Detection of Brain Stroke using Electroencephalography (EEG)

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Abstract – **This paper focuses on identifying an approach to identify stroke non-invasively and cost-effectively using Electroencephalography (EEG). Brain stroke occurs when blood flow to the brain is interrupted and brain cells are deprived of oxygen and nutrients and they begin to collapse. In order to detect a brain stroke, generally a CT scan or MRI is done to identify that specific region. Due to high cost of CT-scan/MRI, we wanted to find an alternative approach that is low cost and effective also. So, CT-scan/MRI and EEG data of the patients suffering from stroke within 48 hours after the onset was taken. The current research analysis is based on detecting the electrical current density different regions of the brain and comparing it with CT-scan/MRI images. Cross-sectional studies show the electrical current density of the cortical surface under hemorrhagic and ischemic stroke conditions. All the patients were examined hemorrhagic or ischemic stroke based on CT-scan/MRI.**

Keywords – Stroke, Ischemic Stroke, Hemorrhagic Stroke, EEG, CT-scan, MRI, Cortical surface

I. Introduction

Brain stroke is one of the most common cause of mortality and chronic adult disability after ischemic heart disease worldwide [1]. It is the second leading cause of death worldwide [1]. As indicated by the World Health Organization, 15 million individuals endure stroke worldwide every year. Out of which 5 million die and another 5 million are for all time debilitated [1]. In developed nations, the frequency of stroke is declining, to a great extent because of the endeavors to lower blood pressure and diminish smoking [2]. But in case of developing countries like India, the frequency of stroke is still high because of unavailability and unaffordability of quality stroke management facilities [3]. The regular hazard factors, that is, dyslipidemia, hypertension, smoking and diabetes are very pervasive and insufficiently controlled for the most part as a result of poor public awareness, inadequate infrastructure [4]. Also, speed is of the most extreme quintessence in guaranteeing the favorable results of stroke patients. This required rapid stroke finding modalities.

Stroke can be comprehensively characterized into two noteworthy categories: ischemic stroke, with around 85-87% occurrence rate, and hemorrhagic stroke, with around 13-15% frequency rate [5]. Ischemic stroke occurs when an artery carrying blood to the brain is blocked, due to which brain is unable to meet its metabolic demands. The consequent deprivation of nutrients and oxygen supply to the brain leads to the collapsing of brain cells leading to poor functionality of the parts of the brain [6]. Hemorrhagic stroke occurs when a weakened blood vessel ruptures and leaks blood into the surrounding brain tissue (intracerebral) or leaks in the area between the brain and the tissue covering the brain (subarachnoid) [7]. Although hemorrhagic stroke is less common as compared to ischemic stroke, but it has much higher rate of morbidity [8]. Currently, EEG is being widely used for detecting brain disorders like stroke, brain trauma as it is non-invasive and have a better temporal resolution as compared to other neuroimaging techniques like CT Scan and MRI. The current research attempts to explore the condition of ischemic and hemorrhagic stroke based on the electrical activation of the brain.

This paper is as organized as follows: Section II focuses on materials and methods, Section III focuses on results and discussion, Section IV focuses on conclusion and Section V on acknowledgements.

II. Materials and Methods

A. Patients

Five stroke patients were recruited with informed consent following the guidelines of declaration of Helsinki [9]. Inclusion criterion for patients with stroke were: age ≥18 years, clinical symptoms consistent with cortical localization and Glasgow Coma Scale (GCS) in the range of 4-13, admittance time to the hospital less than 48 hours of stroke onset. Exclusion criterion consisted of any progressive brain illness, motor response less than M4 and pregnant patients. Treatment was according to the standard protocols. Baseline characteristics are summarized in “Table 1”.

