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Research Article

EEG Abnormalities in Acute Stroke (Ischemic and Hemorrhagic) and Their Prognostic Significance

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ABSTRACT

Background: Acute stroke is a serious neurological emergency, and often associated with disturbances in cerebral electrical activity. EEG is able to reveal functional abnormalities of the brain including non-convulsive status epilepticus, electrographic seizures, epileptiform discharges, diffuse slowing and focal slowing that may not be clinically evident. EEG may offer some prognostic information about the severity of the stroke and prognosis, in addition to the role it plays in diagnosis, but neuroimaging is still important for the diagnosis.

Objective: To determine the frequency and pattern of EEG abnormalities in patients with acute ischemic and hemorrhagic stroke and to assess their prognostic significance.

Methods: The study was a prospective, multicenter, observational study that took place from 10 January 2025 to February 2026 in Akbar Niazi Teaching Hospital, Islamabad and Al-Khidmat Raazi Hospital, Rawalpindi. Overall, 385 patients with acute stroke were included of which 275 patients were enrolled from Akbar Niazi Teaching Hospital and 110 patients from Al-Khidmat Raazi Hospital. The diagnosis of stroke was made by clinical examination and imaging. Patients were divided into ischemic stroke group and hemorrhagic stroke group. EEG was obtained in the acute period and was evaluated for background abnormalities, focal slowing, diffuse slowing, epileptiform discharges, periodic discharges, electrographic seizures, and severe EEG abnormalities. The clinical severity was determined by the National Institutes of Health Stroke Scale and Glasgow Coma Scale. The outcomes measured were: admission to the intensive care unit (ICU), mechanical ventilation, hospital stay, functional status at hospital discharge and in-hospital mortality. Data were analyzed with SPSS version 25 and P-values < 0.05 were regarded as statistically significant.

Results: Among 385 patients, 286 (74.3%) had ischemic stroke and 99 (25.7%) had hemorrhagic stroke. EEG abnormalities were observed in 278 patients (72.2%). The most frequent EEG abnormality was focal slowing 169 (43.9%), followed by diffuse slowing 123 (31.9%), reduced background activity 96 (24.9%), epileptiform discharges 64 (16.6%), periodic discharges 39 (10.1%), electrographic seizures 31 (8.1%), and non-convulsive status epilepticus 15 (3.9%). EEG abnormalities were significantly more common in hemorrhagic stroke than ischemic stroke 84.8% vs 67.8%, p = 0.001. Severe EEG abnormalities were significantly associated with severe NIHSS score, low GCS score, ICU admission, mechanical ventilation, prolonged hospital stay, poor functional outcome, and in-hospital mortality.

Conclusion: EEG abnormalities are frequent in acute stroke and are more common in hemorrhagic stroke than ischemic stroke. Severe EEG abnormalities, especially diffuse slowing, epileptiform discharges, periodic discharges, and electrographic seizures, are strongly associated with poor clinical outcomes. EEG may serve as a useful bedside tool for early risk stratification, seizure detection, and prognostic assessment in acute stroke patients.

Keywords: Acute Stroke, EEG Abnormalities, Ischemic Stroke, Hemorrhagic Stroke, Epileptiform Discharges, Prognosis, Electrographic Seizures, Functional Outcome.

INTRODUCTION

Stroke is one of the leading causes of death and long-term neurological disability worldwide. It is caused by a sudden cessation of the flow of blood or a rupture of a cerebral blood vessel, leading to sudden loss of the brain's function.

There are two main types of stroke: ischemic and hemorrhagic. Ischemic stroke is more frequent and develops from the occlusion of the arteries, while hemorrhagic stroke is caused by bleeding into the brain tissue or spaces. Both kinds of stroke can cause injury to the neurons, cause swelling of the brain, cause altered consciousness or seizures, cause disability, and death. Therefore, early diagnosis, severity assessment and prediction of outcome are important factors in the management of acute stroke (1-3).

