Neuroimaging for diagnosing epilepsy

Abstract

Brain scanning methods were first applied in patients with epilepsy more than 30 years ago. A very substantial literature now exists in this field, which is exponentially increasing. Contemporary neuroimaging studies in epilepsy reflect new concepts in the epilepsies, as well as current methodological developments. In particular, this area is emphasising the role of networks in epileptogenicity, the existence of dynamic phenomena which can be captured by imaging, and is beginning to validate the implementation of neuroimaging in the clinic. Here, recent studies of the last 5 years are reviewed, covering the full range of neuroimaging methods with SPECT, PET and MRI in epilepsy.

Key Word: Neuroimaging, Epilepsy

Introduction

Neuroimaging is central to the evaluation of patients with epilepsy, especially in the identification of structural brain lesions that can serve as epileptogenic foci, and that might be surgically resectable if the patient becomes refractory to medical treatment.

An image may be considered a merely static representation of an object. In the context of a highly dynamic entity such as the brain, imaging might be rather limited as a means to describe relevant phenomena, especially in contrast with the temporally rich data produced using neurophysiological methods. On the contrary, from the earliest era of detailed human brain imaging, dynamically changing phenomena have been central to neuroimaging investigation of epilepsy – for example, imaging seizure dynamics using ictal single photon emission computed tomography (SPECT). Many imaging modalities have been developed to capture dynamic phenomena which may change rapidly or more slowly (such as blood flow, glucose metabolism, and aspects of neurochemistry and neurotransmitter systems). Even imaging modalities capable only of capturing static (structural) phenomena can be repeated serially over time, and capture dynamic and evolving changes related to natural history or treatment interventions.

Neuroimaging in epilepsy has not been immune to a broad criticism of biomedical research, that scientific advances are not translated into benefit for patients sufficiently
quickly. Despite more than three decades of neuroimaging research involving complex brain scanning, relatively few imaging tools are in routine use, and very few are supported by the kind of substantial evidence base which would be required to support the implementation of a new treatment.

**Subjects:**

**CT (computed tomography)**

Because of its relative insensitivity compared to magnetic resonance imaging, computed tomography (CT) has a limited role in the evaluation of patients with seizures. It is usually restricted to the emergency department setting in the evaluation of potential acute symptomatic seizures.

**MRI (magnetic resonance imaging)**

Virtually all patients with new-onset epilepsy should have a magnetic resonance imaging study to identify a potential structural cause of epilepsy including hippocampal sclerosis, brain tumor, dysplasia, vascular malformation, and others. While less than half of patients with epilepsy will have a cause identified on MRI, the sensitivity can be substantially improved by utilizing an epilepsy protocol. Not all MRI findings are relevant; isolated findings of diffuse atrophy, punctate foci of T2 signal abnormalities in the white matter, and other nonspecific findings are not known to be epileptogenic. MRI findings should be correlated with the patient’s seizure semiology and EEG findings; some potentially epileptogenic lesions may be incidental.

- **Imaging techniques**

  **SPECT (Single photon-emission computed tomography)**

  Single photon-emission computed tomography (SPECT) uses photon-emitting radioisotopes attached to molecules that bind to specific components of brain tissue. Radioactivity distribution is imaged using a gamma camera. The brain systems imaged with SPECT depend on the properties of the injected radioligand. Most studies in epilepsy have used technetium-99m hexamethylpropylene amine oxime or technetium-99m ethyl cysteinate diethylene to indicate local cerebral blood flow. It is well established that focal seizures are accompanied by a focal increase in blood flow, which can be captured by an ictal injection of radioisotope. SPECT in epilepsy has recently been
thoroughly reviewed

- **PET**(Positron emission tomography)  
  PET uses positron-emitting radioisotopes and cameras that detect coincident pairs of photons released following positron annihilation. A very wide range of PET radioligands has been produced, but the great majority of PET studies in epilepsy use 18F-labeled fluorodeoxyglucose (18FDG), which reflects the local cerebral metabolic rate for glucose. PET in epilepsy has been thoroughly reviewed.

- **MRS**(Magnetic resonance spectroscopy)  
  Magnetic resonance spectroscopy (MRS) of the hydrogen 1H nucleus is capable of measuring concentrations of many compounds in the brain. Commonly measured compounds include: creatine (Cr)-containing compounds, reflecting local energy metabolism; N-acetyl aspartate (NAA), reflecting neuronal integrity; choline (Cho)-containing compounds, reflecting cell membrane integrity; lactate, detecting anaerobic glycolysis; myoinositol, reflecting glial cell integrity; a combined measure of glutamate and glutamine (GLx); and GABA. MRS findings are often expressed as ratios between measures.

- **VBA**(Voxel-based analyses of structural imaging)  
  Voxel-based morphometry (VBM) is a method used to detect morphological changes throughout the whole brain [3]. The basic concept is to warp all subjects’ brains to a standard brain size and shape, and then examine subtle regional differences in MRI signal between subjects. This method has been criticized because of assumptions and potential confounds. Similar voxel-based analyses may be applied to many other imaging types.

- **DTI**(Diffusion-tensor imaging)  
  Diffusion-tensor imaging (DTI) measures the ease with which water can diffuse through tissue, measured as mean diffusivity or apparent diffusion coefficient. The tendency for diffusion to prefer one direction over another is expressed as fractional anisotropy, which will be especially prominent in white matter tracts where water diffuses in the direction of the axons in the tract. Methods have been developed to identify and connect brain regions with diffusion favoring particular directions to reveal white matter tracts, a technique called tractography.
• **fMRI**(function of MRI)

Changes in brain blood flow are accompanied by changes in blood oxygenation, which can be detected with fMRI because of the so-called blood oxygenation-level-dependent (BOLD) response. If blood flow changes can be deliberately manipulated by controlling a subjects’ activity, the brain regions responsible for that activity may be detected. Similarly, if a particular spontaneous brain-related event can be detected (such as an interictal epileptiform discharge on EEG), the brain regions responsible for generating these phenomena may be identified. Simultaneous EEG–fMRI has recently been reviewed.

**Conclusion**

These other neuroimaging modalities, positron emission tomography (PET), single photon emission computed tomography (SPECT), magnetic source imaging (MSI), are primarily used in the presurgical evaluation of patients with medically refractory epilepsy. These are employed to better define the area of functional defect and epileptogenicity, to identify MRI-occult lesions, and to identify the more active lesion in patients with dual or multiple pathologies. Neuroimaging studies are also used to map neurologic functions as part of surgical planning to predict and limit postoperative neurologic deficits, including sensorimotor, language and memory function.

**References**


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