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Research Article

Diffusion Weighted MRI Patterns in Viral Encephalitis and Their Correlation with Clinical Outcomes

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ABSTRACT

Objectives: To study the DW-MRI pattern in patients with viral encephalitis and to assess its association with clinical outcome.

Methods: It is a descriptive cross sectional study, where the study setting was in the department of radiology at Liaqat National hospital and medical college Karachi from 23 February 2025 till 23 November 2025. The patients with viral encephalitis were selected by consecutive non probability sampling and a total of 89 patients were included with clinically suspected and radiologically confirmed viral encephalitis. The pattern of lesions and their anatomical distribution were used to classify DW-MRI findings. The clinical outcomes were evaluated as complete or incomplete or no recovery. Data was analyzed using a statistical package for social sciences (SPSS) version 26, and a p value of < 0.05 was set as the threshold for significance.

Results: The mean age of the patients was 34.6 ± 11.3 years and 58.4% were males. The pattern of bilateral cerebral involvement occurred in 38.2% of patients and was the most common pattern of DWI involvement. In 57.3% of cases, there was involvement of the temporal lobes. 68.5% of patients made a full neurological recovery. Diffuse cerebral involvement had the worst clinical outcome and there was a significant relationship between diffusion weighted imaging patterns and clinical outcome ($p < 0.001$).

Conclusion: There was a significant relationship between DW-MRI patterns and neurological outcomes in viral encephalitis. The presence of extensive and diffuse diffusion restriction was correlated with poor prognosis and with the presence of neurological deficits.

Keywords: Viral Encephalitis, Diffusion Weighted Imaging, Magnetic Resonance Imaging, Clinical Outcome, Temporal Lobe, Neurological Recovery.

INTRODUCTION

Viral encephalitis is considered a serious inflammatory disease of the brain that is produced by direct invasion of neural tissue by different viruses. The disease is encountered in all age groups and significant morbidity and mortality have been reported throughout the world. The importance of early recognition and timely treatment has been emphasized as delayed diagnosis has been linked to poor neurological outcome and long term disability. Symptoms may be varied, such as fever, altered consciousness, seizures, focal neurological deficits and behavioral changes. The wide variety of presentation has caused a delay in diagnosis in several health care settings.[1]

Viral encephalitis has been a persistent public health problem in developing countries where access to sophisticated neuro-imaging and lab support is limited. A number of viruses have been found to cause encephalitis: Herpes simplex virus, Japanese encephalitis virus, enteroviruses and arboviruses. There are inflammatory changes, causing cytotoxic edemas, damage to neurons and vascular changes that can cause irreversible damage of brain tissue. Even patients who survive can show neurological damage and cognitive dysfunction.[2]

MRI has been considered to be a vital diagnostic modality in suspected encephalitis due to the good soft tissue contrast and ability to demonstrate early parenchymal changes. There are many traditional magnetic resonance (MR) sequences that are currently employed in the detection of inflammatory changes in the brain, such as T1 weighted imaging, T2 weighted imaging, and the fluid attenuated

inversion recovery imaging (FLAIR). In the early stage of the disease, however, conventional sequences might not be able to detect early damage to cells, and this might cause a delay in diagnosis and treatment.[3]

A new technique, called diffusion weighted magnetic resonance imaging, has become an important tool to assess the movement of water molecules on a micro-level within tissue. Restriction of diffusion has been associated with cytotoxic edema and neuronal damage and these changes may appear before abnormalities become evident on conventional imaging sequences. Therefore, diffusion weighted imaging has been used to diagnose early viral encephalitis and has been gaining more interest for the radiologists and neurologists.[4]

There are several diffusion weighted imaging patterns described in viral encephalitis patient. Causing viral agents and the severity of the disease, involvement of temporal lobes insular cortex basal ganglia thalami brain stem and cerebellum have been reported. There are also differences in clinical presentation and disease course which have been linked to differential patterns of diffusion restriction. These imaging patterns could be helpful in diagnosis prognosis and therapeutic planning.[8]

