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SYSTEMATIC REVIEW

Magnetic resonance imaging (MRI) findings in pediatric epilepsy

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ABSTRACT

Background: Epilepsy is a neurological condition characterized by irregular, rapid, and synchronized neuronal discharges from the cerebral cortex. Advances in neuroimaging have significantly enhanced the diagnosis, treatment, and management of pediatric epilepsy. Structural magnetic resonance imaging (MRI), when evaluated by skilled neuroradiologists, facilitates improved identification of the seizure onset zone using epilepsy-specific MRI protocols. **Objective**: This review aims to analyze cerebral MRI findings in pediatric epilepsy across age groups and sexes. **Materials and Methods**: A comprehensive literature review was conducted using major scientific databases, including PubMed, ScienceDirect, and SciELO. Articles were screened based on inclusion criteria, starting with titles, followed by abstract and full-text evaluations. The following keywords were used in the literature search: "Magnetic Resonance Imaging" or "MRI" AND "Childhood" or "Pediatric" AND "Epilepsy." **Results**: Analysis of 16 studies revealed 1,504 MRI anomalies. Cortical malformations were the most frequent anomaly, identified in 230 cases (15%). The second most frequent finding, hippocampal/mesial temporal sclerosis, was observed in 160 subjects (10%). Other anomalies included infections in 76 subjects (5%), brain tumors in 37 subjects (2%), periventricular leukomalacia in 37 subjects (2%), encephalomalacia in 65 subjects (4%), vascular disorders in 41 subjects (2.7%), cysts in 75 subjects (5%), hydrocephalus in 33 subjects (2.1%), and demyelination disorders in 33 subjects (2.1%). **Conclusion**: MRI scanning is particularly beneficial for children with newly diagnosed epilepsy, especially those with focal seizures, focal EEG abnormalities, or abnormal neurological examinations. It is also valuable for children who present with refractory seizures that other imaging modalities are unable to detect.

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Highlights

1. Children with newly diagnosed epilepsy can benefit from MRI scanning, especially if they have focal seizures, focal EEG abnormalities, or abnormal neurological examinations.

2. Analysis of 16 studies revealed 1,504 MRI anomalies. The most frequent was cortical malformations, followed by hippocampal/mesial temporal sclerosis. Other anomalies included infections, brain tumors, periventricular leukomalacia, encephalomalacia, vascular disorders, cysts, hydrocephalus, and demyelination disorders.

BACKGROUND

Epilepsy, one of the most prevalent neurological conditions worldwide, affects approximately 50 million people, with 85% residing in developing nations. Accurate diagnostic classification is essential for determining appropriate treatment approaches (Youssf et al., 2021). In the pediatric population, seizures often necessitate visits to the emergency department (ED) for initial treatment and medical support (Minardi et al., 2019), accounting for 1% of all pediatric ED visits (Ritu et al., 2022). Although epilepsy is a frightening neurological disorder, it is relatively common in childhood, especially under the age of three years, with incidence decreasing as age increases (Minardi et al., 2019). A seizure is defined as an abnormal period of synchronous neuronal excitation for seconds or minutes. Prolonged or continuous seizures are classified as status epilepticus (Scharfman, 2007). The clinical manifestations include loss of awareness, motor abnormalities, sensory disturbances, mood or cognitive impairment, bruising, and, in severe cases, death (Sumadewi et al., 2023), due to abnormal electrical activity in the brain caused by excitation and inhibition imbalance, leading to hyperexcitability and excessive neuronal firing in cortical networks (Sumadewi et al., 2023). Neuroimaging typically reveals abnormal, rapid, and synchronous neuronal discharges from the cerebral cortex (Elmi et al., 2024).

