DIAGNOSIS OF EPILEPSY A NEUROLOGICAL DISORDER USING ELECTROENCEPHALOGRAM (EEG)

Mr. Sanjay Pawar¹, Dr. Mrs. S.R.Chougule² and Mr. A.H.Tirmare³
¹Electronics and Telecommunication Engg., Bharati Vidyapeeth’s College of Engineering Kolhapur
²Electronics and Telecommunication Engg., Sanjay Ghodawat Institute, Itigre
³Electronics and Telecommunication Engg., Bharati Vidyapeeth’s College of Engineering Kolhapur

Abstract- Epilepsy is a common chronic neurological disorder. Epilepsy seizures are transient and unexpected electrical disturbance of the brain. About 50 million people worldwide have epilepsy, and nearly two out of every three new cases are discovered in developing countries. An Electroencephalogram (EEG) is a test that detects electrical activity in your brain using scalp electrodes. An EEG is used to detect problems in the electrical activity of the brain that may be associated with certain brain disorders. An EEG pattern consists of alpha, beta, gamma and theta waveforms according to frequency. EEG is most often used in medical field to diagnose epilepsy, which causes abnormalities in EEG readings

Keyword- Electroencephalogram (EEG), Epilepsy, Neurons, Brain wave pattern, seizures.

I. INTRODUCTION

An Electroencephalogram (EEG) is a medical test that detects electrical activity in brain using small, metal discs (electrodes) which are flat and attached to your scalp with wires. Brain cells communicate with each other via electrical impulses and are active all the time. This activity shows up as wavy lines on an EEG recording. In medical use these lines allow doctors to quickly assess whether there are abnormal patterns. Any irregularities may be a sign of seizures or other brain disorders. EEG, and the related study of ERPs are used extensively in neuroscience, cognitive science, cognitive psychology, neurolinguistics and psycho physiological research[1][2]. Epilepsy is a complex neurological disease characterized by recurrent spontaneous seizures, often accompanied by neurophysiological, cognitive, psychological, and behavioral changes. It is the fourth most common neurological disorder in the United States after migraine, stroke, and Alzheimer disease affecting ~2.2 million people[4] [5].

Cells of the nervous system include neurons and nonneural cells. Neurons or nerve cell communicate information to and from the brain. They are organized to form complex networks that perform the functions of the nervous systems. All nerve cells are collectively referred to as neurons although their size, shape, and functionality may differ widely.
Fig 1 shows the structure of neuron, the cell body is called the soma, from which two types of structures extend: the dendrites and the axon. Dendrites are short and consist of as many as several thousands of branches, with each branch receiving a signal from another neuron. The axon is usually a single branch which transmits the output signal of the neuron to various parts of the nervous system. Each axon has a constant diameter and can vary in size from a few millimeters to more than 1 m in length; the longer axons are those which run from the spinal cord to the feet. Dendrites are rarely longer than 2 mm. and are connected to either the axons or dendrites of other cells. These connexions receive impulses from other nerves or relay the signals to other nerves. The human brain has approximately 10,000 connexions between one nerve and other nerves, mostly through dendritic connections. Neurons are, of course, not working in splendid isolation, but are interconnected into different circuits (“neural networks”), and each circuit is tailored to process a specific type of information.

II. EEG RECORDING METHOD

In conventional scalp EEG, the recording is obtained by placing electrodes on the scalp with a conductive gel or paste. Many systems typically use electrodes, each of which is attached to an individual wire. Some systems use caps or nets into which electrodes are embedded; this is particularly common when high-density arrays of electrodes are needed.

Fig 2 shows electrode placement 10-20 system, 10-20 System of Electrode Placement is a method used to describe the location of scalp electrodes. These scalp electrodes are used to record the Electroencephalogram (EEG) using a machine called an electroencephalograph.

