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Association of electroencephalography changes in patients with acute ischemic stroke

Suman Bhattarai[1]
Manita Raut[1]
Abhishek Man Shrestha[1]
Aditi Singh[1]
Anzil Mani Singh Maharjan[1]
Lekhjung Thapa[1*]

[1]Upendra Devkota Memorial National Institute of Neurological and Allied Sciences, Department of Neurology, Bansbari, Kathmandu, Nepal

***Correspondence:** Lekhjung Thapa, Upendra Devkota Memorial National Institute of Neurological and Allied Sciences, Bansbari, Kathmandu, Nepal
Email: drlekhjung@gmail.com
Tel: +977-9855060509

ABSTRACT

Introduction: Electroencephalography or EEG is an elegant diagnostic tool for the identification of acute ischemic stroke. It corresponds well with its locale and extent. We aim to study the association of EEG changes in patients with acute ischemic stroke.

Materials and methods: A prospective observational study was conducted among 45 patients presented at Upendra Devkota Memorial National Institute of Neurological and Allied Sciences with a diagnosis of acute ischemic stroke from August to October 2017. All eligible patients were subjected to one hour of conventional video encephalography. A descriptive statistics was performed for the baseline variables and bivariate analysis was done to determine the association of EEG changes with all the other baseline characteristics that included demographic characteristics, latency, National Institute of Health Service Scale score, modified Rankin Scale Score, side of lesions and radiological characteristics. Data were analysed using IBM–SPSS version 20.

Results: Majority of participants were male and the mean age of the study population was 61.9 years. Of the total 45 patients, 44.4% had left sided lesion with middle cerebral artery infarction accounting 66.7%. Normal EEG was found in 46.7%. There was statistically significant association of EEG with mRS (p=0.003) and side of lesion (p=0.029).

Conclusion: EEG can be a useful diagnostic tool for detecting side of lesion and degree of morbidity.

Keywords: EEG, video encephalography, acute ischemic stroke, MRI

INTRODUCTION

Electroencephalography (EEG) in acute ischemic stroke provides a timeless non–invasive extent of brain function in form of generalized and focal slowing. With decrease in cerebral blood flow (CBF), changes in both the metabolic and electrical activity of cortical neurons are prominent with associated EEG changes.[1,2] In acute ischemic stroke, the prime insult typically occur prior to clinical presentation and EEG may help to identify patterns to suggest severity, prognosis, and secondary insult such as re–occlusion, edema, or hemorrhagic transformation.[3] Sequential neurological examination and neuroimaging are only capable of identifying delayed cerebral ischemia once the damage becomes clinically or radiographically apparent. In such cases, EEG may be a helpful way to identify and subsequently treat ischemia before the injury becomes irreversible.[4–7]

Brain function is characterized on EEG by waves of certain frequencies. Slower frequencies (typically delta [0.5–3 Hz] or theta [4–7 Hz]) are generated by the thalamus and by cells in layers II–VI of the cortex. Faster frequencies (or alpha, typically 8–12 Hz) derive from cells in layers IV and V of the cortex.[8] All these frequencies are regulated by the reticular activating system, which correlate to the observation of reactivity on the EEG.[9] Pyramidal neurons found in layers III, V, and VI are extremely sensitive to ischemia, thus leading to abnormal changes in the patterns seen in EEG [2].

EEG changes are intently related to CBF.[10] When normal CBF drops to approximately 25 to 35 ml per 100 g per min, the EEG first loses faster frequencies, then as the CBF drops to approximately 17 to 18 ml per 100 g per min, slower frequencies gradually increase. This serves as a crucial ischemic threshold at which neurons begin to lose their transmembrane gradients, leading to infarction. Some EEG changes, such as regional attenuation of faster frequencies without delta (RAWOD), may follow early severe loss of CBF (mean 8.6 ml/100 g/min) usually seen during large occlusive infarction, leading to complications such as edema and herniation.[11]

In early subacute ischemic stroke, the EEG corresponds well with CBF as the oxygen extraction fraction surge to perpetuate cerebral metabolic rate ($CMRO_2$), a period termed "misery perfusion" or stage 2 hemodynamic failures.[12,13] Later, the EEG appears to correspond less with CBF and alternatively begins to correspond with $CMRO_2$ during a period of "luxury perfusion" or stage 3 hemodynamic failure.[12,13] Early in this influential relationship, the threshold for cellular damage is altered such that neuronal loss and reduced protein metabolism may in fact predate changes related to critical CBF, notably in peri–infarct regions.[1] These regions are also intricated by abnormal glutamate release (between 20 to 30 ml per 100 g per min) or peri–infarct depolarizations[1,14]

