CHAPTER 2

OVERVIEW OF EPILEPSY

2.1 INTRODUCTION

The structural, biochemical and electrical abnormalities in human body may cause neurological diseases such as disorders in nerves, brain and spinal cord. These disorders may lead to temporary changes in behaviour and perception. Hence, these have to be assessed clearly. Thus the assessment of these disorders requires a reliable neurological examination that can be carried out by expert neurologists and neuropsychologists. According to the Global Burden of Disease (GBD) study, a collaborative Endeavor of the World Health Organization (WHO), the World Bank and the Harvard School of Public Health, there are nearby 600 types of known neurological diseases which range from migraines to epilepsy. According to the World Health Organization, these disorders and their extent have their effects on more than 1 billion people all around the world (World Health Organization, 2006). This will increases along with the rise in population and hence it becomes a serious threat to human society. Hence in order to overcome the effects of this neurological disorders, the various measures such as preventative measures, lifestyle changes, physiotherapy, neuro-rehabilitation, pain management, medication, or operations performed by neurosurgeons (www.renoveldiscoveries.com/diseases) are carried out.
Confusion, loss of sensation, muscle weakness, paralysis, poor coordination, seizures, pain and altered levels of consciousness (www.medicalmarijuanainc.com/index.php/neurological-disorder) are some of the symptoms of these neurological disorders. Researchers and scientists suggest that the measure of the seriousness of these diseases is mainly based on statistics, based on the countries and organizations that have launched the disease control programs.

2.2 TYPES OF NEUROLOGICAL DISEASES

The statistics reported by WHO suggests that neurological and psychiatric disorders place a vital role in day to day life of a human being. From the survey this clearly stated that the violence of mental trouble, neurological, and behavioral disorders are massive and more than 450 million people all over the world have been affected by the neurological disorders. (http://www.ncbi.nlm.nih.gov/books/NBK11793). As per the records of the Global Burden of Disease Report, more than 33% of people of world population live with disabilities and 13% of the worldwide population lives with neurological and psychiatric disorders. Thus the spectrum of these neurological disorders substantially varies between countries and also between the different regions of same country. It happens due to the variation in environmental conditions, nutritional status, hereditary nature (Abou-Khalil & Musilus, 2006). Neurological are disorders not considered as important as because of lack of awareness among the people, which in turn acts as a barrier in further treatment of the disorders. Hence it is necessary to create awareness among the people and so that they should be aware of the common neurological disorders. This in turn makes them to discourse the issue occurred on them on time in order to prevent complications. (http://www.dnaindia.com/health/1755146/report-at-nerve-s-end-neurologists-in-short-supply-across-country). It is also a responsibility of
the senior neurosurgeons to give awareness among the people about the
detection and prevention of neurological diseases. There is an immediate need
to develop neurology care at all levels of the hierarchy of the health care
pyramid. At the same time it is mandatory to increase the neurology training
institutes to bring awareness about these disorders.

Among the various neurological disorders, the most common
neurological disorders that occur in India includes epilepsy, brain damage
because of birth trauma, Parkinson’s disease, dementia, nerve weakness and
neurological disorders resulting due to nutritional deficiency and revelation
due to neurotoxin chemicals. (Hu et al. 2004).

Thus the various different types of neurological diseases are
discussed as follows

**Dementia:**

This disorder is mainly due to the weakening of intellectual and
other cognitive skills. It act as an interruption towards their social or
occupational contribution. Alzheimer Disease is the most common sub-sect of
Dementia which is most dominant among people of whose age group is 65 and
above.(http://health.usnews.com/health-conditions/brain-health/alzheimers-
disease).

