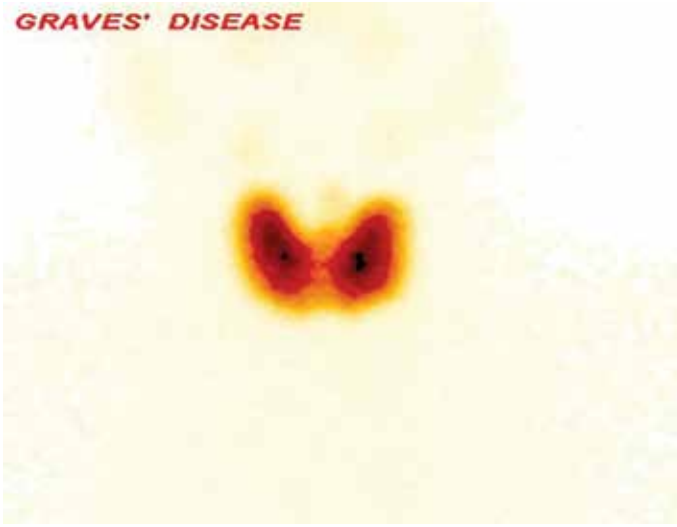

Fig. 2

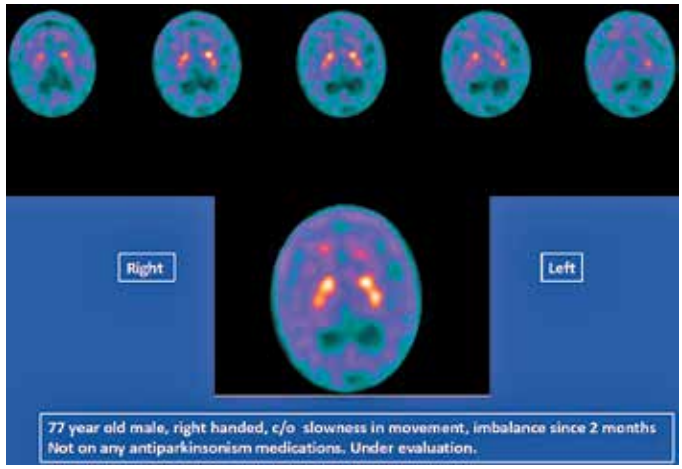

Fig. 3

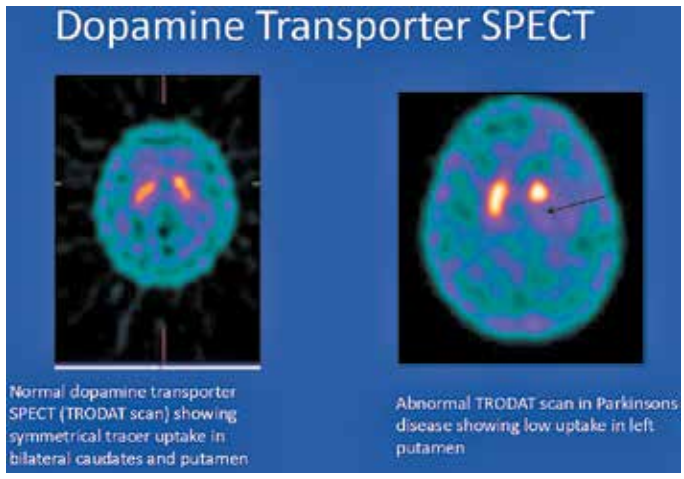

Fig. 4

following row: rest images.), row 5,6 vertical long axis slices from septum (left) to lateral wall (right) (row 5 post stress, row 6, resting) row 7,8 horizontal long axis slices from inferior wall to anterior wall.

