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**Research Article**

# MRI-BASED ASSESSMENT OF STRUCTURAL BRAIN CHANGES IN PATIENTS WITH EPILEPSY: A RETROSPECTIVE OBSERVATIONAL STUDY

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**Abstract**: ***Introduction:*** Epilepsy is a common neurological disorder characterized by recurrent unprovoked seizures resulting from abnormal electrical activity in the brain. Magnetic Resonance Imaging (MRI) plays a pivotal role in identifying structural brain abnormalities that contribute to epileptogenesis and assists in diagnosis, treatment planning, and prognostic evaluation. **Aim**: The present study aims to assess structural brain changes in patients with epilepsy using Magnetic Resonance Imaging (MRI). The objectives are to evaluate cortical and subcortical abnormalities, identify the etiological factors responsible for seizures, determine syndrome-specific structural alterations, assess the diagnostic utility of different MRI sequences, examine the role of MRI as a non-invasive imaging modality, and analyze the distribution of structural changes according to patients' age, sex, and duration of epilepsy. **Materials and Methods:** This retrospective observational study included 100 patients with epilepsy selected from 120 MRI records after applying predefined inclusion and exclusion criteria. MRI examinations performed between 1st January 2019 and 1st June 2019 were analyzed. MRI findings were reviewed using conventional sequences, including T1-weighted, T2-weighted, FLAIR, Diffusion-Weighted Imaging (DWI), Susceptibility-Weighted Imaging (SWI), and post-contrast imaging where available. Cortical thickness measurements were obtained using CAT12 software, and structural changes were compared across different epilepsy syndromes. **Results**: The majority of patients belonged to the 5–15 years age group (38%), with a male predominance (57%). Generalized tonic-clonic seizures were the most common seizure type (38%), while Idiopathic Generalized Epilepsy (60%) was the predominant epilepsy syndrome. MRI detected diverse structural abnormalities, including hippocampal involvement, ischemic lesions, traumatic changes, vascular malformations, and developmental abnormalities. Mesial temporal lobe epilepsy demonstrated characteristic ipsilateral hippocampal changes, whereas quantitative cortical thickness analysis revealed syndrome-specific alterations involving the medial temporal, frontal, and parietal cortices. **Conclusion:** MRI is an effective, non-invasive imaging modality for identifying structural brain abnormalities in epilepsy. High-resolution MRI combined with quantitative cortical and subcortical analysis improves lesion detection, facilitates syndrome classification, and supports appropriate clinical management and surgical planning in patients with epilepsy.

**Keywords**: Epilepsy; Magnetic Resonance Imaging; Structural Brain Changes; Cortical Thickness; Hippocampus; Mesial Temporal Lobe Epilepsy; Idiopathic Generalized Epilepsy; MRI Brain; Neuroimaging; Epileptogenic Lesions.

## INTRODUCTION

Epilepsy is one of the most common chronic neurological disorders worldwide and is characterized by a persistent predisposition to generate unprovoked seizures resulting from abnormal, excessive, or synchronous neuronal activity within the brain. It affects individuals of all age groups and represents a major public health concern because of its significant impact on physical health, cognitive function, psychological well-being, and social integration. Despite remarkable advances in medical therapy, nearly one-third of patients continue to experience seizures despite appropriate antiepileptic treatment, emphasizing the importance of identifying the underlying structural abnormalities responsible for epileptogenesis.[1,2]

Magnetic Resonance Imaging (MRI) has revolutionized the evaluation of epilepsy by providing excellent soft-tissue contrast and superior spatial resolution without exposing patients to ionizing radiation. High-resolution MRI has become the imaging modality of choice for detecting structural brain abnormalities that may serve as epileptogenic foci. The identification of these abnormalities is crucial because it not only aids in establishing the etiology of epilepsy but also influences treatment decisions, particularly in patients being considered for epilepsy surgery.[3,4]