The 10-20 system is based on the relationship between the location of an electrode and the underlying area of cerebral cortex. Each point on figure to the left indicates a possible electrode position. Each site has a letter (to identify the lobe) and a number or another letter to identify the hemisphere location. The letters F, T, C, P, and O stand for Frontal, Temporal, Central, Parietal and Occipital. (Note that there is no “central lobe”, but this is just used for identification purposes.) Even numbers (2,4,6,8) refer to the right hemisphere and odd numbers (1,3,5,7) refer to the left hemisphere. The z refers to an electrode placed on the midline. Also note that the smaller the number, the closer the position is to the midline.

Electrode locations and names are specified by the International 10–20 system [1] for most clinical and research applications. This system ensures that the naming of electrodes is consistent across laboratories. In most clinical applications, 19 recording electrodes (plus ground and system reference) are used [2]. Additional electrodes can be added to the standard set-up when a clinical or research application demands increased spatial resolution for a particular area of the brain. High-density arrays can contain up to 256 electrodes more-or-less evenly spaced around the scalp.

Each electrode is connected to one input of a differential amplifier; a common system reference electrode is connected to the other input of each differential amplifier. These amplifiers
amplify the voltage between the active electrode and the reference (typically 1,000–100,000 times of voltage gain). In analog EEG, the signal is then filtered and the EEG signal is output as the deflection of pens as paper passes underneath. Most EEG systems now days, however, are digital, and the amplified signal is digitized via an analog-to-digital converter, after being passed through an anti-aliasing filter. Analog-to-digital sampling typically occurs at 256–512 Hz in clinical scalp EEG; sampling rates of up to 20 kHz are used in some research applications. During the recording, a series of activation procedures may be used. These procedures may induce normal or abnormal EEG activity that might not otherwise be seen. These procedures include hyperventilation, photic stimulation, eye closure, mental activity, sleep and sleep deprivation. The digital EEG signal is stored electronically and can be filtered for display. Typical settings for the high-pass filter and a low-pass filter are 0.5–1 Hz and 35–70 Hz respectively. The high-pass filter typically filters out slow artifact, such as electrogalvanic signals and movement artifact, whereas the low-pass filter filters out high-frequency artifacts, such as electromyographic signals. An additional notch filter is typically used to remove artifact caused by electrical power lines (60 Hz in the United States and 50 Hz in many other countries) [3].

The EEG signals can be captured with open source hardware such as Open BCI and the signal can be processed by MATLAB or freely available EEG software such as EEGLAB

### III. WAVE PATTERNS OF EEG

EEG waveforms are generally classified according to their frequency, amplitude, and shape, as well as the sites on the scalp at which they are recorded. The most familiar classification uses EEG waveform frequency (i.e. delta, theta, alpha, beta and gamma)

#### A. Delta waves

Fig 3 shows delta waves, delta wave is the frequency range up to 4 Hz. It tends to be the highest in amplitude and the slowest waves. It is seen normally in adults in slow-wave sleep. It is also seen normally in babies. It may occur focally with subcortical lesions and in general distribution with diffuse lesions, metabolic encephalopathy hydrocephalus or deep midline lesions. It is usually most prominent frontally in adults (e.g. FIRDA – frontal intermittent rhythmic delta) and posteriorly in children (e.g. OIRDA – occipital intermittent rhythmic delta).

#### B. Theta waves

Fig 4 shows theta waves, theta is the frequency range from 4 Hz to 7 Hz. Theta is seen normally in young children. It may be seen in drowsiness or arousal in older children and adults; it can also be seen in meditation. Excess theta for age represents abnormal activity. It can be seen as a focal disturbance in focal subcortical lesions; it can be seen in generalized distribution in diffuse disorder or metabolic encephalopathy or deep midline disorders or some instances of hydrocephalus. On the contrary this range has been associated with reports of relaxed, meditative, and creative states.
C. Alpha waves

Fig 5 shows alpha waves, alpha is the frequency range from 7 Hz to 14 Hz. Hans Berger named the first rhythmic EEG activity he saw as the "alpha wave". This was the "posterior basic rhythm" (also called the "posterior dominant rhythm" or the "posterior alpha rhythm"), seen in the posterior regions of the head on both sides, higher in amplitude on the dominant side. It emerges with closing of the eyes and with relaxation, and attenuates with eye opening or mental exertion. The posterior basic rhythm is actually slower than 8 Hz in young children (therefore technically in the theta range).

