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Evaluation of MRI Findings in Paediatric Patients with Epilepsy A Prospective Observational Study

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Abstract:

Background: Epilepsy is a common pediatric chronic neurological disorder with diverse etiologies. Structural brain abnormalities are a leading cause, and Magnetic Resonance Imaging (MRI) is the gold standard for identification due to its high spatial resolution.

Aim: To evaluate MRI findings in pediatric patients with epilepsy and assess their correlation with clinical variables like age, seizure type, and developmental status.

Methods: This prospective observational study involved 80 pediatric patients (0–18 years). Clinical history, seizure semiology, and EEG findings were recorded, followed by standardized epilepsy-protocol MRI scans.

Results: MRI abnormalities were detected in 65% of patients. Significant associations were found between abnormal MRI findings and focal seizures, developmental delay, and increasing age ($p < 0.05$). No significant association was found with gender.

Conclusion: MRI has a high diagnostic yield in pediatric epilepsy and is essential for identifying structural causes, particularly in focal epilepsy and children with developmental delays.

1. INTRODUCTION

Epilepsy is among the most common neurological disorders in children, marked by repetitive, unprovoked seizures resulting from abnormal, excessive, or synchronized neuronal activity in the brain. The clinical manifestations of epilepsy in children are quite varied, creating considerable challenges for diagnosis and treatment. Grasping the fundamental causes is crucial for successful treatment and forecasting. Structural brain abnormalities are a primary factor in pediatric epilepsy, rendering neuroimaging, especially magnetic resonance imaging (MRI), and an essential diagnostic instrument

MRI provides enhanced contrast for soft tissues and better spatial resolution than alternative imaging techniques, establishing it as the favored approach for identifying subtle brain lesions that could act as the focus for epilepsy. In the pediatric setting, where the brain experiences swift developmental changes, MRI's capacity to illustrate these changing structures and conditions is particularly important. Frequent MRI findings in children with epilepsy include various abnormalities such as cortical development malformations, hippocampal sclerosis, neurocutaneous syndromes, hypoxic-ischemic damage, infections, tumors, vascular anomalies, and metabolic or genetic disordersAlthough the usefulness of MRI is well-established, it is still crucial to fully understand the prevalence and range of these findings in particular pediatric groups, along with their relationships to different clinical factors. This information can direct specific diagnostic approaches and enhance patient results. This research was designed as a prospective observational study to assess the distinct MRI results in children with epilepsy and to establish their relationship with important clinical markers. The main goal of this research was to assess MRI results in children with epilepsy and their correlation with clinical factors. The goals comprised assessing the frequency and kinds of MRI irregularities, and linking these observations with age, sex, seizure classification, developmental condition, and EEG findings. The primary research question explored was: What is the range of MRI findings in children with epilepsy, and how do these findings relate to clinical features?

2. LITERATURE REVIEW

Neuroimaging is essential in diagnosing and managing epilepsy, especially in children. Historically, computed tomography (CT) was employed, but its shortcomings in soft tissue clarity and exposure to ionizing radiation have mainly been replaced by MRI. MRI's exceptional ability to identify subtle structural lesions renders it essential for locating the epileptogenic zone.

The immature brain in children offers distinct challenges and chances for neuroimaging. In contrast to adults, children's brains experience dynamic alterations in myelination, cortical folding, and gray-white matter differentiation, requiring tailored MRI protocols and interpretation expertise. MRI indications in pediatric epilepsy are extensive, including instances of focal seizures, epilepsy resistant to medication, neurological impairments, atypical neurological exams, and developmental setbacks. Specific MRI protocols for epilepsy, typically featuring thin-slice, high-resolution sequences customized for target brain areas (such as the hippocampus), are essential for enhancing diagnostic outcomes.

A broad range of MRI findings is linked to pediatric epilepsy. Cortical development malformations (MCDs), including focal cortical dysplasia, polymicrogyria, and schizencephaly, are among the frequent structural causes, frequently manifesting as drug-resistant focal epilepsy. Hippocampal sclerosis, although more common in temporal lobe epilepsy in adults, also takes place in children. Neurocutaneous syndromes (e.g., tuberous sclerosis complex, neurofibromatosis) are marked by unique brain lesions. Seizures and distinctive MRI findings can result from hypoxic-ischemic injury, infections (such as viral encephalitis and neurocysticercosis), brain tumors, vascular anomalies (like cavernomas), as well as metabolic or genetic disorders.