**Parkinson’s disease:**

This type disorder is mainly caused due to deficiency of the
neurotransmitter dopamine. It is mainly due to vascular or inflammatory
changes, which are characterized by rhythmic muscular tremors, rigidity of
movement, festinating, a droopy posture. Thus the Lower levels of dopamine
have serious effects over the movement of muscles.
**Stroke:**

A stroke which is otherwise known as cerebrovascular accident (CVA) is a dangerous condition and it leads to rapid loss of brain function. This mainly occurs due to disruption in the blood supplied to the brain. As a result of this, the brain cells begin to die. (http://www.dartmouth.edu/~dons/part_3/chapter_27.html).

**Brain Tumor:**

Brain tumor is nothing but an abnormal growth of cells which are either malicious or benign which is non-cancerous in nature. Exposition of cancer can be caused due to the formation of tumor. Thus the tumor is developed by abnormal and uncontrolled cell division existing in the brain or may be the presence of such condition in various locations such as cranial nerves, brain envelopes, skull, pituitary and pineal gland etc.,(http://www.ncbi.nlm.nih.gov/books/NBK9553).

**Epilepsy:**

Epilepsy is a chronic neurological disorder of the brain characterized by paroxysmal stereotyped alterations accompanied with extreme discharge in large masses of neurons. It is the second most common chronic non-degenerative neurological disease perceived by neurologists. From the clinical survey, it is observed that there are around 5.5 million people in India are affected by Epilepsy in India (Ray et al., 2002, Chapin et al. 1999).
2.3 ANATOMY OF HUMAN BRAIN

The study carried on the structure of the nervous system is known as Neuro anatomy. Thus the nervous system of a human brain incorporates Central Nervous System (CNS) and Peripheral Nervous System (PNS).

Figure 2.1 shows the cross sectional view of the brain.

![Cross sectional view of brain](https://kristinbell.org/2012/01/)

**Source:** https://kristinbell.org/2012/01/

**Figure 2.1** Cross sectional view of brain

**Central Nervous System (CNS)**

The CNS comprises the brain and the nerves which act as the control center of the body. This CNS is broadly classified into three parts namely:

- Cerebrum,
- Cerebellum and
- Brain Stem.
Cerebrum:

The human cerebral cortex is a thick layer of neural tissue. It covers the major part of the brain. The cortex is divided into four "lobes", namely the frontal lobe, parietal lobe, temporal lobe, and the occipital lobe and is shown in figure 2.2. Each lobe contains numerous cortical areas. Each of them are accompanied with a particular functionality such as vision, motor control, language, etc.


Figure 2.2 3-D Structure of the Brain

Lobes of the Brain:

Frontal Lobe:

Frontal lobe is found in the anterior part of the cerebral hemisphere. It is the largest one among all the lobes. It is the emotional control center and hence it addresses our personality. It is the most susceptible part of the brain. Epilepsy that emerges in the frontal lobe is mentioned to as Frontal Lobe Epilepsy (FLE). It is represented by the occurrence of Partial seizures. The appearance of seizures which does not have any effect on the awareness or memory is called straightforward partial seizures. The symptoms and
clinical manifestations of occurrence of FLE depend on the area of the lobe affected by epilepsy and it may vary from area to area.

**Parietal lobe:**

This lobe lies next to the frontal lobe and in front to the occipital lobe. It plays a vital role in incorporating sensory input from various parts of the body and hence it mainly manages the sensation and perception of the visual system. When this lobe gets affected, it will be represented by the deficits such as abnormalities in body image and spatial relations (Kandel, Schwartz and Jessel, 1991).

Parietal Lobe Epilepsy (PLE) is a rare form of epilepsy. It may be due to head trauma, difficulties in the birth, stroke, or tumor. Among 20% patients, it is caused due to unknown reason. As the parietal lobe includes the processing and integration of sensory and visual perception, seizures originating from this lobe affect both sensory and visual sensations. The most common epilepsy raised due to abnormalities of these lobes is Somatosensory Seizures. Patients affected by this type of seizures suffers physical sensations of lack of feeling and burning, heat, pressure, electricity and pain in their body (epilepsy.med.nyu.edu/epilepsy/types-epilepsy/partietal-lobe-epilepsy).

