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Application of PET and SPECT in epilepsy

Yotin Chinvarun *MD PhD*

Neurology unit, Pramongkutklao hospital and Medical College, Thailand

Abstract

PET and SPECT are valuable clinical tools in the management of patients with medically resistant, partial epilepsy who are under evaluation for surgical treatment. The value of PET for localization of seizure activity has been firmly established for patients with temporal lobe epilepsy and extratemporal lobe epilepsy. It is a very useful test partly because it is non-invasive. The localizing value of ictal SPECT is based on cerebral metabolic and perfusion coupling. Ictal hyperperfusion is used to localize the epileptogenic zone noninvasively, and is particularly useful in MRI-negative partial epilepsy and focal cortical dysplasia. Use of subtraction ictal SPECT coregistered with MRI (SISCOM) improves localization area of hyperperfusion. However, ictal SPECT should be interpreted in the context of full presurgical evaluation

PET IMAGING

PET has been applied for presurgical evaluation since 1970.[1] PET-FDG imaging especially when performed concurrently with surface EEG, may be useful for localizing the seizure focus for surgical resection. FDP-PET imaging remains important tools in localization of ictal onset zone, seizure propagation pathways, and functional deficit zone in the presurgical evaluation of patients with refractory partial epilepsy.[1] Interictal PET demonstrates areas of reduced glucose metabolism that correspond to epileptogenic zone in partial seizures. The value of PET for localization has been firmly established for patients with temporal lobe epilepsy and extratemporal lobe epilepsy.[2]

The sensitivity of FDG-PET to identify foci of seizure onset in temporal lobe epilepsy (TLE) is high at up to 80-90%.[1] In TLE with hippocampal sclerosis, interictal FDG-PET shows up to 100% sensitivity. Mechanism of interictal hypometabolism on FDG-PET remains unclear in TLE. Possibly in TLE with MTS, the hypometabolism is caused by neuronal loss, deafferentation or partial volume effect. Hypometabolism is usually diffuse, involving entire temporal lobe of epileptogenic side, including polar and lateral regions as well as mesial structures.

However, the localization of seizure foci in extratemporal lobe epilepsy is more difficult than with TLE. The hypometabolism of interictal PET is concordant with EEG focus in only 32% in frontal lobe seizure as compared to 77% in temporal lobe seizure.[2] Also, the hypometabolic region is not necessarily congruent with the epileptogenic zone and may extend beyond the epileptogenic lesion.[3] The hypometabolic region usually includes structural lesion, but often extends to involve more than one lobe or a whole hemisphere (Figure 1). Bilateral temporal hypometabolism is also commonly found.[4]

PET has been proposed as to reflect more the functional deficit zone rather than the epileptogenic zone. In spite of this, there is still a good correlation with epileptogenic and a good lateralization. As a result, in cases where the lateralization by PET study is congruent with the other imaging modalities, there is better surgical outcome.[5] It is very useful particularly in cases that are MRI negative or discordant in the various modalities for localization. In extratemporal lobe epilepsy, success rate of surgery is only 50% despite an extensive usage of PET and MRI imaging modalities.[2] The area of abnormal glucose metabolism is commonly larger than epileptogenic zone, therefore the FDG-PET may regionalizes the epileptic focus, but is unable to indicate the exact localization of the epilepsy. In frontal lobe epilepsy, PET provides a correct localization in only 50% of cases with a normal MRI. However, PET together with Ictal SPECT is usually useful as a guide for intracranial grid placement. Ictal PET is usually only obtained by chance. Because the 18FDG uptake occurs in >40 minute period after injection, therefore data usually reflects an amalgam of ictal, postictal and interictal conditions.[6]

Address correspondence to: Dr Yotin Chinvarun, Neurology unit, Pramongkutklao hospital and Medical College, Thailand