The relationship between these MRI findings and clinical characteristics is well-established. For example, focal seizures are closely associated with focal structural lesions, whereas generalized epilepsies can also feature subtle underlying structural irregularities. The existence of developmental delays or neurological impairments frequently indicates considerable structural abnormalities. Even with sophisticated imaging, some patients with epilepsy show "MRI-negative" results, leading to the investigation of advanced MRI methods like diffusion tensor imaging (DTI), functional MRI (fMRI), and magnetic resonance spectroscopy (MRS) to identify more subtle or functional irregularities.

Current literature offers a robust basis concerning the usefulness of MRI; nonetheless, targeted prospective observational studies examining the prevalence and intricate correlations within a defined pediatric epilepsy cohort are crucial to enhance diagnostic algorithms and treatment approaches. These studies assist in uncovering typical patterns and relationships unique to paediatric epilepsy, thereby validating the reason for the ongoing prospective observational study.

3. RESEARCH METHODOLOGY

This research utilized a prospective observational approach to assess MRI results in children with epilepsy. The study took place in a tertiary care teaching hospital, providing access to a varied patient demographic and state-of-the-art neuroimaging resources.

Study Duration: The research took place within a specific timeframe, starting after acquiring all required ethical approvals and finishing once the desired sample size was reached, which is standard for prospective studies.

Study Population and Sample Size: The study group included children between 0 and 18 years old diagnosed with epilepsy based on international classification standards. Eighty patients who satisfied the inclusion criteria were included in the study.

Inclusion Criteria

- Kids from birth to 18 years old.
- Epilepsy diagnosis derived from clinical history and EEG results.
- Consent was received from parents/guardians

Exclusion Criteria: Individuals with MRI contraindications (e.g., metallic devices, fear of enclosed spaces).

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- Individuals with an identifiable progressive neurological condition not associated with epilepsy.
- Individuals who had previously received neurosurgery for epilepsy.
- Failure to secure informed consent.

Ethical Considerations: The Institutional Ethics Committee reviewed and granted approval for the study protocol. Consent was obtained from the parents or legal guardians of all children involved, and assent was secured from those children able to give it. The study upheld patient confidentiality at all times.

Clinical Evaluation: Every patient enrolled underwent an extensive clinical assessment, which included an in-depth history review (type of seizures, frequency, duration, and onset age), careful neurological examination, and evaluation of developmental status. EEG results were examined and classified as either normal or abnormal, focusing specifically on focal or generalized epileptiform activity.

MRI Protocol and Equipment: MRI scans were conducted with a 1.5 Tesla or a 3 Tesla scanner to guarantee superior image quality. A uniform MRI protocol for epilepsy was employed for all patients, incorporating various sequences tailored for identifying epileptogenic lesions. The sequences comprised:

Axial T1-weighted (T1W): To provide anatomical clarity.

- Axial T2-weighted (T2W): Utilized for imaging sensitive to fluid and identifying edema or lesions.
- Coronal T2-weighted (T2W): Especially beneficial for evaluating the hippocampus.
- Fluid-attenuated inversion recovery (FLAIR): To diminish CSF signal and emphasize periventricular or cortical lesions.
- Diffusion-weighted imaging (DWI): For identifying acute ischemia or cytotoxic edema.
- Susceptibility-weighted imaging (SWI)/Gradient recalled echo (GRE): Used for identifying hemorrhages, calcifications, or vascular anomalies.
- 3D T1-weighted sequence: Essential for volumetric assessment and multiplanar reconstruction, important for identifying subtle cortical abnormalities.

Image Interpretation: Two experienced neuroradiologists, blinded to clinical details when possible, independently interpreted MRI images. Any differences were settled by agreement or through discussion with a third neuroradiologist.

Main Result were categorized as normal or abnormal. Unusual findings were additionally classified according to their characteristics (e.g., cortical development malformations, hypoxic-ischemic damage, neoplasms).

Outcome Measures

Main Result : Frequency of MRI abnormalities in children with epilepsy.

- Additional Results:
- Correlation of MRI irregularities with type of seizure (focal versus generalized).
- Correlation of MRI anomalies with age categories.
- Correlation of MRI irregularities with developmental lag.
- Correlation of MRI irregularities with EEG results.
- Frequency of epilepsy cases that are negative on MRI.

