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Role of Magnetic Resonance Imaging in the Evaluation of Seizure

[1]Mr. Rizwan Hameed, [2]Mr. Abdul Wahid, [3]Ms. Insha Imitiyaz, [4]Taljit Singh

[1]Assistant Professor, Department of Radio-Imaging Technology, Sant Baba Bhag Singh University, Jalandhar, Punjab, India.

[2]Assistant Professor, Department of Radio-Imaging Technology, Sant Baba Bhag Singh University, Jalandhar, Punjab, India.

[2] Research Scholar, Department of Radio-Imaging Technology, Maharishi Markandeshwar (Deemed to be University), Mullana, Haryana, India.

[3]Assistant Professor, Department of Radio-Imaging Technology, Sant Baba Bhag Singh University, Jalandhar, Punjab, India.

[3]Research Scholar, Department of Radio-Imaging Technology, Maharishi Markandeshwar (Deemed to be University), Mullana, Haryana, India.

[4]Attendant, M.Sc. (Medical Radiology and Imaging Technology), Sant Baba Bhag Singh University, Jalandhar, Punjab, India.

Abstract: A seizure is a medical disease characterized by brief bursts of uncontrollably high or repetitive brain neuronal activity. Epilepsy is defined as recurrent unprovoked seizures. In developing nations like India, seizures and epilepsy are significant public health issues that have a negative influence on both individuals and society at large. In developing nations such as India, epilepsy and seizures are major public health concerns that have a profound effect on both the individual and the community. Roughly 12 million individuals in India suffer from epilepsy, accounting for one-sixth of the worldwide burden. In India, the incidence of epilepsy has been reported to be 0.2 to 0.6 per 1000 people, but the prevalence ranges from 3.0 to 11.9 per 1000 people.

Aim & Objective: The aim of the study is to comprehensively investigate the role of MRI in evaluation of Seizures.

Material and Methods: The present study was a prospective cross-sectional study of 30 patients presented to the Department of Radiodiagnosis at MMIMSR, MULLANA, Ambala and met the inclusion criteria of the study. The inclusion criteria were to include all those cases who presented with seizures and all of them were subjected to brain MRI. The imaging findings were analyzed, described, and represented in the form of tables and charts.

Results: In this study, the MRI results were normal in 7 (23.33%) cases whereas remaining 23 (76.67%)cases showed a range of abnormalities which includes: tuberculoma 2 cases, granuloma 2 cases, chronic Ischemic Changes 2 cases, diffuse cortical atrophy 5 cases, NCC 6 cases, hematoma 1 case, meningitis 1 case, hypoxic ischemic insult(HII) 2 cases, mesial temporal sclerosis 1 case, hydrocephalus 1 case, encephalomalacia with gliosis 5 cases, chronic infarct 3 cases, lacunar infarct 2 cases, leukomalacia 2 cases, neuroglial cyst 1 case.

Conclusion: According to the study's findings, MR imaging is essential for evaluating individuals who have seizures by confirming or ruling out abnormalities or lesions utilizing a specific MRI seizure procedure. In this investigation, neurocysticercosis was the most prevalent anomaly found.

Keywords: Seizure, MRI, HII, NCC, MTS, Hydrocephalus, tuberculoma.

I. INTRODUCTION

It is possible to create different kinds of medical pictures by adjusting the energies and acquisition technique employed. The term "modalities" refers to the various ways that pictures can be created. Every

modality in medicine has certain uses. In the applied sciences, magnetic resonance imaging is a relatively recent field of study. The advancement of imaging techniques for soft tissues and metabolic functions within the human body has significantly bolstered its importance in biomedical research applications. The comparatively harmless nature of magnetic fields in MRI, together with its "noninvasive" aspect, was one of the primary factors that first generated excitement about the technology employed enables the diagnosis of diseases in individuals nearly all ages. These days, MRI holds significant promise for expanding our outstanding the structure and functions of the human body. NMR serves as foundation for MRI. The term "resonance" describes the requirement to match the (radio)frequency of an oscillating magnetic field, whereas the term "magnetic" pertains to utilizing diverse magnetic fields to affect the spin precession frequency of nuclei within tissue molecules. Although it would be more appropriate to refer to this discipline as NMRI rather than MRI, the term "nuclear" raises a lot of concerns. The public and the medical community have accepted the MRI acronym although it is true that the term "nuclear component" has been suppressed and only describes the benign purpose of the nucleus' "spin" in the procedure. (1) MRI is a marvel of contemporary medicine. MRI offers outstanding contrast for soft tissues and high spatial resolution, allowing it to depict dynamic physiological changes. (2)

Origin of Magnetic Resonance Imaging: Rabi studied the magnetic characteristics of nuclei and, in 1938, made the discovery of nuclear magnetic resonance (NMR). Rabi was captivated by the research of Otto Stern and Walther Gerlach, that demonstrated the inherent quantum features of particles. Felix Bloch and Edward Purcell improved the techniques and successfully detected NMR signal from liquids and solids in 1946, a several years afterward. In 1944, Rabi was awarded the Nobel Prize in physics, and in 1952, Bloch and Purcell were recognized for their findings. Rabi, Bloch, Purcell, and other physicists in this field had set the groundwork, however it wasn't till 1973 that Paul Lauterbur created a technique that produced a significant discovery that revolutionized the application of NMR for imaging by utilizing magnetic field gradients to spatially encode the NMR signal. Peter Mansfield also discovered, about the same time, how to introduce a linear gradient across an object to determine its spatial structure. The pivotal breakthrough in MRI was the concept of using magnetic field gradients to create spatially changing resonance frequencies so as to evaluate the spatial distribution of magnetization. In 2003, Lauterbur and Mansfield received the Nobel Prize in Medicine for their contributions. Since its existence and evolution, MRI has rapidly emerged as an essential medical imaging tools at doctors' disposal. MRI employs magnetic fields and radio waves, distinct from imaging techniques like CT scans, which utilize ionizing radiation. (3)

Principle of Magnetic Resonance Imaging: During an MRI, incoming patient is positioned within a magnetic field, and antennas, or "coils," are positioned all around the body to produce a radio wave pulse. After a certain amount of time, depending on the spatially dependent magnetic traits of the tissue, protons within the patient re-emit their energies in the form of radiowaves that they had previously absorbed. The antennas surrounding the patient pick up radio waves that the patient's protons release. The frequency at which protons resonate termed as resonance frequency changes with position in the patient by utilizing magnetic field gradients to gently alter the intensity of magnetic field strength. As frequency is dependent on the intensity of the magnetic field. MRI system locates each patient signal by analyzing the frequency and phase of the radio waves that are returning. Spin echo imaging is a commonly utilized MRI system operation mode. A series of tomographic pictures representing slices through the body are created by MRI; each point in an image is dependent upon the micro magnetic characteristics of the tissue at that location. (4)