TABLE 1. BASELINE CHARACTERISTICS OF PATIENTS

Patient	Age /Gender	Total EEG Time (mins)	GCS	Motor Response	Type of Stroke	Stroke Location
1	50/F	12	12	M5	Ischemic	α
2	84/M	18	9	M5	Ischemic	β
3	40/M	15	10	M5	Hemorrhagic	γ
4	45/M	16	10	M4	Hemorrhagic	ψ
5	80/M	19	14	M6	Ischemic	€

α – Left Cerebral Peduncle area of Mid Brain; **β** – Middle Cerebral Artery; **γ** – Basal Ganglia; **ψ** – Left Basal Ganglia; **€** – Left Middle Cerebral Artery

B. EEG Registration

EEG was started as soon as possible after admission to the emergency ward, within 48 hours after symptoms onset and it was taken for 15-20 mins in resting state with eyes closed for each patient. A NicoletOne EEG machine was used with a DC coupled amplifier and a sample frequency of 128 Hz. Twenty-one silver chloride electrodes were placed on the scalp according to the 10-20 international EEG system [10]. Electrodes were attached using Elefix conductive paste. Recordings were obtained with the common reference.

C. EEG Analysis

Signal processing was done with MATLAB R2018a using a toolbox called Brainstorm [11]. Before moving forward, all the EEG recordings were visually inspected to check the quality and major artifacts were discarded [12]. EEG analysis was qualitative. Filtering was achieved by using a zero-phase second order Butterworth band pass filter [12]. The challenge in the analysis was to estimate the source location when EEG recordings are already there. In order to do the same, minimum norm imaging has been done which finds a cortical current source density image that approximately fits the data [13]. The only assumption while computing current density at each point of the source grid was that there is a white noise identify matrix covariance [11]. The normalization of each value of current density was done by a function of noise covariance. Current density maps tend to favorably place source activity in superficial region of cortex, thereby dropping the resolution in deeper sulci. The Dynamic Statistical Parametric Mapping (dSPM) has been implemented in which the current density map (units: picoampere-meter) is normalized by the square root of the variance estimates, resulting in z-score statistical map (unit: unitless “z”) [14]. Z score is basically a Z-transformation of current density values into number of standard deviations with respect to a baseline period. The whole-time frame of the data was divided into twenty segments and current density was measured for each of the segment.

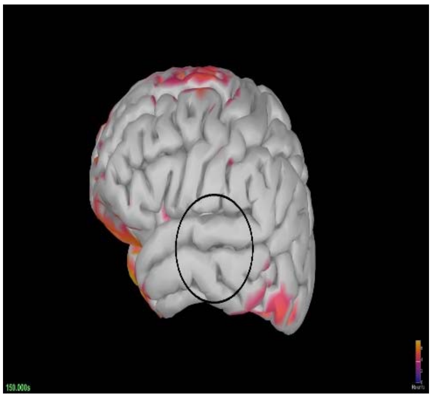
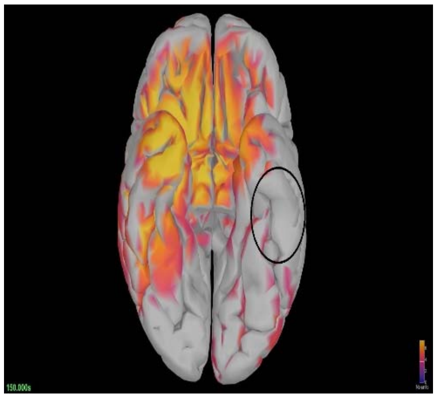
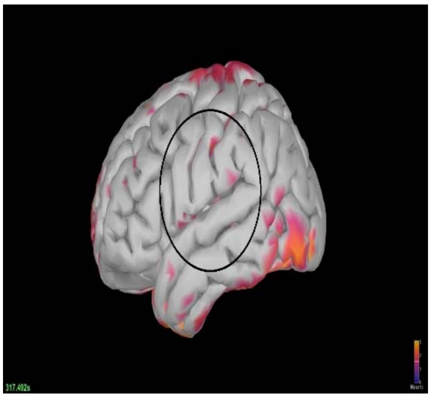
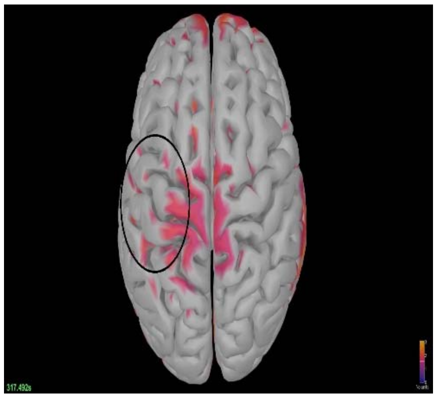
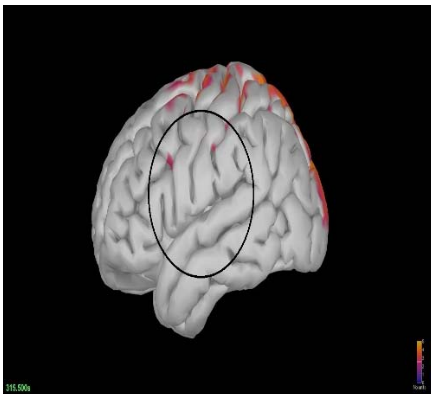
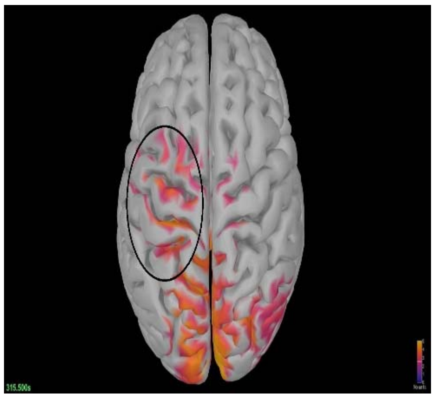
III. RESULTS AND DISCUSSION