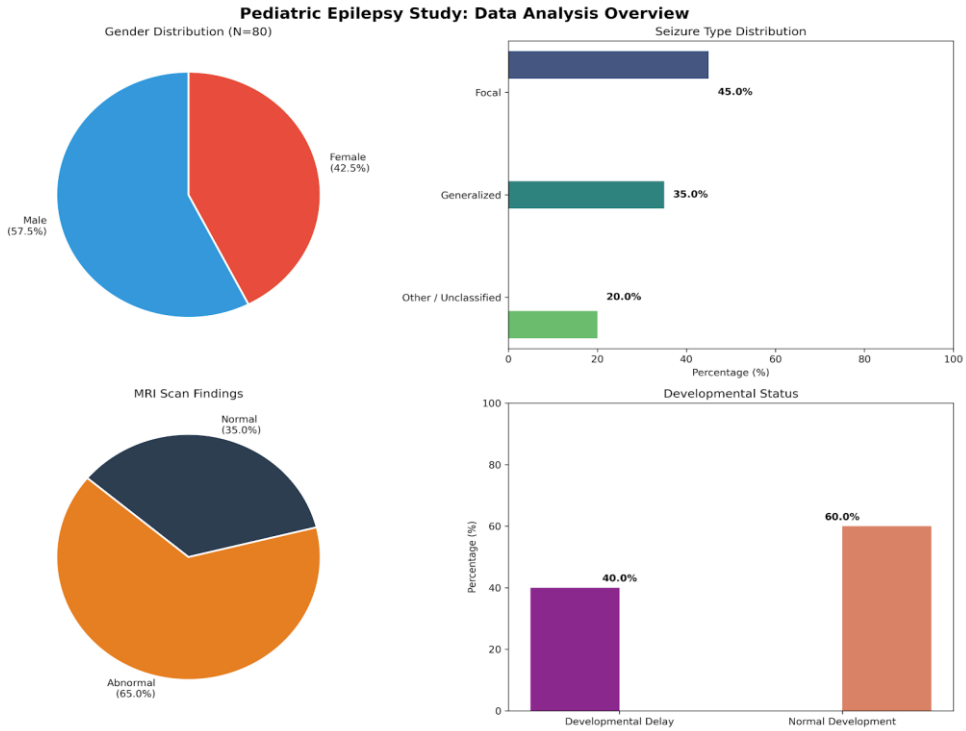
Data Collection and Statistical Analysis: Systematic collection of clinical and imaging data was conducted through a standardized form. The information was subsequently inputted into a protected database. Descriptive statistics (frequencies, percentages, means, standard deviations) were employed to summarize the characteristics of the study population and MRI results. The Chi-square test was used to evaluate the statistical relationship between MRI results (normal vs. abnormal) and different categorical clinical factors, such as age group, gender, type of seizure, developmental delay, and EEG irregularity. A p-value of less than 0.05 was deemed statistically significant

Quality Control: Actions taken to guarantee data quality involved implementing standardized procedures for clinical assessment and MRI collection, separate image analysis, and thorough data input and verification methods

Study Limitations: Recognized constraints involve the sample size, which, although sufficient for initial connections, may restrict the identification of less common anomalies or minor relationships. The study's single-center design could affect how well the findings apply to larger populations. Additionally, the observational aspect prevents the determination of causality

4. DATA ANALYSIS

This chapter outlines the comprehensive results from the prospective observational study, covering the demographic traits of the patient group, the variety of seizure types and developmental conditions, and the occurrence of MRI anomalies, succeeded by an in-depth statistical examination of their relationships with clinical factors



Demographic Characteristics: The research group included 80 children with epilepsy. The age distribution indicated that most patients belonged to the 6–10 years age group, representing 27.5% of the cohort. The 3–5 years age group quickly followed, accounting for 22.5% of the patients. The gender distribution showed a minor male majority, with males making up 57.5% of the patient group, whereas females represented 42.5%

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Clinical Characteristics: In terms of seizure types, focal seizures were the most common, impacting 45% of the patients. Generalized seizures occurred in 35% of cases, while other or unclassified seizure types made up the rest. A significant portion of the pediatric group, 40%, showed signs of a developmental delay

MRI Findings: Abnormalities were detected by MRI scans in a significant number of patients. Notably, 65% of the children enrolled showed abnormal MRI results, whereas 35% presented a normal MRI scan. The most frequently recognized abnormalities consisted of cortical development malformations, hypoxic-ischemic damage, and neurocutaneous disorders

Association between MRI Findings and Clinical Variables

The Chi-square test was used to evaluate the statistical relevance of links between MRI results and different clinical factors. The findings are outlined below