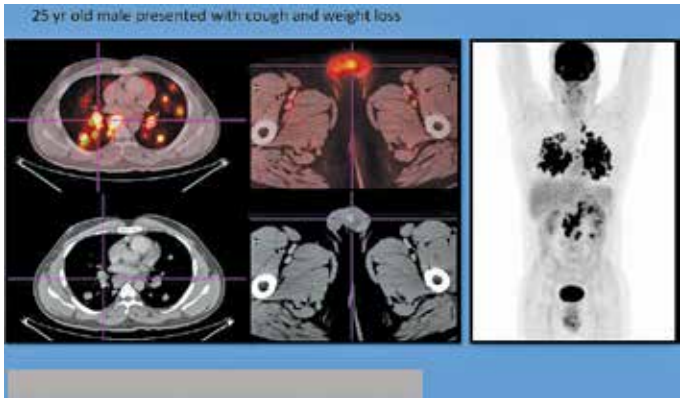

Fig. 5

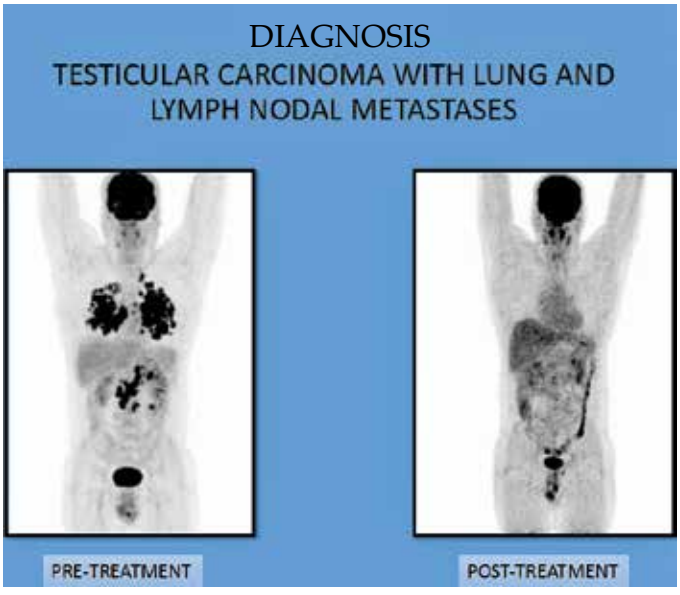

Fig. 6

Images show significant global hypoperfusion on stress images, with stress induced left ventricular dilatation and right ventricular uptake, with complete normalization on resting images. These findings indicate a "high risk scan" pattern. Angiography was advised which showed left main ostial stenosis and a right coronary artery ostial stenosis with graft occlusion.

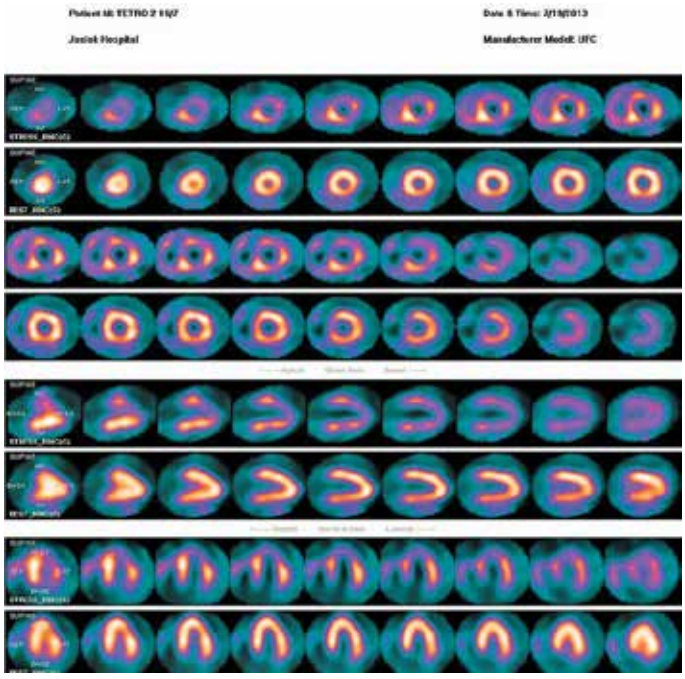

Fig. 7

Myocardial perfusion imaging is vital to 1) diagnose myocardial ischemia 2) document extent and severity of ischemia, 3) to risk stratify patients into those who should be managed medically (low to intermediate risk scan pattern) and those who should undergo interventional revascularization (high risk scan pattern).

In conclusion, Nuclear medicine is an invaluable tool in diagnosis and management of several conditions enumerated in the above tables and illustrative cases.

REFERENCES

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