DOI: https://doi.org/10.53350/pjmhs20231711363

ORIGINAL ARTICLE

Diagnostic Utility of Qualitative MRI and T2 Relaxometry in Hippocampal Assessment for Temporal Lobe Epilepsy

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ABSTRACT

Objectives: To determine the diagnostic value of qualitative MRI and T2 relaxometry in hippocampal assessment for temporal lobe epilepsy.
Study Settings: Department of Radiology, Sheikh Zayed Hospital, Rahimyarkhan.
Duration of Study: January to June 2023
Data Collection: A cross-sectional, single-center study was conducted involving 110 EEG-confirmed seizure patients. All participants underwent MRI with a dedicated epilepsy protocol including T2 relaxometry. Hippocampal T2 relaxation times were calculated by placing Regions of Interest (ROIs) on each slice of the hippocampus.
Results: A total of 110 TLE patients were studied; 65.5% were aged 10–40 years and 58.2% were male. T2 relaxometry detected hippocampal sclerosis in 34.5%, while visual MRI identified 41.8%. Diagnostic accuracy showed 31.8% true positives, 55.5% true negatives, 2.7% false negatives, and 10.0% false positives.
Conclusion: T2 relaxometry showed strong agreement with visual MRI in identifying hippocampal sclerosis. It serves as a reliable adjunct tool for enhancing diagnostic accuracy in temporal lobe epilepsy.
Keywords: Temporal Lobe Epilepsy, Mesial Temporal Sclerosis, T2 Relaxometry, MRI, EEG, Hippocampus

INTRODUCTION

Epilepsy is a chronic neurological disorder characterized by a long-standing tendency to generate spontaneous epileptic seizures.[1] It affects approximately 50 million individuals globally and transcends socio-demographic boundaries. Epidemiological studies have reported a point prevalence ranging from 4 to 10 per 1,000 people, making epilepsy one of the most common neurological conditions. The estimated annual incidence is around 50–60 cases per 100,000 person-years.[2]

Asia, which accounts for more than half of the global population, has an estimated 23 million people living with epilepsy.[3] In Pakistan, however, limited research has been conducted on the burden and management of epilepsy.[4] According to 2019 data, age-standardized prevalence and years lived with disability (YLDs) related to epilepsy were higher in countries with low and low-middle Social Demographic Index (SDI) compared to those with higher SDI. Recent programs initiated in Pakistan aimed at reducing the epilepsy treatment gap and social stigma have shown encouraging outcomes.[5]

Mesial temporal lobe epilepsy (MTLE) is recognized as the most prevalent form of epilepsy in adults, particularly in those with pharmacoresistant temporal lobe epilepsy.[6] Hippocampal sclerosis (HS) is the most frequently observed pathological abnormality in temporal lobe epilepsy (TLE), with approximately 65% of TLE cases attributable to hippocampal involvement alone.[7]

Magnetic resonance imaging (MRI) remains the diagnostic modality of choice for identifying structural brain abnormalities associated with epilepsy. It plays a pivotal role in detecting underlying lesions, evaluating comorbidities, and assessing patients with medically intractable epilepsy who may be suitable candidates for surgical intervention.[8] The clinical guidelines advocate the use of MRI in all epilepsy patients, except for children and adolescents with idiopathic generalized epilepsy who show a favorable response to antiepileptic drugs.

The advent of high-resolution MRI and epilepsy-specific imaging protocols over the past two decades has significantly improved the detection of subtle structural anomalies.[9] Initially, visual (qualitative) evaluation of T2-weighted imaging—based on hyperintense signals and atrophy—was the primary method to correlate hippocampal pathology with observable MRI abnormalities. T2 relaxometry has emerged as a quantitative technique to assess the extent and severity of T2 signal abnormalities.[10]

T2 relaxation times are measured using the Carr-Purcell-Meiboom-Gill (CPMG) sequence, a multiple spin-echo imaging technique.[11] Comparative analysis of hippocampal T2 maps between healthy individuals and epilepsy patients reveals that individuals with hippocampal sclerosis show prolonged T2 relaxation times. Using a combination of visual analysis and T2 relaxometry, Paradeep Singh and colleagues[11] identified hippocampal sclerosis in 62% of the studied cases, as reported in BioMed Research International.

The present study aims to evaluate the diagnostic accuracy of various MRI modalities in identifying hippocampal sclerosis and in quantifying disease progression. This is particularly valuable for patients with medically refractory epilepsy who may benefit from surgical treatment. Given the lack of comparable research within Pakistan, conducting this study is vital for enhancing diagnostic precision and improving clinical management and prognosis for both drug-responsive and drug-resistant epilepsy patients.