Role of Magnetic Resonance Imaging in seizure: Since the outset of 1970s, neuroimaging methods have gradually improved, making it possible to see disease that was previously unknown. Ascertaining if the seizure was caused by a structural anomaly inside the brain or its environs is beneficial. A new era in the diagnosis of epileptogenic lesions began with the use of computed tomography scans for radiological study of the brain. Reduced numbers of patients undergoing surgery without a diagnosis were made possible by the visibility of large structural abnormalities, especially those with calcified components. New understandings of the anatomical basis of epilepsy and the identification of the lesions responsible for uncontrollably occurring seizures have been gained since the use of magnetic resource imaging (MRI) in clinical practice. Preoperatively, MRI has demonstrated greater efficacy in terms of diagnosis for locating the epileptogenic center. Its superior soft-tissue contrast, which enables more intricate imaging of anatomy, its absence of dangerous radiations, and the basal brain's beam hardening artifact are all contributing factors. Because MRIs can diagnose epilepsy more accurately than other diagnostic methods, they are becoming the primary method for neuroimaging studies. (5)

MRI Protocol

➢ **Indications for MRI in patients with seizures:**

- Focal onset of seizures
- Focal deficit on neurological or neuro-psychological examination
- Appearance of generalized or unclassified seizures either during infancy or later in adulthood
- Loss of seizure control or change in seizure pattern. (6)

➢ **Equipments:**

Head coil	Ear plugs
Immobilization pads and straps	Pillows/cushions

➢ **Patient positioning:**

- The patient lies in a supine position and the head is caged within the head coil and head is taken first.
- The position of head is maintained such that the intrapapillary line (IPL) is made parallel to the couch.
- The position of patient is adjusted to ensure that that horizontal alignment light travels through the nasion and the longitudinal alignment line lies in the midline.
- For immobilization purpose, foam cushions and straps are utilized. (7)

➢ **Scout:** Plane GRE localizer or T1Sagittal

➢ **Pulse sequences used:**

Survey-hst	T2w_tse (tr:4645; te:100)
T1w_se_hst (tr:542; te:100)	Dwi_hst (tr: 4046; te:116)
3d_brain view	3d_brain_flair (tr:11000/2800; te:140)
Flair_2mm (tr:11000/2450; te:140)	T2w_tse_2mm (tr:8000; te:125)

➢ **Scan range:** From the foramen magnum to the vertex

➢ **Slice thickness:** 5 mm

➢ **Slice interval:** 1-2 mm (8)

Anatomy of brain: The brain is a nerve tissue organ that controls reaction, feeling, motion, emotions, speech, memory, and mental processes. It also possesses a blood-brain barrier that shields the brain from any dangerous material floating in the blood. (9)

Seizures: A paroxysmal change in neurologic function brought on by abnormally high neuronal electrical activity is known as a seizure. Recurrent seizures that are not brought on by a recent systemic or neurological trauma are the hallmark of epilepsy, a chronic illness. The cerebral cortex's grey matter is the source of aberrant, excessive neuronal activity, which manifests clinically as epileptic seizures. (10) Distinctive diagnosis includes convulsive concussion, convulsive syncope, rigors, movement problems, sleep-related events, and psychogenic non-epileptic episodes. (11) Only 2 percent of people will acquire epilepsy, however up to 10% of people will experience at least one seizure in their lives. Between 34 to 76 new cases are diagnosed per 100,000 people annually. (10)

Classification of seizures: In 2017, the International League Against Epilepsy (ILAE) introduced the ILAE 2017 Classification, a refined system for categorizing seizures with the goal of offering greater precision and detail. An overview of the seizure classification according to this model:

1. **Focal seizures:** Originating in one hemisphere of the brain, these seizures are further distinguished based on whether consciousness remains intact or is impaired.
- **Focal aware seizures (formerly simple partial seizures):** Seizures where consciousness is maintained.
- **Focal impaired awareness seizures (formerly complex partial seizures):** Seizures characterized by varying degrees of impaired consciousness.
- **Focal to bilateral tonic-clonic seizures:** Seizures starting focally and then spreading to involve both hemispheres, resulting in tonic-clonic activity.
2. **Generalized seizures:** Involving both brain hemispheres from the onset and encompassing various subtypes.
- **Absence seizures:** Brief episodes of impaired consciousness with sudden onset and offset.
- **Tonic seizures:** Involuntary muscle contractions leading to stiffness.

- **Atonic seizures:** Characterized by a sudden loss of muscle tone, resulting in falls.
- **Clonic seizures:** Seizures characterized by rhythmic jerking movements.
- **Myoclonic seizures:** Sudden, brief muscle jerks.
- **Tonic-Clonic seizures (formerly grand mal seizures):** Involving stiffening (tonic phase) followed by jerking (clonic phase).

3. **Unknown onset seizures:** Seizures where the onset is not witnessed, making it uncertain whether they are focal or generalized. (12)

Causes of seizures

1. Genetic factors: Certain genetic mutations or inherited conditions can predispose individuals to epilepsy by altering the normal function of ion channels in the brain, affecting neuronal excitability and leading to seizures.

2. Structural brain abnormalities: Structural abnormalities such as cortical malformations, brain tumors, or traumatic brain injuries can disrupt normal neuronal activity and trigger seizures.

3. Developmental disorders: Conditions like autism spectrum disorder, neurodevelopmental delays, or intellectual disabilities may increase epilepsy risk due to underlying alterations in brain structure and function.

4. Perinatal injury: Brain injuries during prenatal, perinatal, or early postnatal periods, such as hypoxic-ischemic encephalopathy or birth trauma, can predispose individuals to epilepsy later in life.

5. Acquired causes:

Brain trauma: Head injuries from accidents, falls, or assaults can cause brain damage, leading to the development of seizures.

Stroke: Interruption of blood flow to the brain due to strokes can cause ischemic or hemorrhagic damage, leading to seizures. **Infections:** Certain infections like meningitis, encephalitis, or brain abscesses can cause inflammation and neuronal damage.

Metabolic disorders: Imbalances in electrolytes or glucose levels can disrupt neuronal function and trigger seizure.

6. Other causes:

Brain tumors: Primary or metastatic brain tumors can cause seizures by exerting mass effect or disrupting neuronal networks. **Vascular malformations:** Abnormalities like arteriovenous malformations in the brain can predispose individuals to seizures.