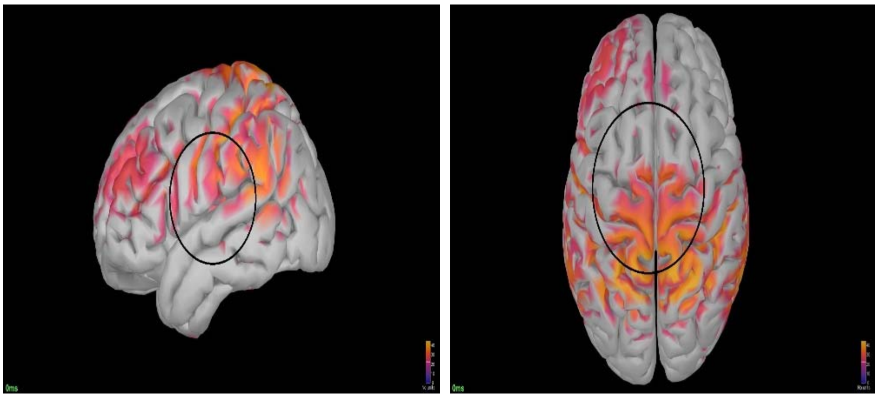
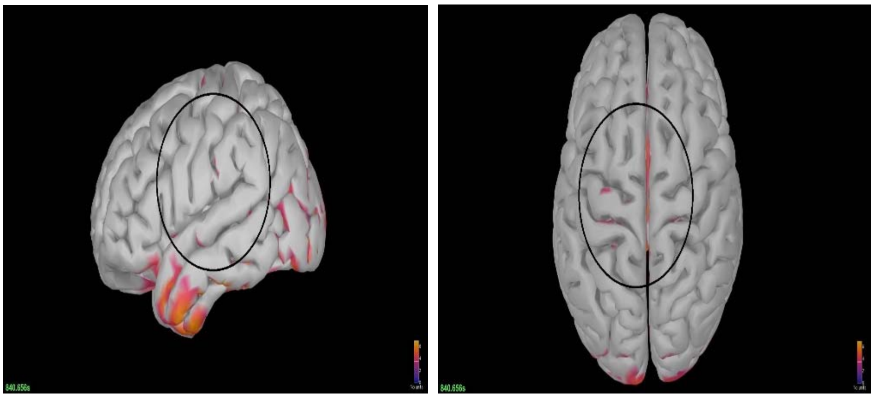
5 patients were included with 3 suffering from ischemic stroke and 2 suffering from hemorrhagic stroke. The current density mapping was done for each patient at different time segments. The task was to analyze the electric potential at the location of stroke and compare it with electric potential of other regions of brain. After visually inspecting the current density mapping on the cortex for each time segment, an average was computed to check the activation in the region of interest. The region of brain having stroke had less or no current density as compared to other regions at an average. The results were verified against CT/MRI images.

