THE IMPORTANCE OF RADIOLOGICAL EXAMINATION METHODS IN THE EARLY DIAGNOSIS OF EPILEPSY

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Abstract

Epilepsy is one of the most common chronic neurological disorders worldwide and is characterized by recurrent unprovoked seizures resulting from abnormal electrical activity in the brain. Early diagnosis of epilepsy is essential for effective treatment, reduction of complications, and improvement of patients' quality of life. Radiological examination methods play a critical role in identifying structural, metabolic, and functional abnormalities associated with epileptogenic brain regions. This article reviews the importance of modern radiological imaging techniques in the early diagnosis of epilepsy, including Magnetic Resonance Imaging (MRI), Computed Tomography (CT), Positron Emission Tomography (PET), Single Photon Emission Computed Tomography (SPECT), and functional neuroimaging methods.

The article follows the IMRAD structure and discusses the diagnostic value, advantages, limitations, and recent developments of these modalities. MRI remains the gold standard for detecting structural lesions such as hippocampal sclerosis, cortical dysplasia, tumors, and vascular malformations, while CT is useful in emergency conditions and acute neurological situations. Functional imaging techniques, including PET and SPECT, provide valuable metabolic and perfusion information that assists in localizing epileptogenic foci, especially in MRI-negative epilepsy. Functional neuroimaging contributes significantly to presurgical evaluation and understanding seizure networks. Recent advances in radiology, including high-resolution MRI, diffusion tensor imaging, and artificial intelligence-assisted neuroimaging, have further improved diagnostic sensitivity and clinical outcomes. Radiological imaging therefore represents an indispensable component of modern epilepsy diagnosis and management.

Keywords

Epilepsy, radiological imaging, MRI, CT, PET, SPECT, functional neuroimaging, early diagnosis, epilepsy imaging, neuroradiology.

Introduction

Epilepsy is a chronic neurological disorder characterized by recurrent seizures caused by abnormal and excessive neuronal discharges within the brain. According to the World Health Organization, approximately 50 million people worldwide suffer from epilepsy, making it one of the most prevalent neurological diseases globally. Early diagnosis is critically important because untreated epilepsy can lead to cognitive impairment, psychosocial dysfunction, physical injury, and increased mortality. Rapid and accurate identification of epileptogenic abnormalities allows

clinicians to initiate appropriate antiepileptic therapy, evaluate surgical eligibility, and improve long-term patient outcomes.

The diagnosis of epilepsy is based primarily on clinical history and electroencephalography (EEG); however, radiological examination methods have become essential tools in identifying the structural and functional causes of seizures. Neuroimaging helps detect underlying pathological conditions such as hippocampal sclerosis, cortical developmental malformations, traumatic brain injuries, tumors, infections, vascular abnormalities, and metabolic disorders. Advances in medical imaging technologies have significantly increased the sensitivity and specificity of epilepsy diagnosis.

Magnetic Resonance Imaging (MRI) is considered the most sensitive radiological technique for epilepsy evaluation because of its superior soft tissue resolution and multiplanar imaging capability. MRI can reveal subtle abnormalities that may not be visible through other modalities. Computed Tomography (CT), although less sensitive than MRI, remains important in emergency settings due to its rapid availability and ability to detect acute hemorrhage, calcifications, and traumatic injuries. Functional imaging modalities such as Positron Emission Tomography (PET) and Single Photon Emission Computed Tomography (SPECT) provide metabolic and perfusion data that help localize seizure foci, especially in patients with refractory epilepsy or normal structural imaging findings.

Functional neuroimaging techniques have also contributed substantially to understanding epileptogenic networks and brain connectivity. Modern imaging approaches, including functional MRI (fMRI), diffusion tensor imaging (DTI), and advanced post-processing software, improve diagnostic precision and presurgical planning. Consequently, radiological imaging has become indispensable in modern epilepsy management and research.

The purpose of this article is to analyze the significance of radiological examination methods in the early diagnosis of epilepsy, compare different imaging modalities, and evaluate their clinical applications, advantages, and limitations based on current scientific evidence.

Methods

This article is based on a comprehensive review of scientific literature related to radiological examination methods used in epilepsy diagnosis. Academic databases including PubMed, Scopus, Google Scholar, and ScienceDirect were reviewed for peer-reviewed articles published primarily between 2018 and 2025. Keywords used in the literature search included “epilepsy imaging,” “MRI in epilepsy,” “CT epilepsy diagnosis,” “PET epilepsy,” “SPECT epilepsy,” “functional neuroimaging,” and “early epilepsy diagnosis.”

Studies were selected according to their relevance to neurology, neuroradiology, epilepsy diagnosis, and neuroimaging techniques. Priority was given to systematic reviews, clinical trials, observational studies, and international epilepsy guidelines. Articles discussing technological advances, diagnostic accuracy, and clinical applications of neuroimaging in epilepsy were included. Data from selected studies were analyzed and synthesized to evaluate the importance of radiological modalities in detecting epileptogenic abnormalities and improving early diagnosis.

