ABSTRACT:
Epilepsy, a common chronic neurological disorder characterized by recurrent unprovoked seizures, has proved to be a diagnostic and therapeutic challenge for clinicians over the years. The rapid advances in neuroimaging techniques have proved pivotal in unraveling the disease. While MRI has replaced CT scan as the imaging modality of choice, modern techniques like SPECT, PET, MRS, fMRI and MSI have had both immediate and far reaching impact on the precise understanding of the structural, functional and electrophysiological basis of epilepsy. However, in this milieu of neuroimaging tools, it is important to maintain a balanced approach. A clear idea regarding the benefits and limitations of each technique is needed for their judicious clinical application.

INTRODUCTION:
Epilepsy, a chronic disorder underlying many diseases is characterized by repeated seizures caused by excessive unprovoked electrical firing of a number of neurons.

Neuroimaging techniques have become essential and germane to the clinician in the understanding, diagnosis and management of epilepsy. The colossal advance made in the sphere of structural and functional brain imaging has revolutionized the approach to epilepsy. The high level of anatomical and metabolic data amassed from the different imaging modalities have had a profound impact on many aspects of epilepsy in clinical practice.

THE HISTORICAL PERSPECTIVE:
From 1909 to 2009, there occurred a gigantic leap in the field of neuroimaging. It started with the stunning discovery of the plain XRay and subsequently the air ventriculography and air encephalography techniques. These however for all their ingenuity were of minor help in understanding of epilepsies. The two pathbreaking discoveries of CT Scan in 1971 and then the MRI Scan in 1976 proved to be instrumental in transforming the world of epilepsy imaging. Over the past decade, the evolution of MRI techniques like the Magnetic Resonance Spectroscopy (MRS), Positron Emission Tomography (PET), Single Photon Emission Computerized Tomography (SPECT) and functional MRI have improved our knowledge of the etiopathogenesis of epilepsy significantly.

THERAPEUTIC IMPLICATIONS OF NEUROIMAGING:
The rationale of neuroimaging in epilepsy is mainly twofold:
1. To identify underlying pathologies such as tumours, granulomas, vascular malformations, traumatic lesions or strokes that merit specific treatment.
2. To facilitate the syndromic and aetiological diagnosis and subsequent accurate prognosis that will aid the patient, their relatives and the clinician.

IMAGING MODALITIES: MERITS AND DEMERITS

COMPUTED TOMOGRAPHY (CT SCAN):
CT Scan, though surpassed by MRI as the technique of choice, has a significant role in the acute seizure scenario and perioperative period. In both these situations the ability of the CT Scan to detect trauma, haemorrhage, hydrocephalus, tumours etc. can profoundly influence the mode of treatment provided for the benefit of the patient. However, the low sensitivity of CT, especially with regards to temporal fossa lesions, has led the International League Against Epilepsy to suggest CT scan as the modality of choice only when MRI is not available or cannot be done due to some reason in the epileptic patients.

MAGNETIC RESONANCE IMAGING (MRI):
MRI is the investigation modality of choice in patients with epilepsy, especially if focal features are present on examination or EEG shows epileptic discharges or if seizures persist despite a previously normal CT scan. Both T1 and T2 as well as the FLAIR images are indispensable in increasing the conspicuity of otherwise undetectable lesions. MRI has made a paramount contribution in identifying mesial temporal sclerosis in patients with intractable seizures.
The images in Figure 1 shows the classical features of hippocampal sclerosis which is pathognomonic of medial temporal sclerosis. In addition to this, hippocampal volumetry and T2 relaxometry can also aid in the accurate diagnosis. MRI thus proves pivotal in the precise identification and subsequent surgical treatment in these patients of mesial temporal sclerosis. Enormous contributions have been made by MRI in identification of malformations of cortical development (MCD). Of these one of the most common and important ones are the band heterotopia and the periventricular nodular heterotopia. These have been depicted in the image in Figure 2.

The diagnosis of malformations like lissencephaly, schizencephaly, pachygyria etc have been rendered much easier by the advances in MRI techniques. The image in Figure 3 shows the classical findings of lissencephaly on MRI. MRI findings can influence disease prognosis and genetic counselling in these malformations. The recognition of focal lesions such as focal cortical dysplasia (FCD), the most common pathology in children with extratemporal seizures has been made simpler by the classical MRI findings of abnormal cortical mantle with disturbed gray white architecture and thickened cortex. This has been depicted in the image in Figure 4.

The finding of a causative lesion on MRI in a new onset seizure makes treatment imperative. The detection of medial temporal sclerosis in the context of temporal lobe epilepsy is a strong prognostic indicator and heralds the need for surgical resection. Despite its seemingly infallible role in epilepsy, MRI does have its shortcomings. The high cost is a deterrent to its use in patients with definite electroclinical diagnosis of idiopathic generalized or benign focal epilepsy from childhood. The clinical utility of MRI is undermined somewhat by its failure in identifying the electrical disorders of the neurons that cause epilepsy. Often the invisible area surrounding the structural lesion visible on MRI may be the actual culprit for epileptogenesis. This can only be identified with the help of electrophysiological studies.