Pediatric epilepsy remains a challenging disease for medical professionals, encompassing diagnostic accuracy, treatment options, and the impact on cognitive, developmental, and behavioral outcomes (Shaikh et al., 2019; Wilmshurst et al., 2014). Neuroimaging and electroencephalography (EEG) have been used to differentiate, confirm, or exclude epilepsy diagnoses (Elmi et al., 2024). Neuroimaging plays a crucial role in determining the etiology of and treatment choice for pediatric epilepsy (Samia et al., 2021), as it identified subtle structural defects, neurocutaneous malformations, calcified or hemorrhagic lesions, and metabolic abnormalities in the brain. Advanced neuroimaging can pinpoint the specific locations of epileptogenic foci or refractory epilepsy (Shaikh et al., 2019). Meanwhile, EEG should be performed after the first unprovoked seizure and within 72 hours post-seizure to predict recurrence and confirm the diagnosis. ECG is also conducted for glucose measurements to differentiate epilepsy from other abnormalities (Urbańska et al., 2024). MRI has been used for neuroimaging due to its safety and superior sensitivity in detecting epileptic lesions and localizing seizures compared to computed tomography (CT) scans (Wilmshurst et al., 2014). Furthermore, MRI can accurately identify seizure onset zones when interpreted by experienced neuroradiologists (Lee, 2020), facilitating interventions such as surgical treatment for intractable or refractory epilepsy (Shaikh et al., 2019).

OBJECTIVE

The study aims to analyze cranial MRI findings in pediatric epilepsy across age groups and sexes.

MATERIAL AND METHODS

Study Design

This systematic review was conducted in accordance with the Preferred Reporting Items of the Systematic Review and Meta-Analysis (PRISMA) guidelines to ensure methodological quality.

Data Collection

A systematic literature search was carried out using major scientific databases, including PubMed, ScienceDirect, and SciELO. The following keywords were used in the literature search: ("Magnetic Resonance Imaging" or "MRI") AND ("Childhood" or "Pediatric") AND ("Epilepsy"). Two authors

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independently screened article titles to identify studies meeting the inclusion criteria, followed by an assessment of the abstracts and full texts of the selected studies. This review has not been registered.

Eligibility Criteria

Specific criteria were applied to select studies for inclusion. The inclusion criteria included: (1) subjects were under 18 years; (2) studies used a cross-sectional or cohort design involving MRI and pediatric or childhood epilepsy; (3) patients had confirmed epilepsy, based on EEG and/or the International League Against Epilepsy (ILAE) criteria. The exclusion criteria were as follows: (1) patients had a history of trauma and febrile seizures; (2) editorials, letters, comments, review abstracts, conference abstracts, news articles, book chapters, case reports, and review articles; (3) epilepsy was not confirmed by EEG and/or ILAE criteria; (4) subjects experienced a first-time seizure.

Study Selection and Data Extraction

Using the inclusion and exclusion criteria to determine relevance, two authors independently screened articles based on their titles and abstracts. Articles unrelated to the topic were excluded. Subsequently, the authors evaluated full-text articles of the remaining studies to identify those meeting the inclusion criteria. Studies with incomplete were excluded. To minimize potential reporting and data collection bias, the authors also extracted data from the selected studies. The extracted data were organized in a predefined table. Consensus was used to resolve any disagreements between the authors.

