REVIEW ARTICLE

Effectiveness of Magnetic Resonance Imaging in Comparison to Electroencephalography in Newly Diagnosed Seizure Patients

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Abstract

In newly diagnosed seizure patients though the norm is to do an electroencephalogram (EEG), underlying structural abnormalities will be better depicted on magnetic resonance imaging (MRI), and EEG may turn out to be normal. Since a wide variety of structural abnormalities in the brain can lead to seizures, studies had shown that MRI was more effective in detecting lesions accurately in addition to an EEG, so it is better to include MRI as a first line of investigation in seizure patients for early detection, treatment, and better prognosis of underlying structural abnormality.

Keywords: Electroencephalogram, Magnetic resonance imaging, Seizures.

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Introduction

A seizure is defined as an "outburst of abnormally synchronized electrical activity in the brain which can affect either small or large areas producing clinical manifestations which can be sudden, transient, and brief." Approximately 2–5% of the world's population is affected by seizures. The most common non-traumatic neurological disorders in the USA in decreasing order of frequency are migraine, cerebrovascular disease, Alzheimer's disease, and epilepsy (4th common).[1]

Early diagnosis can play a vital role in the early initiation of treatment and a better prognosis. During the initial assessment of seizures, EEG is done as a standard routine investigation, and MRI is kept optional. However, in newly diagnosed seizures, solely doing EEG cannot pick up any underlying structural abnormalities induced by seizures, and mostly EEG turns out to be normal in a study conducted in the pediatric population.[2] Magnetic resonance imaging can detect any structural abnormality and treatment can be initiated soon. Contrary to its belief, a normal EEG does not indicate a normal MRI and there are chances of seizure-induced brain abnormalities being missed. Hence, I would like to review the findings of EEG and MRI in patients presenting with seizures to see if EEG is a good indicator of MRI and if using MRI as a first-line investigational tool can be of an added advantage in better detection of underlying lesions.

Methodology

An electronic search strategy was used to select the studies from different databases like PubMed, PubMed central, Google Scholar, and Research Gate. A combination of keywords like "correlation between EEG and MRI in seizures", "EEG", and "MRI epilepsy protocol" were used to select the studies. Detailed study was done from the results of the standard articles with these keywords. The selected articles were further assessed for the quality of research and included in the review.

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Seizures and Epilepsy

In 2014, the International League Against Epilepsy (ILAE) reported that, one should consider epilepsy if any of the following are present:[3]

- At least two unprovoked (or reflex) seizures occurring greater than 24 hours apart.
- One unprovoked (or reflex) seizure and a probability of further seizures similar to the general recurrence risk after two unprovoked seizures, occurring over the next 10 years.
- Diagnosis of an epilepsy syndrome.

The new classification system of seizures first categorizes based on where they originate in the brain and three main categories are present as follows:[4]

- *Generalized onset:* Affects the brain bilaterally or a major area on both sides of the brain.
- *Focal onset:* Used instead of "partial seizures". Starts unilaterally in the brain.
- *Unknown onset:* Unclear regarding the origin of seizure location.

Kim et al. studied seizure-induced characteristics on MRI (SCM) in a retrospective study consisting of 69 patients. Epileptiform

discharges on EEG were compared to MRI. Clinically patients with first seizures were divided into:[5]

- *First unprovoked seizure:* Which occurs without an acute precipitating neurological deficit, metabolic disease, or previous central nervous system (CNS) injury.
- *Acute symptomatic seizure:* Transient factor temporarily reducing the threshold limit for seizures affecting the brain.
- *Remote symptomatic seizure:* Due to identifiable causes affecting the brain such as tumors or stroke.
- *Status epilepticus:* Two or more seizures with loss of consciousness or duration of a seizure lasting more than 5 minutes.