Autoimmune disorders: Autoimmune encephalitis, multiple sclerosis, or systemic lupus erythematosus (SLE) can involve the central nervous system, leading to inflammation and seizures.

Pathophysiology of seizures

- **Neuronal hyperexcitability:** At the core of seizure development lies the hyperexcitability of neurons in the brain. This hyperexcitability can arise from various factors, including genetic mutations affecting ion channels, alterations in neurotransmitter function, or structural abnormalities in the brain.
- **Imbalance of neurotransmitters:** Neurotransmitters are chemical messengers that facilitate communication between neurons. The balance between excitatory and inhibitory neurotransmitters is crucial for maintaining normal neuronal function. Gamma-aminobutyric acid (GABA) is the primary inhibitory neurotransmitter, while glutamate is the main excitatory neurotransmitter. Disruptions in this balance, such as decreased GABAergic inhibition or increased glutamatergic excitation, can lead to neuronal hyperexcitability and predispose individuals to seizures.
- **Ion channel dysfunction:** Ion channels are membrane proteins that regulate the flow of ions into and out of neurons, thereby controlling neuronal excitability. Mutations or abnormalities in ion channels, particularly voltage-gated sodium channels, can lead to aberrant neuronal firing and increased susceptibility to seizures.
- **Genetic factors:** Certain genetic mutations are associated with an increased risk of seizures and epilepsy.

II. Material and methodology:

The current study was a comparative cross-sectional investigation carried out at the Department of Radiodiagnosis, MMIMSR, Mullana, spanning from December 2023 to April 2024.

Type of study: Descriptive Cross-sectional.

Duration of study: The study was carried out for a period from December 2023 to April 2024.

Study setting: Department of Radio-Diagnosis, MMIMSR, Mullana.
Sample size: This study was conducted on 30 patients in Radiology department.

Inclusion and exclusion criteria: The study delineated specific inclusion and exclusion criteria as follows:

- **Inclusion criteria:** All the patients present with seizures.
  Cases were included irrespective of age/sex.
- **Exclusion criteria:** Contraindications to MRI studies.
  Patients with history of metabolic disturbances (hepatic/renal failure), were not included in the study.

Ethical clearance:
Ethical Clearance Certificate was obtained from the Institutional Ethical Committee of Maharishi Markandeshwar Institute of Medical Sciences and Research, MMDU, Mullana, Ambala.
Study procedure:
All patients were chosen according to the specific inclusion and exclusion criteria. A thorough history, comprehensive physical examination and routine and appropriate investigations were conducted for each patient.
Equipments:
MRI examinations for all patients included in the study were conducted using 1.5 Tesla scanner (ACHIEVA, PHILIPS MEDICAL SYSTEMS, THE NETHERLANDS) MR MACHINE in the Department of Radio-Diagnosis and Imaging, MMIMSR, Mullana, Ambala.

III. Results

Observations:
A prospective hospital-based study was undertaken involving 30 patients to assess the role of MRI in the evaluation of seizures.

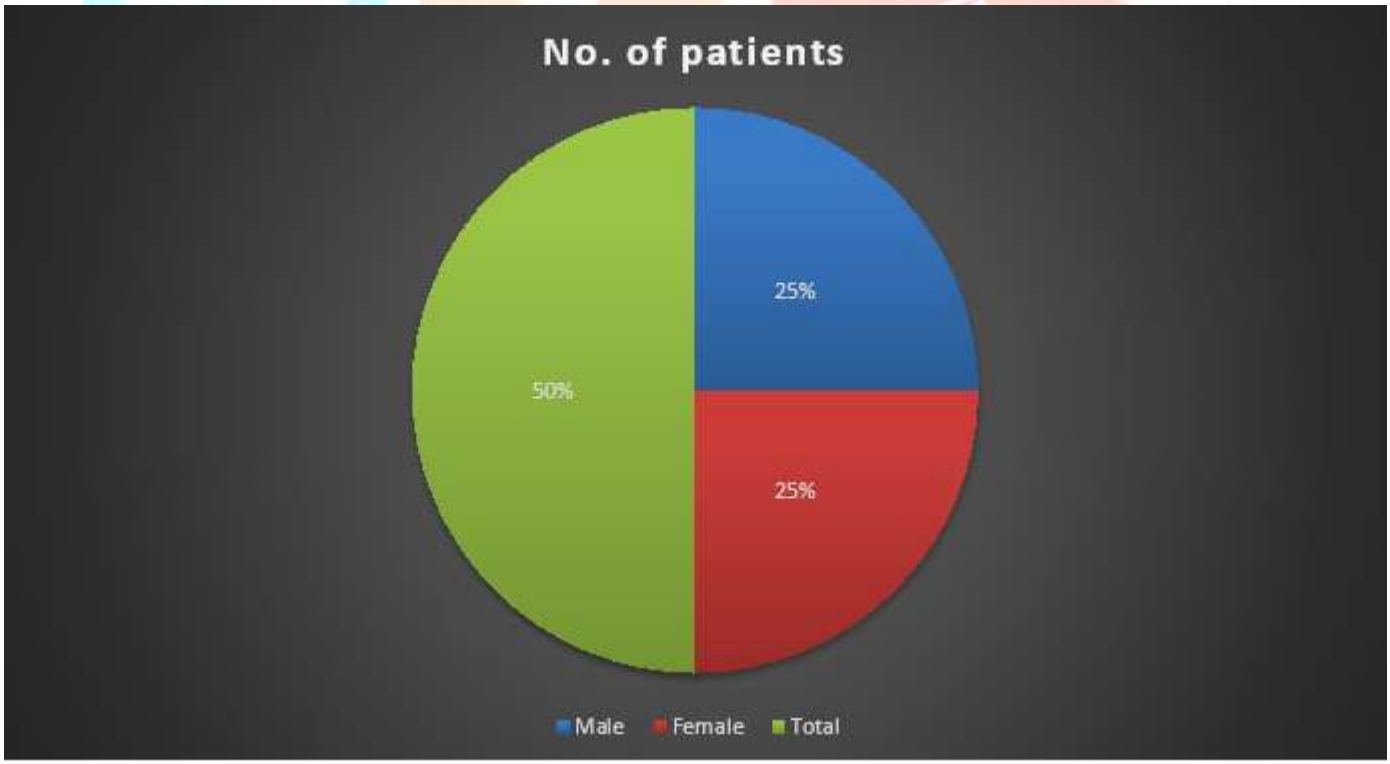

Fig 1.1 Distribution of patient as per sex/gender

Fig 1.1 shows that distribution of patients according to sex/gender. Out of 30 patients, 15 patients (50%) are male while the remaining 15 patients (50%) are females.