For patient no. 1, the 3D plot of current density mapping of EEG recording shows less activation in and around temporal and parietal lobe as compared to other regions like frontal and occipital lobe but area around temporal has less activation at an average and the same is verified from the CT-scan images that indicated infarcts in left cerebral peduncle area of mid brain (Fig. 1 and 2). For patient no. 2, the 3D plot of current density mapping of EEG recording shows less activation in temporal and some part of parietal and frontal lobe as compared to other regions at an average (Fig. 3 and 4) and the same is verified from the CT-scan images that indicated infarcts in middle cerebral artery. For patient no. 3, the 3D plot of current density mapping of EEG recording shows less activation around basal ganglia region of the brain as compared to other regions like temporal, occipital and frontal lobe at an average and the same is verified from the CT-scan images that indicated bleed in basal ganglia (Fig. 5). For patient no. 4, the 3D plot of current density mapping of EEG recording shows less activation in some regions of the brain like parietal and some part of frontal, occipital and temporal as well at an average, but the accuracy level is less in this case (Fig. 6 and 7). It cannot be said with surety that rupture is in which region only based on current density map like the MRI images indicated rupture in left basal ganglia accurately.

“Table 2” summarizes the region of stroke, type of stroke, coordinates of lesion and 3D plot of EEG recording on the cortex along with labelling the less activated region and the percentage of activation in that particular region. The CT-scan/MRI examination was done before EEG recording and diagnosed by a qualified neurologist. Out of 5 patients, the results came out to be correct in identifying the location of stroke for 4. The results were comparably better in case of ischemic than hemorrhagic stroke. It can be clearly stated that for better accuracy, a greater number of patients are required and with that a classification of ischemic and hemorrhagic stroke might be possible.

TABLE 2. SUMMARY OF EEG MANIFESTATIONS OF CURRENT DENSITY MAPPING ON THE CORTEX

Patient	**Type of Stroke**	**Stroke Location**	**MNI Coordinates of Lesion**	**3D Plot of EEG Recording on the Cortex**
1	Ischemic	Left Cerebral Peduncle area of Mid Brain	-65.7 -29.4 44.9	  2% Activation in the marked region
2	Ischemic	Middle Cerebral Artery	-53.8 -16.0 45.7	  10% Activation in the marked region
3	Hemorrhagic	Basal Ganglia	-1.1 -21.8 22.9	  8% Activation in the marked region

4	Hemorrhagic	Left Basal Ganglia	-66.6 -5.2 12.0	 25% Activation in the marked region
5	Ischemic	Left Middle Cerebral Artery	69.6 -11.0 19.4	 3% Activation in the marked region