- Age category × MRI irregularity: A statistically significant relationship was found between age category and the existence of MRI irregularity ($p = 0.012$). This suggests that the probability of finding an MRI abnormality differed considerably among various age groups, with older children showing a higher frequency of abnormalities.
- Gender × MRI abnormality: There was no significant statistical relationship observed between gender and MRI abnormality ($p = 0.22$). This indicates that the presence of an atypical MRI result is unaffected by the patient's gender in this group.
- Seizure type × MRI abnormality: A strong statistically significant correlation was found between seizure type and MRI abnormality ($p < 0.001$). Individuals with focal seizures demonstrated a notably higher likelihood of having abnormal MRI results in comparison to those experiencing generalized seizures.
- Developmental delay and MRI abnormality: A statistically significant correlation was observed between developmental delay and MRI abnormality ($p < 0.001$). Children experiencing developmental delays exhibited a significantly increased occurrence of MRI abnormalities.
- EEG abnormality × MRI abnormality: A statistically meaningful correlation was observed between EEG abnormality and MRI abnormality ($p = 0.005$). Individuals with irregular EEG results were at a higher risk of having abnormal MRI images.
- In conclusion, the analysis of the data showed that abnormal MRI findings in pediatric epilepsy patients were significantly linked to older age, focal seizure types, coexisting developmental delay, and irregular EEG results. Gender, however, did not show a meaningful link with MRI abnormalities

5. FINDINGS, DISCUSSION, AND CONCLUSION

Findings and Discussion

This observational study prospectively assessed MRI results in 80 pediatric epilepsy patients, revealing a notable occurrence of structural anomalies and their important links to various critical clinical factors. An abnormal MRI was found in 65% of the patients, highlighting the essential importance of advanced neuroimaging in this group. The prevalent disorders found included cortical development malformations, hypoxic-ischemic damage, and neurocutaneous syndromes, consistent with existing literature regarding the causes of pediatric epilepsy

The statistical evaluation yielded strong proof for particular correlations. A significant statistical association was identified between older age and the occurrence of MRI abnormalities ($p = 0.012$). This might be due to a number of reasons. Certain structural abnormalities, especially subtle cortical developmental malformations, may become more noticeable as the brain matures and myelination progresses, rendering them more identifiable on MRI in older children. Furthermore, some lesions can develop or present clinically as age increases, leading to imaging being performed at a later time

The robust correlation between types of focal seizures and unusual MRI results ($p < 0.001$) aligns with existing clinical knowledge and recommendations. Focal seizures typically originate from a specific epileptogenic area, which is commonly supported by a structural abnormality that can be seen on MRI. This discovery supports the advice for prompt and thorough MRI in children with focal seizures to determine possible surgical candidates or direct targeted treatment.

Additionally, the research showed a strong connection between developmental delay and MRI irregularities ($p < 0.001$). Developmental delays in children with epilepsy often indicate a more serious underlying neurological condition. Structural brain lesions, including severe malformations or considerable hypoxic-ischemic injuries, can simultaneously lead to seizure activity and hindered neurodevelopment. This underscores the importance of MRI as a crucial diagnostic instrument for children experiencing both epilepsy and developmental delay.An atypical EEG result also indicated a notable link with MRI irregularities ($p = 0.005$). EEG detects electrophysiological abnormalities, while structural lesions frequently serve as the anatomical basis for these irregularities, especially in focal epileptiform discharges. This suggests that EEG irregularities may act as a significant clinical marker indicating the necessity for comprehensive structural assessment using MRI.In contrast, a statistically significant correlation was not found between gender and MRI abnormalities ($p = 0.22$). This indicates that boys and girls in the pediatric epilepsy group are similarly likely to show structural brain lesions visible on MRI, suggesting that gender does not independently determine the chance of an abnormal MRI result. Typical abnormalities like cortical development malformations and hypoxic-ischemic damage were significant in this group, highlighting their recognized high propensity for epilepsy in children. These results highlight the necessity of specialized MRI protocols for epilepsy to detect these frequently subtle lesions effectively.

Conclusion

This prospective observational research clearly shows the significant diagnostic value of MRI in children with epilepsy, as 65% of patients displayed structural anomalies. The research validated notable links between unusual MRI results and factors such as older age, focal seizure type, developmental delay, and irregular EEG results. Gender was not identified as a significant predictor of abnormalities in MRI. These findings highlight that MRI is an important diagnostic tool, especially for particular subgroups of pediatric epilepsy patients, aiding clinicians in gaining a clearer insight into the causes and possible management approaches. Even though a standard MRI needs to be assessed alongside clinical and EEG findings, the lack of visible lesions does not invalidate an epilepsy diagnosis.