Diffusion–weighted magnetic resonance images (DWI MRI) are suited of identifying changes at CBF 35 to 40 ml per 100 g per min within 30 minutes[15] In contrast, EEG identifies changes at the same CBF within seconds and grants for continuous monitoring of these changes over time. This can be pivotal to identify evolving ischemic changes after treatment with tissue plasminogen activator, when the computer tomography is negative during early infarction, or when there is a mismatch between DWI MRI and the clinical examination.[2]

MATERIALS AND METHODS

This is a prospective observational study conducted at Upendra Devkota Memorial National Institute of Neurological and Allied Sciences (UDMNINAS) from August to October 2017. Informed consent was obtained from all the patients enrolled. The local ethical committee approved the use of the data for the purpose of study. None of the patients had history of seizures, stroke and cerebral lesions or was suspected of having seizures during hospital stay in order to avoid misinterpretation of EEG findings that could have affected EEG findings. All the patients

presenting to UDMNINAS with diagnosis of Acute Ischemic Stroke (diagnosed by history, clinical examination and MRI with diffusion) were subjected to 1 hour of 10 to 20 international VEEG using a digital VEEG recorder (Xltek, a division of Natus 2568 Bristol Circle Circle Oakville, Ontario, Canada, L6H 5S1, Natus Database Version 8.0.1 Build 4451, Natus Medical Inc). VEEG was evaluated by a Neurologist with special training in EEG by blinding to other evaluated factors (patients, stroke characteristics and magnetic resonance imaging findings). VEEG was classified according to RAWOD classification. The pattern (embolic– multiple, scattered, smaller lesions; territorial– isolated, larger lesions; lacunar– smaller, isolated, subcortical lesions) were recorded. Descriptive analysis was performed for all the variables. The association of EEG changes with the baseline variables were done using chi–square tests. P<0.005 was considered to be statistically significant.

RESULTS

Table1: Characteristics of demography, Latency, NIHSS, mRS and side of lesions (n=45)

Variables		n	%
Age in years	25-45	7	15.6
	46-55	7	15.6
	56-65	12	26.7
	66-75	11	24.4
	>75	8	17.8
Gender	Male	32	71.1
	Female	13	28.9
Latency in hours	<3	4	8.9
	3 to 24	22	48.9
	24 to 72	13	28.9
	72-168	5	11.1
	>168	1	2.2
NIHSS	1-5	14	31.1
	6-15	29	64.4
	16-21	2	4.4
Modified Rankin Scale	0-1	6	13.3
	2	10	22.2
	3	8	17.8
	4	12	26.7
	5	9	20.0
Side of lesion	Right	18	40.0
	Left	20	44.4
	Both	6	13.3
	Normal	1	2.2

Abbreviations: NIHSS: National Institute of Health Stroke Scale

Our study included 45 participants with AIS. The characteristics of the participants as shown in Table–1 reflect that most of them were between 56 to 75 years of age (23, 51.3%) and males (32, 71.1%). It was observed that majority of the patients had latency of 3–24 hrs (22, 48.9%), had NIHSS score of 6–15 (29, 64.4%), mRS score of above 3 (31, 46.7%) and mostly lesion on left side (20, 44.4%).

Table 2: Radiological characteristics (n=45)

Characteristics		n	%
CT scan	Normal	7	15.6
	MCA infarction	26	57.8
	PCA infarction	1	2.2
	Lacunar infarction	11	24.4
MRI scan	Normal	1	2.2
	MCA infarction	30	66.7
	PCA infarction	1	2.2
	Lacunar infarction	12	26.7
	Small vessel infarction	1	2.2
ECHO	Normal	34	75.6
	Valvular heart disease	11	24.4
Carotid Doppler (n=44)	Normal	20	45.5
	Atherosclerotic changes	9	20.5
	Low velocity flow	6	13.6
	Very low velocity flow	7	15.9
	Complete occlusion	2	4.5
EEG	Normal	21	46.7
	Both Theta	2	4.4
	Both Delta	3	6.7
	Left Theta	6	13.3
	Left Delta	7	15.6
	Right Theta	2	4.4
	Right Delta	4	8.9