Structural abnormalities detected on MRI include hippocampal sclerosis, focal cortical dysplasia, developmental malformations, brain tumors, vascular malformations, sequelae of ischemic injury, traumatic brain injury, infections, gliosis, and neurodegenerative changes. Hippocampal sclerosis remains the most frequently identified lesion in patients with temporal lobe epilepsy, whereas focal cortical dysplasia is increasingly recognized as a common cause of drug-resistant epilepsy in children and young adults. Advances in MRI technology, including three-dimensional volumetric imaging, fluid-attenuated inversion recovery (FLAIR), diffusion-weighted imaging (DWI), susceptibility-weighted imaging (SWI), and high-resolution T1- and T2-weighted sequences, have substantially improved the detection of subtle epileptogenic lesions that were previously considered MRI-negative.[5,6]

The accurate identification of structural lesions has important clinical implications. Patients with identifiable MRI abnormalities generally have a better-defined diagnosis, improved localization of the epileptogenic zone, and a higher likelihood of successful surgical intervention when medical therapy fails. Conversely, individuals with normal MRI findings may require additional functional imaging techniques such as positron emission tomography (PET), single-photon emission computed tomography (SPECT), or advanced MRI post-processing for further evaluation. Thus, MRI serves as an indispensable component of the comprehensive assessment of epilepsy, complementing clinical history and electroencephalography (EEG).[7,8]

Recent developments in neuroimaging have further expanded the role of MRI beyond lesion detection. Quantitative volumetric analysis, cortical thickness measurements, diffusion tensor imaging (DTI), functional MRI (fMRI), and artificial intelligence-based image analysis have enhanced the understanding of structural and network-level brain alterations associated with epilepsy. These techniques have demonstrated that epilepsy often involves widespread cortical and subcortical structural changes rather than isolated focal lesions, contributing to cognitive impairment and disease progression.[9]

Retrospective observational studies evaluating MRI findings provide valuable information regarding the spectrum of structural abnormalities encountered in routine clinical practice, their etiological distribution, and their association with different epilepsy syndromes. Such studies also help determine the most effective MRI protocols for detecting epileptogenic lesions and contribute to improving diagnostic accuracy and patient management. Therefore, the present study aims to assess MRI-based structural brain changes in patients with epilepsy, identify the underlying etiological factors, evaluate syndrome-specific imaging findings, and determine the optimal MRI sequences for lesion detection in patients presenting with epilepsy.[10]

The present study aims to assess structural brain changes in patients with epilepsy using Magnetic Resonance Imaging (MRI). The objectives are to evaluate cortical and subcortical abnormalities, identify the etiological factors responsible for seizures, determine syndrome-specific structural alterations, assess the diagnostic utility of different MRI sequences, examine the role of MRI as a non-invasive imaging modality, and analyze the distribution of structural changes according to patients' age, sex, and duration of epilepsy.

# MATERIALS AND METHODS

**Study Design:** Retrospective observational study.

**Study Population:** Patients with epilepsy who underwent MRI brain examination in the Department of Radiodiagnosis, referred from the Departments of Medicine, Surgery, and Pediatrics.

**Sample Size:** A total of 120 MRI records were screened. After applying the inclusion and exclusion criteria, 100 patients were included in the final analysis.

**Study Duration:** MRI records obtained between 1st January 2019 and 1st June 2019 were retrospectively analyzed.

**Study Place:** Department of Radiodiagnosis, in collaboration with the Departments of Medicine, Surgery, and Pediatrics. MRI examinations were performed using a Siemens 1.5 Tesla MRI scanner at Atmajyoti Centre.

**Inclusion Criteria:**

- Patients with medically refractory focal or partial epilepsy referred for MRI evaluation with suspected structural epileptogenic abnormalities (e.g., hippocampal sclerosis, perinatal hypoxic injury, brain tumors, vascular malformations, cortical dysplasia, or hamartomas).
- Patients diagnosed with secondary generalized epilepsy.
- Patients diagnosed with primary generalized epilepsy.
- Patients with epilepsy associated with traumatic brain injury or cerebrovascular accident.

**Exclusion Criteria:**

- MRI records of patients with progressive neurological disorders.
- MRI records of patients who had previously undergone neurosurgical procedures for epilepsy.

