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THE ROLE OF POSITRON EMISSION TOMOGRAPHY-COMPUTED TOMOGRAPHY (PET-CT) IN MEDICALLY REFRACTORY EPILEPSY

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Abstract

Objective: *To evaluate and compare the diagnostic accuracy of Magnetic Resonance Imaging (MRI) and Positron Emission Tomography-Computed Tomography (PET-CT) in localizing the epileptogenic zone in patients with drug-resistant epilepsy (DRE).*

Methods: *From June to December 2024, 180 patients with DRE at Armed Forces Hospital, Rawalpindi, were cross-sectionally assessed using both MRI and PET-CT imaging. Using clinical and imaging consensus as the reference standard, we calculated the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of both modalities. Chi-square analysis was used to assess statistical associations between imaging findings and clinical evaluation.*

Results: *PET-CT demonstrated higher sensitivity (88.72%) and NPV (83.64%) compared to MRI (69.77% and 58.02%, respectively). PET-CT also showed greater diagnostic concordance (66.24%) than MRI (38.01%). When both imaging findings were concordant, the combined use of MRI and PET-CT achieved the highest diagnostic agreement (46.87%, $p < 0.05$); discordant or negative findings were associated with reduced diagnostic clarity.*

Conclusion: *In DRE—especially in MRI-negative cases—PET-CT offers greater utility than MRI in identifying the epileptogenic zone. The combined use of both modalities enhances diagnostic accuracy and supports their integration into routine clinical evaluation of DRE.*

INTRODUCTION

About 30% of epilepsy patients globally have drug-resistant epilepsy, defined as the failure of sufficient trials of two tolerated and suitably chosen antiepileptic medications to achieve prolonged seizure independence [1-2]. DRE management presents major difficulties for both reducing the related psychosocial and cognitive effects as well as for managing seizure activity. Effective clinical management depends on precise identification of the epileptogenic zone (EZ), the area of brain liable for producing seizures [3-4]. Advanced imaging techniques, particularly MRI and PET-CT leading front stage, have resulted from the demand for exact localization [5].

High-resolution structural information provided by MRI, lets one see brain shape and identify possible structural anomalies including malformations of cortical development, mesial temporal sclerosis and focal cortical dysplasia [6]. When first evaluating patients with DRE, it is the main imaging instrument used. MRI is critical for detecting structural brain abnormalities and informing further diagnostic steps [7-8]. MRI's great spatial resolution nonetheless may not be able to identify minor lesions or anomalies in cases of non-lesional epilepsy, therefore affecting the EZ's localization [9].

Conversely, PET-CT, functional imaging method based on radiotracers such as 18F-fluorodeoxyglucose (FDG), highlights areas of hypo- or hypermetabolism, therefore offering supplementary information [10]. This method assesses cerebral glucose metabolism. Particularly in cases when MRI is negative, interictal PET scans in DRE often show areas of hypometabolism matching the EZ. In non-lesional epilepsy particularly and in guiding the implantation of intracranial electrodes for further localization, PET-CT is quite helpful. Its ability to identify minute metabolic alterations improves its relevance in complicated instances and helps to clarify epileptogenic networks [11].

MRI and PET-CT taken together has proved to raise patient outcomes and diagnostic accuracy. Concordance between MRI and PET-CT findings enhances diagnostic confidence and accuracy in localizing the epileptogenic zone [12]. When MRI is not clear-cut, PET-CT can offer vital information and help to focus the region of interest for targeted clinical evaluation. Emerging multimodal imaging methods, such MRI-PET fusion, which combines structural and functional data into single representation and provides more exact delineation of EZ, enable this synergistic approach [13].

In this regard, this study attempts to give thorough comparison of MRI and PET-CT in the evaluation of DRE, stressing their respective advantages, disadvantages and clinical settings in which each modality may be most helpful. Enhancing diagnostic precision and long-term seizure control in patients with DRE depends on recognizing the complementary roles of these imaging modalities.

Materials and Methods

Study Design and Setting

Conducted between June 2024 and December 2024 at Armed Forces Hospital, Rawalpindi, this cross-sectional study was purposed to assess, in patients with DRE, the accuracy of MRI Brain and PET-CT in the location of the epileptogenic zone.

Sample Size and Sampling Technique

Based on the projected DRE in the population and necessity of statistical power to find notable variations between imaging modalities, the sample size of 180 patients was computed. Patients fitting the inclusion criteria were sought using non-probability consecutive sampling method.