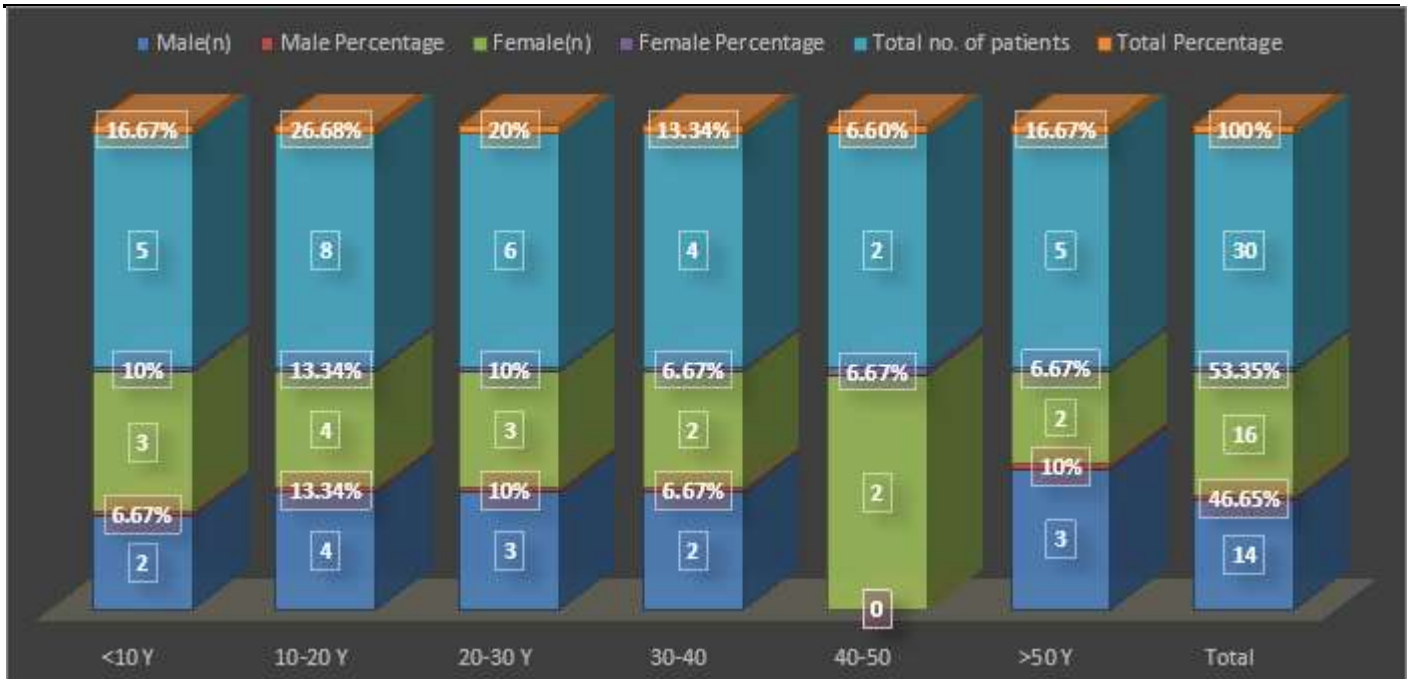

Fig 1.2 Distribution of patients as per age

Fig 1.2 shows that distribution of patients as per age, 16.67%(n=5) were in the age group of 1-10 years, 26.68%(n=8) patients were in the age group of 10-20 years, 20% (n=6) were in the age group of 20-30 years, 13.34%(n=4) patients were in the age group of 30-40 years, 6.60%(n=2) patients are in the age range of 40-50 years, 16.67%(n=5) patients were in the age group of >50 years.

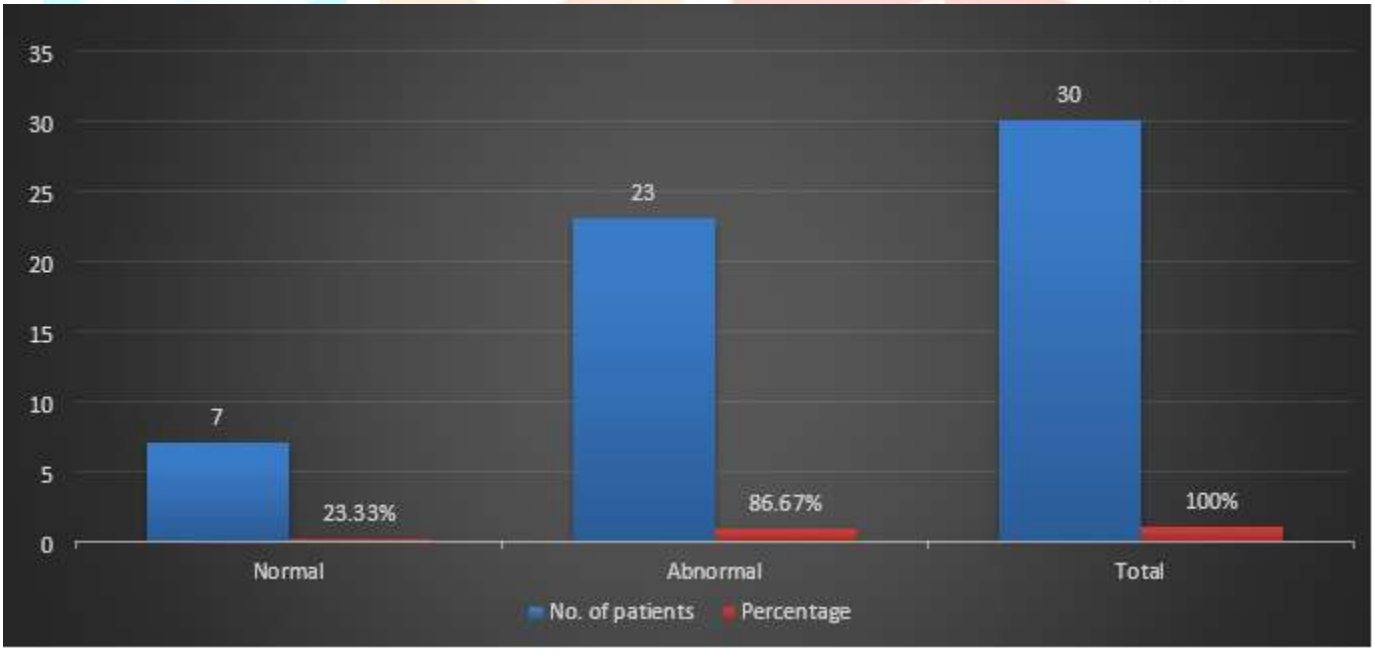

Fig 1.3 Distribution of patients as per normal and abnormal MRI

Fig 1.3 shows that distribution of patients as per normal and abnormal MRI. In our study, out of 30 patients, 7 patients (23.33%) have normal MRI investigation whereas 23 patients (86.67%) have abnormal MRI investigation.