**Occipital lobe:**

This lobe is located in the hinder part of the brain and among all the lobes, it is the smallest one (http://dailyhealthcenter.net/Lobes-Of-The-Brain.html). It is the visual processing center and thus it covers the major portion of the anatomical visual cortex. The characteristic features of this lobe are visuo spatial processing, discrimination of movement and color (Westmoreland *et al.*, 1994). Visual hallucinations and illusions are the major causes for the disorders occurred in this lobe. Distorted perceptions causes manifest in viewing objects so that appearance of the object is resized from its
actual size, objects lacking color or objects having abnormal coloring. Occipital seizure is mainly occurred during the day, due to television, video games or any flicker stimulation system (Destina et al., 2000). This type of seizures initiate from an epileptic focus and limited within the occipital lobes. They may be spontaneous or may be caused by external visual stimuli.

**Temporal lobe:**

It is the region of cerebral cortex and is located underneath the lateral fissure on both the cerebral hemisphere. It is concerned with retention of visual memories, comprehending languages, long term memory, storing new memory and emotions. The upper and the medial part of the lobe, receives auditory input from the thalamus and acts as a relay for the information received from the ears. The lower part of the lobe carries out the visual processing which is helpful in recognition of objects and patterns.

Temporal Lobe Epilepsy (TLE) is a form of focal epilepsy, where a chronic neurological condition is characterized by recurrent seizures. TLE is the most common form of refractory epilepsy.

**Cerebellum:**

The part of the brain positioned just above the brain stem and it occupies 10% of the total volume of the brain. It contains a contribution around 50% of the brain’s total neurons. It is well protected from traumatic injuries comparatively to that of frontal, temporal lobes and brain stem. It plays a vital role in the synchronization of voluntary motor movement, balance and equilibrium and muscle tone. The classic Jacksonian cerebellar seizures appear to encounter only a few cases in the present-day population.(http://www.neuro.iastate.edu/Uploads/seizures_jackson.pdf).
**Brain Stem:**

This is the posterior part of the brain which connects the spinal cord with the brain system. It plays a major role in the regulation of cardiac and respiratory functions. It also synchronizes the Central Nervous System, which is responsible for maintaining consciousness and regulation of sleep. Brainstem lesions may be responsible for the presence of seizures in patients with multiple sclerosis (Papathanasiou *et al*., 2010).

The PNS is a part of the nervous system, which consists of nerves and it connects the Central Nervous System (CNS) to the limbs and organs.

**2.4 ELECTROENCEPHALOGRAM**

The electroencephalogram (EEG) was discovered by the German psychiatrist Hans Berger in 1929. It was a historical breakthrough and thus it is a novel tool for neurologic and psychiatric diagnostic tool. It was known that brain produces electrical stimulation for every motory response, but the idea behind the recording of spontaneous brain electrical current was unknown. Canton was the first to who discovered the findings of brain by recording electrical pulses from the exposed brain of rabbits. Based upon this as a platform, Berger performed a first EEG electrocorticogram recording during a neurosurgical operation on a 17 year old boy. During this period, the diagnostic tools like lumbar puncture, pneumoencephalography and ventriculography were present and were implemented only to detect and localize "sick sites" in the brain. Hence the discovery of electroencephalography was an innovative invention in the advancement of neuroscience and for neurologic and neurosurgical practitioners (Tudor *et al*., 2005). EEG updated the neurologic and neurosurgical procedures, and associated for about 40 years (1930-1970) until the invention of computer tomography.
The human brain contains about 10 billion nerve cells, or neurons. The network of neurons present in the brain tremendously forms a parallel information processing system. Neurons are responsive cells in the nervous system. It transmit information by varying the flow of electrical currents across their membranes and which in turn leads to the generation of electric and magnetic fields and are recorded from the surface of the scalp (Brazier 1949, Isaacs et al. 2000).