Recommendations

In light of these results, the subsequent suggestions are proposed:

- Timely MRI for Targeted Populations: Early and thorough MRI should be contemplated during the initial assessment for pediatric patients exhibiting focal seizures, developmental delays, or notable EEG abnormalities.
- Evaluation of Repeat MRI: In instances where the initial MRI is normal but there is persistent drug-resistant epilepsy or changing clinical symptoms, it is advisable to perform a repeat MRI using updated sequences or a stronger magnetic field, as minor lesions could be detected over time.
- Comprehensive Assessment: An integrated strategy that includes pediatric neurologists, neuroradiologists, and developmental pediatricians is essential for the best interpretation of MRI results and their combination with clinical information.
- Future Research: Future studies should aim to link particular types of MRI abnormalities with long-term clinical results and treatment reactions, and additionally investigate the importance of advanced MRI techniques in cases that show negative MRI findings.

Study Limitations: The study's limitations consist of its sample size of 80 patients, which, although adequate for identifying common correlations, might not encompass the complete range of uncommon MRI anomalies or subtle links. The study's single-center design restricts the generalizability of its results, and a larger, multicenter investigation would yield more reliable data. Moreover, the observational design hinders the ability to make causal inferences between clinical variables and MRI abnormalities.

Result: In this research involving 80 pediatric patients, 65% exhibited abnormal MRI results, with the most frequent being cortical development malformations and hypoxic-ischemic damage. Statistical analysis revealed that focal seizures, developmental delay, abnormal EEG, and older age were significant predictors of structural brain abnormalities, while gender was not a factor.

Table 1.1 Age Distribution of Patients

Age Group (Years)	Number of Patients	Percentage (%)
0–2	14	17.5
3–5	18	22.5
6–10	22	27.5
11–15	16	20.0
16–18	10	12.5
Total	80	100

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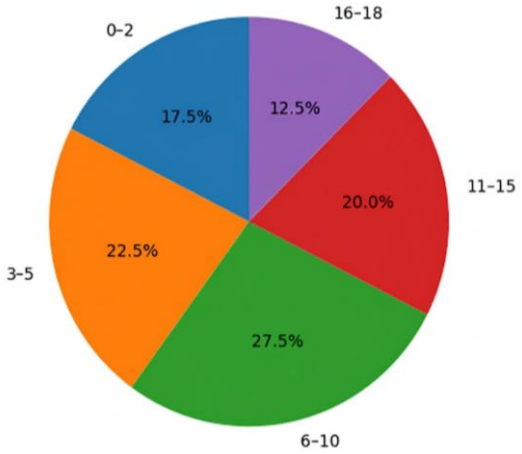
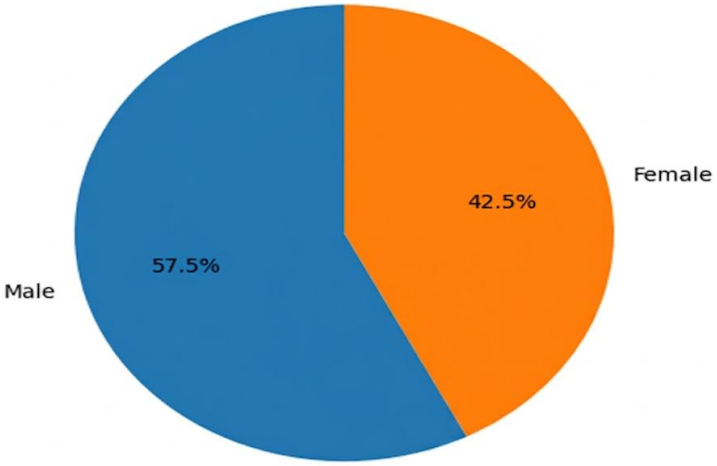