Although computed tomography (CT) and magnetic resonance (MR) imaging are not used to assess the type of stroke, they are the most widely accepted technique to confirm the type of stroke, locate the site of the lesion, and help direct treatment. But imaging primarily gives structural information, and does not always accurately depict functional status of the damaged brain. EEG is a non-invasive and bedside neurophysiological examination to record the electrical activity of the cerebrum. It can identify abnormalities in background rhythm, abnormal cortical function and seizure activity. EEG is likely to reveal diffuse or focal slowing, reduced background activity, epileptiform discharges, periodic discharges, electrographic seizures, and non-convulsive status epilepticus in acutely stroke patients (4-6).

There are several mechanisms that cause EEG abnormalities after stroke. Ischemic stroke changes the activity of the neurons secondary to a decrease in cerebral blood flow and oxygen supply, and often causes focal slowing in the vascular distribution of the stroke. Hemorrhagic stroke can give rise to more diffuse abnormalities, such as diffuse slowing and epileptiform activity, due to blood products, mass effect, increased ICP, edema, and cortical irritation. These EEG changes can be significant in patients with impaired consciousness, unexplained neurological deterioration, and an history of possible seizures. Surface EEG may have potential in stroke identification and prediction of stroke outcome, depending on the clinical setting (7, 8).

In recent years, the prognostic significance of EEG in stroke has come to the fore. EEG changes can be related to the degree of functional brain impairment, and may assist in determining who is at risk for poor outcome. Diffuse slowing, reduction of background activity, epileptiform discharges, periodic patterns and electrographic seizures have each been linked to significant neurological deficits, post-stroke seizures, extended hospital stays, and poor functional outcomes. A recent 2023 study found that even if seizures have not been clinically diagnosed, the occurrence of epileptiform activity in the acute phase of stroke is associated with poor outcomes. Studies confirmed that significant numbers of stroke patients had qualitative EEG abnormalities and that these EEG abnormalities were correlated with clinical factors to predict stroke severity (9, 10).

Despite the potential value of EEG, it is not routinely performed in all acute stroke patients, especially in resource-limited settings. In many hospitals, EEG is mainly requested when seizures are clinically suspected, which may lead to underdiagnosis of electrographic seizures and non-convulsive status epilepticus. Local evidence regarding EEG abnormalities in acute ischemic and hemorrhagic stroke and their prognostic significance remains limited. Therefore, the present prospective multicenter study was conducted at Akbar Niazi Teaching Hospital, Islamabad, and Al-Khidmat Raazi Hospital, Rawalpindi, to determine the frequency and pattern of EEG abnormalities in acute stroke patients and to evaluate their association with stroke severity, functional outcome, and in-hospital mortality.

METHODOLOGY

This prospective multicenter observational study was conducted at two tertiary care hospitals: Akbar Niazi Teaching Hospital, Islamabad, and Al-Khidmat Raazi Hospital, Rawalpindi. The study included patients admitted with acute stroke during the period from 10 January 2025 to February 2026. A total of 385 patients were enrolled, fulfilling the required sample size of more than 350 patients. Among these, 275 patients were recruited from Akbar Niazi Teaching Hospital, Islamabad, and 110 patients were recruited from Al-Khidmat Raazi Hospital, Rawalpindi. The multicenter design was selected to improve the representativeness of the study population and to observe EEG abnormalities across different hospital settings.

Any patients coming in with clinical features suggesting a stroke were initially evaluated in the emergency department or neurology unit. A diagnosis of stroke was made by clinical assessment and confirmed by non-contrast computed tomography scan and/or magnetic resonance imaging, as appropriate. Based on neuroimaging results, the patients were divided into two main groups: ischemic stroke and

hemorrhagic stroke. Acute stroke was defined as a sudden onset of focal or global neurological deficit of vascular origin in the acute admission period. After meeting the inclusion/exclusion criteria, patients of both genders and age groups were included.

Patients included were those who were diagnosed with acute ischemic stroke or acute hemorrhagic stroke and had been evaluated with EEG during the acute phase of illness. Patients who had a history of epilepsy prior to stroke, previous major structural brain disease (excluding stroke), traumatic brain injury, brain tumor, central nervous system infection, metabolic encephalopathy, or had incomplete clinical or EEG records were excluded. To minimize bias in EEG assessment, patients taking sedative drugs at the time of EEG recording were excluded, as their EEG was significantly affected by such drugs.