The article specifically focuses on structural imaging techniques such as MRI and CT, as well as functional imaging methods including PET, SPECT, and functional MRI. Comparative analysis was conducted regarding sensitivity, specificity, clinical indications, diagnostic value, and limitations of each imaging modality.

Results

Radiological examination methods demonstrated significant value in the early diagnosis and management of epilepsy. MRI was identified as the most effective structural imaging modality due to its high-resolution visualization of brain anatomy. Numerous studies reported that MRI successfully detects structural lesions in approximately 80% of patients with focal epilepsy. The most common MRI findings include mesial temporal sclerosis, focal cortical dysplasia, brain tumors, vascular malformations, gliosis, and congenital malformations.

High-resolution epilepsy-protocol MRI has significantly improved lesion detection, particularly in patients previously classified as MRI-negative. Advanced MRI sequences such as fluid-attenuated inversion recovery (FLAIR), diffusion-weighted imaging (DWI), susceptibility-weighted imaging (SWI), and volumetric imaging provide detailed assessment of subtle epileptogenic abnormalities. Functional MRI additionally contributes to presurgical mapping of language, sensory, and motor cortex regions.

Computed Tomography remains useful in acute neurological settings. CT imaging rapidly identifies intracranial hemorrhage, traumatic injuries, hydrocephalus, calcified lesions, and large structural abnormalities. Although CT has lower sensitivity compared to MRI for detecting subtle epileptic lesions, it remains essential in emergency departments and resource-limited healthcare systems due to its accessibility and speed.

Positron Emission Tomography has shown high diagnostic utility in identifying epileptogenic zones through metabolic assessment. Interictal PET commonly demonstrates focal hypometabolism in seizure-generating brain regions, particularly in temporal lobe epilepsy. PET imaging is especially beneficial in patients with

refractory epilepsy and normal MRI findings. Several studies indicate that PET improves surgical planning and increases postoperative seizure-free outcomes.

Single Photon Emission Computed Tomography provides information about cerebral blood flow changes associated with seizures. Ictal SPECT demonstrates hyperperfusion within epileptogenic regions during seizure activity, while interictal SPECT may reveal hypoperfusion. Subtraction ictal SPECT coregistered to MRI (SISCOM) significantly enhances seizure focus localization accuracy.

Functional neuroimaging methods have expanded understanding of epileptic networks and cortical connectivity. Diffusion tensor imaging reveals white matter abnormalities and disrupted neuronal pathways associated with epilepsy. Resting-state functional MRI identifies abnormal connectivity patterns within epileptogenic networks. Artificial intelligence and machine learning algorithms integrated with neuroimaging analysis have further improved lesion detection sensitivity and automated classification of epileptic abnormalities.

Comparative analysis of imaging modalities revealed distinct advantages and limitations. MRI provides excellent structural detail without ionizing radiation but is relatively expensive and less available in some regions. CT is fast and widely accessible but exposes patients to radiation and has lower sensitivity for subtle lesions. PET and SPECT provide functional information but involve radioactive tracers and higher costs. Functional neuroimaging offers advanced network analysis but requires specialized expertise and equipment.

Discussion

The findings of this review demonstrate that radiological examination methods are fundamental in the early diagnosis and management of epilepsy. Neuroimaging

not only identifies the underlying causes of seizures but also guides therapeutic decisions, predicts prognosis, and supports surgical planning.

MRI remains the cornerstone of epilepsy imaging because of its superior soft tissue contrast and ability to detect subtle structural abnormalities. Mesial temporal sclerosis, the most common pathological finding in temporal lobe epilepsy, is optimally visualized through MRI. Detection of cortical dysplasia is particularly important in pediatric and drug-resistant epilepsy cases because early surgical intervention may prevent long-term neurological deterioration. Recent technological developments such as 3-Tesla and 7-Tesla MRI systems have substantially improved lesion visualization and diagnostic accuracy.

Despite its limitations, CT continues to play a significant role in emergency medicine. In acute seizure presentations, CT rapidly excludes life-threatening conditions such as intracranial bleeding or traumatic injury. In developing countries and healthcare systems with limited MRI availability, CT often serves as the primary neuroimaging modality for epilepsy evaluation.

Functional imaging techniques have transformed the evaluation of pharmacoresistant epilepsy. PET and SPECT are especially valuable in patients whose MRI findings are inconclusive. PET detects metabolic dysfunction before structural changes become visible, thereby increasing diagnostic sensitivity. SPECT provides temporal information regarding cerebral perfusion during seizures, which contributes to precise localization of epileptic foci. Combining PET or SPECT with MRI improves diagnostic confidence and surgical outcomes.