In the book Magnetic Resonance Scanning and Epilepsy, authors SS Spencer and DD Spencer in their chapter "Correlation of MRI and EEG"[6] opined that, in patients having refractory epilepsy, localization of seizures using EEG and MRI correlation had helped patients be seizure free after surgical removal. Temporal lobe epilepsy (TLE) patients were studied retrospectively and it was demonstrated that atrophy of the hippocampal region is in fact not a direct indicator of underlying TLE as it can be found in people without seizures.

Role of Electroencephalogram

Electroencephalogram plays a pivotal role in the diagnosis and management of patients presenting with seizures along with various other investigations. It is a readily available, cost-effective, and non-invasive method of demonstrating the physiological manifestations of abnormal cortical excitability in seizures. However, EEG has its limitations. Scalp electrodes may not pick up deeper lying signals from epileptogenic foci. Short duration of routine EEG may result in patients not showing interictal epileptiform discharge (IED) in their first EEG study.

Role of Magnetic Resonance Imaging

Although computed tomography (CT) is the investigation of choice in patients presenting with seizures during an emergency situation, MRI tends to be the modality of choice in diagnosing an underlying structural abnormality producing a seizure.

A dedicated MRI protocol for Epilepsy:

- High-resolution coronal oblique T2WI (2–3 mm slice thickness, no interspace gap) acquired along the plane perpendicular to hippocampal long axis.[7] Temporal lobe encephaloceles which are usually overlooked can be identified.
- Coronal T2W FLAIR images (3 mm slice thickness, no interspace gap) helps to detect T2W signal abnormalities in the hippocampus and cortical and subcortical signal abnormalities as in case of focal cortical dysplasia (FCD).
- Coronal FLAIR + coronal 3D-inversion recovery (IR) sequence clearly visualizes subtle focal abnormalities, such as in case of Bottom-of-sulcus dysplasia.
- Coronal imaging is better than axial in picking up cortical thickening, gray-white matter interface blurring, and associated signal abnormalities based on the orientation of sulci.
- 3D T2W FLAIR cube sequence if acquired in the sagittal plane can be reformatted in any plane as per requirement. In extratemporal epilepsy, it is better to acquire images tangential and perpendicular to the abnormal gyrus.
- T2*-W gradient recalled echo (GRE) or susceptibility weighted imaging (SWI) increases sensitivity for focal epileptic foci by enhancing identification of calcifications, hemorrhages, and small vascular malformations. Coronal T2*GRE sequence is used to detect lesions near skull base.
- More advanced sequences like 3D-T1W GRE isotopic sequences like magnetization prepared rapid acquisition (MPRAGE) GRE and spoiled gradient-recalled acquisition (SPGR) using high spatial resolution provide good gray-white matter differentiation and are better at evaluating cortical thickness. Disturbances in cortical migration also becomes more evident.
- Sometimes 3D sequences may be used for hippocampal segmentation and measurement of volume.[7]

Crocker et al. explained the importance of neuroimaging in patients with first seizures. Although structural abnormalities can be picked out in the brain, differentiation between epileptogenic and incidental lesions were found to be difficult. In addition, the prognosis could not be determined; however, it aided in the management of epilepsy by clinicians more effectively. Usage of standard MRI protocols tailored for diagnosis in epilepsy with advanced sequences such as diffusor tensor imaging, magnetic resonance spectroscopy, thinner slices proved to pick up even subtle structural abnormalities which may go missed otherwise. In future, clinicians will opt for neuroimaging in all patients with new-onset seizures, using more sophisticated post-processing sequences in MRI which will be more widely used by then, and addition of other modalities like magnetoencephalogram (MEG).[8,9]

Common Etiologies of Seizures which can Produce Structural Abnormalities on MRI

In practice, focal epilepsy can be grouped into mesial temporal lobe epilepsy (MTLE) and neocortical epilepsy. This is done since clinical, MRI, and pathologic findings in MTLE are usually very specific and consistent [most common being hippocampal sclerosis (HS)], whereas in neocortical epilepsy, these findings are more varied, and the structural abnormality causing it consists of a wider spectrum of etiologies.[10]