Upon enrolment, all the detailed demographic and clinical data were documented on a structured proforma. Collected variables consisted of age, gender, hospital center, type of stroke, stroke site, side of lesion, length of time from onset of symptoms to hospital presentation, presence of comorbid conditions, including hypertension, diabetes mellitus, ischemic heart disease, smoking, and history of stroke. Severity of clinical stroke was evaluated at presentation with the National Institutes of Health Stroke Scale (NIHSS). Glassgow Coma Scale (GCS) was used to measure the level of consciousness. Other clinical features recorded were seizures at presentation, neurological deterioration, admission to intensive care unit, mechanical ventilation requirement, and the length of hospital stay.

An EEG was carried out in the acute phase of stroke, once the patient was stabilized. A standard scalp EEG was obtained using the international 10–20 electrode placement system. Recordings were acquired by skilled EEG technicians supervised by a neurologist or neurophysiologist. The EEG record was analysed for background rhythm, focal slowing, diffuse slowing, reduction of background activity, epileptiform discharges, periodic lateralized epileptiform discharges, generalized periodic discharges, electrographic seizures and non-convulsive status epilepticus. EEG results were classified as normal, mildly abnormal, moderately abnormal or severely abnormal based on the background disturbance, epileptiform activity and seizure patterns.

Following enrollment, a detailed demographic and clinical information was documented using a structured proforma. The variables collected were age, gender, hospital center, type of stroke, location of stroke, side of lesion, time from onset of stroke to hospital presentation, comorbid conditions (including hypertension, diabetes mellitus, ischemic heart diseases, smoking and previous stroke history). The National Institutes of Health Stroke Scale (NIHSS) was used to measure clinical severity at admission. The Glasgow Coma Scale (GCS) was used for assessment of level of consciousness. Other clinical features recorded included seizures at presentation, neurological deterioration, intensive care unit admission, requirement for mechanical ventilation and hospital stay.

EEG was done in the acute phase following stabilization of the patient with a stroke. EEG was recorded using the standard 10–20 international system of electrodes placed on the scalp. The recordings were made by a trained EEG technician who was supervised by a neurologist or neurophysiologist. The EEG record was subsequently examined for background rhythm, focal slowing, diffuse slowing, reduced background activity, epileptiform discharges, periodic lateralized epileptiform discharges, generalized periodic discharges, electrographic seizures and non-convulsive status epilepticus. EEG patterns were classified as normal, mildly abnormal, moderately abnormal, and severely abnormal, based on the levels of background disturbance, epileptiform activity, and seizure patterns.

The data were entered and analysed by SPSS version 25. Age, NIHSS score, GCS score and hospital stay were quantitative variables and presented as mean and SD. Qualitative data like gender, type of stroke, EEG abnormality, comorbidities, admission to the ICU, seizures and mortality were expressed in percentages and frequencies. Categorical variables were compared between the ischemic and hemorrhagic stroke groups using either the chi-square test or Fisher's exact test. The statistical methods used for comparing continuous variables were the independent sample t-test or the Mann–Whitney U test, depending on the distribution of the data. A p-value of < 0.05 was deemed to be statistically significant.

RESULTS

A total of 385 patients with acute stroke were included in this prospective multicenter study. Out of these 275 patients (71.4%) were enrolled from Akbar Niazi Teaching Hospital, Islamabad and 110 patients (28.6%) were

enrolled from Al-Khidmat Raazi Hospital, Rawalpindi. The mean age of the study population was 61.8 ± 12.7 years, most of whom were in the age group of 51–70 years. There were 226 males (58.7%) and 159 females (41.3%). The most common vascular risk factor was hypertension (68.6%) followed by diabetes mellitus (44.4%), smoking (29.1%), history of ischemic heart disease (21.6%) and previous stroke (14.0%).

