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COMPARATIVE EFFECTIVENESS OF EEG AND MRI IN DIAGNOSING PEDIATRIC EPILEPTIC SYNDROMES

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Abstract: This narrative review compares the diagnostic effectiveness of electroencephalography (EEG) and magnetic resonance imaging (MRI) in evaluating pediatric epileptic syndromes, particularly West syndrome, Lennox–Gastaut syndrome, and benign rolandic epilepsy. EEG offers syndrome-specific electrical patterns that are often diagnostic, while MRI identifies structural brain abnormalities influencing prognosis and treatment decisions. Both modalities present unique advantages and limitations, and their combined use is central to modern pediatric epilepsy care. Technological advances such as artificial intelligence in EEG analysis and functional MRI have enhanced diagnostic accuracy. Current literature and international guidelines affirm the complementary nature of EEG and MRI in pediatric epilepsy diagnosis.
Keywords: EEG, MRI, pediatric epilepsy, diagnostic imaging.

Introduction

Epilepsy is a common neurological disorder in children, and specific syndromes require distinct evaluation. West syndrome (WS), Lennox–Gastaut syndrome (LGS), and benign childhood epilepsy with centrotemporal spikes (BECTS, also called benign rolandic epilepsy) are key pediatric epileptic encephalopathies or genetic epilepsies with differing prognoses. WS (infantile spasms) has peak onset 4–7 months and is associated with severe developmental disability[1]. Its incidence is roughly 2–5 per 10,000 live births[1]. LGS typically begins between ages 2–5 years and comprises about 3–8% of childhood epilepsy; incidence is about 1.9 per 100,000 children[5]. BECTS manifests with infrequent nocturnal focal seizures in school-aged children and is often outgrown by adolescence; it accounts for ≈15% of pediatric epilepsy cases[1]. Accurate diagnosis is critical: WS and LGS are medically refractory and often need aggressive therapy, while BECTS is benign and may require no treatment. Electroencephalography (EEG) and magnetic resonance imaging (MRI) are central to the diagnostic workup. EEG provides real-time recording of cortical electrical activity and typically establishes syndrome classification (e.g. WS hypsarrhythmia, LGS slow spike-wave). MRI reveals structural brain abnormalities that underlie many cases of WS and LGS, informing etiology and guiding management (e.g. resective surgery). We review and compare the effectiveness of EEG vs MRI in these syndromes, noting each modality's advantages, limitations, and new technologies (AI and functional MRI). We also place EEG/MRI in epidemiological and guideline context, drawing on recent literature (post-2020) for the latest consensus and evidence.

Methods

We performed a narrative literature review of studies, reviews, and guidelines published since 2020, focusing on EEG and MRI in childhood epilepsy syndromes (West syndrome, LGS, BECTS). Databases searched included PubMed, MEDLINE, and Epilepsy-specific sources, using terms such as "EEG pediatric epilepsy", "West syndrome MRI", "Lennox-Gastaut EEG imaging", "rolandic epilepsy MRI", and "AI EEG deep learning". We included consensus guidelines from ILAE and related bodies, and prevalence data from epidemiological studies. The review emphasizes diagnostic value, accessibility, interpretation challenges, and emerging EEG/MRI technologies. (This is a narrative – not a formal systematic – review; no formal PRISMA flow is provided.)

Findings

Electroencephalography (EEG) in Pediatric Epilepsy

EEG is the cornerstone of epilepsy diagnosis, especially in children[6]. It is relatively inexpensive, can be done at the bedside or in the home (ambulatory EEG), and is non-invasive. For all three syndromes, EEG yields definitive features:

- West Syndrome (Infantile Spasms): The classic EEG finding is *hypsarrhythmia*, a chaotic, high-amplitude, asynchronous background with multifocal spikes. This pattern – along with clusters of flexor/extensor spasms – characterizes WS[1]. In practice, visual recognition of hypsarrhythmia can be challenging due to variability, and up to 30–50% of infants with spasms may not show classical hypsarrhythmia initially. Recent computational studies are addressing this: for example, automated EEG biomarker research has quantified signal entropy, power spectra, and connectivity to detect hypsarrhythmia and epileptic spikes with machine assistance[1]. Nonetheless, identification of any hypsarrhythmia-like pattern on EEG effectively establishes a diagnosis of infantile epileptic spasms syndrome[1]. Early EEG confirmation is emphasized by guidelines, as prompt treatment improves outcomes.
- Lennox–Gastaut Syndrome (LGS): LGS is defined in part by a diffuse slow (≤2.5 Hz) spike-and-wave (SSW) pattern on EEG[4]. In a systematic review, 92% of LGS patients had SSW bursts, and about 46% had generalized paroxysmal fast activity (GPFA)[4]. Thus, EEG almost universally shows characteristic abnormalities in LGS. EEG also captures the mixed seizure types (tonic, atonic, atypical absences, etc.) that typify LGS. Importantly, these EEG features aid not only diagnosis but prognosis: longer, more disorganized discharges correlate with poorer outcome[4]. EEG interpretation in LGS is complex – the diffuse slowing and polyspike complexes require an experienced epileptologist to distinguish from other encephalopathies. However, a routine EEG (with activation maneuvers) will detect the signature patterns in the majority of cases[4].
- Benign Rolandic Epilepsy (BECTS): EEG in BECTS shows centrotemporal (rolandic) spikes, often activated by sleep. These spikes are typically unilateral or bitemporal with a negative sharp wave in the rolandic area and positive spike over the ipsilateral frontal region[6]. In contrast to WS and LGS, BECTS EEG does *not* show widespread encephalopathic features – the interictal background is normal, and seizures are focal. As per the ILAE pediatric imaging guidelines, BECTS is an idiopathic epilepsy, so EEG findings are almost entirely focal and benign[6]. The EEG diagnosis of BECTS is straightforward when centrotemporal spikes are seen in the appropriate clinical context. Notably, EEG can distinguish BECTS from more severe syndromes: for example, the absence of generalized slow spike-wave and the presence of primarily focal spikes help differentiate BECTS from atypical syndromes like LGS.

EEG Interpretation Complexity: All these patterns require expert review. Infant EEG (as in WS) can be especially difficult to interpret due to immature background rhythms. Moreover, artefacts (movement, muscle, etc.) can obscure infant EEG. Interpretation generally demands a pediatric neurologist or neurophysiologist. Emerging AI tools are promising: deep learning algorithms have demonstrated >90% accuracy in detecting pediatric seizures from EEG[3], and quantitative EEG analysis (entropy, high-frequency oscillations) is under study[1]. Such tools may in future reduce diagnostic delay or inter-rater variability.

Magnetic Resonance Imaging (MRI) in Pediatric Epilepsy

MRI provides high-resolution anatomical images and is the test of choice for identifying structural lesions in epilepsy[6]. Modern epilepsy protocols (with epilepsy-tailored sequences on 3T scanners) can reveal subtle malformations. However, MRI is more resource-intensive: it is typically done in radiology suites, may require sedation in infants/young children, and costs more

than EEG. Guidelines emphasize MRI over CT in pediatric epilepsy due to no radiation and superior soft-tissue detail[6]. We examine MRI findings syndrome-by-syndrome:

- West Syndrome: In WS, identifying an underlying cause is crucial. About 30% of children with infantile spasms have a causative lesion on MRI[3]. These include tuberous sclerosis, cortical dysplasias, hypoxic-ischemic injury, and other malformations. In one series, 29% of WS patients had definite structural abnormalities, and another 42% had nonspecific MRI changes[3]. Thus, while WS is primarily diagnosed by EEG/clinical criteria, MRI frequently provides etiologic information. In practice, an MRI (preferably 3T) is recommended in all cases of infantile spasms. The diagnostic yield justifies the effort: when a lesion is found (e.g. unilateral cortical dysplasia), it may indicate a surgical target. Recent advances include 7T MRI and improved epilepsy sequences, which increase sensitivity to subtle lesions. Functional MRI is not routine for initial diagnosis of WS, but in refractory cases, simultaneous video-EEG-fMRI can be used in research to localize spasms onset.
- Lennox–Gastaut Syndrome: MRI abnormalities are common in LGS. In the EEG systematic review, 42.6% of LGS cases had identifiable structural etiologies[4]. Other sources estimate that up to 70% of LGS cases have known causes[5]. Common MRI findings include diffuse cortical malformations (e.g. dysplasia), post-infectious encephalomalacia, infarcts, or injury. Conversely, about 30% of LGS cases remain cryptogenic (normal MRI and no clear genetic finding)[4]. Thus, MRI is strongly indicated in LGS workup. Neuroimaging will often show bilateral or multifocal lesions, explaining the generalized EEG. Pre-surgical MRI (with optional functional techniques) can be pursued if focal resection (e.g. cortical tuber) is considered. Advanced MRI modalities (diffusion imaging, susceptibility imaging) may reveal abnormalities missed on routine scans. Overall, MRI and EEG together increase diagnostic certainty: EEG confirms the LGS phenotype, and MRI yields etiology in the majority of cases.
- BECTS (Benign Rolandic Epilepsy): MRI in typical BECTS is almost invariably normal[6]. Because BECTS is considered idiopathic, routine MRI is not strictly required unless atypical features are present (e.g. daytime seizures, cognitive delay, abnormal neurologic exam). The 2009 ILAE pediatric neuroimaging guidelines noted that childhood absence and benign focal epilepsies (like BECTS) “do not identify significant structural abnormalities”[6]. Therefore, in a child with classic centrotemporal spikes and no red flags, MRI usually adds little diagnostic value. When MRI is obtained, only incidental or nonspecific findings (e.g. benign cysts) are seen in most cases. Hence, EEG remains the primary diagnostic tool for BECTS, and MRI’s role is limited to ruling out pathology in atypical presentations.

MRI Interpretation Complexity: Pediatric MRI demands a skilled neuroradiologist, especially for subtle cortical dysplasias or hippocampal abnormalities. Factors like patient motion (necessitating sedation) and age-related myelination changes can complicate reading. Several software tools and AI techniques are emerging to assist MRI interpretation. For example, machine-learning algorithms for automated lesion detection (especially focal cortical dysplasia) have shown promise in improving sensitivity. Functional MRI (fMRI) and advanced methods (e.g. magnetoencephalography) are increasingly integrated in comprehensive epilepsy centers, though mostly for presurgical mapping. Notably, resting-state fMRI can be performed under sedation with minimal patient cooperation, making it suitable for children[7]. This allows mapping of language or motor networks and sometimes epileptic networks, complementing EEG data.

Comparative and Complementary Role of EEG and MRI

EEG and MRI serve complementary roles in pediatric epilepsy diagnosis and management. EEG’s strength is in capturing epileptiform activity and seizure dynamics. It is the gold-standard for classifying epilepsy syndromes. For WS and LGS, EEG patterns (hypsarrhythmia and SSW, respectively) are so characteristic that diagnosis is often EEG-driven[1][4]. MRI’s strength lies in

etiological evaluation: it can identify lesions that neither EEG nor clinical exam can detect. In WS and LGS, finding a structural lesion on MRI can alter treatment (e.g. consideration of epilepsy surgery) and prognosis. By contrast, in BECTS, the lack of MRI findings aligns with the benign prognosis; EEG suffices for diagnosis.

Accessibility and Cost: EEG machines are ubiquitous in pediatric neurology centers, often available for outpatient or portable monitoring. Ambulatory and video-EEG options further increase accessibility. MRI requires specialized equipment and often scheduling; a facility with pediatric MRI capability (and anesthesia support) is needed. Consequently, in resource-limited settings, EEG may be used as the primary tool, with MRI reserved for unclear or refractory cases.