Most common structural abnormalities giving rise to neocortical lesions include low-grade tumour, cortical developmental malformations, post-traumatic and post-ischaemic lesions, inflammatory infectious scars, cavernous malformations, and arteriovenous malformations.[11]

Doescher et al. conducted the first study in a group of school children with normal intelligence with new-onset seizures.[2] A prospective study was conducted in ~ 181 children comparing EEG and MRI findings in new onset seizures. Usually, EEG is kept as a standard line of investigation for evaluating seizures, and MRI is kept optional. However, in this study, it was found that a normal EEG doesn't imply a normal MRI, so an EEG cannot be used as a good indicator for ordering an MRI, hence, necessitating the need to use MRI in new-onset seizure patients.[12]

Özkan et al. conducted a retrospective study with 40 patients over a period of 3 years to accurately diagnose the lesion in patients with mesial temporal sclerosis (MTS) by correlating EEG and MRI findings.[13] They revealed that the most common MRI abnormality seen in MTS was hippocampal atrophy which can be detected better at the corpus level rather than anterior regions. Volumetric MRI measurements may be obtained as well. If EEG findings and MRI findings were both found on the ipsilateral side, prognosis post operatively turned out to be better. Differential diagnosis for hippocampal volume loss included Alzheimer's disease, vascular dementia, and Parkinson's disease except for MTS.[14]

Similar studies were conducted recently in pediatric populations. Mohan et al., in their prospective study, compared the importance of EEG and MRI findings in 112 children with new-onset seizures.[15] They concluded that both MRI and EEG play a central role in accurately evaluating seizure patients by picking up structural abnormalities on MRI, the most common being infection and inflammation in their study, followed by hypoxic ischemic encephalopathy (HIE).

Xuan et al. conducted a prospective study in 112 children with partial seizures over a period of 18 months to evaluate correlation between EEG and MRI findings.[16] It was found that children with partial seizures had underlying structural abnormalities, and EEG and MRI were not correlating, hence, proving that EEG cannot only be used as tool for ordering an MRI.

Seizure-induced Signals on MRI

In addition to structural abnormalities which can cause seizures, seizures *per se* can also produce some changes on MRI. Seizure-induced signal changes on MRI are defined as hyperintensities seen in the brain which do not apply to cerebral arterial territories. Kim et al., in a retrospective study, explained that SCM were commonly found in ipsilateral hippocampus, thalamus and cerebral cortex, unilateral cortex, ipsilateral thalamus, and cerebral cortex or bilateral hippocampi.[5] However, only few studies are available on transient signal changes induced by seizures leaving it to an area that needs more research. This will require follow-up as the MRI findings are transient.

Conclusion

In the initial work up of patients presenting with seizures, though the norm is to do an EEG and keep MRI optional, there was no significant correlation between EEG and MRI findings indicating that EEG is not an accurate indicator in ordering an MRI, and previous studies showed that patients had an abnormal MRI despite having a normal EEG which suggests that certain structural abnormalities causing seizures may be missed out. Hence, for an effective management of patients with seizures, it would be better to do MRI along with EEG as a first line of investigation for seizures. This will help in the early initiation of treatment and guide neurosurgeons, thereby enabling a better prognosis in case of underlying lesions.