**Statistical Analysis:** The collected data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) version 26.0 (IBM Corp., Armonk, NY, USA). Categorical variables were expressed as frequencies and percentages, whereas continuous variables were presented as mean ± standard deviation (SD). The normality of continuous data was assessed using the Shapiro–Wilk test. Comparisons between two independent groups were performed using the Independent Student's t-test for normally distributed variables and the Mann–Whitney U test for non-normally distributed variables. Comparisons among more than two groups were carried out using One-way Analysis of Variance (ANOVA) followed by appropriate post-hoc analysis. Associations between categorical variables were evaluated using the Chi-square test or Fisher's exact test, wherever applicable. A p-value <0.05 was considered statistically significant. The results were presented in the form of tables, charts, and graphs to facilitate interpretation of the study findings.

# RESULTS

**Table 1. Demographic Characteristics of the Study Population**

| Variable | Category | Frequency (n) | Percentage (%) |
|---|---|---|---|
| Age Group (years) | 5–15 | 38 | 38 |
| | 16–26 | 9 | 9 |
| | 27–37 | 21 | 21 |
| | 38–48 | 16 | 16 |
| | 49–59 | 7 | 7 |
| | 60–70 | 5 | 5 |
| | >70 | 4 | 4 |
| Sex | Male | 57 | 57 |
| | Female | 43 | 43 |

**Table 2. Clinical Characteristics of Epilepsy Patients**

| Variable | Category | Frequency (n) | Percentage (%) |
|---|---|---|---|
| Clinical Type | GTCS | 38 | 38 |
| | SGTCS | 21 | 21 |
| | SPS | 12 | 12 |
| | CPS | 12 | 12 |
| | PGTCS | 10 | 10 |
| | Absence Seizure | 4 | 4 |
| | Myoclonic Seizure | 3 | 3 |
| Epilepsy Syndrome | Idiopathic Generalized Epilepsy (IGE) | 60 | 60 |
| | Right & Left MTLE | 20 | 20 |
| | Other Epilepsies | 20 | 20 |

**Table 3. Distribution of Etiological Diagnoses in the Other Epilepsy Group**

| Diagnosis | Frequency (n) | Percentage (%) |
|---|---|---|
| AI | 3 | 15 |
| CE | 3 | 15 |
| CI | 3 | 15 |
| DM | 1 | 5 |
| H | 1 | 5 |
| I | 6 | 30 |
| T | 2 | 10 |
| VM | 1 | 5 |
| Total | 20 | 100 |

**Table 4. Distribution of Patients According to Age Group and Sex**

| Age Group (years) | Male n (%) | Female n (%) | Total n (%) |
|---|---|---|---|
| 5–15 | 24 (42.1) | 14 (32.6) | 38 (38.0) |
| 16–26 | 4 (7.0) | 5 (11.6) | 9 (9.0) |
| 27–37 | 11 (19.3) | 10 (23.3) | 21 (21.0) |
| 38–48 | 7 (12.3) | 9 (20.9) | 16 (16.0) |
| 49–59 | 4 (7.0) | 3 (7.0) | 7 (7.0) |
| 60–70 | 4 (7.0) | 1 (2.3) | 5 (5.0) |

| | | | |
|---|---|---|---|
| >70 | 3 (5.3) | 1 (2.3) | 4 (4.0) |
| Total | 57 (100.0) | 43 (100.0) | 100 (100.0) |

**Table 5. Comparison of Cortical Thickness Across Epilepsy Syndromes**

| Brain Region | Pediatric IGE (n=30) | Male IGE (n≈32) | Female IGE (n≈28) | Right MTLE (n=11) | Left MTLE (n=9) |
|---|---|---|---|---|---|
| Right Medial Temporal | 2.69 ± 0.08 | 2.68 ± 0.06 | 2.67 ± 0.12 | 2.71 ± 0.08 | 2.80 ± 0.08 |
| Left Medial Temporal | 2.77 ± 0.04 | 2.71 ± 0.07 | 2.71 ± 0.11 | 2.80 ± 0.04 | 2.77 ± 0.04 |
| Right Frontal Lobe | 2.54 ± 0.04 | 2.48 ± 0.07 | 2.56 ± 0.05 | 2.48 ± 0.04 | 2.46 ± 0.05 |
| Left Frontal Lobe | 2.50 ± 0.08 | 2.46 ± 0.07 | 2.45 ± 0.04 | 2.47 ± 0.08 | 2.47 ± 0.08 |
| Right Parietal Lobe | 2.25 ± 0.03 | 2.20 ± 0.08 | 2.17 ± 0.07 | 2.28 ± 0.03 | 2.28 ± 0.04 |
| Left Parietal Lobe | 2.26 ± 0.03 | 2.20 ± 0.08 | 2.17 ± 0.07 | 2.32 ± 0.02 | 2.37 ± 0.03 |