Several clinical factors have affected the outcome of viral encephalitis, such as age, level of consciousness, presence of seizures and extent of the brain involvement. The utility of neuroimaging has been a growing interest as a possible prognostic marker, as imaging can objectively assess the tissue damage. Restriction of diffusion has been suggested as a marker of permanent damage to the brain and insufficient functional recovery in various neurological diseases. In the case of viral encephalitis, similar findings have been proposed, but there have been inconsistent data to support it.[6]

A previous study has shown that having widespread restriction and bilateral cerebral involvement may be related to poor outcome and mortality. There has been some suggestion that isolated lesions and early recovery of diffusion abnormalities are a favorable prognosis. However, the correlation between the DWI pattern(s) and clinical outcome remains poorly understood. Reported findings have been inconsistent, due to differences in the study design and the small sample sizes, as well as variation in the outcome measures used.[7]

Thus, the contribution of diffusion weighted imaging to the prediction of neurological outcome has continued to be a matter of study. The vast majority of studies have been directed at the diagnostic role of MRI and only few towards the prognostic relevance of diffusion changes. Imaging and clinical information may vary by region, and data from developing countries are sparse. These constraints have left uncertainties about how useful diffusion weighted imaging is in the routine clinical evaluation of prognosis.[8]

One of the other issues that have been of concern is the lack of a uniform classification of diffusion weighted imaging patterns in viral encephalitis. Variable definitions on the focal lesions, multifocal lesions and diffuse cerebral involvement are used by different authors. This diversity has hindered direct comparisons of studies and has made it difficult to develop imaging markers of outcome that are universally accepted. Another point is that many investigations have not had long term follow up, and the effect of imaging on neurological recovery is not completely understood.[9]

The increasing study of magnetic resonance imaging in tertiary healthcare institution has created an opportunity to explore diffusion weighted imaging findings in depth. There is a possibility that better knowledge of the typical diffusion pattern and its prognostic value would be helpful in early risk stratification and patient management. If imaging markers can be identified that are predictive of poor outcome, then they can aid in clinical decision making and inform the level of monitoring and rehabilitation intensity.

Although there have been significant developments in neuroimaging of diffusion weighted magnetic resonance imaging (DW-MRI) patterns in viral encephalitis, there is still much that is not understood about them and their relationship with clinical outcome. There are some limited regional studies and inconclusive results from past studies which point to the need for additional research in this area. The role of diffusion restriction patterns in predicting outcome is still not well defined and the link between the degree of brain involvement and neurological outcome needs to be further assessed.

The aim of this study was to identify the DW-MRI pattern in patients with viral encephalitis and their relationship with clinical outcome to provide clues to the prognosis of encephalitis and neurological recovery.

MATERIALS AND METHODS

Study Design and Setting

Descriptive Cross Section study was carried out at Department of Radiology in Liaqat National Hospital and Medical College Karachi. This study is conducted for a period of 9 months starting from 23 February 2025 to 23 November 2025. The study aimed to assess the DW-MRI pattern in patients with viral encephalitis, and to identify its correlation with clinical outcome. A total of 89 patients was included in the study. Patients were recruited using consecutive non probability sampling technique during the study period.

Sample Size Calculation

The number of patients (n = 89) has been determined using the World Health Organization sample size calculator. The margin of error was set at 10%, and a 95% confidence interval was used, with a predicted proportion of abnormal DW-MRI results in patients with viral encephalitis based on previous published data. The sample size calculated was adequate for this to establish the relationship between imaging findings and clinical outcomes.

Study Population

Patients who attended the emergency department (ED) to the neurology department and were hospitalized with a clinical diagnosis of viral encephalitis were screened for inclusion in the study.Patients with a clinical diagnosis of viral encephalitis referred for computed tomography (CT) or magnetic resonance imaging (MRI) of the brain in the neurology department were screened for inclusion. Patients with the pre-defined inclusion criteria were included after informed consent (patient or legal guardian).

Inclusion Criteria

Patients of either gender between 18 and 70 years of age were included in the study. Patients who met criteria for clinical features of viral encephalitis (fever, altered mental status, seizures, focal neurological deficits, behavioral abnormalities, confusion) were included. The study included patients who had MRI assessments suggestive of encephalitis, and those who had diffusion weighted imaging sequences. Those who had laboratory confirmation of viral infection or a strong clinical diagnosis (defined by the treating neurologist) were also included.

