Study of Normal and Abnormal EEG

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***Abstract*—Electroencephalogram (EEG) is the most efficient medical imaging tool to analyze and interpret the characteristics of the brain disorder which helps the physician to diagnose the brain disorder patient. EEG signal is a representation of electrical activity over the surface of the brain with respect to time, this electrical activity is caused by the firing of neurons. If these neurons fire in anomalous manner, results in sudden impulses which can be stated as Seizures. If this unusual firing of nerve cells occurs in severe, may result in a shake and loss of control in the subject sometime. EEG waveform information about frequency, amplitude and shape are entirely dependent on the subjects age, state of alertness and location on scalp where the EEG is drawn with electrodes. An EEG waveform is said to be abnormal when the EEG waveform exhibits unusual characteristics which does not match to the subject's state of alertness, age and other factors. In this article it is to study the different types of EEG waveforms both in the case of normal and abnormal and further concentrated on the abnormalities both in the foam of Epileptical and Non-Epileptical. These abnormalities are internally classified as focal and generalized seizures. The comparable tabular form is given to the each type of EEG waveform based on their characteristics.**

***Index Terms*-Abnormal EEG, EEG characteristics, Epileptical Seizures, Non-Epileptical Seizures.**

I. Introduction

The Electroencephalogram is a recording of electrical activity generated by the brain. However, EEG is obtained by placing electrodes on the scalp. Human brain consists of millions of neurons, where each neuron generates small electric impulses in their respective region. EEG signal ranges from about 0.5μV to 100μV peak to peak in a normal adult, which is 100 times lower than ECG signal and it is approximately in the order of Millivolt (mV)when measured with subdural electrodes such as needle electrodes [1]. EEG waveforms are generally classified according to their frequency, amplitude, region of occurrence on the scalp and other characteristics. But, these classifications are entirely dependent on the factors like subjects age, state of alertness, age etc. Here, for the classification EEG waveform, preliminary waveforms are alienated as the normal and abnormal and that abnormal EEG in the preliminary stage is further classified into focal and generalized abnormal seizures, which state that focal abnormality gives that it regards the particular function or area of the psyche and that touches the portion of the body which belong to affected region on the psyche. Generalized or localized abnormality is the case where abnormality affects every function of the psyche, which may involve the entire body. However, EEG cannot give complete etiology of dysfunctions related to the brain, its sensitivity in various episodes guide the physician to diagnose the level of consciousness, sleep disorders, epilepsy, tumors, lesions etc. The block flow diagram is presented below to show that how the EEG is classified.

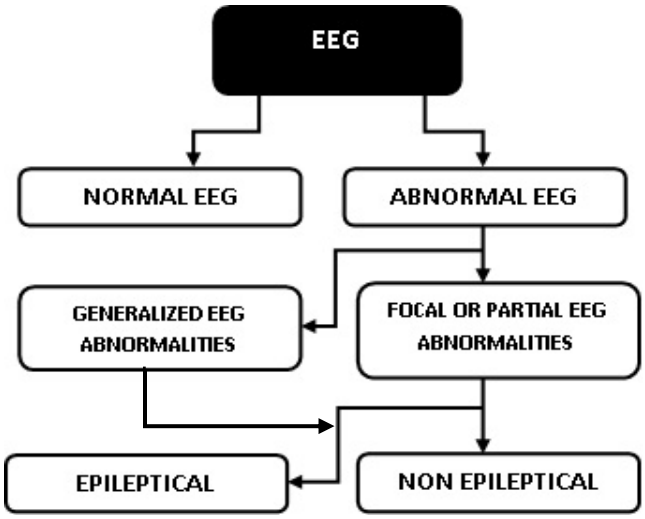

Fig. 1. Block Flow diagram of EEG waveforms.