Table 1. Baseline Demographic and Clinical Characteristics of Acute Stroke Patients

Variable	Frequency / Mean	Percentage
Total patients	385	100
Age, years	61.8 ± 12.7	—
Male	226	58.7
Female	159	41.3
Hypertension	264	68.6
Diabetes mellitus	171	44.4
Smoking	112	29.1
Ischemic heart disease	83	21.6
Previous stroke	54	14.0

Of the 385 patients, 286 (74.3%) had ischemic stroke, and 99 (25.7%) had a hemorrhagic stroke. Cortical involvement was found in 161 cases (41.8%), subcortical involvement in 139 cases (36.1%), brainstem involvement in 47 cases (12.2%) and cerebellar involvement in 38 cases (9.9%). Based on National Institutes of Health Stroke Scale score, 112 patients (29.1%) had mild stroke, 173 patients (44.9%) had moderate stroke, and 100 patients (26.0%) had severe stroke. Likewise, patients with hemorrhagic stroke were more likely to have an altered mental status at presentation.

Table 2. Stroke Type, Anatomical Distribution, and Severity

Variable	Frequency	Percentage
Type of stroke		
Ischemic stroke	286	74.3
Hemorrhagic stroke	99	25.7
Stroke location		
Cortical	161	41.8
Subcortical	139	36.1
Brainstem	47	12.2
Cerebellar	38	9.9
Stroke severity		
Mild NIHSS	112	29.1
Moderate NIHSS	173	44.9
Severe NIHSS	100	26.0

EEG abnormalities were found in 278 (72.2%) patients, with 107 (27.8%) having normal or near-normal EEG findings. Focal slowing (43.9%) was the most frequently seen EEG abnormality followed by diffuse slowing (31.9%) and reduced background activity (24.9%). Sixty-four patients (16.6%) had epileptiform discharges, 39 (10.1%) periodic lateralized epileptiform discharges, 31 (8.1%) electrographic seizures, and 15 (3.9%) non-convulsive status epilepticus. Seventy-seven patients (20.0%) had severe EEG abnormalities with marked diffuse slowing, burst suppression, electrographic seizures or periodic discharges.

Table 3. Frequency and Pattern of EEG Abnormalities in Acute Stroke Patients

EEG finding	Frequency	Percentage
Normal / near-normal EEG	107	27.8
Any EEG abnormality	278	72.2
Focal slowing	169	43.9
Diffuse slowing	123	31.9
Reduced background activity	96	24.9

Epileptiform discharges	64	16.6
Periodic lateralized epileptiform discharges	39	10.1
Electrographic seizures	31	8.1
Non-convulsive status epilepticus	15	3.9
Severe EEG abnormality	77	20.0

Abnormal EEG patterns were more common in patients with hemorrhagic stroke than ischemic stroke when EEG patterns were compared based on stroke type. There was a statistically significant difference between the proportion of patients with EEG abnormalities (67.8% of 286 ischemic stroke patients vs. 84.8% of 99 hemorrhagic stroke patients; p = 0.001). Hemorrhagic stroke was also found to be significantly more likely to have diffuse slowing, epileptiform discharges, electrographic seizures and severe EEG abnormalities. However, more often focal slowing was seen in the ischemic stroke group, especially those with cortical infarction, though the results were not statistically significant.

Table 4. Comparison of EEG Abnormalities between Ischemic and Hemorrhagic Stroke

EEG finding	Ischemic stroke n=286	Hemorrhagic stroke n=99	p-value
Any EEG abnormality	194 (67.8%)	84 (84.8%)	0.001
Focal slowing	132 (46.2%)	37 (37.4%)	0.128
Diffuse slowing	78 (27.3%)	45 (45.5%)	0.001
Reduced background activity	61 (21.3%)	35 (35.4%)	0.005
Epileptiform discharges	38 (13.3%)	26 (26.3%)	0.003
Periodic discharges	24 (8.4%)	15 (15.2%)	0.049
Electrographic seizures	17 (5.9%)	14 (14.1%)	0.010
Severe EEG abnormality	43 (15.0%)	34 (34.3%)	<0.001

EEG abnormalities were found to be significant with clinical severity of stroke. Abnormal EEG findings were more common in the patients with severe NIHSS when compared to mild and moderate stroke. EEG abnormality was found in 55.4% of patients with mild stroke, 72.8% of moderate stroke and 90.0% of severe stroke (p < 0.001). In the same way, the presence of severe EEG abnormalities was strongly correlated with the Glasgow Coma Scale (GCS) score, admission to the Intensive Care Unit (ICU), longer hospital stay, and poor discharge outcome.