Exclusion Criteria

Those who had bacterial meningitis, tuberculous meningitis, fungal infections or autoimmune encephalitis were not included in the study. No patients were included with a history of primary brain tumors, previous cerebrovascular accidents, demyelinating disorders or traumatic brain injury. Contrariwise, patients with medical contraindications to MRI (cardiac pacemaker, metallic implants or severe claustrophobia) were excluded. Outcome assessment was incomplete in some patients and the MRI exam was of poor quality in other patients, and patients who were lost to follow up were also excluded from the study.

Data Collection Procedure

After approval from the institutional review committee all eligible patients were enrolled. Information with regard to the demographic and clinical data were gathered on a structured proforma, which included the age at presentation, gender, presenting symptoms, history of illness, seizures, and neurological examination. Hospital records were consulted for baseline laboratory investigations and CSF.

All MR examinations were carried out with a magnetic resonance imaging system with a strength of 1.5 T. The imaging protocol consisted of axial T1 weighted imaging, axial and coronal T2 weighted imaging, fluid attenuated inversion recovery and diffusion weighted imaging and apparent diffusion coefficient mapping. Further post contrast sequences were performed if clinically indicated.

The MRI findings of the DW-MRI were independently read by two experienced consultant radiologists, unaware of the final clinical outcome. Diffusion restriction was identified as hyperintense signal on DWI with hypointense signal on ADC maps. The restriction patterns were classified as focal unilateral, bilateral, multifocal and diffuse cerebral. All anatomical distribution of lesions temporal lobes, frontal lobes, parietal lobes, occipital lobes, thalami, basal ganglia, brain stem and cerebellum was also documented.

Clinical Outcome Assessment

Clinical outcomes (including hospital discharge and follow up visits) were measured. The clinical evaluation performed by the neurologist treating the patient categorized neurological recovery into complete and partial or no recovery. Successful recovery was considered to be complete, when neurological symptoms

resolved and there were no significant residual deficits. Persistent neurological impairment, cognitive dysfunction and functional disability or death were considered partial or no recovery.

Quality Control Measures

All MRI scans were carried out using a standard departmental protocol. To reduce observer bias, the interpretation of DWI results was done independently by two radiologists. A consensus interpretation was developed in instances of conflict by cooperative review. Data was checked for accuracy and completeness prior to statistical analysis.

Ethical Considerations

The study was approved by the Institutional Review Committee of Liaqat National Hospital and Medical College, Karachi before starting the study. The study followed ethical principles in accordance with the declaration of Helsinki. All participants or legal guardians gave written informed consent prior to their enrollment. Patient information was appropriately kept confidential during the study. The data were anonymized, and only used for research. Patients were informed that they would not be penalized for their refusal to participate in the study, and the study was voluntary.

Statistical Analysis

The data collected was fed into the computer and analyzed using SPSS version 26. The data on quantitative variables (age and duration of illness) were presented as mean and standard deviation. Qualitative variables such as gender presenting symptoms, diffusion weighted magnetic resonance imaging patterns, anatomical distribution of lesions, and clinical outcomes were described in terms of frequency and percentage. The correlation of diffusion weighted imaging pattern with clinical outcome was evaluated by chi square test or fisher exact test as appropriate. To compare mean age between outcome groups, independent sample t test were performed. A level of $p<0.05$ was deemed to be statistically significant. The results were presented in tables and figures to make the results easy to interpret and compare.

RESULTS

Demographic Characteristics of the Study Population

A total of 89 patients with viral encephalitis were included in the study. The mean age of the study population was 34.6 ± 11.3 years with an age range of 18 to 68 years. The majority of patients belonged to the age group of 31 to 50 years. There were 52 males and 37 females giving a male to female ratio of 1.4 to 1. The demographic profile demonstrated a slight male predominance among patients with viral encephalitis. The age and gender distribution of the study population are presented in Table 1.