II. Normal EEG Waveforms

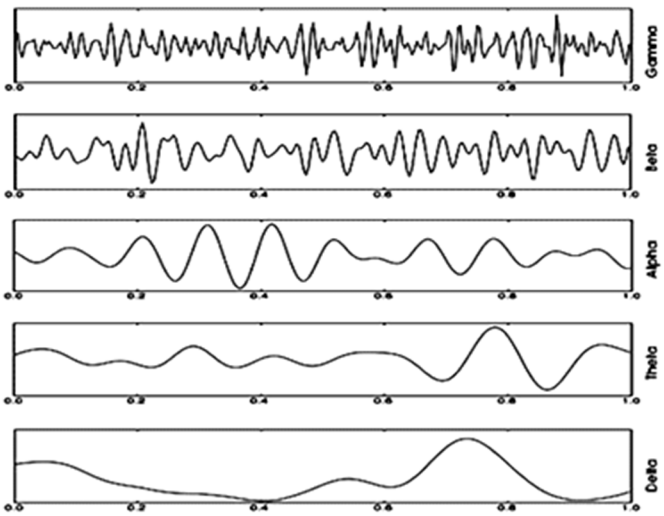

Fig. 2. Representation of EEG signal based on different frequency bands.

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The EEG waveform is said to be normal when the EEG recording does not bear any unusual seizures. Waveform exhibits unusual characteristics like frequent, long or continuous seizures when the subject affected by tumor or any case of the brain disorder which can be consider EEG as abnormal.

A. EEG frequency bands

Although EEG signal ranges widely, based on the clinical interest the EEG waveform consider in the range between 0.3 to 30Hz. This clinically considered frequency range of EEG signal is divided into different frequency bands which can be stated as alpha, theta, delta and gamma frequencies. These frequencies are generated by the different action done by the neural system. These are purely dependent on the subject's age, state of alertness, and other factors [2, 3, 4, 5, 12]. The pictorial representation of the frequency bands of EEG signal is shown in Fig. 2.

The classification of the normal EEG waveform based on the frequencies and its state of occurrence when subject undergoes EEG recordings. These characteristics are compared in below TABLE I. The EEG waveform is called as abnormal in the following comparison when one frequency band exhibits properties of higher or lower frequency band properties. The properties of each frequency band have its own unique nature like shape, amplitude etc.

TABLE I. CLASSIFICATION OF EEG WAVES BASED ON FREQUENCIES

Type of Waveform	Characteristics	State of occurrence	Abnormality
Alpha waves	• **Frequency range 8-13hz** • Amplitude is mostly less than 50μV	• When subject is Awaken but relaxed with closed eyes	• If present in frontal regions may suspect as depression and attention problems. • Head injuries
Beta waves	• **Frequency range 13-30hz** • Small in amplitude symmetric	• When the subject gives Alertness, mental effort • When taken drugs	• Deficient beta may rise to lack of concentration and problem solving. • Excessive beta may rise to sleep disorders, hyper activeness
Theta waves	• **Frequency range 4-8hz** • Larger amplitude than beta	• Early stages of drowsiness. • Day dreaming	• If seen in awake adults • Head injuries and brain lesions
Delta waves	• **Frequency range 3hz or less** • Large amplitude	• Deep, dreamless sleep, non-REM sleep • unconscious	• If seen in awake adults • result of a lesion or tumor • may indicate damage from a stroke
Gamma waves	• **Frequency range is Greater than 30Hz** • Small in amplitude	• Motor Functions • higher mental activity	• Abnormal when for continuous for a long time

B. Sleep episode and spike EEG waveforms

There are other kinds of EEG waveforms which occur naturally in some episode like sleep spindles and some occur in the stage 2 of the NREM sleep. Further, they can be called as sleep disturbances, as some of these types may occur before and after when the subject change its state of alertness. Where these waveforms may also exhibit abnormality when they occur repeatedly and in seizure manner. Severe and high repetition of these sleep and spike episodes exhibition can also be considered as abnormality. These are described and classified in TABLE II.

Sleep episode spike can be found in a normal subject, when the subject is changing from one state of alertness to another. These patterns can be recorded and analyzed using EEG. This type of spikes helps subject to shift from one state to another state of alertness easily and successfully.