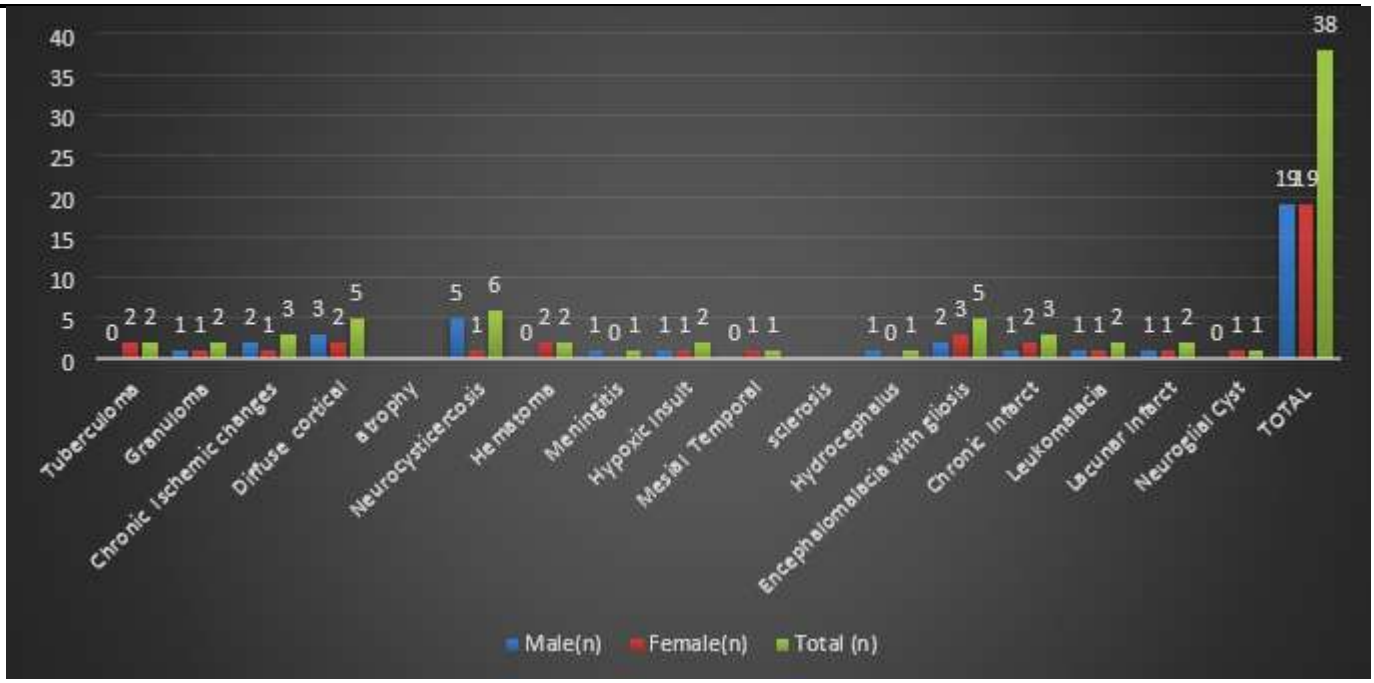

Fig 1.4 Distribution of MRI findings as per number of findings in patients

Fig 1.4 shows that distribution of MRI findings as per number of findings in patients. It was observed that majority of the male patients had NCC (5 out of 19) and majority of females had Encephalomalacia with gliosis (3 out of 19). Overall, NCC was observed as the most common findings, followed by Encephalomalacia with gliosis and diffuse cortical atrophy.