Table 1: Demographic Characteristics of the Study Population

Variable	Value
Total patients	89
Mean age (years)	34.6 ± 11.3
Age range (years)	18–68
Age 18–30 years	26 (29.2%)
Age 31–50 years	42 (47.2%)
Age >50 years	21 (23.6%)
Male	52 (58.4%)
Female	37 (41.6%)

Clinical Presentation of Patients

The most common presenting symptom was fever which was observed in 82 patients followed by altered level of consciousness in 67 patients. Seizures were documented in 43 patients while focal neurological deficits were observed in 31 patients. Headache and behavioral disturbances were also frequently encountered. The clinical presentation of the study participants is summarized in Table 2. These findings indicate that viral encephalitis presented with diverse neurological manifestations and often required neuroimaging for confirmation of diagnosis.

Table 2: Clinical Presentation of Patients with Viral Encephalitis

Clinical Feature	Frequency	Percentage
Fever	82	92.1%

Altered consciousness	67	75.3%
Headache	49	55.1%
Seizures	43	48.3%
Focal neurological deficits	31	34.8%
Behavioral changes	27	30.3%
Vomiting	22	24.7%

Diffusion Weighted Magnetic Resonance Imaging Patterns

Diffusion weighted magnetic resonance imaging demonstrated abnormalities in all enrolled patients. Bilateral cerebral involvement was the most frequent imaging pattern and was observed in 34 patients. Focal unilateral involvement was identified in 25 patients while multifocal lesions were present in 20 patients. Diffuse cerebral involvement was observed in 10 patients. These findings suggested that viral encephalitis demonstrated a wide range of diffusion restriction patterns with varying degrees of cerebral involvement. The distribution of diffusion weighted imaging patterns is presented in Table 3.

Table 3: Diffusion Weighted Magnetic Resonance Imaging Patterns

Imaging Pattern	Frequency	Percentage
Focal unilateral involvement	25	28.1%
Bilateral involvement	34	38.2%
Multifocal lesions	20	22.5%
Diffuse cerebral involvement	10	11.2%
Total	89	100%

Anatomical Distribution of Diffusion Restriction

Analysis of lesion location demonstrated that the temporal lobes were the most commonly involved region and were affected in 51 patients. The frontal lobes were involved in 32 patients while thalamic involvement was observed in 24 patients. Basal ganglia lesions were present in 19 patients and brain stem abnormalities were identified in 11 patients. Cerebellar involvement was the least common finding. The anatomical distribution of lesions is summarized in Table 4. The predominance of temporal lobe involvement was consistent with the known neurotropism of several viral pathogens particularly herpes simplex virus.

Table 4: Anatomical Distribution of Diffusion Restriction

Site of Involvement	Frequency	Percentage
Temporal lobes	51	57.3%
Frontal lobes	32	36.0%
Parietal lobes	18	20.2%
Occipital lobes	12	13.5%
Thalami	24	27.0%
Basal ganglia	19	21.3%
Brain stem	11	12.4%
Cerebellum	7	7.9%

Clinical Outcomes of Patients

Assessment of clinical outcomes revealed that complete neurological recovery occurred in 61 patients while 28 patients demonstrated partial recovery or persistent neurological deficits. Among patients with poor outcomes three deaths were recorded during the hospital stay. The overall recovery rate was therefore favorable although a substantial proportion of patients experienced residual neurological impairment. The clinical outcomes are presented in Table 5.

Table 5: Clinical Outcomes of Patients

Outcome	Frequency	Percentage
Complete recovery	61	68.5%
Partial recovery	25	28.1%
Death	3	3.4%

Total	89	100%

Association between Diffusion Weighted Imaging Patterns and Clinical Outcomes

A significant association was observed between diffusion weighted imaging patterns and neurological outcomes. Patients with focal unilateral lesions demonstrated the highest rate of complete recovery while those with diffuse cerebral involvement had the poorest outcomes. Bilateral and multifocal lesions were also associated with increased rates of residual neurological deficits. The difference in outcomes among various imaging patterns was statistically significant with a p value of less than 0.001. These findings indicate that the extent and pattern of diffusion restriction may serve as important prognostic indicators in patients with viral encephalitis.