Inclusion and Exclusion Criteria

Patients who were clinically diagnosed with DRE; defined as failure of at least two antiepileptic medicines to control seizures were included in the study if they were undergoing advanced neurodiagnostic assessment. Every participant fell between the ages of eighteen and sixty-five. The study excluded patients having history of psychiatric illnesses, past brain surgeries or contraindications to MRI or PET-CT (e.g., claustrophobia or pregnancy).

Data Collection Procedures

Using standardized questionnaire, data was gathered including demographic information (age, sex), clinical history (age of seizure onset, duration of epilepsy, seizure frequency) and imaging findings. Every patient had extensive neurological assessment then MRI Brain and PET-CT imaging. Focusing on high-resolution T1-weighted, T2-weighted and fluid-attenuated inversion recovery (FLAIR) sequences to find structural anomalies, MRI Brain was done utilizing 3.0 Tesla scanner. Cerebral glucose metabolism was assessed by PET-CT with 18F-fluorodeoxyglucose (FDG) tracer.

Imaging Analysis

Two board-certified neuro-radiologists blinded to one another's findings separately assessed the MRI and PET-CT pictures. MRI results were categorized as negative, no apparent abnormalities, or positive, presence of structural anomalies. If focal hypometabolism was found, indicative of the epileptogenic zone, PET-CT findings were classified as positive. Radiologists resolved differences by consensus.

Statistical Analysis

Data was examined with SPSS version 26. Clinical and demographic traits were gathered using descriptive statistics. Using clinical and imaging consensus as the reference standard, we computed the sensitivity, specificity, PPV and NPV of MRI and PET-CT in localizing the epileptogenic zone. With p-value of 0.05 regarded statistically significant, chi-square test and Fisher's exact test were used to evaluate the relationship between imaging findings and clinical diagnosis.

Ethical Considerations

Approved ethically by the Institutional Review Board of Armed Forces Hospital in Rawalpindi All participants signed written informed permission, therefore guaranteeing anonymity and ability to withdraw from the study at any point without compromising their therapeutic treatment.

Results

Comprising 180 patients with DRE, current study had mean age of 32.8 years and somewhat larger number of men (54.4%). Indicating a chronic illness, mean duration of epilepsy was 17.2 years and average age of seizure start was 15.6 years. The most often occurring lesion in MRI-positive cases was mesial temporal sclerosis (19.4%), followed by focal cortical dysplasia (15.6%). Reflecting considerable past medical therapy, most patients had attempted two (41.7%) or more AEDs (33.3%) (Table 1).

MRI revealed positive results for 55.0% of patients; PET-CT had higher detection rate of 74.44%. A useful supplemental imaging modality, chi-square analysis indicated a statistically significant difference ($p<0.05$), showing that PET-CT is more successful in spotting epileptogenic zones than MRI (Table 2).

When looking for the epileptogenic zone, MRI and PET-CT were compared; PET-CT beat MRI in all respects. Comparatively to MRI's 69.77 and 64.91%, PET-CT boasted greater sensitivity (88.72%) and specificity (70.18%). Furthermore surpassing MRI's PPV of 76.25% and NPV of 58.02% was PET-CT's PPV of 80.74% and NPV of 83.64%. This implies that, particularly in situations when MRI could not be able to clearly identify the epileptogenic zone, PET-CT is more dependable in this regard (Figure 1).

PET-CT has more concordance with diagnostic concordance (66.24%) in the correlation between imaging results.Furthermore less is the discordant rate for PET-CT (8.21%) than for MRI (16.99%). The difference is statistically significant ($p<0.05$), therefore verifying the higher diagnostic accuracy of PET-CT in identifying the epileptogenic zone. Moreover, the highest diagnostic agreement (46.87%) was observed when both MRI and PET-CT findings were concordant ($p<0.05$). On the other hand, conflicting results or negative findings from both modalities were associated with the reduced probability of surgical success, therefore stressing the need for multimodal imaging in comprehensive diagnostic evaluation of DRE (Figure 2).