Abbreviations: CT, Computer tomography; ECHO, Electrocardiography; EEG, Electroencephalography; MCA, Middle cerebral artery; MRI, Magnetic resonance imaging; mRS, modified Rankin Scale; NIHSS, National Institute of Health Stroke Scale; PCA, Posterior cerebral artery

Table 2 represents the radiological characteristics such as computer tomography (CT), MRI, electrocardiography (ECHO), Carotid Doppler and EEG. The neuro–imaging showed that most of the cases had MCA infarction in both CT (26, 57.8%) and MRI (30, 66.7%). Reports were normal in majority of them with ECHO (34, 75.6%), Carotid Doppler (20, 45.5%) and EEG (21, 46.7%).

The association of EEG with several patient characteristics has been depicted in Table 3. It

suggests that the association of EEG was statistically significant with mRS (p=0.003) and side of lesion (p=0.029). It can be observed that most of the participants who had normal EEG has lower mRS (score 2 and below was observed in 10 or 22.2% participants) scores while left δ was mostly observed in those who had mRS score 5 (5, 11.1%). However, those with left side lesion mostly had either normal EEG (8, 17.8%) followed by Left δ (6, 13.3%) and Left θ EEG (5, 11.1%).While those with right side lesion had wide variety of EEG though mostly normal (9, 20.0%) and right δ EEG (4, 8.9%).

Table 3: Cross tabulation of EEG with baseline variables (n=45)

Variables		EEG							P-value[a]
		Normal	Both θ	Both δ	Lt θ	Lt δ	Rt θ	Rt δ	
Age in years	25-45	5(11.1)	0	0	0	1(2.2)	0	1(2.2)	
	46-55	0	0	1(2.2)	3(6.7)	1(2.2)	1(2.2)	1(2.2)	
	56-65	6(13.3)	1(2.2)	0	1(2.2)	3(6.7)	1(2.2)	0	0.087
	66-75	5(11.1)	1(2.2)	1(2.2)	2(4.4)	2(4.4)	0	0	
	>75	5(11.1)	0	1(2.2)	0	0	0	2(4.4)	
Gender	Male	12(26.7)	2(4.4)	2(4.4)	5(11.1)	6(13.3)	2(4.4)	3(6.7)	0.428
	Female	9(20.0)	0	1(2.2)	1(2.2)	1(2.2)	0	1(2.2)	
Latency in	3	2(4.4)	0	1(2.2)	1(2.2)	0	0	0	
hours	3-24	9(20.0)	0	0	3(6.7)	5(11.1)	1(2.2)	4(8.9)	
	24-72	7(15.6)	2(4.4)	2(4.4)	1(2.2)	0	1(2.2)	0	0.290
	72-168	2(4.4)	0	0	1(2.2)	2(4.4)	0	0	
	>168	1(2.2)	0	0	0	0	0	0	
NIHSS	1-5	9(20.0)	1(2.2)	1(2.2)	2(4.4)	0	0	1(2.2)	
	6-15	12(26.7)	1(2.2)	2(4.4)	3(6.7)	6(13.3)	2(4.4)	3(6.7)	0.371
	16-21	0	0	0	1(2.2)	1(2.2)	0	0	
Modified	0-1	5(11.1)	0	0	0	0	0	1(2.2)	
Rakin Scale	2	5(11.1)	1(2.2)	2(4.4)	2(4.4)	0	0	0	
	3	6(13.3)	0	1(2.2)	0	0	0	1(2.2)	0.003*
	4	3(6.7)	1(2.2)	0	4(8.9)	2(4.4)	0	2(4.4)	
	5	2(4.4)	0	0	0	5(11.1)	2(4.4)	0	
Side lesion	Right	9(20.0)	1(2.2)	1(2.2)	0	1(2.2)	2(4.4)	4(8.9)	
	Left	8(17.8)	1(2.2)	0	5(11.1)	6(13.3)	0	0	0.029*
	Both	3(6.7)	0	2(4.4)	1(2.2)	0	0	0	
	Normal	1(2.2)	0	0	0	0	0	0	
CT scan	Normal	4(8.9)	0	0	1(2.2)	1(2.2)	0	1(2.2)	
	MCA	7(15.6)	2(4.4)	2(4.4)	4(8.9)	6(13.3)	2(4.4)	3(6.7)	0.409
	PCA	1(2.2)	0	0	0	0	0	0	
	Lacunar	9(20.0)	0	1(2.2)	1(2.2)	0	0	0	
MRI scan	Normal	1(2.2)	0	0	0	0	0	0	
	MCA	9(20.0)	2(4.4)	2(4.4)	4(8.9)	7(15.6)	2(4.4)	4(8.9)	
	PCA	1(2.2)	0	0	0	0	0	0	0.770
	Lacunar	9(20.0)	0	1(2.2)	2(4.4)	0	0	0	
	Small vessel	1(2.2)	0	0	0	0	0	0	
EEG	Normal	15(33.3)	1(2.2)	1(2.2)	6(13.3)	6(13.3)	1(2.2)	4(8.9)	0.132
	Abnormal	6(13.3)	1(2.2)	2(4.4)	0	1(2.2)	1(2.2)	0	
Carotid	Normal	11(25.0)	1(2.3)	1(2.3)	4(9.1)	1(2.3)	1(2.3)	1(2.3)	
Doppler	AC	4(9.1)	0	2(4.5)	0	0	1(2.3)	2(4.5)	
(n=44)	LVF	2(4.5)	0	0	1(2.3)	3(6.8)	0	0	0.201
	VLVF	3(6.8)	1(2.3)	0	0	2(4.5)	0	1(2.3)	
	CO	0	0	0	1(2.3)	1(2.3)	0	0	