**Table 6. Comparison of Subcortical Brain Structures Among Epilepsy Syndromes**

| Structure | Pediatric IGE | Male IGE | Female IGE | Right MTLE | Left MTLE |
|---|---|---|---|---|---|
| Right Thalamus | 8.38 ± 0.12 | 8.11 ± 0.50 | 7.90 ± 0.29 | 8.08 ± 0.12 | 8.05 ± 0.13 |
| Left Thalamus | 8.15 ± 0.07 | 7.87 ± 0.42 | 7.87 ± 0.42 | 7.72 ± 0.06 | 7.71 ± 0.07 |
| Right Hippocampus | 4.13 ± 0.05 | 4.08 ± 0.08 | 4.08 ± 0.35 | 3.45 ± 0.04 | 4.13 ± 0.05 |
| Left Hippocampus | 3.86 ± 0.08 | 3.89 ± 0.10 | 3.87 ± 0.28 | 3.83 ± 0.08 | 3.32 ± 0.08 |

**Figure: 1. Distribution of Etiological Diagnoses in the Other Epilepsy Group**

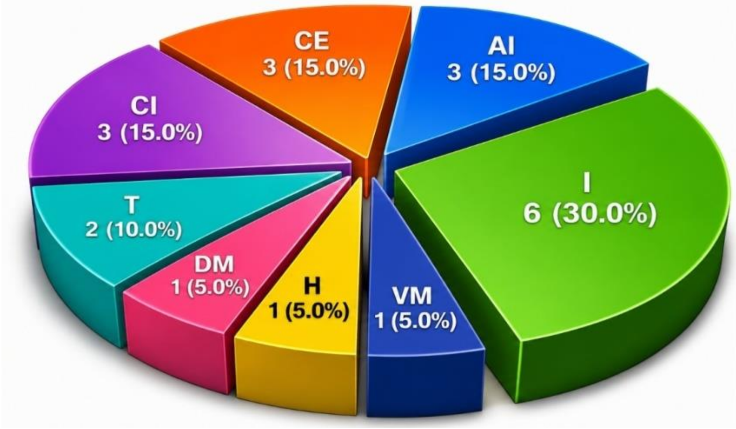


**Figure: 2. Comparison of Subcortical Brain Structures Among Epilepsy Syndromes**

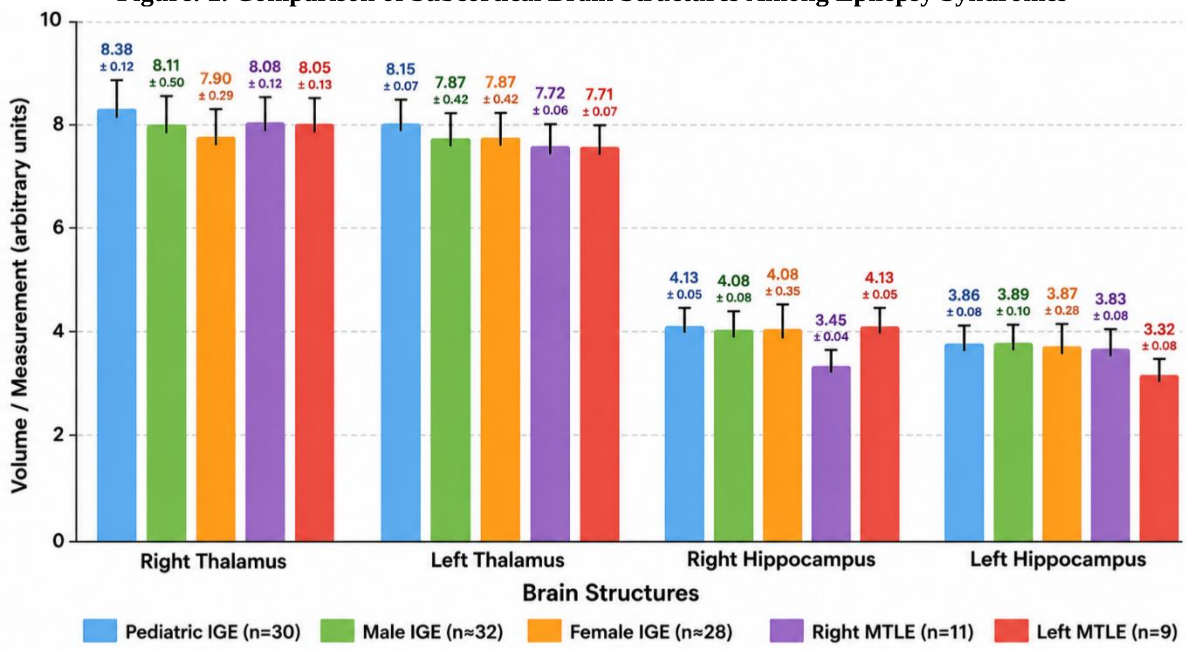

Table 1 summarizes the demographic profile of the 100 patients included in the study. The largest proportion of patients belonged to the 5–15 years age group, accounting for 38 (38.0%) cases, followed by the 27–37 years age group with 21 (21.0%) patients. Patients aged 38–48 years constituted 16 (16.0%) of the study population, while 9 (9.0%) patients were in the 16–26 years age group. Older age groups were less frequently represented, including 7 (7.0%) patients aged 49–59 years, 5 (5.0%) aged 60–70 years, and only 4 (4.0%) patients above 70 years of age. With regard to sex distribution, 57 (57.0%) patients were males and 43 (43.0%) were females, demonstrating a slight male predominance among patients with epilepsy undergoing MRI evaluation.