**SINGLE PHOTON EMISSION CT (SPECT):**

SPECT is a nuclear imaging technique based on the knowledge of seizures causing increased ictal region cerebral perfusion and decreased interictal perfusion. It is useful in supporting the localization of epilepsy when performed in a carefully monitored ictal or early postictal examination compared with an interictal scan. The image in Figure 6 shows a typical SPECT scan in the ictal and interictal phase. This may be used in presurgical evaluation and it helps to guide the placement of intracranial electrodes in the context of other imaging data being equivocal. However, from the interventional standpoints, ictal or interictal SPECT has...
limited role. Barring certain ictal SPECT patterns in subtypes of temporal and extratemporal epilepsy, the role of SPECT is confined to the localization of ictal onset and study of propagation patterns. In recent times, the evolution of Substraction Ictal SPECT Coregistered MRI (SISCOM) has greatly augmented the accuracy of SPECT. This may be a tool for the future.

**POSITRON EMISSION TOMOGRAPHY (PET):**

PET Scan with $\text{F}^{18}$ fluorodeoxyglucose (FDG-PET) and $\text{H}^{15}$O water ($\text{H}_2\text{O}^{15}$) show hypometabolic areas in the epileptogenic region during interictal phase. They are helpful in the lateralization of temporal lobe epilepsy, without intracranial EEG recording of seizures, in whom there is discordance of data between MRI, EEG and other imaging modalities. The Figure 5 gives a clear image of a typical FDG PET SCAN. However, caution is needed as the ictal zone may be at the border of the hypometabolic zone and not at the maximum hypometabolic area. There are no proven indications for ligand/neuroreceptor PET in clinical epileptological practice. Techniques like 11C Flumazenil (FMZ) PET may aid in precise localization in patients of medial temporal sclerosis with a negative MRI. It can also guide in intracranial placement of EEG electrodes in MRI negative patients with neocortical seizures. Unfortunately, despite its advances, FDG PET or ligand PET has no role in influencing therapeutic decisions. Their scope is limited to presurgical localization, especially in cases with diagnostic discordance.

**MAGNETIC RESONANCE SPECTROSCOPY (MRS):**

MRS provides an excellent noninvasive biochemical tool for measuring brain metabolites. Evaluated primarily in temporal lobe epilepsy, proton MRS provides a sensitive measure to lateralize metabolic dysfunction. Phosphorus ($\text{P}^{31}$), MRS has moderate sensitivity based on abnormal phosphocreatine/inorganic phosphate ratio. The clinical utility of MRS has been compromised by the present limitation of spatial coverage limits. Moreover, whether the data provided by this modality benefits the overall management of the patient is debatable. Recent studies have suggested that MRS evidence of disease progression might impact disease therapy in future, but larger studies are awaited to substantiate this claim. Neurotransmitter MRS like GABA and Glutamate MRS studies are another area of potential therapeutic implications being actively pursued at present.

**FUNCTIONAL MRI (fMRI):**

fMRI utilizes very rapid scanning techniques that demonstrate alterations in blood oxygenation. This technique is used in presurgical delineation of functional areas such as language, motor and visual cortices. The clinical utility of this technique lies in predicting the occurrence of sensorimotor deficit following the lesion resection. This is all the more significant in cases where the anatomical structures are distorted by mass effect. Recent studies are on to determine the role of fMRI in studying of memory. However, like the other newer imaging modalities the role of fMRI in the medical management of epilepsy is obscure.

**MAGNETIC SOURCE IMAGING (MSI):**

MSI or Magnetoencephalography (MEG) is a unique, noninvasive, nonhazardous tool of functional brain mapping of both normal and abnormal brain areas. The primary advantage of MSI over EEG is that the magnetic fields are not altered by the skull and other surrounding brain structures, thus permitting more accurate localization of brain functions. MEG/MSI is clinically useful in the exact localization of epileptogenic zones for surgical resection as an alternative to costlier, invasive procedures. MEG/MSI also have an instrumental role in the exact localization of the “eloquent” brain areas that minimize postoperative neurodeficits and also obviates the need for invasive brain mapping procedures. However, the extremely high cost and low availability of MSI has precluded its use currently in clinical epilepsy practice.

**CONCLUSION:**

The mammoth strides in the field of neuroimaging have opened up new vistas in the understanding of the neuropathological abnormalities that are instrumental in seizure genesis. The emergence of functional and electrophysiological imaging techniques has provided enormous insight into the structural, functional and electrophysiological aspects of epilepsy that might impact treatment modalities and disease prognosis. However, even in these halcyon days of neuroimaging it is
Usefulness and Limitation of Neuroimaging in Epilepsy

Important to weigh the positives and negatives with an unbiased approach. The high costs, low widespread availability and the various technical shortcomings have placed the advanced imaging modalities at a still nascent stage with precariously limited clinical application. A balanced, multimodality approach involving the different imaging modalities might be the ideal answer to the epileptic jigsaw and prove to be a boon to both the patients and the clinician.

REFERENCES:

2. Recommendations for neuroimaging of patients with epilepsy; Commission on Neuroimaging of the International League Against Epilepsy, Epilepsia 1997; 38: 1255-6.