Neuroimaging in epilepsy

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Abstract

Epilepsy is a common neurological disorder with diverse etiologies. Neuroimaging plays an important role in workup of patients with epilepsy. It helps to identify brain pathologies that require specific treatment; and also in formulating syndromic and etiological diagnoses so as to give patients and their relatives an accurate prognosis. Magnetic resonance imaging, specially the 3 tesla MRI is the imaging of choice because of its ability to detect small lesions like mesial temporal sclerosis, cortical dysplasias, small tumors, etc that are not detected by conventional MR or CT scan of brain. Identification of these lesions often helps in managing refractory epilepsies more effectively. However, cost and non-availability of MR in large part of the country necessitate the use of CT as an alternative. CT is often the initial investigation and also useful in acute situations. Functional imagings are used for pre-surgical work-up of refractory epilepsy cases with an aim to identify the epileptogenic focus and to delineate functional areas nearing the focus. .

Key Words

Epilepsy, magnetic resonance imaging, single photon emission computerized tomography, positron emission tomography, neuroimaging

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Introduction

Seizures may occur in up to 10% of the population, whereas epilepsy is a chronic disease that is characterized by recurrent seizures that may affect about 2% of the population. Although primarily defined by EEG abnormalities, it is presently recognized that epilepsy is often associated with gross or subtle structural or metabolic lesions of the brain. Modern structural and functional brain imaging methodologies have made a colossal impact on the diagnosis and management of epilepsies.[1-4] The combination of appropriate new imaging techniques has led to greater insights into the pathophysiology underlying symptomatic epilepsies. The rationale in clinical practice for the use of neuroimaging in epilepsy is to identify pathologies such as granulomas, malformations, vascular or traumatic lesions, tumors, etc. that require specific treatment; and also help in the formulation of syndromic and etiological diagnoses so as to give patients and their relatives an accurate prognosis.

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Imaging Modalities

Computerized tomography

Computerized tomography (CT) scan uses ionizing radiation and can generate excellent hard tissue imaging contrast with moderately good soft tissue resolution. CT scan has a number of advantages like lower cost, ready accessibility, scan speed, etc. which provide a relatively reliable imaging modality for most patients.[5] In addition, new generation CT scanners can generate an image of the brain in seconds.

Although the use of CT for epileptic patients has reduced with availability of MRI, CT is still the imaging of choice for these patients under certain conditions. CT can accurately detect hemorrhage, infarcts, gross malformations, lesions with underlying calcification, and large tumors. Although CT is often of secondary or adjunctive importance, it serves as a significant backup to ultrasound in neonates and young infants.[6,7] However, the sensitivity of CT in patients with epilepsy has not been found to be higher than 30% in unselected patient populations.[8] The lower sensitivity of CT is due to poor resolution of the temporal fossa due to which it is not useful in detecting mesial temporal lobe sclerosis, one of the most common pathologies in refractory epilepsy. CT scan may fail to detect abnormalities in up to 50% of patients with epileptogenic structural lesions such as mesial temporal sclerosis, small tumors, malformations, etc.

MRI of brain

MRI is the imaging procedure of choice for the investigation of patients with epilepsy. The advantages of MRI over CT scan are numerous and do not need further elaboration. However, the disadvantages of MRI are its unavailability for larger number of patients, higher cost, and the requirement for longer time periods for scanning. The sensitivity of MRI in detecting abnormalities in patients with epilepsy is in part associated with pathologies underlying epilepsy, and also by MRI techniques and the experience of interpreting radiologists. Mesial temporal sclerosis, small tumors, and trauma are more common in adults.[9] In contrast, developmental malformations constitute the most common abnormality in infants and young adults detected by MRI.[10-12]

MRI epilepsy protocols have been established in many centers to improve sensitivity and specificity. MRI abnormalities are identified in 80% of patients with refractory focal epilepsy and 20% of patients with a single unprovoked seizure or epilepsy in remission. The major role of MRI is in the identification of structural abnormalities that underlie seizure disorders like identification of mesial temporal sclerosis and malformation of cortical development.

Functional neuroimaging

Functional neuroimaging has been used for localizing cerebral dysfunction, predominantly through disturbances in an individual's metabolism or blood flow. The techniques available include SPECT, PET, functional MRI, and magnet resonance spectroscopy (MRS).