Table 2 presents the clinical characteristics of epilepsy among the study participants. Generalized Tonic-Clonic Seizures (GTCS) were the most common clinical presentation, observed in 38 (38.0%) patients. This was followed by Secondary Generalized Tonic-Clonic Seizures (SGTCS) in 21 (21.0%) patients. Both Simple Partial Seizures (SPS) and Complex Partial Seizures (CPS) were recorded in 12 (12.0%) patients each, while Primary Generalized Tonic-Clonic Seizures (PGTCS) accounted for 10 (10.0%) cases. Less common seizure types included Absence Seizures in 4 (4.0%) patients and Myoclonic Seizures in 3 (3.0%) patients. Regarding epilepsy syndromes, Idiopathic Generalized Epilepsy (IGE) was the predominant subtype, affecting 60 (60.0%) patients. Both Right and Left Mesial Temporal Lobe Epilepsy (MTLE) and Other Epilepsies contributed 20 (20.0%) cases each.

Table 3 depicts the etiological diagnoses among the 20 patients categorized under the "Other Epilepsies" group. The most frequent diagnosis was Idiopathic epilepsy (I), accounting for 6 (30.0%) patients. Acute Infarction (AI), Cerebral Edema (CE), and Cerebral Infarction (CI) were each observed in 3 (15.0%) patients. Traumatic lesions (T) were identified in 2 (10.0%) cases. Less common etiologies included Demyelinating disease (DM), Hamartoma (H), and Vascular Malformation (VM), each contributing 1 (5.0%) patient. These findings demonstrate the heterogeneous spectrum of structural brain abnormalities detected on MRI among patients with non-idiopathic epilepsy.