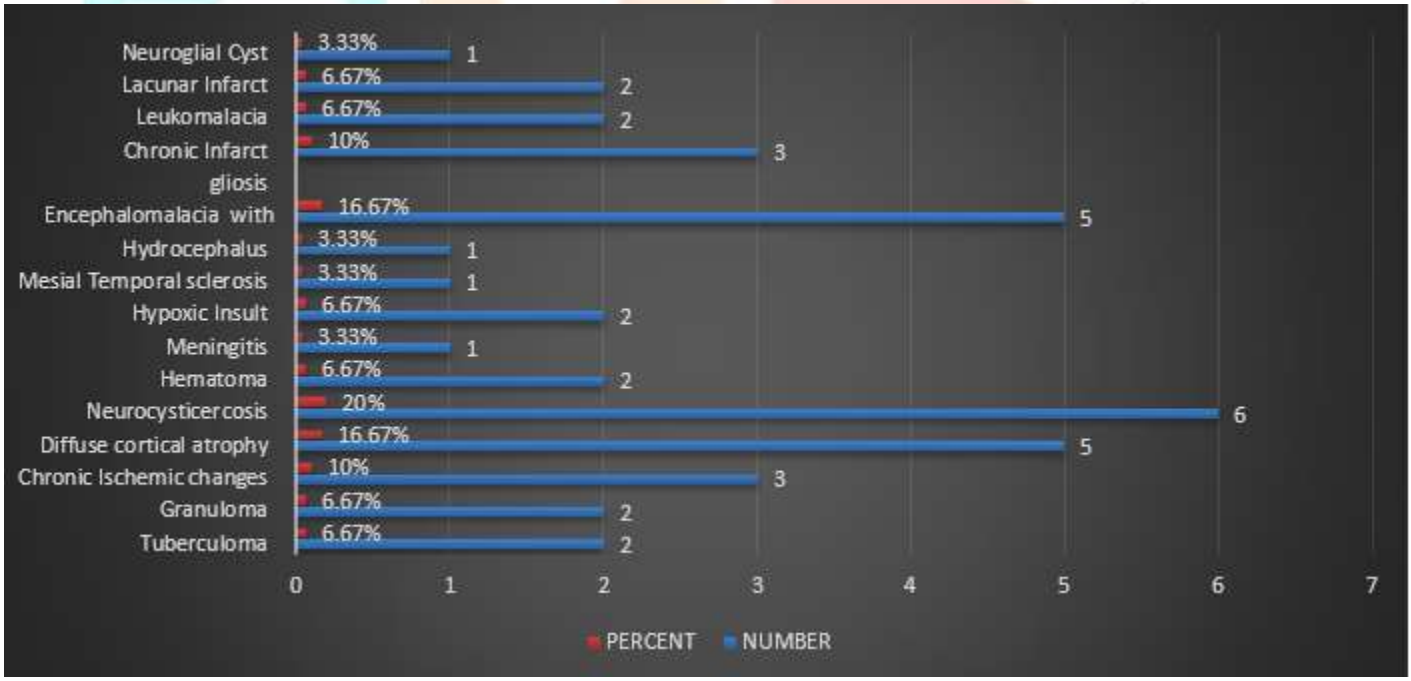

Fig 1.5 Distribution of MRI findings as per number of patients

Fig 1.5 shows that NCC was the most common finding in the patients, followed by encephalomalacia with gliosis and diffuse cerebral atrophy, whereas Mesial temporal sclerosis, neuroglial cyst and hydrocephalus was least observed.

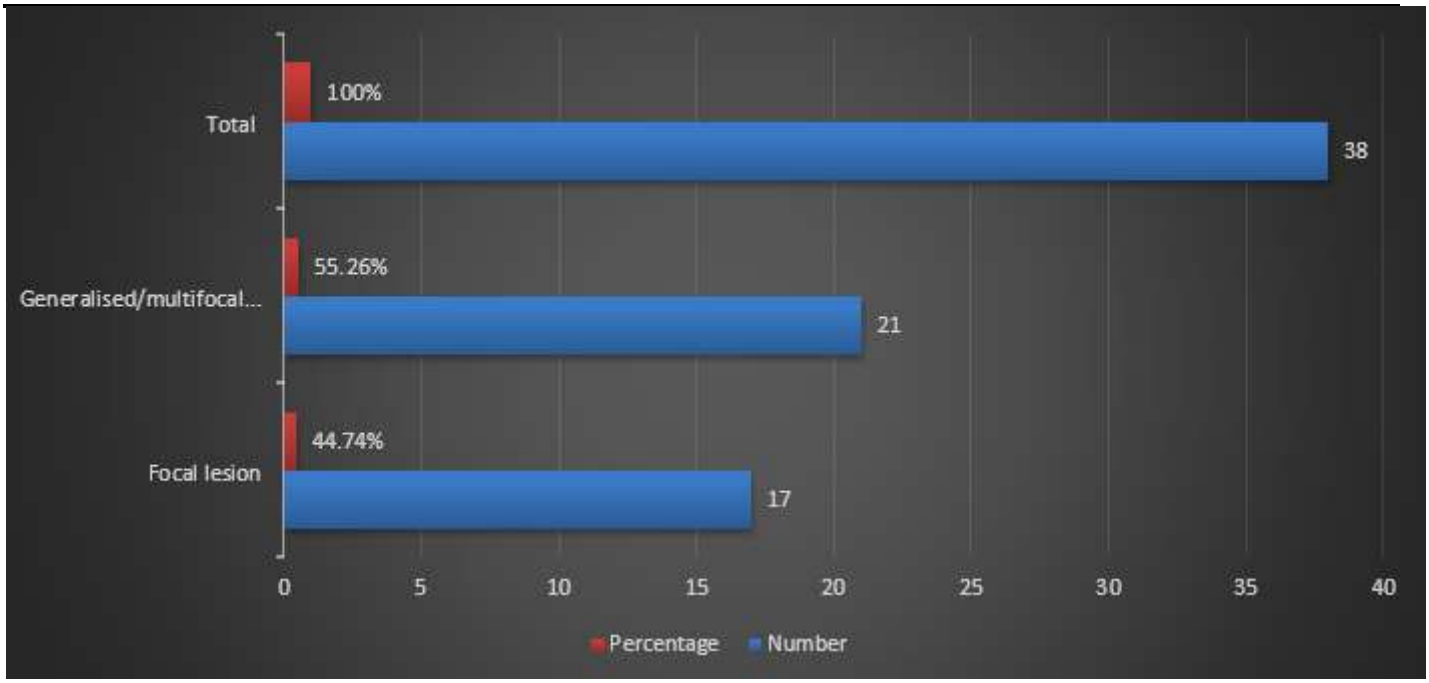

Fig 1.6 Distribution of MRI findings as per type of lesion

Fig 1.6 shows that distribution of MRI findings as per type of lesion. Among 38 findings observed in 23 abnormal studies, 17 findings (44.74%) were focalised in nature while 21 findings (55.26%) were generalised in nature.

