FUNCTIONAL BRAIN IMAGING

Uma Ravishankar, N.Savita, M.U.Siddique, Surbhi Pande
Department of Nuclear Medicine
Indraprastha Apollo Hospitals, Sarita Vihar, Mathura Road, New Delhi –110076 India.

Abstract : *Neuronuclear imaging with SPECT and PET enables non-invasive evaluation and quantification of local tissue functions like regional cerebral blood flow, metabolism, receptor binding status and neurotransmission processes. SPECT and PET imaging therefore, is rapidly finding a place in routine diagnostic work up and management of a host of neurological and psychiatric disorders like epilepsy, neurodegenerative disorders, cereberovascular disease , movement disorders, malignant brain tumors, obsessive–compulsive disorder, schizophrenia, depression, panic disorder, and drug abuse. Potential of PET in radiotherapy treatment planning, neuropharmacology, and drug development also holds a lot of promise.*
Key words: *Brain SPECT, PET, epilepsy, neurodegenerative disorders, neuroreceptor imaging*

INTRODUCTION

Neuroimaging provides a direct window in to the brain's structure and functioning. Structural imaging techniques, such as CT and routine MRI, are used primarily to evaluate anatomy, providing a highly detailed but structural imaging of brain structure. Functional brain imaging techniques such as single emission computed tomography (SPECT) and positron emission tomography (PET), provide dynamic picture of the brain functioning i.e. metabolism and blood flow, chemistry and neurotransmission processes. While structural imaging techniques are very helpful in identifying gross changes in brain structure, functional imaging technique allows us to appreciate the working physiology of the brain[1].

PET studies have confirmed that regional cerebral blood flow changes are generally coupled with changes in regional brain metabolism. Decreased metabolic activity results in hypoperfusion, whereas increased metabolic activity results in hyperperfusion. Although hypoperfusion may occur as a result of vascular changes, functional brain imaging is particularly valuable for neuropsychiatrician for its ability to detect changes in perfusion that are secondary to metabolic changes. In comparison to PET scanning, SPECT scanning is about 3-4 times less expensive, is more widely available, and with the more recent scanner is able to provide spatial resolution images of 6-9 mm –closely approaching the 4-6 mm resolution of PET studies.

SPECT scanners typically use a rotating gamma camera gantry with one to three detector heads. The imaging data are subsequently reconstructed and reoriented in three orthogonal (coronal, sagittal and transaxial) image planes.

CLINICAL APPLICATIONS OF FUNCTIONAL BRAIN IMAGING

These methods have increasingly been employed in the diagnosis and management of many neurological conditions such as epilepsy, neurodegenerative disorders, cereberovascular disease, movement disorders, malignant brain tumors, obsessive–compulsive disorder, schizophrenia, depression, panic disorder, and drug abuse.

SEIZURE DISORDERS

SPECT brain scans can study perfusion in epilepsy patients , particularly those with focal epilepsy emanating from the medial temporal lobes and producing complex partial seizures. Ictal, postictal and interictal studies allow identifying focuses of epileptic discharges that increase cerebral perfusion during seizure and reduce perfusion postictally and interictally. These studies are used as preoperative investigations and have become important adjunct to clinical and electrophysiological evaluation of patients with epilepsy who are surgical candidates.F-18 FDG PET can localizes epileptic foci as areas of hypometabolism interracially.[3]