TABLE II. CLASSIFICATION OF EEG WAVES BASED ON SLEEP AND SPIKE

Type of wave form	Characteristics	State of occurrence	Abnormality
K- complex waves	• Delta frequency, large amplitude, sharp apex. Symmetric • it was followed by rhythmic theta waves • **Occur in Bifrontal regions**	• Occur each time the patient is aroused partially from sleep • Stage 2 of sleep	• If it's found in awake state
V waves	• Sharp waves, Easy to recognize, • **Occur in Parasagittal regions**	• Usually occur after sleep disturbances like k-complex • During sleep stage-2	• If it's found in awaken state
Lambda waves	• Bilaterally positive waves, Triangular in shape and generally symmetric • **Occur in Occipital region**	• When subject is Awaken, • Most evident when the subject stares at a blank, uniform surface like reading and watching TV	• If found when concentrating and problem solving
Positive Occipital Sharp Transients of Sleep (POSTS)	• Bilaterally positive waves, Triangular in shape • **Seen in Occipital region**	• During stage-2 of sleep	• When occur in stage -1 of sleep
Sleep spindles	• Frequency-upper levels of alpha or lower levels of beta, lasts for second or less • Increase in amplitude initially and then decrease slowly, symmetric • **Found in Parasagittal regions**	• During stage 2 of sleep	• If spindles found in awaken state it is considered as seizures

Mu waves	• Asymmetric, rhythmic rounded in one direction with sharp side in another direction, frequency having one half of the fast beta activity • **Seen in Parasagittal regions**	• When the cortex is exposed or if subjects has structural brain defects	• If found even when motor action is done
Benign Epileptic Transients of Sleep (BETS)	• Usually sharp, small waves occur on one or both sides (usually asynchronous) • **Seen in the temporal and frontal regions**	• Rare in children and frequent in adults	• Occur in epileptic patients

III. Abnormal EEG Waveforms

EEG waveform is said to be abnormal when the recording states that the brain activity affected by undesired seizures in irregular or continuous intervals. The Abnormal EEG differentiated as Epileptical and Non- Epileptical seizures. These seizures can be generalized or focal, which state the risk associated with them. The normal EEG and focal and generalized EEG seizures are shown in Fig. 3.

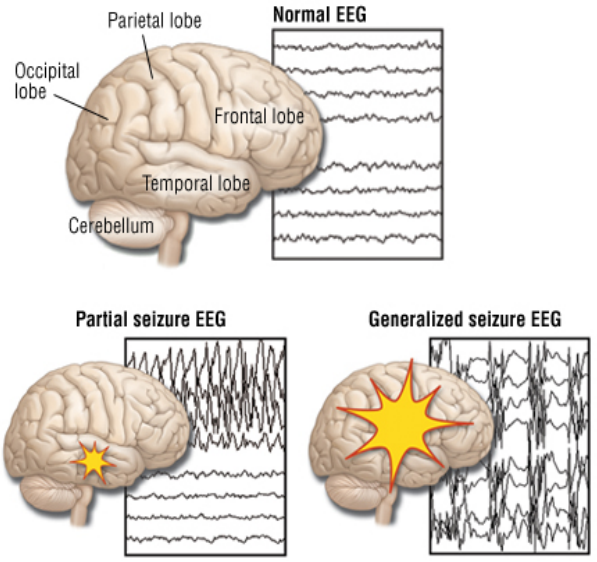

Fig. 3. Focal and generalized EEG Seizure [13].

A. Generalized EEG abnormality

A generalized EEG abnormality basically affects the entire brain and may not be symmetric in distribution. Generalized patterns may be described further as maximal in one region of the scalp (e.g., Frontal) or in certain hemisphere compared to the other. Identification of generalized abnormality may require analysis of the EEG by several channels to determine, because it is lack of focal point. Artifacts also sometimes appear as a generalized EEG abnormality which has to be removed with careful analysis [2-5, 11].

B. Focal EEG Abnormality

A Focal EEG abnormality which affects the particular region of the brain called focal point. Identification of an abnormality as focal abnormality may require focal point where the seizure occurs repeatedly only in its respective region. This kind of abnormality brings dysfunction to the respective organ or part of the body which associated with the seizure focal point of the brain [2-5, 10].