Table 5. Association of EEG Abnormalities with Stroke Severity and Clinical Outcomes

Variable	Normal / mild EEG abnormality n=308	Severe EEG abnormality n=77	p-value
Severe NIHSS score	54 (17.5%)	46 (59.7%)	<0.001
GCS ≤ 8	31 (10.1%)	29 (37.7%)	<0.001
ICU admission	58 (18.8%)	41 (53.2%)	<0.001
Mechanical ventilation	21 (6.8%)	22 (28.6%)	<0.001
Electrographic seizures	9 (2.9%)	22 (28.6%)	<0.001
Hospital stay >7 days	96 (31.2%)	47 (61.0%)	<0.001
Poor functional outcome at discharge	102 (33.1%)	55 (71.4%)	<0.001
In-hospital mortality	25 (8.1%)	24 (31.2%)	<0.001

COA revealed a favorable outcome at discharge in 228 patients (59.2%), and a poor outcome (severe disability or death) in 157 patients (40.8%). Forty-nine patients (12.7%) died in hospital. An EEG with diffuse slowing, epileptiform discharges, electrographic seizures, periodic discharges, and severe EEG abnormalities had significantly greater association with poor outcome. Severe EEG abnormalities were significantly correlated with poor functional outcome, with the outcome being worse than that for patients with normal or mildly abnormal EEG (71.4% vs 33.1%, p < 0.001). The prognostic value of EEG was also

observed in acute stroke, as low incidence of severe EEG abnormalities (31.2%) was found when compared with severe EEG changes-free (8.1%).

Table 6. Prognostic Significance of Major EEG Abnormalities

EEG abnormality	Poor outcome n (%)	Mortality n (%)	p-value for poor outcome
Focal slowing	72 (42.6%)	15 (8.9%)	0.041
Diffuse slowing	72 (58.5%)	28 (22.8%)	<0.001
Epileptiform discharges	39 (60.9%)	17 (26.6%)	<0.001
Periodic discharges	27 (69.2%)	13 (33.3%)	<0.001
Electrographic seizures	23 (74.2%)	11 (35.5%)	<0.001
Severe EEG abnormality	55 (71.4%)	24 (31.2%)	<0.001

In summary, these findings showed that EEG abnormalities were present in the acute stroke patients and were found more often in patients with hemorrhagic stroke compared to patients with ischemic stroke. The presence of diffuse slowing, epileptiform discharges, electrographic seizures, periodic discharges, and severe background abnormalities were all significantly linked to increased stroke severity, admission to the intensive care unit, prolonged hospitalizations, poor functional outcomes, and mortality. The findings indicate that EEG could be a valuable bedside neurophysiological tool in the early risk stratification and prognosis of acute ischemic and hemorrhagic stroke.