These electric fields are measured by employing small electrodes on the scalp. The potentials which arise between these different electrodes placed on the scalp are amplified and then recorded using electroencephalogram (EEG). When the Electrical activity is recorded using EEG, a tiny magnetic field is generated by the neurons of the brain. They are measured using Magnetoencephalogram (MEG), which came into existence in 1970 (Yu et al. 2002, Li & Paul 2010, Wang et al. 2004).

Applications of EEG

EEG is usually used to detect Seizures.

It identifies disorders like Epilepsy, Brain Tumor, Stroke, Dementia etc.

It not only deals with the physiological level of the brain but also anatomy of the brain. For example, some of the applications, where EEG finds its eminence are Brain-Computer Interface (BCI), Brain Machine Interface (BMI), and Human-Computer Interaction (HCI) (Cuellar et al. 2016).

A cerebral or Brain Computer Interface (BCI) helps the people who have communication problems. They are related to their surroundings using a computer and electrophysiological signals from the brain (Liang et al. 2006).
BMI offers a solution to a lack of control for paralyzed or prosthetic limbs. Development in the areas of Neuroprostheses and BMI has an opening for victims of trauma and for the people affected from stroke and for the people who become handicapped due to paralytic attack or amputations. The BMI utilizes neuroprosthetics implanted in the brain to extract spatial degrees of freedom (e.g. Up/down, left/right) from the number of neurons excited. It also helps the patients to communicate their thoughts through a computer. For a physically challenged people, a thought controlled movement of wheel chair is made possible.

The second major category of diagnostic tests is imaging. Specialized imaging tests include Computer Tomography (CT) scans, Magnetic Resonance Imaging (MRI) scans, functional Magnetic Resonance Imaging (fMRI) and Positron Emission Tomography (PET) scans. These scans help medical practitioners to know the lesions or abnormalities present in the brain patients (Wu et al. 2016, Serby et al. 2005, Kousarrizi et al. 2009, Lehnertz, K 1999).

EEG is one of the ancient devices and has ensured its position in the evolution of neuroimaging devices due to the following reasons:

- Considerably it has lower hardware costs when compared to the other techniques.

Due to the advancement in wireless EEG sensors, it becomes mobility. But the other equipment such as fMRI, SPECT, PET, NIRS, or MEG are bulky and immobile. For example, MEG can be used only in the magnetically shielded rooms whereas fMRI requires 1-ton magnet and should be again placed in a shielded room.
• It has a very good progressive resolution in the order of milliseconds.
• It is quite lenient to artifacts when compared to other neuroimaging techniques.
• EEG produces a better study of the responses to auditory stimuli.
• It does not magnify claustrophobia as MRI, fMRI, CT, PET.
• It is not exposed to radioactivity.
• It is very simple because of its non-invasive nature.
• It also plays a significance role in the field of neuroimaging so that it can be integrated with other advanced technological devices such as MRI, fMRI etc.

**Working of EEG**

Electroencephalography is the science/technique to record and analysation of electrical activity of the brain. Electrodes are the sensors, which are placed on or under the scalp and are connected to an electroencephalograph. It converts electrical impulses into the vertical movement of a pen over a sheet of paper. These electrodes sense the brain waves. The sensed waves are amplified by the EEG machine and recorded in the form of wave pattern on graph paper or a computer screen. From the recordings, the overall activities of millions of neurons present in the brain are analyzed and the electrical activity pattern produced on an EEG can detect conditions which affects the brain (Muller et al. 1999, Millan et al. 2000).
**Electrode Placement**

Electrodes made of stainless steel are small metal discs, tin, gold or silver covered with a silver chloride (AgCl) coating. The electrodes are placed on the scalp with a help of a conductive gel. The output of these electrodes is given as an input to the differential amplifiers. The 10-20 System is an International placement guide for positioning the electrodes on the scalp. Thus it provides relationship between the location of an electrode and the underlying area of cerebral cortex covering a distance from naison (dip between nose and forehead) and inion (the bump at the back of the head above the neck).