Table 4 illustrates the age-wise distribution of patients according to sex. Among males, the highest proportion belonged to the 5–15 years age group (24; 42.1%), followed by the 27–37 years group (11; 19.3%). In females, the 5–15 years age group also represented the largest category with 14 (32.6%) patients, followed by the 27–37 years group with 10 (23.3%) patients and the 38–48 years group with 9 (20.9%) patients. The proportions of males and females were similar in the 49–59 years age group (4 vs. 3 patients), whereas very few patients were older than 60 years. Overall, males (57.0%) outnumbered females (43.0%) across nearly all age groups, confirming a modest male predominance in the study population.

Table 5 compares cortical thickness measurements across different epilepsy syndromes. The right medial temporal cortex demonstrated mean cortical thickness values ranging from 2.67 ± 0.12 mm in Female IGE patients to 2.80 ± 0.08 mm in Left MTLE patients. Similarly, the left medial temporal cortex showed relatively greater cortical thickness in Right MTLE (2.80 ± 0.04 mm) and Left MTLE (2.77 ± 0.04 mm) compared with the IGE subgroups. In the frontal lobes, cortical thickness remained relatively uniform, with values between 2.45 ± 0.04 mm and 2.56 ± 0.05 mm, showing only minor intergroup variation. The parietal lobes exhibited the lowest cortical thickness values among all examined regions, ranging from 2.17 ± 0.07 mm in Female IGE to 2.37 ± 0.03 mm in Left MTLE. Overall, medial temporal regions demonstrated comparatively greater cortical thickness than frontal and parietal cortices, while MTLE patients exhibited subtle regional differences suggestive of syndrome-specific structural alterations.

Table 6 presents the comparison of subcortical brain structures among different epilepsy syndromes. The right thalamic measurements were highest in the Pediatric IGE group (8.38 ± 0.12) and lowest in Female IGE (7.90 ± 0.29). Similarly, the left thalamus showed the greatest value in Pediatric IGE (8.15 ± 0.07) and comparatively lower values in both Right MTLE (7.72 ± 0.06) and Left MTLE (7.71 ± 0.07). Marked differences were observed in hippocampal measurements. The right hippocampus demonstrated a substantial reduction in Right MTLE (3.45 ± 0.04) compared with Pediatric IGE (4.13 ± 0.05), Male IGE (4.08 ± 0.08), Female IGE (4.08 ± 0.35), and Left MTLE (4.13 ± 0.05). Likewise, the left hippocampus showed the lowest measurement in Left MTLE (3.32 ± 0.08), whereas the remaining groups exhibited values ranging from 3.83 ± 0.08 to 3.89 ± 0.10. These findings indicate predominant ipsilateral hippocampal involvement in mesial temporal lobe epilepsy, while thalamic measurements remained relatively preserved across the different epilepsy syndromes.

## DISCUSSION

The present study demonstrated that epilepsy was most frequently observed in the 5–15 years age group (38%), followed by the 27–37 years age group (21%), indicating that epilepsy remains a major neurological disorder affecting both pediatric and young adult populations. A slight male predominance (57%) was also observed. Similar observations were reported by Hauser and Kurland, who found that epilepsy has its highest incidence during childhood and adolescence, with a modest male predominance attributed to greater exposure to perinatal insults, head trauma, and central nervous system infections.[11] Likewise, Banerjee et al. reported that males constituted nearly 55% of epilepsy patients in their MRI-based study, supporting the demographic findings of the present investigation.[12] The predominance of younger patients in our study emphasizes the importance of early neuroimaging for identifying potentially treatable structural abnormalities.

Generalized tonic-clonic seizures (GTCS) constituted the most common seizure type (38%) in the present study, followed by secondary generalized seizures (21%), while idiopathic generalized epilepsy accounted for 60% of all epilepsy syndromes. These findings are comparable to those reported by Sander and Shorvon, who observed generalized seizures as the most frequent clinical presentation in newly diagnosed epilepsy, particularly in younger individuals.[13] Similarly, Semah et al. demonstrated that idiopathic generalized epilepsy represented the largest proportion of epilepsy syndromes among patients undergoing MRI evaluation, whereas mesial temporal lobe epilepsy remained the predominant focal epilepsy syndrome.[14] The distribution observed in the present study reflects the diverse spectrum of epilepsy encountered in routine clinical practice.