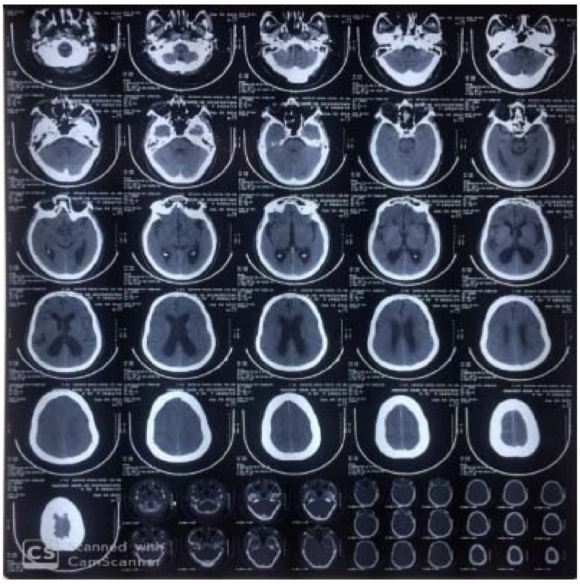


Figure. 1 CT-scan image of patient no. 1

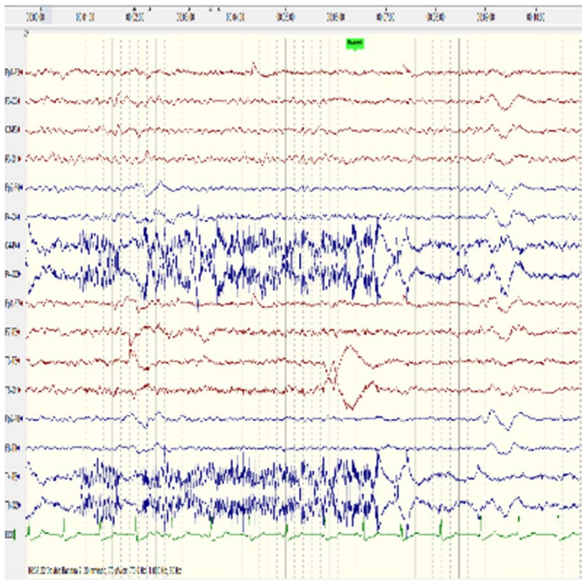


Figure. 2 EEG recording of patient no. 1

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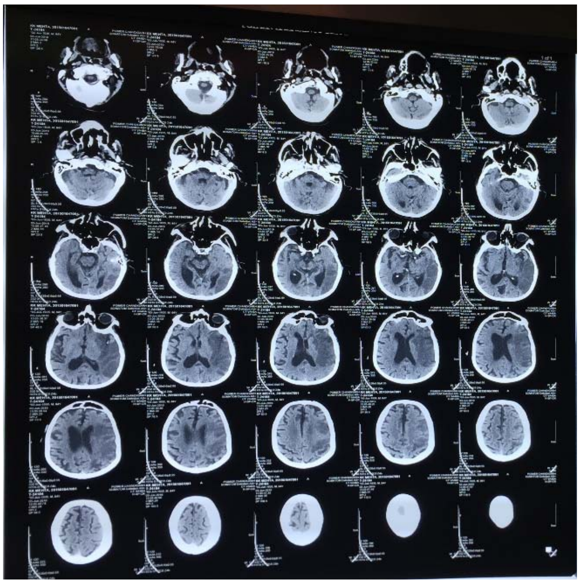