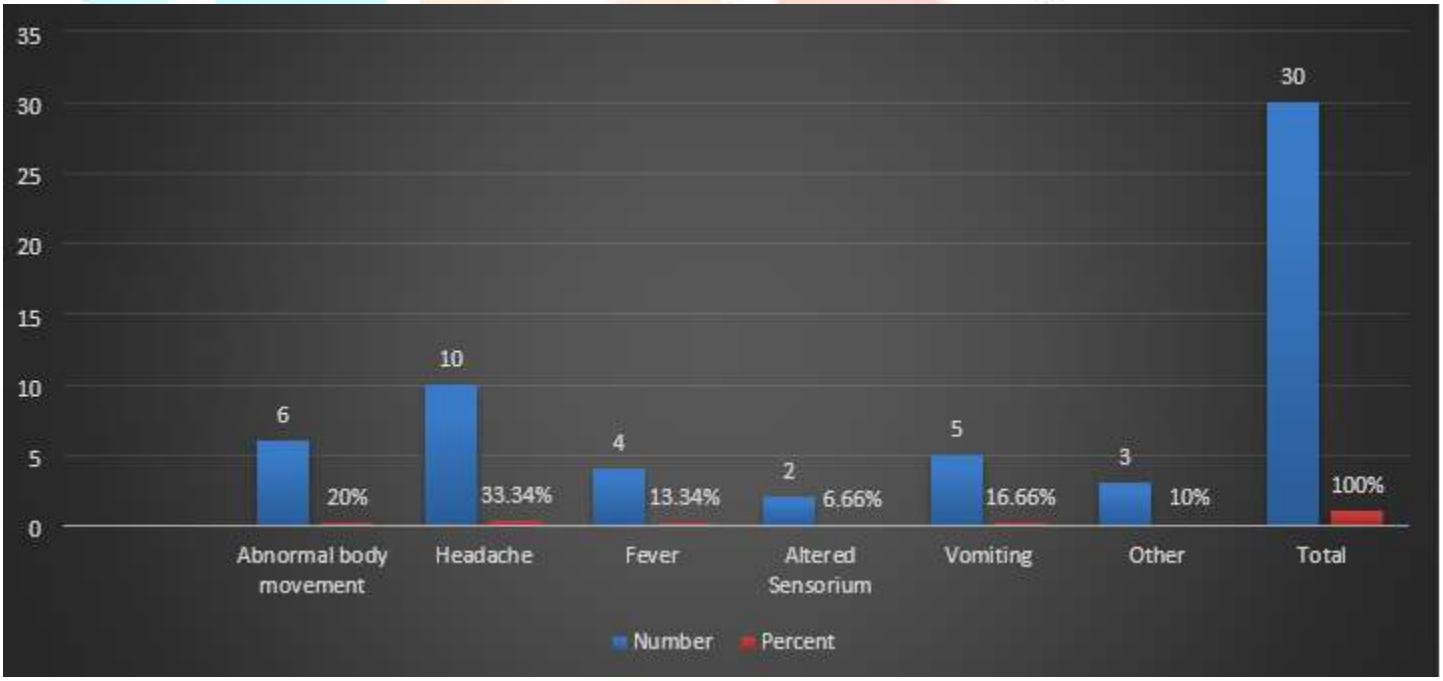

Fig 1.7 Distribution of patients as per clinical symptoms

Fig 1.7 shows that distribution of patients as per clinical symptoms, 33.34% (n=10) had headache, 20% (n=6) had abnormal body movements, 16.66% (n=5) had vomiting, 13.34% (n=4) had fever, 6.66% (n=2) had altered sensorium and 10% (n=3) had other manifestations.

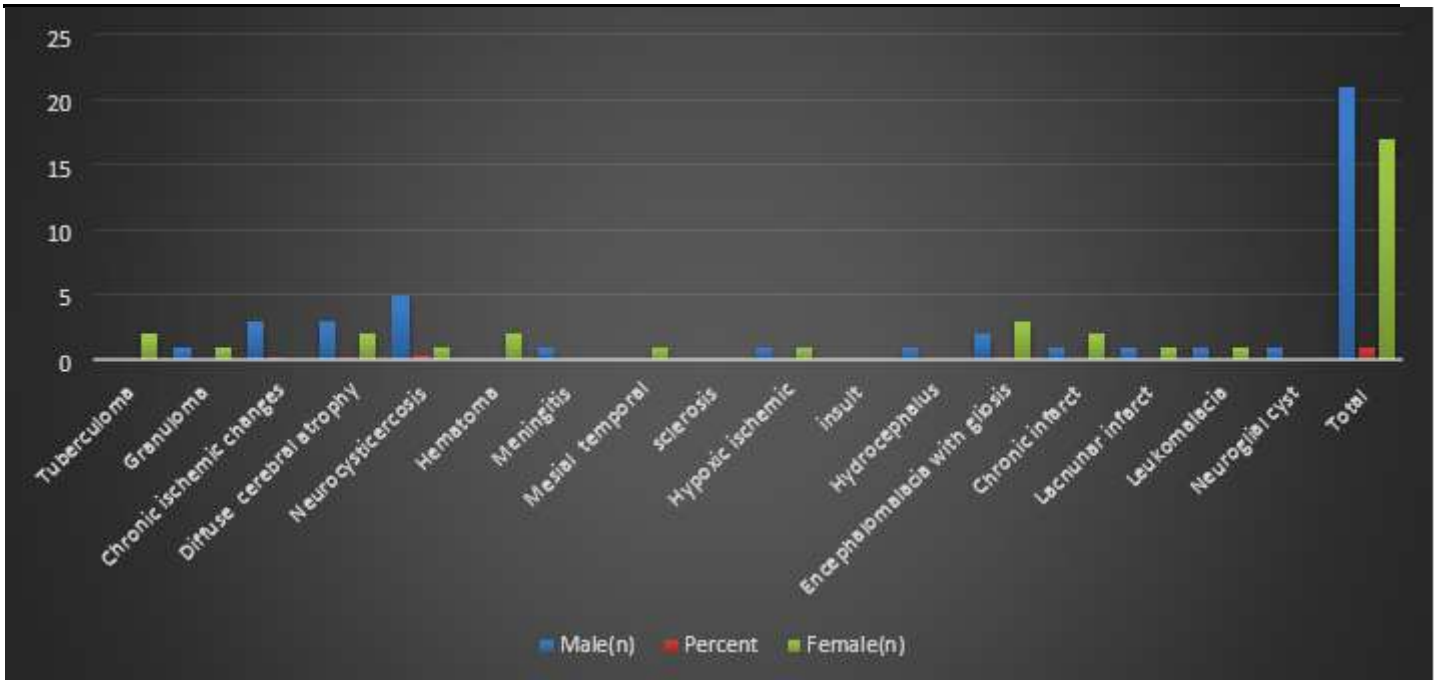

Fig 1.8 Association of MRI Diagnosis with gender.

Fig 1.8 shows that association of MRI Diagnosis with gender. Findings like hypoxic ischemic insult, lacunar infarct, leukomalacia and granuloma were equal in both the sexes, whereas neurocysticercosis was found to be common in males than female, encephalomalacia with gliosis was more common in female.