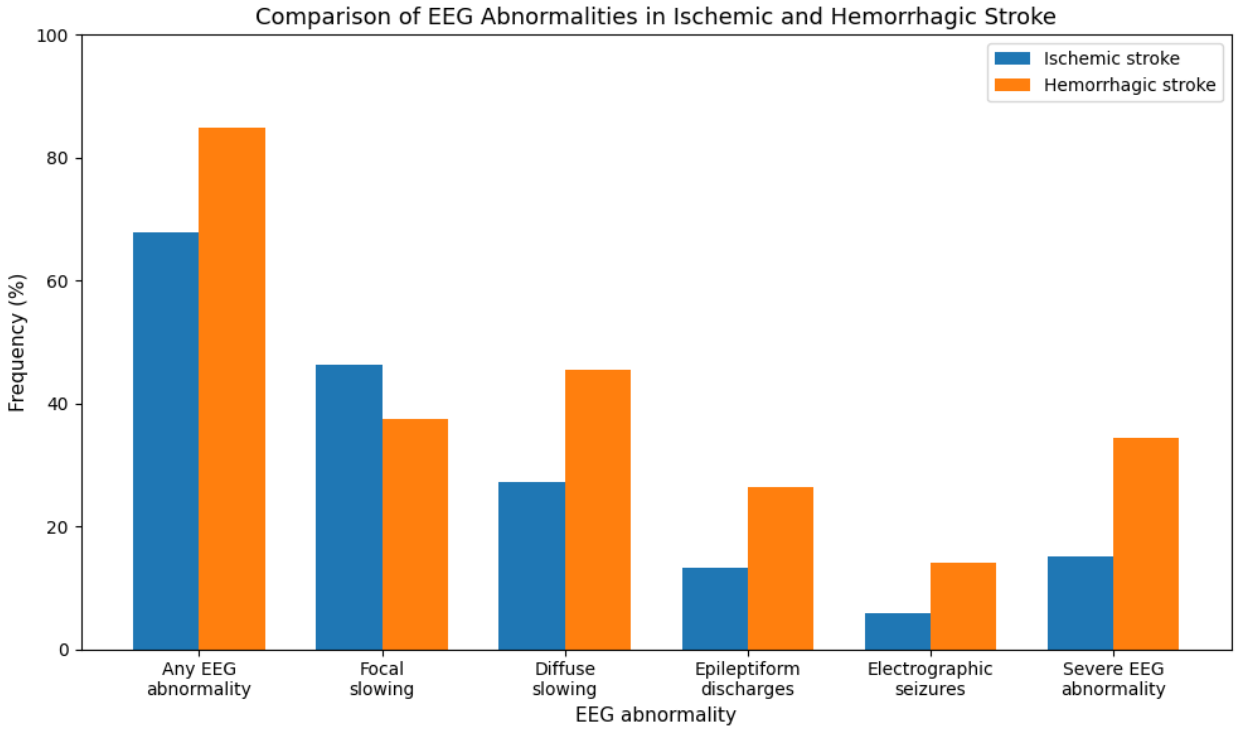

Figure 1. Comparison of EEG Abnormalities in Ischemic and Hemorrhagic Stroke

The graph shows that overall EEG abnormalities, diffuse slowing, epileptiform discharges, electrographic seizures, and severe EEG abnormalities were more frequent in hemorrhagic stroke, while focal slowing was slightly more common in ischemic stroke.

DISCUSSION

In the present prospective multicenter study, EEG abnormalities were observed in a large proportion of patients with acute stroke, indicating that disturbances in cerebral electrical activity are common during the early phase of both ischemic and hemorrhagic stroke. In this study, abnormal EEG findings were present in 72.2% of patients, with focal slowing, diffuse slowing, reduced background

activity, epileptiform discharges, periodic discharges, and electrographic seizures being the main patterns. These findings are in line with previous evidence showing that EEG changes are frequently detected after acute cerebrovascular injury because neuronal electrical activity is highly sensitive to reduced cerebral perfusion, cortical injury, edema, and secondary metabolic stress. Mecarelli et al. also reported a high frequency of EEG abnormalities in acute stroke patients, including focal or diffuse slowing, epileptiform abnormalities, and periodic lateralized epileptiform discharges. Similarly, recent literature has emphasized that EEG may provide useful bedside information in acute stroke by reflecting functional brain impairment beyond structural findings seen on CT or MRI (11-13).