EEG is a nothing but a record of brain activity. It is an outcome of the movement of thousands of neurons in the brain. According to the stimulation level of person, the brain activity varies. i.e. Fast wave patterns are observed while the person is in excited state or otherwise slow waves are recorded in EEG. The EEG is used for recording the brain activities for various research purposes during sleep condition and also in diagnosing various disorders such as dementia, epilepsy, tumors, schizophrenia etc. Figure 2.3 and 2.4 represents placement of 10-20 electrodes in side view and overhead view. 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 represent Frontal, Temporal, Central, Parietal and Occipital respectively (Ioannides 2004).
An imaginary lobe called central lobe is utilized by the Electroencephalographers for the purpose of easy identification. Even numbers (2, 4, 6, and 8) refers the right hemisphere and odd numbers (1, 3, 5, and 7) refers the left hemisphere. An electrode placed on the midline is referred as z. Electrodes with small numbers is closer to the midline than electrodes with larger numbers. The "10" and "20" refers to the inter electrode distance. Thus
the number of electrode usage can varies according the size of the head. For example, in case of new born baby, as the size of the head is small, the usage of number of electrodes is also significantly reduced (Schalk et al. 2000, & Ballard 1999).

Thus each EEG channel is made from two inputs; one input is from electrodes placed at various locations and the second input is reference voltage. For the generation of reference voltage, different numbers of approaches are utilized and this type of design is referred to as montages. Different types of montages are described below:

**Common Reference:**

In this design, a common reference point is given as one of the inputs to the differential amplifier. Each channel of EEG is formed by the potential difference between one scalp electrode and the reference channel. The choice of the reference electrode is very significant and it depends upon location of the electrode which is electrically silent. Thus, Cz is usually used as a reference voltage.

**Average Reference:**

This type is similar to the common reference montage. The only difference is that instead of using a single electrode as a reference point, a common reference is created by summing all the activity from the electrode, averaging it. Then the averaged value is passed through a high value resistor.

**Bipolar:**

In this type configuration, all the scalp electrodes are connected to form a chain like structure. Thus, an electrode serves as an input for one differential amplifier serves as a reference voltage for the next cycle.
Signal Frequencies

The recorded waveforms of EEG reproduce the cortical electrical activity. The signal intensity of EEG is measured in terms of microvolts (µV). Thus each stimulus or a mental activity causes deviation in the activities of neurons. A person who is suffered by with a brain disorder will have a different group of neurons activities for a same kind of activity performed on a person without any disorder. Thus brain potentials are classified broadly into

- Spontaneous brain potentials and
- Event potentials.

Spontaneous brain potentials

The signal frequencies which represent electrical activity originating from human brain are named as Spontaneous brain potentials.

Thus the frequencies of the brain are classified as follows

Delta

Delta waves are a high amplitude brain wave whose frequency is about 0.5 to 4 Hz and is represented in figure 2.5. Normally, Delta waves are associated with the stage 3 of deep sleep. So it is also known as as slow-wave sleep (SWS). It is mainly used to characterize the depth of sleep.

In case of adults, it is more prominent in the frontal part (e.g. FIRDA – Frontal Intermittent Rhythmic Delta) whereas in case of children, it is in posterior part (e.g. OIRDA – Occipital Intermittent Rhythmic Delta).
Theta waves shown in figure 2.6 occur most often in sleep and are dominant only in deep meditation. It acts as a gateway for learning. It is found to be normal up to 13 years of age. Excess theta in adults represents abnormal activity.

Alpha

The frequency ranges of alpha waves ranges between 7.5 to 12.5 Hz. Normally, it starts off from the occipital lobe during wakeful relaxation with closed eye and is shown in figure 2.7.
Beta waves can be classified into three types namely:

- Low Beta Waves (ranges from 12.5–16 Hz)
- Beta Waves (ranges from 16.5–20 Hz) and
- High Beta Waves (ranges from 20.5–28 Hz).