Table 6: Association between Diffusion Weighted Imaging Patterns and Clinical Outcomes

Imaging Pattern	Complete Recovery n (%)	Partial or No Recovery n (%)	p value
Focal unilateral involvement	22 (88.0%)	3 (12.0%)	
Bilateral involvement	24 (70.6%)	10 (29.4%)	
Multifocal lesions	11 (55.0%)	9 (45.0%)	
Diffuse cerebral involvement	4 (40.0%)	6 (60.0%)	
Total	61 (68.5%)	28 (31.5%)	<0.001

Comparison of Mean Age According to Neurological Recovery

Patients who achieved complete recovery had a lower mean age than those with partial or no recovery. The mean age of patients with complete recovery was 33.2 ± 10.5 years while the mean age of patients with unfavorable outcomes was 37.6 ± 12.1 years. However the difference did not reach statistical significance. The findings are shown in Table 7.

Table 7: Comparison of Mean Age According to Neurological Recovery

Recovery Outcome	n	Mean Age (years)	SD	p value
Complete recovery	61	33.2	10.5	
Partial or no recovery	28	37.6	12.1	0.091

Overall analysis demonstrated that diffusion weighted magnetic resonance imaging provided important information regarding the extent of cerebral involvement in viral encephalitis. Patients with localized diffusion restriction generally had favorable outcomes whereas diffuse and multifocal abnormalities were associated with persistent neurological deficits and mortality. These findings support the potential role of diffusion weighted imaging patterns as prognostic markers in patients with viral encephalitis and emphasize the importance of early magnetic resonance imaging evaluation in clinical practice.

DISCUSSION

In the present study, DW-MRI patterns were studied in the patients of viral encephalitis and correlated with neurological outcome. The results revealed that the patients all had abnormal diffusion restriction, and there were several patterns of cerebral involvement identified. Bilateral cerebral lesions were the most common imaging pattern and the most common anatomical location was the temporal lobe. There was a significant association between diffusion weighted imaging patterns and clinical outcomes. Those with focal unilateral lesions had a better prognosis, while diffuse cerebral involvement led to persistent neurologic deficits.11

The present study revealed a slight male dominance and a mean age of 40 years in the fourth decade. In other previous investigations, in which viral encephalitis occurred mainly in young and middle aged adults, similar age distributions have been reported. This demographical profile may be explained by exposure patterns and/or differences in host immunity. In the present study, there was a higher proportion of males which has been reported earlier and may be due to variations in the risk factors of environment and occupation.[12]

Altered consciousness and fever were the most common clinical features in this series. A

significant number of patients also had seizures and focal neurologic findings. Similar results have been reported in earlier studies where fever and mental status changes were the typical presentation of viral encephalitis. The neurological spectrum of symptoms can often be confusing for diagnosis and underscores the role for neuroimaging in the early evaluation of suspected cases.[13]

Inflammatory diseases of the central nervous system (CNS) are now an indispensable area of application of diffusion weighted magnetic resonance imaging (dwMRI). The present study showed that all patients could be identified as having cerebral injury using diffusion restriction. The same has been observed previously, one such case being a diffuse-weighted imaging's ability to identify abnormalities earlier than conventional magnetic resonance sequences. In the diagnosis of encephalitis and other acute neurological disorders, diffusion weighted imaging has proven to be useful in depicting cytotoxic edema and early neuronal injury.[14]

The most common diffusion weighted imaging pattern in the present study was bilateral cerebral involvement. Previous reports have also shown that in severe cases of viral encephalitis there are extensive bilateral abnormalities. The presence of bilateral lesions has been thought to represent generalized inflammatory damage and has been associated with poor clinical presentation. A high percentage of bilateral involvement in the current study might be due to the fact that many patients were seen in late stages of disease.[15]

In the present investigation the temporal lobes were the most common brain regions involved. This is similar to what was seen in previous studies in which the characteristic imaging abnormality of HSE was temporal lobe abnormalities. Specific neural invasion/replication mechanisms have been associated with the predilection of certain viruses for the limbic system. These current results, then, reinforce the known role of temporal lobe involvement as a key radiological feature in viral encephalitis cases.[16]