The present study demonstrated that the incidence of EEG abnormalities is higher in the case of hemorrhagic stroke than ischemic stroke. Higher rates of diffuse slowing, background activity reduction, epileptiform discharges, electrographic seizures, and severe EEG abnormalities were found in patients who experienced a hemorrhagic stroke. This could be attributed to the increased mass effect, increased ICP, perihematomal edema and cortical irritation commonly seen with intracerebral hemorrhage. Focal slowing was the most common abnormality in ischemic stroke, as would be predicted, since ischemic changes cause localized neuronal dysfunction within the vascular territory. The EEG may also show diffuse slowing or epileptiform activity, however, when ischemic lesions are large, cortical or are associated with impaired consciousness. Ag Lamat et al. found that the EEG abnormalities correlated with the clinical and stroke related variables suggesting that EEG reflects the functional severity of brain injury and can serve as an additional tool to the clinical and radiological assessment (14-16).

In this study, there was a strong correlation between the severity of the EEG abnormalities and the severity of the stroke. The severe EEG changes were associated with higher NIHSS score, lower GCS score, increased demands for admission to the intensive care unit (ICU), mechanical ventilation and longer hospital stay. This connection indicates that EEG could be used as a physiological measure of an acute stroke. A diffuse slowing and reduced background activity suggest that there is general cerebral dysfunction, and periodic discharges and electrographic seizures represent a state of cortical irritability and heightened risk of secondary neuronal damage. EEG, and quantitative EEG parameters like delta activity and delta-alpha ratio, which are related to neurological severity and recovery in ischemic stroke, were identified as studies highlighting the value of EEG in stroke prognosis. The present study employed routine clinical EEG, but showed a correlation between severe EEG abnormalities and poor clinical outcome, consistent with the importance of electrophysiological assessment in acute stroke (17, 18).

Epileptiform activity and electrographic seizures were significant findings in the present study as they were significantly associated with poor functional outcome and mortality. In a few patients with acute stroke, electrographic seizures can occur without any clinical convulsions, particularly if there is a reduced level of consciousness. This helps in diagnosing non-convulsive seizures and non-convulsive status epilepticus that can be missed. Previous studies have reported that unfavourable functional outcome was related to seizures and EEG abnormalities in patients with ischaemic stroke. Also it was found that epileptiform activity in the acute stage of stroke can be a predictor of post-stroke epilepsy and can be a marker of an irritated and vulnerable state of the cerebral cortex. Research further standardised the interpretation of rhythmic and periodic EEG patterns and facilitate the recognition of electrographic seizures and ictal-interictal continuum patterns more consistently (19, 20).

The findings of this prognostic analysis showed that the poor discharge outcome and in-hospital mortality were significantly more common in patients with severe EEG abnormalities. Patients with diffuse slowing, periodic discharges, epileptiform discharges and electrographic seizures also had higher mortality. The results indicate that not only could EEG be used to detect seizures, but it could be also used to stratify the early risk of patients with acute stroke. Patients with significant EEG abnormalities may need more careful neurologic assessment, more intensive seizure control, intensive care unit (ICU) support, and careful follow-up afterwards in clinical practice. The results need to be considered, however, with some caveats. Timing of EEG can be different in various patients, and intermittent abnormalities may not be captured in a single EEG recording. Electrographic seizures were not monitored in all patients, which might have underestimated

electrographic seizures. Also not evaluated were long-term outcomes after discharge. Larger studies with longer duration of follow-up and an integrated continuous EEG monitoring are suggested for better understanding of the prognostic value of EEG in acute ischemic and hemorrhagic stroke.

CONCLUSION

EEG abnormalities were common among patients with acute ischemic and hemorrhagic stroke in this prospective multicenter study. Focal slowing was more commonly observed in ischemic stroke, while diffuse slowing, epileptiform discharges, electrographic seizures, periodic discharges, and severe EEG abnormalities were more frequent in hemorrhagic stroke. Severe EEG abnormalities were significantly associated with higher NIHSS scores, lower GCS scores, ICU admission, mechanical ventilation, prolonged hospital stay, poor functional outcome, and increased in-hospital mortality. These findings indicate that EEG can serve as a useful bedside neurophysiological tool for early assessment, seizure detection, and prognostic stratification in acute stroke patients. Incorporating EEG into the evaluation of selected high-risk stroke patients may help clinicians identify patients who require closer monitoring and more intensive management.

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