Notes: [a]χ^2test; *significant at p<0.05

Abbreviations: AC, Atherosclerotic changes; CO, Complete occlusion; CT, Computer tomography; EEG, electroencephalography; VLVF, Very low velocity flow; Lt, Left; LVF, Low velocity flow; MCA, Middle cerebral artery; MRI, Magnetic resonance imaging; mRS, modified Rankin Scale; NIHSS, National Institute of Health Stroke Scale; PCA, Posterior cerebral artery; Rt, Right

DISCUSSION

Our study showed that most of the patients were male (71.1%), aged 56–65 years, with latency of 3 to 24 hrs having moderate stroke (NIHSS 6 to 15) with mRS score of 4, presented with left sided acute ischemic infarction. Abnormal EEG was observed in 46% of the patients. Previous studies show that 48% and 86% of such patients have abnormal EEG depending on stroke population and stroke size.[16,17] In our study, most of the cases were left MCA territory infarction diagnosed by CT and MRI (26, 57.8%) and 30, 66.7%) respectively. MRI bas been found to be even more precise and more informative than CT in the morphological evaluation of stroke; where MRI lesion can be visualized within about 2 to 6 hours after the vascular accident, whereas CT scan demonstration usually requires 1 to 5 days before positive results are obtained.[18,19] Electrophysiological changes following functional changes may appear earlier than structural changes and may better identify changes in neuronal function that predate structural changes in acute ischemic stroke in emergency department.[20, 21] EEG provides useful information about the localization of acute cerebral ischemia, but recording densities of 64 channels or higher is required for accurate spatial characterization of focal stroke–related EEG changes.[23] Early EEG delivers useful information to select those patients who develop malignant edema in patients with malignant MCA infarction.[24]

The association of EEG was statistically significant with mRS (p=0.003) as supported by other study and side of lesion (p=0.029)[25] suggesting that most of the participants who had normal EEG has lower mRS (score 2 and below was observed in 10 or 22.2% participants) scores.

Other variables such as age, gender, latency, NIHSS score, carotid doppler did not show association with the EEG changes in acute ischemic stroke in our study in opposition to study. [22] Evidence suggests that study of brain function adds favorable intuitions in acute ischemic stroke [23]. EEG has well–established value for measuring altered brain function in the acute ischemic stroke [2, 24–28] and overcomes many of these challenges but has not been widely adopted.

The limitation of the study was little number of patients and 21 electrodes international 10–20 system.

CONCLUSION

EEG is a continuous, non–invasive measure of brain function which can predict the side of lesion and disability in terms of modified Rankin Scale.

COMPETING INTEREST

The authors declare that there are no competing interests regarding the publication of this paper.

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