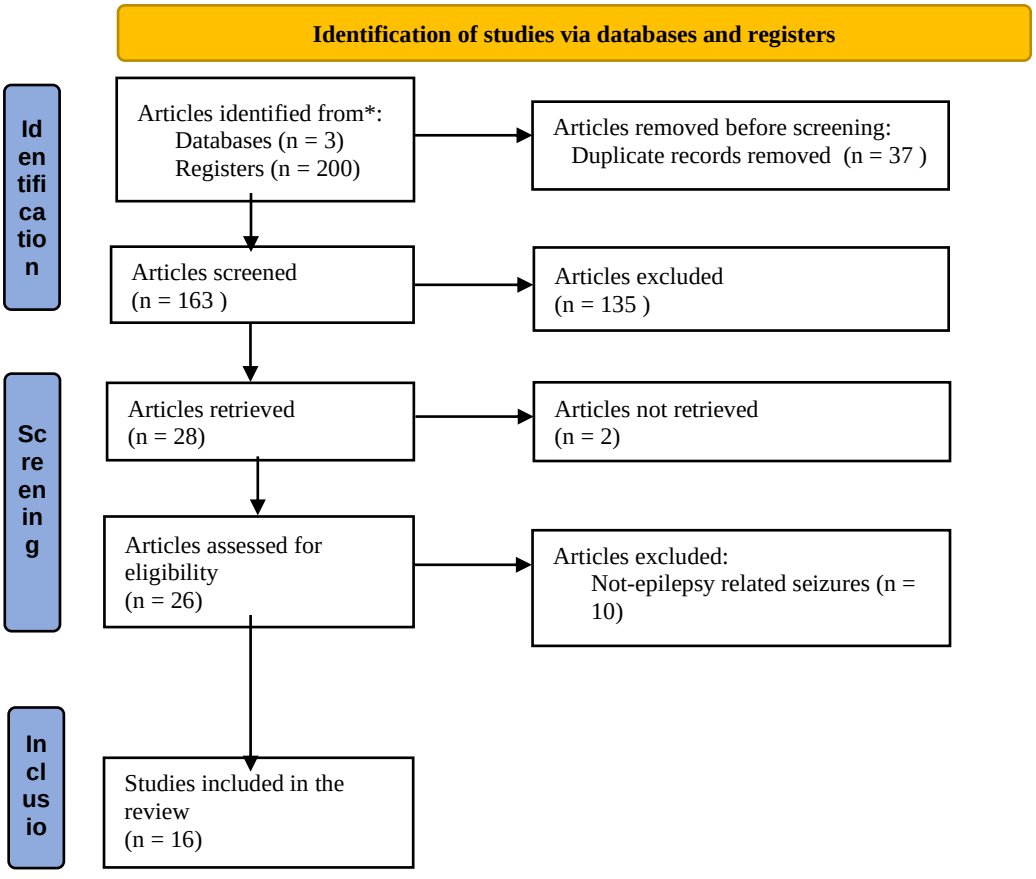

Figure 1. PRISMA flowchart depicting the process of determining eligible research studies.

The extracted data were summarized in tables using Microsoft Excel software, including the following details: first author, year of publication, study design, number of patients, sex distribution, number of MRI-positive cases, and the most common abnormalities detected on MRI.

During the abstract screening process (n = 200), 37 duplicate records and 135 studies that did not meet the specified population criteria were excluded. Of the 28 articles evaluated, two could not be retrieved, and 10 were excluded for ineligibility. Ultimately, 16 articles were included in this review.

RESULTS

A total of 3,336 patients from 16 studies who met the ILEA or EEG criteria for epilepsy were included in this review. Age data were reported in 12 of the studies, with an average age of 6.39 years. Among the included studies, four employed cross-sectional design, and one was a retrospective cohort study. Of the subjects, 1,374 (41.2%) were female, while 1,962 (58.8%) were male. MRI abnormalities were identified in 1,504 individuals (45%).

Table 1. Summary of the baseline characteristics of the studies

No.	Author	Year	Study Design	Number of Patients (N)	MRI+	Age	Sex	
							Male	Female
1	Yapici et al.	2024	Retrospective cohort	359	141	7.5	191	168
2	Samia et al.	2021	Retrospective cohort	288	95	-	180	108
3	Raafat et al.	2024	Cross-sectional	107	81	2.33	74	33
4	Apolot et al.	2022	Cross-sectional	147	109	5.82	101	46
5	Elmi et al.	2024	Cross-sectional	102	45	9.06	63	39
6	Wongladaro et al.	2004	Retrospective cohort	100	91	7.41	43	57
7	Amirsalari et al.	2012	Retrospective cohort	200	57	7.7	115	85
8	Xuan et al.	2020	Retrospective cohort	112	39	2.33	58	54
9	Durá-Travé et al.	2012	Retrospective cohort	457	134	-	233	224
10	Youssf et al.	2021	Cross-sectional	40	22	8.93	23	17
11	Dirik et al.	2018	Retrospective cohort	222	92	-	147	75
12	Alam-Eldeen et al.	2015	Retrospective cohort	181	66	4.25	96	85
13	Mundhe et al.	2022	Retrospective cohort	100	85	6.2	58	42
14	Anand et al.	2017	Retrospective cohort	95	84	4.25	64	31
15	Dirik et al.	2018	Retrospective cohort	220	89	-	147	73
16	Balik et al.	2024	Retrospective cohort	606	274	7.4	369	237
	TOTAL			3336	1504	6.39	1962	1374