C. Epileptical EEG Abnormality

The EEG abnormalities, mainly classified as Epileptical and Non-Epileptical. The Epileptical abnormality EEG pattern shows up with repeated seizures and like the characteristics of a patient suffering with Epilepsy. Epilepsy is defined as a brain disorder characterized by a long-term tendency to generate epileptic seizures [2-5, 7-9]. An Epileptical form of abnormalities is described in below TABLE III.

Grand Mal also called as Tonic-Clonic Generalized seizure. This abnormality takes subject into unconsciousness and vicious muscle contractions. In all the abnormalities show up by the epilepsy, affects muscle tone and usual sensation of taste, vision, hearing and smell.

TABLE III. Classification of EEG waves in Epileptical EEG Abnormality

Epileptical abnormality	Characteristics of EEG signal	Result
Grand Mal	• Sudden spikes • Followed by body stiffening	• Unconscious • Tongue biting during seizure
Absence instance	• Takes place for few seconds and post-ictal	• Brief loss of consciousness • staring for long to same
MYOCLONIC	• Bilateral, irregular and scattered	• Jerking
CLONIC	• Bilateral, irregular and occur both sides of hemisphere at the same time	• Repetitive and jerking
TONIC	• Spikes and sharp waves make a contrast of muscles	• Muscle stiffness
ATONIC	• Excessive activity of brain, more seizures	• Loss of muscle tone
Focal Simple seizures	• Seizures frequently occur in sensory and psychological regions	• Jerking, unusual sensation of vision, hearing, smell and taste
Focal Complex seizures	• Sudden and Repetitive seizures	• Decrement of awareness, • Loss of body control
Partial seizure with secondary generalization	• First, Seizure associated with the part of the brain later it affects the entire brain and may loss the conscious like in the generalization	• Unconscious stage

D. Non-Epileptical EEG Abnormality

The Non-Epileptical form EEG abnormalities are caused by the brain injury which is a focal cerebral dysfunction due to a certain structural lesion and it also occurs in the preexisting structural abnormalities [2-6]. Non-Epileptical EEG waveforms are described in below TABLE IV.

TABLE IV. CLASSIFICATION OF EEG WAVES IN NON-EPILEPTICAL EEG ABNORMALITY

Type of EEG waveform	Characteristics of EEG signal	Abnormality caused
Polymorphic delta activity (PDA)	• Focal and irregular, delta frequencies	• When Structural lesion or a sub cortical dysfunction
Frontal Intermittent Rhythmic Delta Activity (FIRDA)	• Bilateral, synchronous, frequency of 2.5to 3 Hz	• When Deep middle lesions and tumor
Occipital intermittent Rhythmic Delta Activity (OIRDA)	• Rhythmic, frequency range of 3-4 Hz	• When Lesions in occipital lobe, • Presence of epilepsy
Temporal intermittent Rhythmic Delta Activity (TIRDA)	• 1-4 Hz, 50-100uv, Short burst for 3sec, repetitive, Rhythmic saw-toothed, sinusoidal • More specificity than FIRDA and OIRDA	• When subject has Temporal lobe epilepsy
Generalized asynchronous slow activity	• Frequency less than 4 Hz, It depends on the age and state of alertness	• Always abnormal in awake adults
Focal attenuation	• Occurs at certain frequencies	• Focal cortical lesion, Tumor, cerebral ischemia, swelling of the scalp
Generalized attenuation	• Beta activity, 20uV in amplitude • It severely suppresses delta and theta frequencies	• Cortical generalized injury
Other abnormal activity	• Alpha coma: having alpha frequencies and unconscious • Spindles coma: when EEG shows spindle activity in unconscious	• After cardiac arrest and coma • Head injury, stroke

IV. CONCLUSION

As the EEG signal is obtained from the different region of the scalp by placing different electrodes at different regions. These EEG readings can be used to have better analysis and interpretation, it helps the physician to diagnosis for a particular brain disorder patient because each EEG waveform is characterized in age, state of alertness, region of the scalp, abnormality and their unique characteristics. By this we can understand the EEG waveform and its abnormality by knowing the above characteristics.

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