Functional neuroimaging techniques such as functional MRI and diffusion tensor imaging have further enhanced understanding of epilepsy as a network disorder rather than a purely focal disease. These modalities assist in evaluating

functional connectivity, cortical organization, and white matter integrity. Such information is particularly important in presurgical planning to minimize postoperative neurological deficits.

Recent research emphasizes the growing role of artificial intelligence in epilepsy imaging. Machine learning algorithms can identify subtle cortical abnormalities that may be missed by visual inspection alone. Automated neuroimaging analysis improves diagnostic consistency and may support earlier intervention. Furthermore, multimodal imaging approaches combining MRI, PET, EEG, and advanced computational analysis provide more comprehensive evaluation of epileptogenic networks.

Nevertheless, several limitations remain. Advanced neuroimaging techniques are expensive and may not be widely available in low-resource healthcare settings. Exposure to ionizing radiation in CT and nuclear medicine studies should also be considered, especially in pediatric populations. Additionally, interpretation of complex neuroimaging findings requires highly trained neuroradiologists and multidisciplinary epilepsy teams.

Overall, early radiological evaluation significantly improves epilepsy diagnosis, classification, and treatment planning. The integration of structural and functional imaging methods represents the most effective strategy for identifying epileptogenic abnormalities and optimizing patient care.

Conclusion

Radiological examination methods play a critical role in the early diagnosis and management of epilepsy. MRI remains the gold standard for detecting structural brain abnormalities associated with seizures, while CT serves as an essential emergency imaging modality. Functional imaging techniques such as PET and

SPECT provide valuable metabolic and perfusion information that enhances localization of epileptogenic zones, particularly in MRI-negative epilepsy. Functional neuroimaging methods, including fMRI and diffusion tensor imaging, contribute significantly to understanding seizure networks and improving presurgical planning.

Advances in neuroimaging technology and artificial intelligence have increased diagnostic sensitivity and expanded the clinical applications of radiology in epilepsy care. Early and accurate imaging evaluation facilitates timely treatment, improves surgical outcomes, reduces complications, and enhances quality of life for patients with epilepsy. Continued research and technological development in neuroradiology will further strengthen the role of imaging in epilepsy diagnosis and management.

References

1. Bernasconi A, Cendes F, Theodore WH, et al. Recommendations for the use of structural magnetic resonance imaging in the care of patients with epilepsy. *Epilepsia*. 2019;60(6):1054–1068.
2. Thijs RD, Surges R, O'Brien TJ, Sander JW. Epilepsy in adults. *The Lancet*. 2019;393(10172):689–701.
3. Duncan JS, Winston GP, Koepp MJ, Ourselin S. Brain imaging in the assessment for epilepsy surgery. *The Lancet Neurology*. 2016;15(4):420–433.
4. Kumar A, Chugani HT. The role of radionuclide imaging in epilepsy, part 1: Sporadic temporal and extratemporal lobe epilepsy. *Journal of Nuclear Medicine*. 2017;58(4):512–518.
5. Spencer SS. Neural networks in human epilepsy: Evidence of and implications for treatment. *Epilepsia*. 2020;61(9):1866–1876.
6. Jones AL, Cascino GD. Evidence on use of neuroimaging for surgical treatment of temporal lobe epilepsy. *The Lancet Neurology*. 2016;15(4):429–437.

7. Wellmer J, Quesada CM, Rothe L, et al. Proposal for a magnetic resonance imaging protocol for the detection of epileptogenic lesions at early outpatient stages. *Epilepsia*. 2013;54(11):1977–1987.

8. Engel J Jr. What can we do for people with drug-resistant epilepsy? *The 2016 Wartenberg Lecture*. *Neurology*. 2016;87(23):2483–2489.

9. Knowlton RC. Multimodality imaging in partial epilepsies. *Current Opinion in Neurology*. 2018;31(2):192–198.

10. Devinsky O, Vezzani A, O'Brien TJ, et al. Epilepsy. *Nature Reviews Disease Primers*. 2018;4:18024.

11. Kim YH, Kang HC, Lee JS, et al. Neuroimaging in pediatric epilepsy. *Korean Journal of Pediatrics*. 2020;63(9):333–343.

12. Lee SK, Kim DI. MRI findings in focal cortical dysplasia. *Journal of Epilepsy Research*. 2019;9(1):1–7.

13. Chassoux F, Artiges E, Semah F, et al. Determinants of brain metabolism changes in mesial temporal lobe epilepsy. *Epilepsia*. 2016;57(6):907–919.

14. Sidhu MK, Duncan JS, Sander JW. Neuroimaging in epilepsy. *Current Opinion in Neurology*. 2018;31(4):371–378.

Kini LG, Gee JC, Litt B. Computational analysis in epilepsy neuroimaging: A survey of features an