A significant number of patients also had involvement of the thalamus and basal ganglia. Similar patterns have been observed in studies in areas where Japanese encephalitis and arboviral infections are common. Involvement of deep grey matter structures has been correlated with extensive neurological deficit and higher risk of persisting deficits. Based on the results of the present study, the distribution of diffusion abnormalities could be of value, both in the understanding of the etiology and prognosis.[17]

An important aim of the current study was to assess if patterns of diffusion weighted imaging correlated with neurological outcomes. It was found that there was a significant association between the level of diffusion restriction and the recovery of the patient. Focal unilateral lesions were associated with excellent and diffuse cerebral involvement was associated with the poorest prognosis. These have been reported in previous studies in which widespread diffusion abnormalities have been associated with increased short and long term neurological disability and mortality.

The pathophysiological mechanisms may provide an explanation for the relationship between diffusion restriction and poor outcome. Diffusion restriction represents cytotoxic edema that results from the inability of cellular energy metabolism and disruption of ion transport mechanisms. Chronic cytotoxic damage can lead to permanent neurological damage and tissue necrosis. Thus, more severe diffusion restriction could represent more severe cerebral injury and less neurological recovery.[19]

The finding in the present study was also that the multifocal lesions had less favourable outcomes than the localized abnormalities. This has been reported in the past, with multifocal involvement being correlated with long hospital stays and cognitive dysfunction. Multiple lesions can suggest widespread dissemination of the virus in the CNS, suggesting that the immune response is more intense.[20]

Patients with poor outcomes had a higher mean age than the others who recovered totally, but the difference was not statistically significant. The effect of age on prognosis has been conflicting in previous investigations. There have been some studies that have shown that older age is an independent predictor of poor outcome, and others that have not shown that there is a significant association. There is no statistical significance in the present study that might be attributed to the relatively small sample size, and to the prevalence of younger individuals among the subjects of the study.[21]

The results of this study have implications for clinical practice. Specific DWI patterns can help early risk stratification, aid in the identification of patients that need intensive monitoring and supportive care. Diffuse cerebral involvement or extensive bilateral lesions may warrant more

frequent neurological monitoring and early rehabilitation planning in patients. Therefore, the prognostic information delivered by the DWI could be used in conjunction with the clinical assessment and enhance the patient management algorithm.

The present results also add to the body of evidence which suggests a role for magnetic resonance imaging as a prognostic instrument in viral encephalitis. Prior research has been largely directed toward the role of neuroimaging in diagnosis, and far fewer studies have been conducted on the role of neuroimaging in predicting outcome. The present study has shown a strong correlation between diffusion values and the outcome of recovery and they lay further groundwork that DWI can be a useful parameter to measure the severity of the disease and prognosis.[23]

The advantages of the present study are that a standardized magnetic resonance imaging protocol was used and imaging findings were interpreted separately by experienced radiologists. The study was further strengthened through the incorporation of outcome assessment, which further increased the clinical relevance of the study. The results could then be helpful to radiologists and neurologists in determining the prognosis of diffusion abnormalities and could help in the development of evidence-based management pathways.

While these are some of the strengths, some observations need to be taken with a pinch of salt. The patterns of viral encephalitis may vary according to geographical location and causative pathogens. Overlapping imaging findings can occur with various viral agents and are best interpreted along with clinical and laboratory data; therefore, diffusion weighted imaging should be used in addition to clinical and laboratory data. Larger multicenter studies with longer follow up periods could be helpful in clarifying the prognostic value of diffusion abnormalities and help to establish a standard imaging based prognostic model in viral encephalitis patients.

CONCLUSION

In patients with viral encephalitis, there was a strong correlation between the DW-MRI pattern and neurological outcome. Favorable recovery was seen with focal lesions and poor prognosis with diffuse cerebral involvement. Hence the importance of DWI in prognosis was approved and its use in the early assessment of the patient supported.

Limitations

This study was performed in one tertiary care center and the generalization was limited. A small number of patients was included and long term neurological follow up was not done. Etiological correlation was limited as viral detection was only possible by molecular methods in some patients.

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