Table 1: Demographic and Clinical Characteristics of the Study Population (n = 180)

Characteristics	Frequency (%)
Age (years) **Mean ± SD**	**32.8 ± 12.4**
Sex n(%)	
Male	98 (54.4)
Female	82 (45.6)
Age of Seizure Onset (years) **Mean ± SD**	**15.6 ± 5.8**
Duration of Epilepsy (years) **Mean ± SD**	**17.2 ± 9.3**
Seizure Frequency (per month) **Mean ± SD**	**6.7 ± 4.1**

Lesion Type (MRI Positive Cases) n(%)	
Mesial Temporal Sclerosis	35 (19.4)
Focal Cortical Dysplasia	28 (15.6)
Malformations of Cortical Development	22 (12.2)
Others	15 (8.3)
Previous AEDs Tried n(%)	
One	45 (25)
Two	75 (41.7)
Three or more	60 (33.3)

Table 2: Distribution of MRI and PET-CT Findings (n = 180)

Imaging Modality	Positive Findings	Negative Findings	Total	Chi-Square	p-value
MRI	99 (55.0%)	81 (45.0%)	180	4.78	0.029*
PET-CT	134 (74.44%)	46 (25.56%)	180		

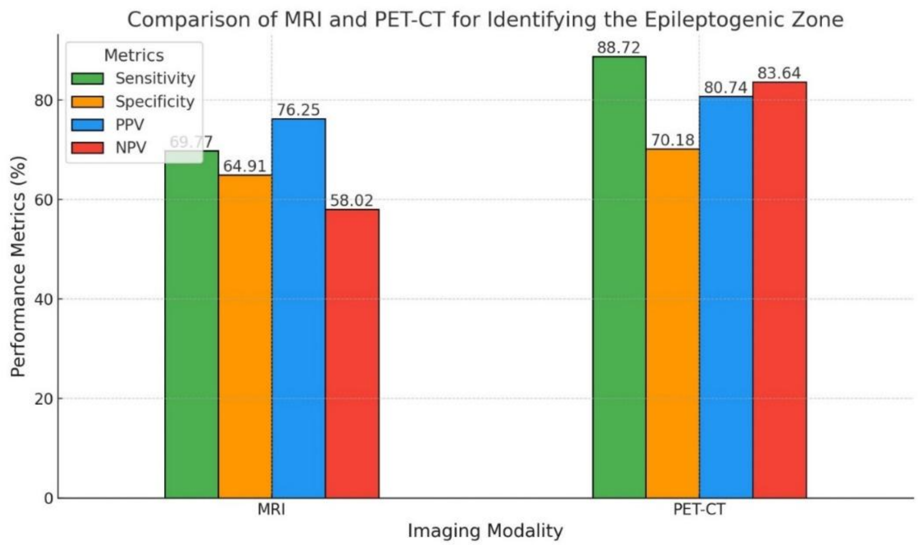

Figure 1: Comparison of MRI and PET-CT for identifying the epileptogenic zone

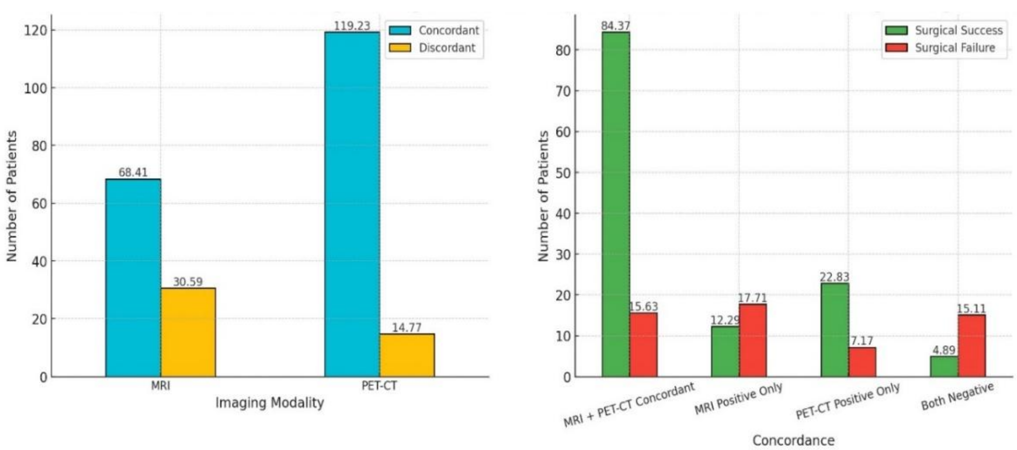

Figure 2: Comparison of imaging modality findings and concordance impact on clinical confidence in DRE

a: Association between MRI and PET-CT findings and diagnostic agreement
b: Impact of concordant Imaging findings on clinical confidence