Single photon emission computerized tomography

Single photon emission computerized tomography (SPECT) is a nuclear medicine imaging method that allows for the quantitative and qualitative evaluation of regional cerebral perfusion.[13] It is not indicated in most of the patients with epilepsy but has an important role in presurgical evaluation of refractory epilepsy patients. The use of SPECT in epilepsy stems from the known association of seizures with increased ictal regional cerebral perfusion or interictal decrease in perfusion.[14] Ictal SPECT shows a sensitivity of 60–90% in localizing the epileptic focus.

Positron emission tomography

Like SPECT, Positron emission tomography (PET) is most useful in patients with refractory epilepsy who are candidates for surgery.[15-16] In temporal lobe epilepsy, interictal PET shows hypometabolism in the epileptogenic region in approximately 70–80% of the patients, although PET is not very sensitive in extratemporal lobe epilepsy.

However, in place of Fluoro-deoxy glucose (FDG) ligand or neuro-receptor PET studies improve sensitivity and specificity for temporal lobe epilepsy. AMT PET can differentiate between epileptogenic and nonepileptogenic lesions in the interictal state in children with tuberous sclerosis.[17]

Magnetic resonance spectroscopy

Magnetic resonance spectroscopy can provide noninvasive biochemical measurements of specific brain metabolites.[18] Spectroscopy has demonstrated abnormalities related to *N*-acetylaspartate (NAA), creatinine, and choline signals in patients with epilepsy.[19-20] The abnormalities typically consist of reduced NAA signal and increases choline and creatinine signals. These findings are consistent with histopathological characteristics of reduced numbers of neuronal cells with neuronal dysfunction and increased glial cellularity. MRS is extremely sensitive in detecting metabolic changes in dysfunctioning epileptic zone;, it can even detect metabolic changes when structural imaging yields normal results.

Functional-MRI

Functional-MRI (fMRI) utilizes very rapid scanning techniques that can theoretically demonstrate changes in blood oxygenation. This technique has been used in the presurgical evaluation of epileptic patients to map functional areas such as language, motor, and visual cortices with high accuracy, which is essential before epilepsy surgery. It is also used to predict deficit after temporal lobe resection.

In acute situations

CT scan is an appropriate initial investigation in seizures that develop in the context of a neurological insult such as head injury, intracranial hemorrhage, or infarcts. This is because most of the lesions can be picked up by CT and also because MRI may be technically difficult in acute settings. However, MRI may be needed if CT scan is negative or inconclusive, *e.g*., in a suspected case of encephalitis.

The nonacute situation

Ideally MRI should be done in all patients with epilepsy with the exception of patients who have a definite diagnosis of idiopathic epilepsy like benign myoclonic epilepsy in infancy, juvenile myoclonic epilepsy, and childhood epilepsy with centrotemporal spike.

MRI is particularly indicated when there is:

1. Evidence of progressive focal deficit on neurological or neuropsychological examination.
2. Difficulty in obtaining control of seizures with first-line antiepileptics.
3. Loss of control of seizures with antiepileptics or a change in the pattern of seizures, which may imply a progressive underlying lesion.

4. Onset of apparently generalized seizure in the earlier years of life or adulthood.
5. Evidence of partial onset seizure on history or EEG.

However, MRI is not widely available in developing countries, hence, CT scan may be the initial investigation for epilepsy patients in chronic settings. However, as CT scan has low sensitivity particularly in detecting small tumors, vascular malformation, and mesial temporal sclerosis, MRI may be indicated in the following situations:

a. Patient with apparently generalized seizure but does not respond to AED
b. Patients who develop progressive neurological or neuropsychological deficit
c. Patient present with partial with or without secondary generalized epilepsy and CT scan is negative or inconclusive and/or the patient is not responding to treatment.

MRI may be avoided if CT shows a cortical infarct in a patient with a partial seizure. When CT shows a single ring-enhancing lesion in a patient presenting with partial epilepsy, CT scan can be repeated after three months rather than doing an MRI. Similarly, MRI is usually avoided if the CT scan shows a calcified granuloma, which can present with partial seizure.

Therefore, CT scan should be the initial investigation in patients with epilepsy both in acute and nonacute situations. Thus, MRI should be restricted to certain patients as already discussed and newer imaging modalities should be used only by comprehensive epilepsy care units.

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http://www.ilae-epilepsy.org/visitors/initiatives/GEMINDbook.cfm.

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