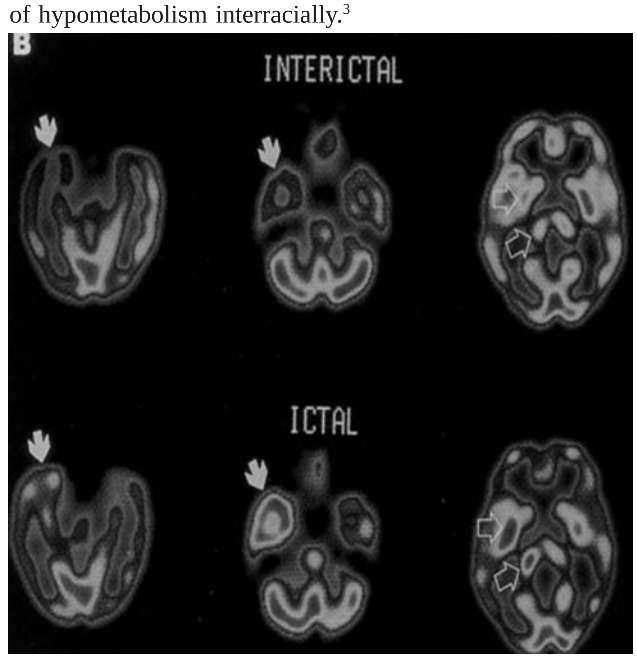


Fig1: *Coronal view of ictal brain SPECT in a patient with complex partial seizures showing hyperperfusion in right temporal lobe..*

Correspondence: **Dr. Uma Ravi Shankar**
e-mail: umaravi@vsnl.com

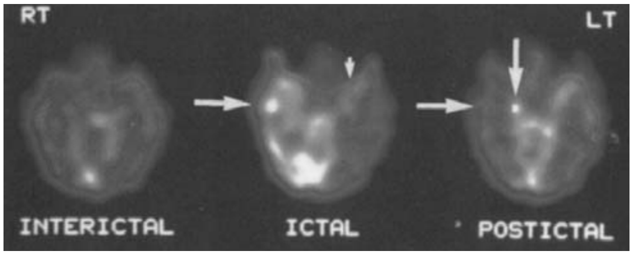


Fig 2: *Coronal views depicting change in regional blood flow during ictal, inter ictal and post ictal phases.*

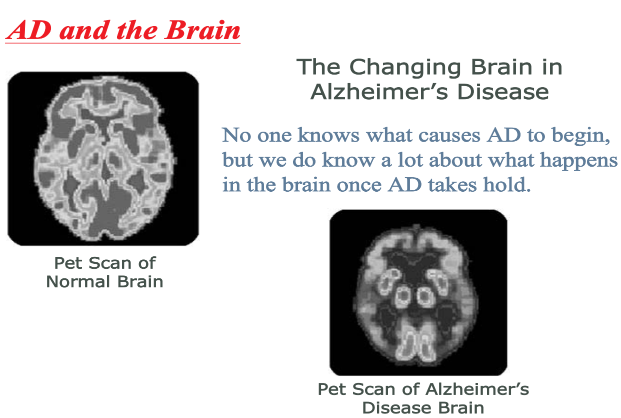
DEMENTIA

SPECT and F-18 FDG PET imaging has shown clinical utility in the differential diagnosis and early detection before onset of clinical deterioration.

Alzheimer's disease is now recognized as a common cause of dementia. AD has characteristic pathological findings. Abnormal tangles of nerve fibers and degenerative neurotic plaques are seen. The patient's degree of dysfunction is related to the number of these abnormal cortical structures.

The classical scintigraphic pattern for AD on SPECT perfusion imaging is bilateral posterior temporal and parietal hypoperfusion. The area of reduced perfusion is secondary to reduced brain metabolism in areas of neuronal depletion. With severe disease, frontal lobe hypoperfusion is seen as well[4].

Fronto-temporal dementia patients generally tend to show bilateral frontal and bilateral temporal lobes glucose hypometabolism.Vascular dementia tends to result in symmetric and focal areas of hypometabolism . In Picks disease most common PET findings is bilateral frontal and anterior temporal hypometabolism.[5]



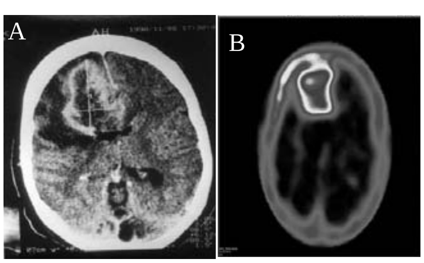


Figure 3 *A. Coronal section of frontal glioblastoma multiforme showing contrast enhancement in CT. B. Corresponding SPECT slice of the same patient showing avid* ^{99m}*TC-GHA concentration*