References

1. Hirtz D, Thurman DJ, Gwinn-Hardy K, Mohamed M, Chaudhuri AR, Zalutsky R. How common are the "common" neurologic disorders? Neurology 2007;68(5):326–337. DOI: 10.1212/01.wnl.0000252807.38124.a3.
2. Doescher JS, deGrauw TJ, Musick BS, Dunn DW, Kalnin AJ, Egelhoff JC, et al. Magnetic resonance imaging and electroencephalographic findings in a cohort of normal children with newly diagnosed seizures. J Child Neurol 2006;21(6):491–495. PMID: 16948933.
3. Fisher RS, Boas W van E, Blume W, Elger C, Genton P, Lee P, et al. Epileptic seizures and epilepsy: definitions proposed by the International League Against Epilepsy (ILAE) and the International Bureau for Epilepsy (IBE). Epilepsia 2005;46(4):470–472. DOI: 10.1111/j.0013-9580.2005.66104.x.
4. Fisher RS, Cross JH, D'Souza C, French JA, Haut SR, Higurashi N, et al. Instruction manual for the ILAE 2017 operational classification of seizure types. Epilepsia 2017;58(4):531–542. DOI: 10.1111/epi.13671.
5. Kim SE, Lee BI, Shin KJ, Ha SY, Park J, Park KM, et al. Characteristics of seizure-induced signal changes on MRI in patients with first seizures. Seizure 2017;48:62–68. DOI: 10.1016/j.seizure.2017.04.005.
6. Spencer SS, Spencer DD. Correlation of MRI and electroencephalogram. In: Shorvon SD, Fish DR, Andermann F, Bydder GM, Stefan H, editors. Magnetic Resonance Scanning and Epilepsy. Boston, MA: Springer US; 1994. pp. 139–143 (NATO ASI Series). Available from: https://doi.org/10.1007/978-1-4615-2546-2_24.
7. MR Epilepsy/Seizure WWO Neuro Protocol|OHSU. Available from: https://www.ohsu.edu/school-of-medicine/diagnostic-radiology/mr-epilepsy-seizure-wwo-neuro-protocol.
8. Wang ZI, Jones SE, Ristic AJ, Wong C, Kakisaka Y, Jin K, et al. Voxel-based morphometric MRI post-processing in MRI-negative focal cortical dysplasia followed by simultaneously recorded MEG and stereo-EEG. Epilepsy Res 2012;100(1–2):188–193. DOI: 10.1016/j.eplepsyres.2012.02.011.
9. Crocker CE, Pohlmann-Eden B, Schmidt MH. Role of neuroimaging in first seizure diagnosis. Seizure 2017;49:74–78. DOI: 10.1016/j.seizure.2016.05.015.
10. von Oertzen J, Urbach H, Jungbluth S, Kurthen M, Reuber M, Fernandez G, et al. Standard magnetic resonance imaging is inadequate for patients with refractory focal epilepsy. J Neurol Neurosurg Psychiatry 2002;73(6):643–647. DOI: 10.1136/jnnp.73.6.643.
11. Cendes F, Theodore WH, Brinkmann BH, Sulc V, Cascino GD. Neuroimaging of epilepsy. Handb Clin Neurol 2016;136:985–1014. DOI: 10.1016/B978-0-444-53486-6.00051-X.
12. Berg AT, Testa FM, Levy SR, Shinnar S. Neuroimaging in children with newly diagnosed epilepsy: a community-based study. Pediatrics 2000;106(3):527–532. DOI: 10.1542/peds.106.3.527.
13. Özkan D, Çetinkaya Y, Özyilmaz A, Çelik HT, Misirli CH, Tireli H. Correlation of electroencephalography and magnetic resonance imaging in patients with mesial temporal sclerosis. Noro Psikiyatr Ars 2018;55(2):135–139. DOI: 10.5152/npa.2017.13783.
14. Cendes F, Leproux F, Melanson D, Ethier R, Evans A, Peters T, et al. MRI of amygdala and hippocampus in temporal lobe epilepsy. J Comput Assist Tomogr 1993;17(2):206–210. DOI: 10.1097/00004728-199303000-00008.
15. Mohan B, Mane R, Karthik GA, Raj V, Parthasarathy P, Bhat V. Utility of magnetic resonance imaging (MRI) and it's comparison with electroencephalogram (EEG) in first onset seizures in children. Int J Contemp Med Surg Radiol 2018;3(2):B4–B7. DOI: 10.21276/ijcmsr.2018.3.2.2.
16. Xuan NM, Tuong TTK, Huy HQ, N HS. Magnetic resonance imaging findings and their association with electroencephalogram data in children with partial epilepsy. Cureus 2020;12(5):e7922. DOI: 10.7759/cureus.7922.