METHODOLOGY

The study was a cross-sectional design, conducted at the Department of Radiology, Sheikh Zayed Medical College/Hospital, Rahim Yar Khan.The sample size was determined using the WHO sample size calculator, assuming a prevalence of 62%, a 95% confidence level, and an absolute precision of 10%, resulting in a required sample of 110 patients. Inclusion criteria comprised patients aged 10 to 60 years of either gender with a diagnosis of temporal lobe epilepsy (TLE), established through clinical evaluation and/or electroencephalogram (EEG) findings, in accordance with predefined operational definitions. Exclusion criteria included patients with implanted metallic pacemakers or a known history of claustrophobia, rendering them unsuitable for MRI examination.

After clearly outlining the study objectives and procedures, written informed consent was secured from each participant in accordance with ethical guidelines.Each patient underwent brain MRI using a 1.5 Tesla Philips Achieva scanner. Two assessment

Received on 03-07-2023
Accepted on 25-10-2023

modalities were employed to evaluate hippocampal pathology: qualitative visual assessment and quantitative T2 relaxometry.

T2 relaxometry was performed using an 8-echo Carr-Purcell-Meiboom-Gill sequence with the following imaging parameters: echo time (TE) range of 22–352 ms, repetition time (TR) of 3000 ms, slice thickness of 5 mm, and field of view (FOV) of 230 mm. Eight spin-echo images were acquired per oblique coronal slice across varying echo times. A monoexponential curve-fitting algorithm was applied to voxel intensities across all echoes to generate T2 relaxation time maps. Regions of interest (ROIs) were manually drawn within the anterior (head), middle (body), and posterior (tail) segments of the hippocampus. ROI placement was standardized using anatomical landmarks to ensure reproducibility and to avoid partial volume effects from adjacent cerebrospinal fluid. A mean T2 relaxation time greater than 116 milliseconds was considered indicative of hippocampal sclerosis.

For visual assessment, images were qualitatively analyzed for features of hippocampal atrophy including decreased volume, architectural distortion, asymmetry between hippocampi, hyperintensity on T2-weighted images, and hypointensity on T1-weighted images relative to the contralateral side. MRI scanning was performed by a certified radiologic technologist under direct supervision of the principal investigator. All image interpretations were conducted by the principal investigator and reviewed in consultation with the academic supervisor. Data were documented using a structured proforma specifically developed for this study. Statistical analysis was conducted using SPSS version 23. Descriptive statistics were applied to summarize the data: mean±standard deviation for continuous variables (e.g., age) and frequencies with percentages for categorical variables (e.g., gender, true positive/negative outcomes). Diagnostic accuracy of T2 relaxometry was determined using visual interpretation as the gold standard.

RESULTS

A total of 110 patients diagnosed with temporal lobe epilepsy were included in the study. The age distribution revealed that the majority of participants (n = 72, 65.5%) were between 10 and 40 years of age, while the remaining 38 patients (34.5%) were aged between 41 and 60 years. Regarding gender, males constituted a slightly higher proportion with 64 patients (58.2%), whereas females comprised 46 patients (41.8%).(Table 1)

Table 1: Demographic and Diagnostic Characteristics of Patients (n = 110)

Variable	Group	Frequency	Percent
Age Group	10–40 years	72	65.5%
	41–60 years	38	34.5%
Gender	Male	64	58.2%
	Female	46	41.8%
Quantitative HS (T2 > 116)	Yes	38	34.5%
	No	72	65.5%
Visual Assessment of HS	Yes	46	41.8%
	No	64	58.2%

On quantitative analysis using T2 relaxometry, hippocampal sclerosis (defined as T2 relaxation time >116 ms) was identified in 38 patients (34.5%), while 72 patients (65.5%) showed no evidence of hippocampal sclerosis. Visual assessment of MRI scans indicated hippocampal sclerosis in 46 patients (41.8%), and the remaining 64 patients (58.2%) were classified as normal based on qualitative criteria.