Figure. 3 CT-scan image of patient no. 2

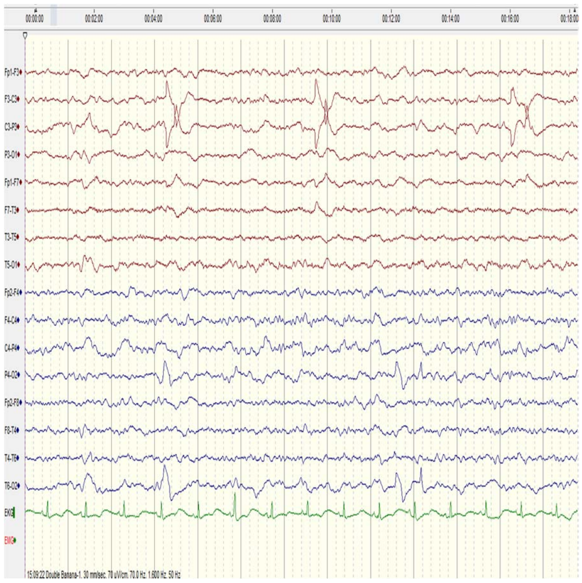

Figure. 4 EEG recording of patient No. 2

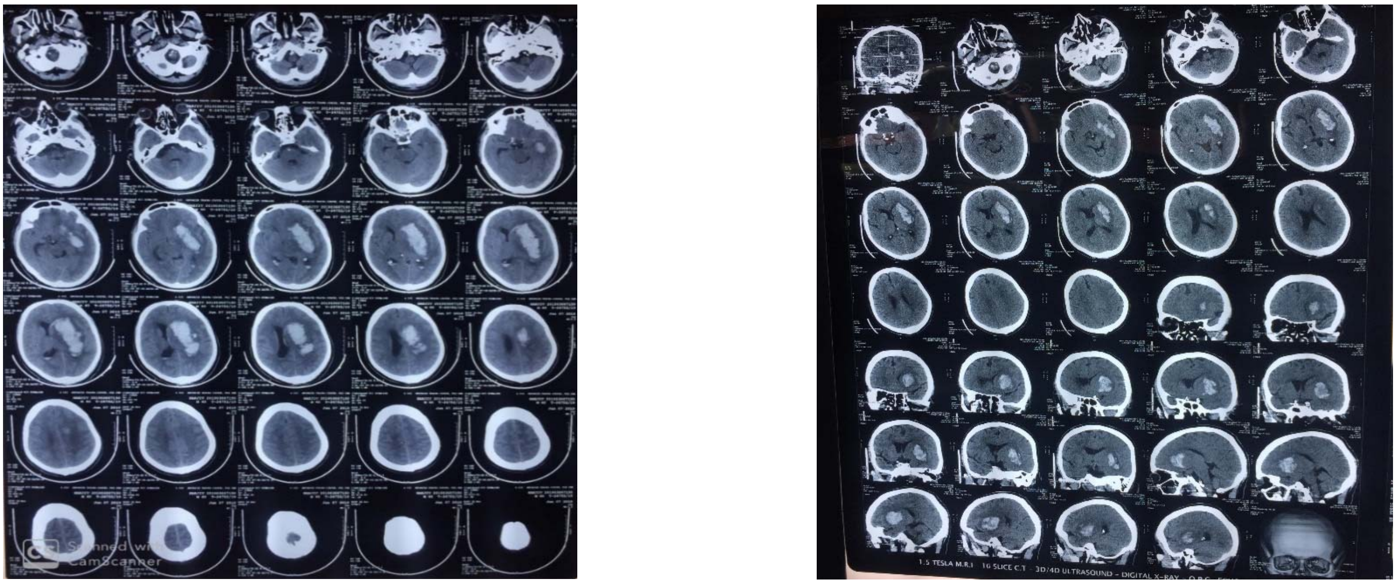

Figure. 5 CT-scan images of patient no. 3

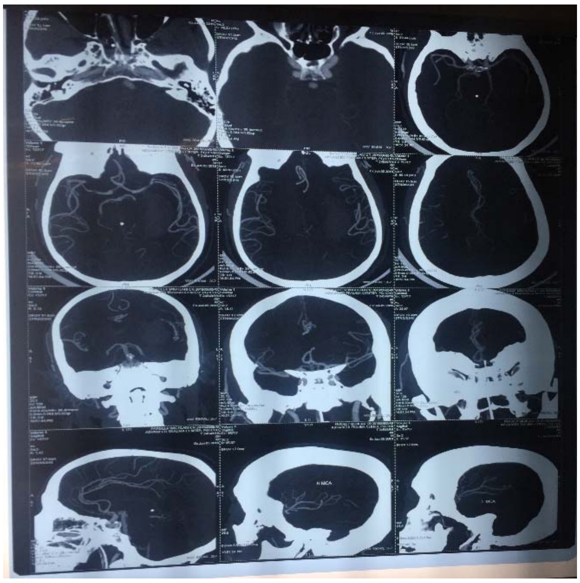

Figure. 6 MRI of patient no. 4

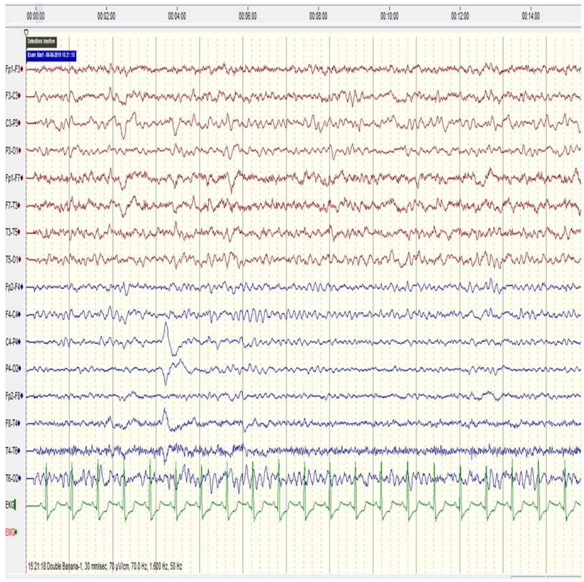

Figure. 7 EEG recording of patient no. 4

IV. CONCLUSION

In this paper, the electrical activation for different regions of different types of stroke has been studied. The current density at each source has been estimated. While comparing it with CT-scan/MRI images, it has been seen that a cost-effective and non-invasive device like EEG can be successfully used in order to detect a stroke. Clearly, it gives an intuitive idea that a further analysis can be done using EEG data to detect the type of stroke and region of lesion more accurately.

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