Data on 1,504 MRI abnormalities from the 16 studies are summarized in Table 2. The abnormalities were categorized into the ten most common findings. Cortical malformations were the most common abnormality identified in 230 (15%) individuals. The second most common abnormality was hippocampal/mesial temporal sclerosis identified in 160 (10%) individuals. Other abnormalities included infections in 76 subjects (5%), brain tumors in 37 subjects (2%), periventricular leukomalacia in 37 subjects (2%), encephalomalacia in 65 subjects (4%), vascular disorders in 41 subjects (2.7%), cysts in 75 subjects (5%), hydrocephalus in 33 subjects (2.1%), and demyelination disorders in 33 subjects (2.1%).

Table 2. MRI abnormality findings in childhood epilepsy

No.	Author	MRI+	Findings									
			Hippocampal/ mesial temporal sclerosis	Periventricular leukomalacia	Cortical malformations	Encephalo-malacia	Infections	Brain tumors	Vascular disorders	Cysts	Hydroce-phalus	Demyelination disorders
1	Yapici et al.	141	5	-	10	-	-	9	2	-	-	8
2	Samia et al.	95	8	9	1	18	-	-	-	7	4	-
3	Raafat et al.	81	5	1	-	-	-	-	-	-	2	-
4	Apolot et al.	100	48	16	-	-	2	-	-	-	2	-
5	Elmi et al.	45	14	2	2	4	2	1	-	-	1	-
6	Wongladaro et al.	91	24	-	34	-	8	3	5	-	-	-
7	Amirsalari	57	-	-	-	-	-	8	3	19	-	-

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No.	Author	MRI+	Findings									
			Hippocampal/ mesial temporal sclerosis	Periventricular leukomalacia	Cortical malformations	Encephalo-malacia	Infections	Brain tumors	Vascular disorders	Cysts	Hydroce-phalus	Demyelination disorders
	et al.											
8	Xuan et al.	39	-	-	5	1	-	-	-	-	-	-
9	Dura-Trave et al.	134	-	-	54	-	-	-	8	-	-	-
10	Youssf et al.	22	3	-	9	-	-	10	-	-	-	-
11	Dirik et al.	92	-	-	-	23	-	4	-	9	9	6
12	Alam-Eideen et al.	66	-	1	51	3	7	-	10	-	-	-
13	Mundhe et al.	85	14	-	9	-	32	-	5	2	3	2
14	Anand et al.	84	4	-	21	-	25	-	-	-	-	3
15	Dirik et al.	89	3	8	-	16	-	2	-	10	12	5
16	Balik et al.	274	32	34	-	-	-	-	8	28	-	9
	Total	1504	160	37	230	65	76	37	41	75	33	33

DISCUSSION

Epilepsy is the most common neurological condition in children with long-term medication and morbidities. While EEG evaluation and seizure history are frequently used for diagnosis, MRI is recommended for etiologic workup and determining an intervention (Dirik and Sanlidag, 2018). EEG is particularly valuable as it provides high-quality information about brain function in children with epilepsy. Additionally, it reveals structural abnormalities (Bernasconi et al., 2019), playing an important role in the diagnostic workup in children suspected of having epilepsy by localizing the epileptic zone (Noachtar and Rémi, 2009) and identifying abnormal brain structures that may cause epilepsy or neurodevelopmental impairment. These advancements have also opened up opportunities for epilepsy surgery (Bernasconi et al., 2019).