A diagnostic accuracy comparison of T2 relaxometry against visual MRI assessment is presented in Table 2. Of the 38 patients who were visually diagnosed with hippocampal sclerosis, 35 (31.8% of the total sample) were correctly identified as true positives by T2 relaxometry, while 3 patients (2.7%) were missed, representing false negatives. Among the 72 patients without visual evidence of hippocampal sclerosis, T2 relaxometry correctly identified 61 cases as true negatives (55.5%), whereas 11 cases (10.0%) were incorrectly classified as false positives. The total number of T2 positive cases was 46 (41.8%), and T2 negative cases were 64 (58.2%).(Table 2)

Table 2: Diagnostic Accuracy of T2 Relaxometry Compared to Visual Assessment (n = 110)

	Visual HS Present (Yes)	Visual HS Absent (No)	Total
T2 Positive (T2 > 116 ms)	35 (31.8%) – True Positive	11 (10.0%) – False Positive	46 (41.8%)
T2 Negative (T2 ≤ 116 ms)	3 (2.7%) – False Negative	61 (55.5%) – True Negative	64 (58.2%)

DISCUSSION

This study evaluated the diagnostic accuracy of T2 relaxometry against visual MRI assessment in identifying hippocampal sclerosis (HS) among patients with temporal lobe epilepsy (TLE). Our results demonstrated a high sensitivity (92.1%) and specificity (84.7%) for T2 relaxometry when compared to visual assessment, underscoring its value as a complementary modality in the diagnostic workup of epilepsy.

Our results align with those of Aleena Elizabeth Andrews et al.[12], who assessed hippocampal volume in patients with focal onset seizures with impaired awareness through visual analysis and MR volumetry. Their study highlighted that volumetry could detect subtle bilateral or unilateral hippocampal atrophy in more cases than visual assessment (28.3% vs. 24.5% on the right; 18.86% vs. 16.98% on the left). This supports the observation that quantitative imaging methods are more sensitive than visual analysis in identifying hippocampal changes, particularly in early or subtle pathology.

Further validation of quantitative imaging is evident in the work of Gavin P. Winston et al[13] who developed and tested an automated method for hippocampal T2 relaxometry using dual-echo imaging and multi-atlas–based hippocampal segmentation. Their study involving 50 patients with HS and 50 controls revealed that automated T2 values strongly correlated with manual assessments ($r > 0.89$, $p < 0.001$) and were more reproducible. Importantly, they demonstrated that combining hippocampal T2 values and volume metrics improved differentiation between HS patients and healthy individuals. These findings reinforce the relevance of combining structural and relaxometric assessments for optimal diagnostic accuracy.

In line with this, Redha Okta Silfina et al[14] introduced a computer-aided diagnosis (CAD) tool that quantitatively assessed T2-FLAIR signal intensity, achieving 81% accuracy and 90% sensitivity. Similarly, Gleichgerrcht et al[15] employed deep learning to detect unilateral TLE on MRIs considered normal by experts. Their convolutional neural network reliably identified laterality and pathology, showcasing the diagnostic potential of AI even in challenging cases. Together, these studies emphasize the evolving role of quantitative and automated tools—whether through T2 relaxometry, volumetry, or AI—in enhancing consistency and reducing subjectivity in epilepsy imaging.

Collectively, these studies converge on a key theme: while visual interpretation remains clinically valuable, it is inherently limited by observer experience and variability. Quantitative methods such as T2 relaxometry, MR volumetry, and AI-enhanced segmentation augment diagnostic precision and reproducibility, particularly in borderline or visually equivocal cases. Moreover, these tools may offer correlations with clinical parameters such as seizure duration and frequency, further supporting their application in monitoring disease progression and evaluating surgical candidacy.

Despite these strengths, one limitation of the present and referenced studies is the variability in imaging sequences, relaxometry protocols, and sample sizes, which may influence

inter-center reproducibility. Additionally, manual region-of-interest (ROI) placement in relaxometry remains operator-dependent, although recent advances in automation—such as those proposed by Winston et al.[13]—may mitigate this issue. Future studies with larger cohorts and standardized imaging protocols are necessary to establish robust normative values and further validate the clinical utility of relaxometry.

CONCLUSION

T2 relaxometry emerges as a robust, non-invasive, and accessible imaging tool for the evaluation of mesial temporal sclerosis in patients with temporal lobe epilepsy. When combined with EEG and clinical data, it significantly enhances diagnostic accuracy, particularly in cases with subtle or equivocal findings on conventional MRI. Future integration with AI and volumetric tools may further refine its utility, ensuring timely and accurate diagnosis for optimal management and surgical planning in drug-resistant epilepsy.

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This article may be cited as: Majeed S, Haidari FA, Khan F, Khan A, Zaidi B, Arshad F: Diagnostic Utility of Qualitative MRI and T2 Relaxometry in Hippocampal Assessment for Temporal Lobe Epilepsy. Pak J Med Health Sci, 2023;17(11):363-365.