BRAIN TUMORS

Primary brain tumors constitute about 10% of all tumors. SPECT studies with Tl-201 and Tc-GHA are useful in determining tumor viability and differentiating recurrence/ residual tumour from post radiation fibrosis and tumour necrosis. Tumor cells of higher histological grades, because of their increased mitotic activity, exhibit increased metabolism in comparison with normal brain tissue. FDG-PET thus provides important prognostic information as higher uptake correlates with higher histological grade and shorter survival[6]. PET is also useful in monitoring and timely detection of transformation of low grade tumor into a high grade variety, which can significantly influence treatment planning in such cases. PET also provides objective evidence of response to therapy.

STROKE

The role of SPECT with cerebral perfusion agents like HMPAO and ECD in the evaluation of cerebrovascular diseases is not significant in patients with obvious stroke. However, there are specific indications, where SPECT studies play a crucial role, such as determination of critical hemodynamically significant stenosis and carotid artery by-pass patients who are candidates for PTCA procedure.[7]

Cerebral perfusion SPECT is also widely used for estimation of degree for cerebral ischemia. Particularly, cerebral perfusion SPECT is valuable for decision if thrombolysis therapy should be done for embolic cerebral ischemia. When the ratio of ipsilateral to contra lateral perfusion is in the range of 0.4 to 0.7 on SPECT, thrombolysis therapy can be applied in patients without acute cerebral infarction.

NEUROPSYCHIATRIC DISORDERS

The present status of brain SPECT in psychiatric disorders is still, investigational. In spite of considerable research interest in this area, specific perfusion patterns of the various diseases have not been conclusively identified.. However, perfusion and receptor imaging findings may be used as an additional diagnostic tool to guide clinicians searching for a definite diagnosis.

In conditions like Schizophrenia, which comprises a group of closely related disorders characterized by a particular type of disordered affect, behavior, and thinking . Brain SPECT aids in the diagnosis - most frequent pattern being hypofrontality, especially during a specific task; perfusional changes in the basal ganglia, possibly related to the use of neuroleptic drugs; and temporal lobe hypoperfusion, usually on the left side and frequently associated with ipsilateral frontal lobe hypoperfusion. In addition, Semi quantitative analysis of neurorecepter imaging may help predict treatment outcome: with therapy, the ratio of the basal ganglia to the frontal cortex decreased in good responders and increased in poor responders.[8]

In conditions like depression, The typical brain SPECT pattern is hypoperfusion of the the prefrontal area and temporal lobes, cingulate gyrus, and left caudate nucleus in patients free of medication, the prefrontal, limbic, and paralimbic areas in both unipolar and bipolar depression; and the lateral frontal area in acute depression in the elderly. Hypofrontality is shown to be associated with severe negative symptoms. Functional imaging therefore is a potentially useful tool in initial evaluation and prognosis.[9]

The typical perfusion patterns in brain SPECT is also being used to study pathophysiology and diagnosis of other disorders like obsessive compulsive disorders, panic disorders, Gille's de la tourette syndrome etc.

EMERGING TRENDS FUNCTIONAL BRAIN IMAGING

In the coming times, functional imaging with SPECT and PET is expected to play an important role in Neuropharmacology and drug development. PET and SPECT neuroreceptor ligand studies will allow use of in vivo techniques to study pharmacodynamics, biodistribution, receptor occupancy and also assess therapeutic efficacy of drugs.

PET and SPECT ligands for neurorecepter imaging, like F18 Flouro-L-dopa,11C-Nomifensine, I123-BCIT(10) etc are being evaluated for diagnosis of parkinsonism. Similarly, in vivo amyloidal plaque imaging with 18F-FDDNP holds a lot of promise in facilitating early diagnosis of Alzheimer's disease. The development of a host of ligands for benzodiazepine, serotogenic, opioid receptors would permit better understanding of the pathophysiology of various CNS disorders.

PET will also be crucial in radiation treatment planning, and will allow better delineation of biological target volumes as detection of microscopic extension, which is beyond the limits of conventional modalities, would be possible.

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