D. Beta waves

Fig 6 shows beta waves, beta is the frequency range from 15 Hz to about 30 Hz. It is seen usually on both sides in symmetrical distribution and is most evident frontally. Beta activity is closely linked to motor behavior and is generally attenuated during active movements. Low-amplitude beta with multiple and varying frequencies is often associated with active, busy or anxious thinking and active concentration. Rhythmic beta with a dominant set of frequencies is associated with various pathologies, such as Dup15q syndrome, and drug effects, especially benzodiazepines. It may be absent or reduced in areas of cortical damage. It is the dominant rhythm in patients who are alert or anxious or who have their eyes open.

E. Gamma waves

Fig 7 shows gamma waves, gamma is the frequency range approximately 30–100 Hz. Gamma rhythms are thought to represent binding of different populations of neurons together into a network for the purpose of carrying out a certain cognitive or motor function.

Mu range is 8–13 Hz and partly overlaps with other frequencies. It reflects the synchronous firing of motor neurons in rest state. Mu suppression is thought to reflect motor mirror neuron systems, because when an action is observed, the pattern extinguishes, possibly because of the normal neuronal system and the mirror neuron system "go out of sync" and interfere with each other.

IV. DETECTION OF EPILEPSY

The International Federation of Societies for Electroencephalography and Clinical Neurophysiology (IFSECN) describes interictal discharges as a subcategory of "epileptiform pattern," in turn defined as "distinctive waves or complexes, distinguished from background activity, and resembling those recorded in a proportion of human subjects suffering from epileptic disorders...." This somewhat circular definition makes clear that criteria must be verified empirically.

Interictal discharges may be divided morphologically into sharp waves, spikes, spike-wave complexes (also called spike-and-slow-wave complexes), and polyspike-wave complexes (also
called multiple-spike-and-slow-wave-complexes). In practical terms, the morphological distinctions are less important than the certainty with which these entities can be distinguished from physiologic or nonspecific sharp transients. The other major issue is that some artifacts look like interictal discharges and require a well-trained electroencephalographer to interpret the waveforms accurately. If there is doubt, a repeat EEG may be of great benefit to sort things out, as misinterpretation may lead some patients to be placed on seizure medications needlessly. IEDs may occur in isolation or in brief bursts; bursts longer than a few seconds are likely to represent electrographic seizures rather than interictal discharges.

The following changes are observed in EEG wave forms for epilepsy detection:
A. Sharp wave - Transient, clearly distinguishable from background activity, with pointed peak at conventional paper speeds and a duration of 70-200 milliseconds (ms)
B. Spike - Same as sharp wave, but with duration of 20 to less than 70 ms
C. Spike-and-slow-wave complex - Pattern consisting of a spike followed by a slow wave (classically the slow wave being of higher amplitude than the spike)
D. Multiple spike-and-slow-wave complex - Same as spike-and-slow-wave complex, but with 2 or more spikes associated with one or more slow waves

V. ADVANTAGES OF EEG

There are many advantages of using EEG, which are mention as below
A. Hardware costs are significantly lower than those of most other techniques [6].
B. EEG prevents limited availability of technologists to provide immediate care in high traffic hospitals [7].
C. EEG sensors can be used in more places than fMRI, SPECT, PET, MRS, or MEG, as these techniques require bulky and immobile equipment[8].
D. EEG has very high temporal resolution, on the order of milliseconds rather than seconds [8].
E. EEG is relatively tolerant of subject movement, unlike most other neuroimaging techniques [9].
F. EEG is silent, which allows for better study of the responses to auditory stimuli.
G. EEG does not involve exposure to high-intensity (>1 tesla) magnetic fields, as in some of the other techniques, especially MRI and MRS [10].
H. EEG does not involve exposure to radioligands, unlike positron emission tomography [11].