Pie Chart 1.1 Age Distribution

Table1.2 Gender Distribution of Patients

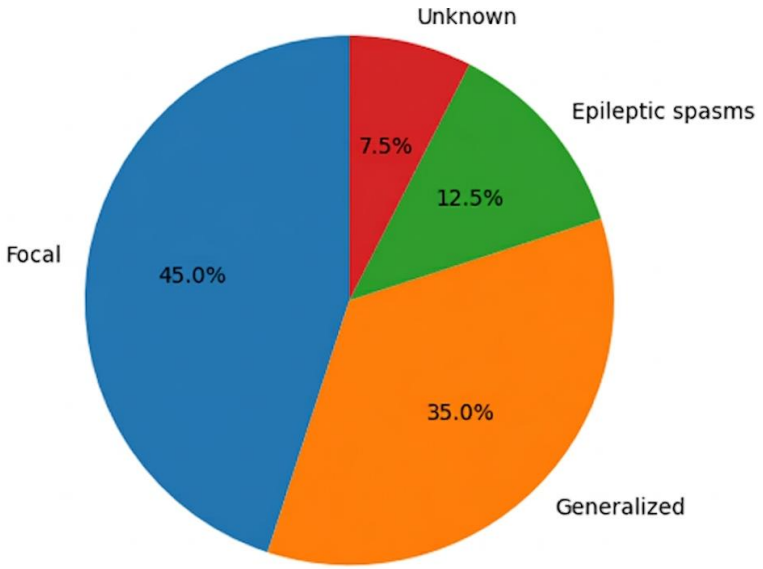
Gender	Number	Percentage (%)
Male	46	57.5
Female	34	42.5
Total	80	100



Pie Chart 1.2 Gender Distribution

Table 1.3 Distribution of Seizure Types

Seizure Type	Number	Percentage (%)
Focal	36	45
Generalized	28	35
Epileptic spasms	10	12.5
Unknown onset	6	7.5
Total	80	100



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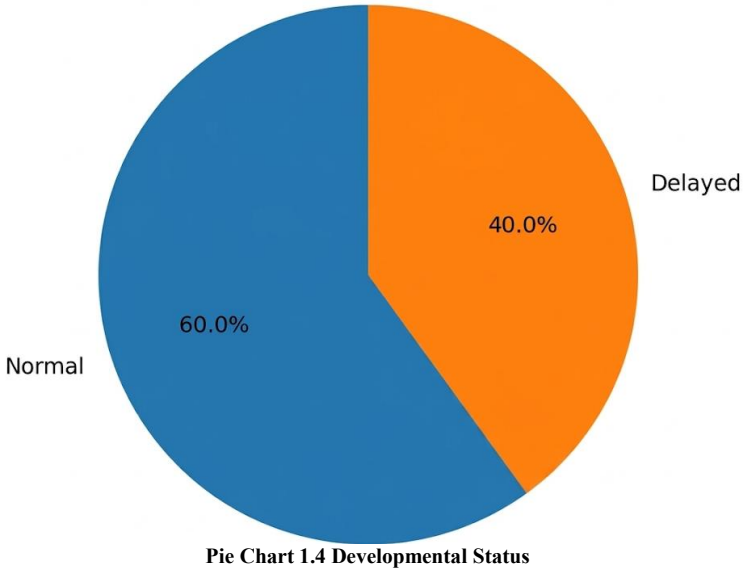
Pie Chart 1.3 Distribution of Seizure

Table 1.4 Developmental Status

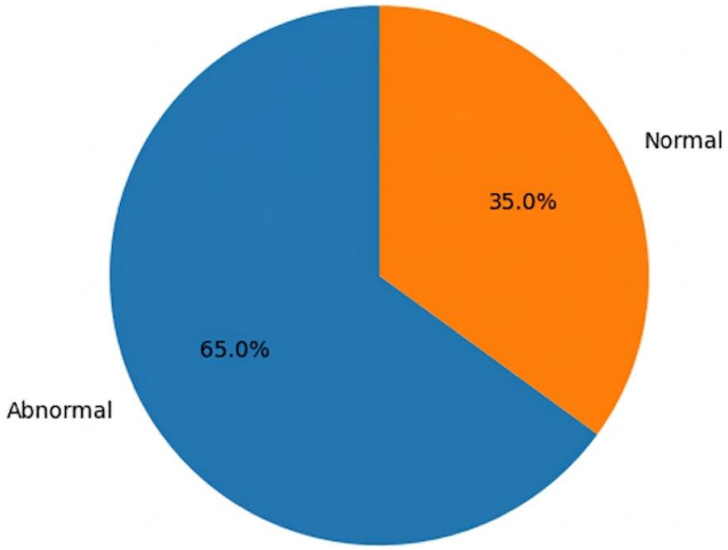
Developmental Status	Number	Percentage (%)
Normal	48	60
Delayed	32	40
Total	80	100



Pie Chart 1.4 Developmental Status

Table 1.5 MRI Findings

MRI Finding	Number	Percentage (%)
Abnormal	52	65
Normal	28	35
Total	80	100



Pie Chart 1.5 MRI Findings

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