Discussion

Identifying the epileptogenic zone in patients with DRE using MRI and PET-CT revealed significant differences in diagnostic yield and clinical utility between the two modalities. The results showed that PET-CT is valuable tool in the diagnostic assessment of DRE patients since it has better sensitivity, specificity and predictive values. The MRI can identify structural brain abnormalities, it has become the main imaging tool used in first evaluations of epilepsy. Common in patients with DRE, MRI results can point out mesial temporal sclerosis, focal cortical dysplasia and other anomalies of cortical development. The present investigation, however, showed that MRI by itself found the epileptogenic zone in only 55% of the instances, thereby leaving significant fraction of patients without the definitive localization. This result is in line with earlier studies showing MRI has limited sensitivity in non-lesion epilepsy and in patients with minor cortical abnormalities that might not be readily apparent on conventional MRI sequences [14-15].

The rather low sensitivity of MRI in this cohort might be ascribed to some lesions, especially in individuals with non-lesional or extra-temporal epilepsy, which exceed the spatial resolution of typical MRI techniques [16-17]. In these situations, new imaging technologies including functional MRI and high-field 7T MRI have shown enhanced sensitivity but are not generally accessible due to technological constraints and great prices [18]. Therefore, even if MRI is rather helpful in identifying structural anomalies, its restrictions call for the adoption of supplementary modalities such as PET-CT to improve localization accuracy.

Unlike MRI, PET-CT showed much higher sensitivity and specificity in identifying the epileptogenic zone, together with the better concordance with diagnostic results. Often corresponding with the seizure focus, PET-CT detects areas of aberrant metabolism using radiotracers including FDG. Even in MRI-negative patients, areas of interictal hypometabolism on PET-CT have been demonstrated to correlate rather nicely with the epileptogenic zone [19]. Given 45% of the instances in this study show MRI fails to detect apparent structural abnormalities, this feature makes PET-CT very beneficial in such cases.

Furthermore, PET-CT's higher NPV, showing its dependability in excluding non-epileptogenic areas, therefore lowering the probability of needless intrusive searches. This result fits the research of Wang et al. (2024) [20], who found similar diagnostic value of PET-CT in localizing seizure foci in patients with MRI-negative epilepsy. Particularly in complicated circumstances when structural imaging alone is inadequate, PET-CT's capacity to identify minute changes in glucose metabolism emphasizes its function as a complimentary tool to MRI.

Further supporting the clinical value of integrating MRI and PET-CT is the observed concordance between both modalities. With successful diagnostic results, PET-CT exhibited greater concordance rate than MRI. Additionally decreased discordance rates for PET-CT confirm its accuracy in localizing the epileptogenic zone.

In cases when only one modality was positive or both were negative, diagnostic confidence was reduced, when MRI and PET-CT findings were concordant. This conclusion is in line with earlier research stressing the need of multimodal imaging in comprehensive epilepsy evaluation [21]. Studies have particularly indicated that concordant PET-CT and MRI results predicted lower recurrence rates and improved post-surgical seizure outcomes [22]. Therefore, especially in patients with uncertain or contradictory imaging data, the integration of both modalities in pre-surgical evaluation should be taken under consideration to maximize diagnostic outcome.

The results of this study directly inform clinical decision-making in patients with DRE. Patients with concordant MRI and PET-CT results had far higher chance of seizure independence following surgery than those with discordant or negative results. This implies that instead of depending just on one modality, surgical candidates should be chosen according on multimodal imaging findings. A positive PET-CT can provide vital information in circumstances where MRI is negative or equivocal, therefore guiding further investigations such as advanced imaging or electrophysiology for additional localization and restricting the area of interest.

Future research should try to confirm these results in bigger, multicenter cohorts and investigate the use of cutting-edge PET tracers, such 11C-flumazenil, which might have better specificity for epileptogenic zones.

Conclusion

Based on its better sensitivity, specificity and predictive values, this study shows that PET-CT much outperforms MRI in spotting the epileptogenic zone in drug-resistant epilepsy. Especially in cases of equivocal MRI findings, PET-CT is a vital tool in diagnostic evaluation. MRI and PET-CT used together enhances diagnostic accuracy, aiding in improved clinical management and seizure monitoring. These results supported the clinical management of patients with DRE adopting multimodal imaging technique in order to ensure timely diagnosis and effective individualized management.

Conflict of Interest: No.

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