This study is among the few that examine how brain MRI findings can be used to identify the underlying etiologic causes of childhood epilepsy, their association with different types of epilepsy, and the impact of factors such as drug resistance and dosage on the effectiveness of the treatment. In order to provide effective seizure control, cranial magnetic resonance imaging (MRI) is essential for identifying candidates for polytherapy or monotherapy as well as candidates for drug-resistant surgery. In their study, Yapici et al. discovered that 141 (39.3%) patients showed MRI pathological abnormalities associated with the etiology of epilepsy. Across all age categories, the most frequent etiologic cause was prior parenchymal injury (39.7%). In terms of the correlation between MRI positivity and drug resistance, 67.6% of MRI-negative cases showed a full response to therapy, whereas 72% of drug-resistant cases showed MRI positivity. Before initiating treatment, MRI helps doctors identify whether an etiologic factor is the root cause of childhood epilepsy. A notable predictor of drug resistance and response to antiseizure medications is MRI positivity (Yapici and Aksu Uzunhan, 2024).

At a tertiary hospital in Kenya, up to one-third of children who underwent MRI scans got positive results for abnormalities. The most frequent abnormalities included periventricular leukomalacia (n = 9: 3.1%), cerebral atrophy (n = 11: 3.8%), neuronal migration disturbances (n = 11: 3.8%), encephalomalacia associated with chronic infarcts (n = 18: 6.3%), and hippocampal sclerosis (n = 8: 2.8%). Imaging abnormalities were independently associated with clinical comorbidities and interictal epileptiform activity on EEG (Samia et al., 2021). Similarly, at Ramathibodi Hospital in Thailand, cortical dysplasia was the most frequent cause of epilepsy in children under the age of fifteen. Cortical dysplasia was the most frequent cause of partial or complex partial seizures in children, followed by mesial temporal sclerosis and a combination of cortical dysplasia and mesial temporal sclerosis. MRI offers accurate classifications of epilepsy etiology (Wongladarom et al., 2004). Apolot et al. (2022) found that structural brain abnormalities were present in two-thirds of children with epilepsy in Uganda. Their study demonstrated that abnormal brain MRI results were positively correlated with abnormal EEG activity. As a result, it was recommended that EEG be considered prior to MRI for children with epilepsy undergoing imaging examinations (Apolot et al., 2022).

A study by Elmi et al. (2024) showed that MRI and EEG results did not significantly correlate ($p = 0.779$). Similarly, a study by Ngo Minh et al. (2020) revealed several MRI abnormalities in children, but the correlation was unclear. Their findings demonstrated that in children with partial epilepsy, normal MRI findings do not necessarily predict normal EEG findings (Xuan et al., 2020). Moreover, the use of standardized grading systems during MRI examinations revealed a high percentage of significant anomalies in children with epilepsy, which could have implications for developing practice guidelines for this population (Durá-Travé et al., 2012).

Age, dysmorphic appearance, positive family history of epilepsy, abnormal EEG, and abnormal physical examination were factors significantly correlated with abnormal MRI findings. Amirsalari et al. (2012) observed that although 98% of children with epilepsy had abnormal EEGs, most MRI findings were benign. Given the high cost of MRI and the limited number of patients benefiting from active intervention based on MRI findings, the study recommended using EEG to confirm epilepsy and performing MRI on patients with abnormal physical examinations, focal neurological deficits, or focal EEG abnormalities.

MRI results may not always correlate with interictal epileptiform discharges (IED). Structural abnormalities detected via MRI did not significantly correlate with focal IED. However, 68% of cases with multifocal discharges identified through interictal EEG demonstrated abnormalities on MRI. These findings suggest that MRI can be valuable in detecting anomalies in patients with multifocal IED during the early stages of diagnosis (Dirik and Sanlidag, 2018).

CONCLUSION

Using an appropriate seizure protocol, MRI serves as the primary imaging modality for evaluating pediatric patients with epilepsy. It helps establish an accurate diagnosis, guide treatment decisions, and improve prognosis. MRI aids in the evaluation of children with newly diagnosed epilepsy, particularly those with focal seizures, focal EEG abnormalities, or abnormal neurological examinations, as well as those who present with refractory seizures that cannot be identified by other imaging modalities.

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Conflict of Interest

The authors have no conflict of interest to declare.

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Author Contribution

Conceptualization: AS., LKB.; methodology: AS.; data collection and extraction: AS., LKB.; data analysis and interpretation: AS., LKB.; manuscript writing: AS., LKB.; critical revision: LKB; statistical analysis: AS., LKB.

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