VI. CONCLUSION

EEG is a valuable tool in the diagnosis of epilepsy and provides insight into neuronal activity that cannot be obtained with other methods. An EEG is the sole method of recording and evaluating the discharges of neurons causing seizures. Scalp EEG is quite specific for epilepsy but its sensitivity is low, in part because many patients with epilepsy do not display abnormal interictal EEG activity. The EEG is invaluable in establishing a diagnosis for many conditions including generalized epilepsy. EEG may not be helpful with normal rhythms or nonspecific diffuse activity. However, a normal EEG in an untreated patient may be useful as it may exclude some conditions where abnormalities are expected to be high. EEG is also useful with uncommunicative patients.

REFERENCES

[1] Towle, Vernon L.; Bolaños, José; Suarez, Diane; Tan, Kim; Grzeszczuk, Robert; Levin, David N.; Cakmur, Raif; Frank, Samuel A.; Spire, Jean-Paul (1993). "The spatial location of EEG electrodes: Locating the best-fitting sphere relative to cortical anatomy". Electroencephalography and Clinical Neurophysiology.
[2] "Guideline Seven A Proposal for Standard Montages to Be Used in Clinical EEG". Journal of Clinical Neurophysiology.
[3] Niedermeyer E.; da Silva F.L. (2004). Electroencephalography: Basic Principles, Clinical Applications, and Related Fields. Lippincott Williams & Wilkins.
[4] Fisher RS, van Emde Boas W, Blume W, et al. Epileptic seizures and epilepsy: definitions proposed by the International League Against Epilepsy (ILAE) and the International Bureau for Epilepsy (IBE). Epilepsia. 2005;46(4):470-472.
[5] England MJ, Liverman CT, Schultz AM, Strawbridge LM. Epilepsy across the spectrum: promoting health and understanding [Epub October 4, 2012]. Epilepsy Behav. 2012;25(2):266-276.

[6] Vespa, Paul M.; Nenov, Val; Nuwer, Marc R. (1999). "Continuous EEG Monitoring in the Intensive Care Unit: Early Findings and Clinical Efficacy". Journal of Clinical Neurophysiology.

[7] Schultz, Teal L. (2012). "Technical Tips: MRI Compatible EEG Electrodes: Advantages, Disadvantages, And Financial Feasibility In A Clinical Setting". Neurodiagnostic Journal 52.1: 69–81.

[8] Hämäläinen, Matti; Hari, Riitta; Ilmoniemi, Risto J.; Knuutila, Jukka; Lounasmaa, Olli V. (1993). "Magnetoencephalography-theory, instrumentation, and applications to noninvasive studies of the working human brain". Reviews of Modern Physics.

[9] O'Regan, S; Faul, S; Marnane, W (2010). "2010 Annual International Conference of the IEEE Engineering in Medicine and Biology": 6353–6. ISBN 978-1-4244-4123-5.

[10] Schenck, John F. (1996). "The role of magnetic susceptibility in magnetic resonance imaging: MRI magnetic compatibility of the first and second kinds". Medical Physics. 23 (6): 815–50.

[11] Yasuno, Fumihiko; Brown, Amira K; Zoghbi, Sami S; Krushinski, Joseph H; Chernet, Eyassu; Tauscher, Johannes; Schaup, John M; Phebus, Lee A; Chesterfield, Amy K; Felder, Christian C; Gladding, Robert L; Hong, Jinsoo; Halldin, Christer; Pike, Victor W; Innis, Robert B (2007). "The PET Radioligand [11C]MePPEP Binds Reversibly and with High Specific Signal to Cannabinoid CB1 Receptors in Nonhuman Primate Brain". Neuropsychopharmacology. 33 (2): 259–69.