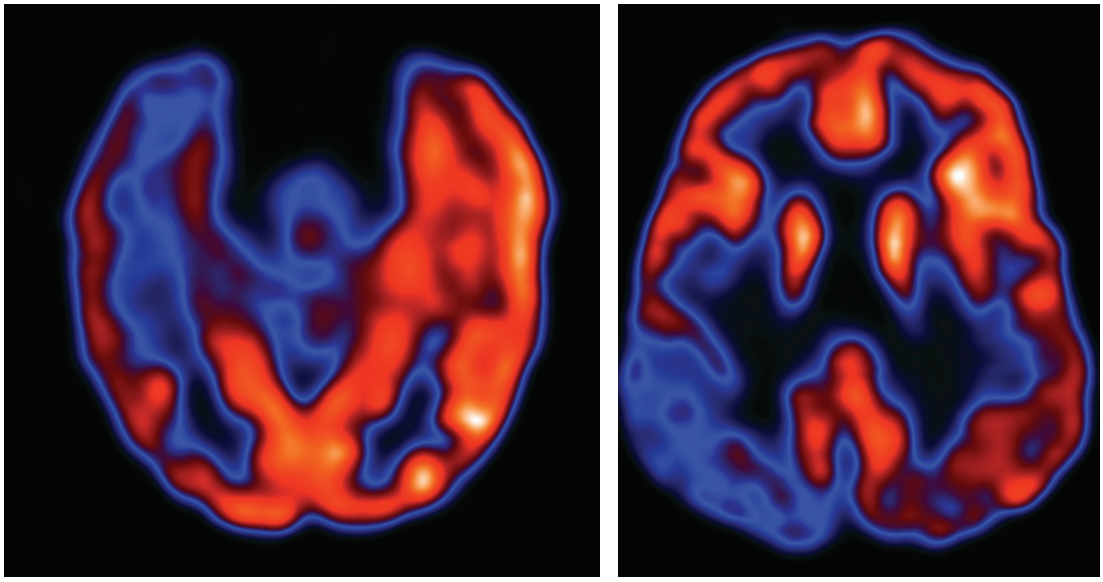

Figure 1. Interictal FDG-PET of parietal lobe epilepsy showing extensive area of hypomentabolism.

PET can also be used to evaluate the progression of the disease.[7] In the longitudinal PET study, sequential PET can be used to evaluate the progress of disease particularly in pediatric epilepsy patients. There has been reports of good correlation of cortical hypometabolism change with improvement in seizure frequency, which may be a marker for disease progress.

There may also be promising development using a multimodal approach in the near future. Fusion PET-MRI system with high resolution research tomography PET (HRRT-PET), using PET coregistered with high resolution MRI (such as 7T MRI) may be a useful tool to study the molecular-genetic and functioning of brain in epilepsy patients.

PET can also be used to evaluate the specific receptor system. Receptors PET scanning that have been developed include GABAA receptor (Flumazenil: FMZ), alpha methyl tryptophan receptors and others. They aim to identify the specific receptor in refractory epileptic patients. They are likely to become important in the future and may provide insights and understandings of the complexes mechanisms of refractory epilepsy.[8] It can be used to study development and termination of seizures. It has an invaluable role in the epileptogenesis research and to identify the underlying cause of epilepsy.

SPECT IMAGING

Ictal SPECT is able to demonstrate the ictal neuronal activation and is a noninvasive marker of ictal onset zone. It is particularly useful in MRI-negative partial epilepsy and focal cortical dysplasia. Interpretation of ictal SPECT is confounded by propagation of ictal activity, or early switch from ictal hyperperfusion to postictal hypoperfusion during brief seizures, which can be minimized by early ictal SPECT injections. Ictal hypoperfusion may reflect ictal inhibition or deactivation. Postictal and interictal SPECT studies are less useful to localize ictal-onset zone.[9] The area of highest ictal hyperperfusion usually represents the ictal-onset zone, unless seizure has propagated.

Ictal SPECT injected during simple partial seizure give no information in about 40% of cases whereas ictal SPECT injected during complex partial seizure has a higher yield (92%).[9] However, ictal SPECT injected during secondarily generalized seizures may give multiple regions of hyperperfusion. Duration of injected seizure is very important in interpretation of ictal SPECT imaging.[9] After injection in vein, tracer takes about 30 seconds to reach the brain.[5] The postictal switch (i.e., switch from ictal hyperperfusion to postictal hypoperfusion) usually takes about 1–2 minute in TLE.[10] In extratemporal seizures, it last ≥10–15 seconds after ictal SPECT injection. Therefore, early ictal SPECT injections is required to obtain a good localizing information.

Interpretation of ictal SPECT images should always be done in the context of a full presurgical evaluation. The use of subtraction ictal SPECT coregistered with MRI (SISCOM) improves

localization area of hyperperfusion.[11] Statistical parametric mapping analysis of ictal and interictal SPECT difference images of selected groups of patients is a promising method to highlight regions of significant hyper- and hypoperfusion.[12] The technique may also provide new insights to pathophysiology of seizures.

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