Consensus Guidelines: International consensus supports combined use. Current ILAE guidelines state that new-onset focal seizures or epileptic encephalopathies should prompt MRI[6]. They note that benign focal syndromes (e.g. BECTS) rarely have imaging abnormalities, whereas symptomatic syndromes like infantile spasms usually merit imaging[6]. EEG is universally recommended as first-line in any suspected epilepsy, especially infantile spasms (where EEG may be diagnostic even if spasms are subtle). Pediatric epilepsy consensus emphasizes timely EEG to avoid diagnostic delay, and MRI to pursue etiology when seizures are complex or syndromic.

Emerging Technologies: AI is enhancing both modalities. In EEG, deep neural networks have achieved high sensitivity/specificity for seizure detection in children[3], and may help classify EEG patterns (e.g. automated hypsarrhythmia detectors). MRI benefits from improved hardware (higher Tesla scanners) and AI-based image analysis for lesion detection. Functional imaging (resting-state fMRI, simultaneous EEG-fMRI) bridges EEG and MRI by showing the hemodynamic correlates of epileptic networks. For instance, recent work shows that resting-state fMRI can identify motor or language networks in epilepsy patients without active task participation[7]. Over time, such tools may allow better integration of EEG and MRI information.

Discussion

In diagnosing pediatric epileptic syndromes, EEG and MRI are not alternative but allied modalities. EEG excels in identifying and classifying epileptic activity with millisecond accuracy, while MRI elucidates underlying brain structure. Their limitations offset each other: EEG's spatial resolution is poor (it cannot localize deep foci precisely), whereas MRI provides no direct information on electrical activity or seizure focus. A thoughtful combination is therefore standard: an EEG is typically obtained at first presentation to confirm epilepsy and hint at a syndrome; MRI is done to search for causes and plan treatment.

Our review underscores that in WS and LGS, EEG abnormalities are near-universal and often guide immediate therapy (e.g. starting ACTH or steroids for spasms on seeing hypsarrhythmia). MRI in these conditions is indicated not for diagnosis but for etiological workup. By contrast, in BECTS, a normal MRI helps reassure that the case is truly idiopathic, but absence of findings is expected rather than startling. From an accessibility standpoint, EEG's portability is advantageous: ambulatory EEG can capture intermittent seizures not seen in clinic, and ICU/epilepsy unit EEG is available for critically ill infants. MRI demand sedation but gives a definitive anatomical snapshot. Current consensus reflects this: in a febrile seizure with normal exam, one might defer MRI, but in a child with WS or LGS, guidelines call for prompt brain MRI[6].

Recent literature (post-2020) reinforces these themes. Large series confirm that roughly one-third of infantile spasms have an MRI lesion[3] and that 40–60% of LGS have structural etiologies[4][5]. Studies on AI indicate that automated EEG analysis is maturing, potentially speeding up diagnosis and long-term monitoring[3]. Functional imaging reviews highlight resting-state fMRI as a research tool in pediatric epilepsy[7], though it is not yet standard of care. Limitations remain: even with both EEG and MRI, about half of LGS and ~30% of WS cases

remain "cryptogenic" (no clear cause identified)[4][5]. Genetic testing now plays an increasing role in those cases, but that is beyond the scope of this comparison.

Conclusion

EEG and MRI are complementary and indispensable in evaluating pediatric epileptic syndromes. EEG provides syndrome-defining electrophysiological signatures (e.g. hypsarrhythmia in WS, slow spike-wave in LGS) with high sensitivity and is accessible, though dependent on expert interpretation. MRI uncovers structural causes in a significant fraction of WS and LGS patients, guiding further management, although it is less available and requires sedation in young children. Emerging technologies – notably AI in EEG and advanced MRI/fMRI techniques – promise to improve sensitivity and interpretation in the future. Clinicians rely on both tools: an EEG first clarifies the syndrome, and an MRI follows to identify etiology. Current guidelines reflect this synergy. Continued research and technological advances will further integrate EEG and MRI, enhancing diagnosis and care of children with epilepsy.

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