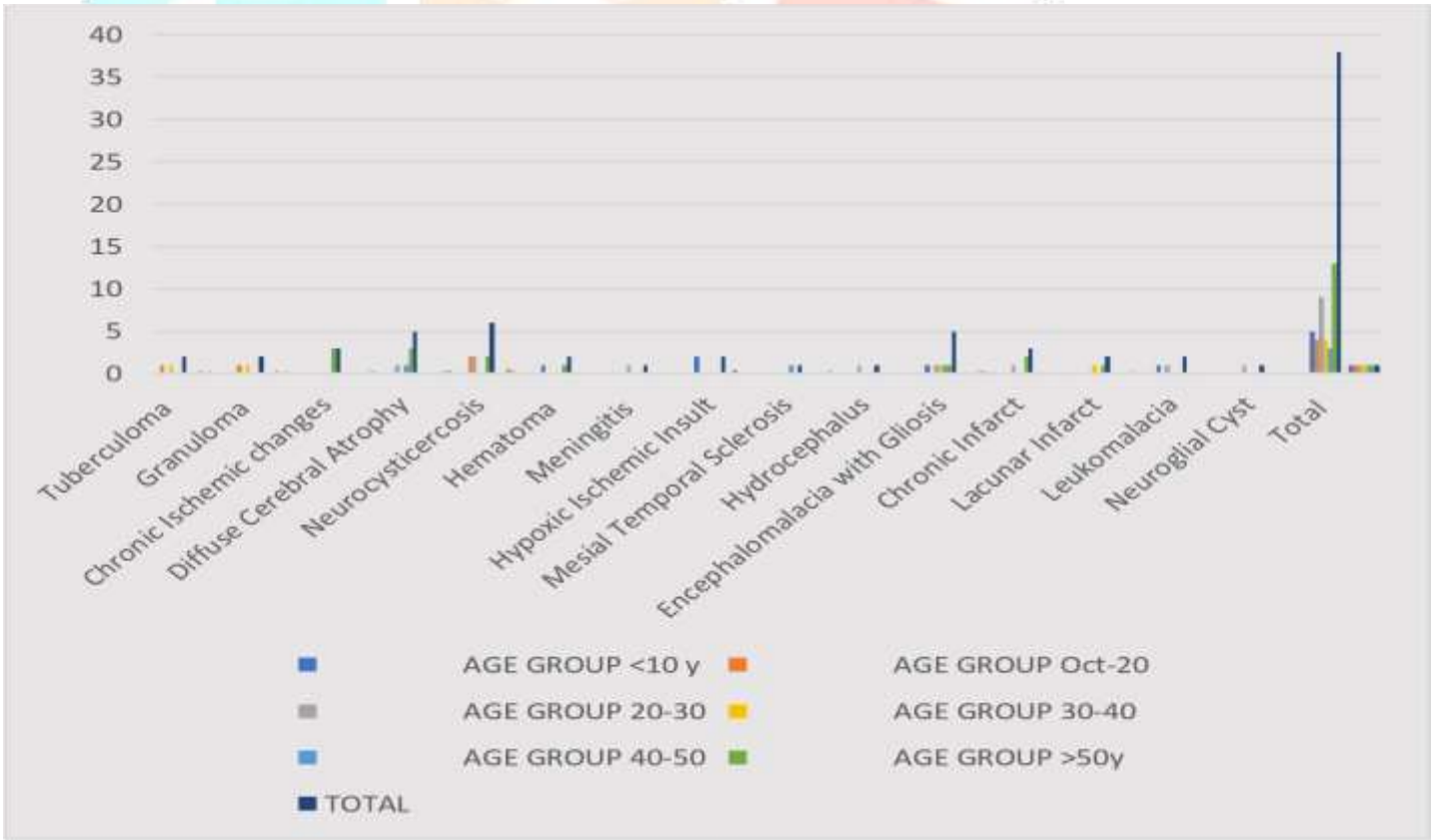

Fig 1.9 Association of MRI diagnosis with age group

Fig 1.9 shows that association of MRI diagnosis with age group, chronic ischemic changes, diffuse cerebral atrophy chronic infarct were common in the age group >50 years, whereas other manifestations were common in younger age groups.

IV. Discussion:

In a meticulously conducted prospective study carried out in the Department of Radiology, MMIMSR, Mullana, the pivotal role of MRI in assessing seizures was examined, involving a cohort comprising 30 patients.

The gender distribution within the study cohort displayed a striking equilibrium, with precisely 15 male (50%) and 15 female (50%) participants, indicating a gender-neutral trend in seizure occurrences. Upon closer inspection of age demographics, a diverse representation emerged, with the largest proportion falling within the 10-20 years age bracket (26.68%), followed by individuals aged >50 years (16.67%). No participants were observed within the 40-50 years age range, warranting further investigation into potential age-specific dynamics or selection biases. This is in contrast with the study conducted by **Namrita Dhar et al. and Avadhesh Pratap Singh, et al.** Both of the study found male prevalence in their patient sample.

An examination of the MRI data revealed a significant majority of abnormalities: 23 patients (86.67%) had results that deviated from normal instances, while just 7 patients (23.33%) had unremarkable results. Examining the MRI data in greater detail revealed that neurocysticercosis was more common in male patients, but encephalomalacia with gliosis was more common in female patients, indicating different pathogenic tendencies in the two genders. It was observed that majority of the male patients had NCC (5 out of 19) and majority of females had Encephalomalacia with gliosis (3 out of 19). Overall, NCC was observed as the most common findings, followed by Encephalomalacia with gliosis and diffuse cortical atrophy. A study conducted by **Namrita Dhar et al.** similarly observed NCC as the major finding on MRI.

Further stratification of MRI findings according to lesion type unveiled a heterogeneous landscape, with 44.74% of observations characterized as focal lesions and the remaining 55.26% as multifocal or generalized in nature, indicative of the diverse underlying etiologies contributing to seizure pathogenesis. Clinically, a spectrum of symptoms manifested, with headache emerging as the most prevalent complaint (33.34%), closely followed by abnormal body movements (20%) and vomiting (16.66%), underscoring the multifaceted clinical presentations associated with seizures.

Association analyses delved into the intricate interplay between gender, age, and MRI diagnoses, revealing age-related predilections such as chronic ischemic changes and chronic infarct, that were more commonly observed in individuals aged >50 years. This comprehensive exploration underscores the indispensable role of MRI in unravelling the enigmatic labyrinth of seizures, shedding light on the nuanced demographic and clinical factors that shape diagnostic outcomes and guide personalized clinical management strategies.

V. Conclusion:

This article makes a substantial contribution to our understanding of seizures, particularly in terms of using MRI as a diagnostic tool. The balanced gender distribution seen in the patient sample demonstrates that seizures affect every individual regardless of gender, emphasizing the universality of this neurological condition. Furthermore, the range of ages represented emphasizes the significance of taking age into account while evaluating and managing seizures. The prevalence of abnormalities discovered by MRI highlights the diagnostic value of this imaging modality, allowing doctors to identify underlying diseases that contribute to seizure development.

The detailed gender-specific and age-related tendencies found in certain MRI diagnoses shed light on the complicated interplay of demographic factors in seizure genesis. For example, the difference in prevalence of neurocysticercosis and encephalomalacia with gliosis between genders shows that there may be gender-specific susceptibility or disease processes. the link between certain MRI findings, such as chronic ischemia alterations and chronic infarction, and older age groups emphasizes the importance of age in understanding seizure pathogenesis. This study emphasizes the importance of MRI in strengthening our diagnostic capabilities and improving our understanding of seizures. By illuminating the various underlying pathologies and demographic subtleties associated with seizures, MRI allows clinicians to make more precise diagnosis and adapt treatment options. Further investigation of the complex interplay of gender, age, and MRI findings will be critical for improving our approach to seizure evaluation and enhancing patient outcomes in clinical practice.

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