Among patients classified under the "Other Epilepsies" group, idiopathic epilepsy was the most common diagnosis (30%), followed by vascular and ischemic lesions, cerebral edema, and traumatic brain injury. These findings are in agreement with the observations of Berg et al., who reported that structural lesions such as cerebrovascular disease, traumatic brain injury, infections, and developmental abnormalities account for a substantial proportion of focal epilepsies identified on MRI.[15] Similarly, Guerrini emphasized that advances in neuroimaging have significantly increased the recognition of structural etiologies including cortical malformations, vascular malformations, and post-traumatic lesions responsible for epilepsy.[16] The wide variety of etiologies observed in our study further highlights the indispensable role of MRI in determining the underlying cause of seizures.

The age- and sex-wise analysis demonstrated that both male and female patients were predominantly represented in the pediatric age group, with males exceeding females across most age categories. Comparable findings were reported by Beghi, who noted a higher incidence of epilepsy among males and children, particularly during the first two decades of life.[17] Similar demographic trends were also observed by Forsgren et al., who found that childhood epilepsy constitutes a significant proportion of newly diagnosed epilepsy cases, while male predominance remains relatively consistent across different age groups.[18] The demographic distribution observed in the present study therefore closely resembles previously published epidemiological data.

Quantitative cortical thickness analysis demonstrated subtle differences across epilepsy syndromes, with relatively greater alterations involving the medial temporal cortex compared with frontal and parietal regions. Patients with mesial temporal lobe epilepsy exhibited greater regional cortical abnormalities than those with idiopathic generalized epilepsy. These findings correspond well with the work of Lin et al., who demonstrated widespread cortical thinning involving temporal, frontal, and parietal cortices in patients with temporal lobe epilepsy using automated cortical thickness analysis.[19] Similarly, McDonald et al. reported that cortical abnormalities in epilepsy extend beyond the epileptogenic focus and involve distributed cortical networks responsible for cognitive dysfunction and disease progression.[20] The present findings therefore support the concept that epilepsy is associated with diffuse structural brain alterations rather than isolated focal lesions.

The present study demonstrated marked ipsilateral hippocampal volume reduction in patients with mesial temporal lobe epilepsy, whereas thalamic measurements showed relatively smaller intergroup variations. The right hippocampus was significantly smaller in right MTLE, while the left hippocampus demonstrated maximal reduction in left MTLE, reflecting characteristic hippocampal involvement. These observations closely resemble those reported by McDonald et al., who demonstrated selective hippocampal atrophy corresponding to the side of seizure onset in mesial temporal lobe epilepsy.[20] Furthermore, Lin et al. observed that hippocampal structural abnormalities are frequently accompanied by secondary changes involving thalamic and extratemporal regions, suggesting that epilepsy affects widespread neuronal networks rather than isolated anatomical structures.[19] The present findings therefore reinforce the established role of MRI-based quantitative structural analysis in accurately localizing epileptogenic lesions and differentiating epilepsy syndromes.

## CONCLUSION

The present retrospective observational study demonstrates that Magnetic Resonance Imaging (MRI) is a highly valuable and non-invasive imaging modality for evaluating structural brain abnormalities in patients with epilepsy. MRI successfully identified a wide spectrum of cortical and subcortical structural changes, with idiopathic generalized epilepsy being the most common epilepsy syndrome and mesial temporal lobe epilepsy showing characteristic hippocampal involvement. Generalized tonic-clonic seizures were the predominant clinical presentation, while structural abnormalities such as ischemic lesions, traumatic changes, vascular malformations, and developmental abnormalities contributed significantly to secondary epilepsies. Quantitative assessment of cortical thickness and subcortical structures revealed syndrome-specific patterns that enhanced lesion localization and improved understanding of epileptogenic networks. The study also demonstrated that MRI findings correlate with patient demographics and epilepsy subtype, thereby facilitating accurate diagnosis and appropriate treatment planning. Overall, high-resolution MRI, combined with advanced quantitative analysis, plays a pivotal role in the early detection of epileptogenic lesions and supports individualized clinical management, prognosis, and surgical decision-making in patients with epilepsy.

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