Normally, Beta waves are coupled with waking consciousness and is represented in Figure 2.8.
**Gamma:**

The frequency of the Gamma ranges from 30 Hz-100 Hz. Gamma represents the binding of a massive collection of neurons take in account for carrying out an assured cognitive or motor function (http://www.biomedresearches.com/root/pages/researches/epilepsy/electrical_activity.html).

**Evoked Potentials:**

These types of potentials occur due a brain reaction which results in stimulating the amplitude up to few hundred times lower than the EEG level.

**Morphology of brain waves:**

Morphology refers to the shape of brain waveform. Spike and Sharp wave are the two most important morphologies.

**Spike:**

Spike is nothing but a transient waveform with a pointed peak of duration between 20-70msec.

**Sharp wave:**

It is also a transient waveform with a pointed peak of duration between 20-70msec. But this transient waveform is an isolated wave or pattern that is distinct from the original activity.

2.5 **EPILEPSY**

Epilepsy is the most common non-infectious neurological disease which have significant psychological, social as well as medical consequences
and may be life threatening (WHO, 2006). Figure 2.9 depicts the EEG signals at the beginning of the seizure and during seizure.

Figure 2.9  EEG signal depicting the beginning of the seizure and during seizure.

2.5.1  Etiology of Epilepsy

The word epilepsy is derived from the Greek word *epilambanein*. The meaning of this word is to seize or attack (World Health Organization, 2001). The earliest medical texts on epilepsy were produced by the Babylonians around 1050BC and indicate that they believed epilepsy was caused by demons and ghosts (Wilson and Reynolds, 1990). The Greek physician Hippocrates has been endorsed with writing the first book about epilepsy. In this book he described about the brain dysfunction and claimed against the thought that seizures were supernatural (Bladin, 2001). However, during the middle Ages (5th -15th century), possession, magic and witchcraft again became the dominant explanations for the illness (Masia and Devinsky,
These mythical beliefs continue in some cultures even today (Awaritefe, Longe, and Awaritefe, 1985; Baskind and Birbeck, 2005) and almost certainly contribute to the stigma sometimes attached to the condition.

Classification of Epilepsy

Epilepsy is a persistent disorder and has the propensity of two or more unprovoked seizures (World Health Organization, 2001). A seizure is a manifestation presumed to result from an abnormal and excessive discharge of a set of neurons in the brain (Fisch et al. 1999). Seizures are predetermined events which possess a distinctive beginning and ending and it leads to unusual sensations, emotions or behavior, muscle spasms, loss of consciousness or convulsions etc., The unprovoked seizure means that the seizure was not been precipitated by the factors such as the excessive consumption of alcohol, the frequent use of recreational drugs, unfavorable reactions to prescribed medications, fevers from acute illnesses, metabolic conditions such as diabetes or very recent head injury (Subasi & M. I. Gursoy 2010). However, an individual may feel frequent daily seizures or just a few seizures over a lifetime (Petrosian 1995). But the lifetime risk of an individual having a seizure is only about five percent (Trostle, 2005). People with epilepsy may suffer many different types of seizures. The International League against Epilepsy (ILAE) has developed a classification system for epilepsy related seizures (Higuchi 1988, Balli & Palaniappan 2009).
Categorization of Seizures

The classification of Seizure types follow the classification proposed by the International League Against Epilepsy (ILAE) in 1981. Differentiating between seizure types is very significant as different types of seizure may different outcomes and treatments.

Thus the seizures are generally categorized into two types namely

Partial or focal and

Generalized seizure and is represented in Figure. 2.10.

Again the Partial Seizures are further classified into

Simple and
Complex seizures.

At the same time, the generalized seizures are classified into
Absence,
Tonic -clonic,
Atonic and
Myoclo seizures.

**Partial seizures:**

This type of seizures occurs when the neuron activations are limited to the part of cerebral hemisphere. This in turn causes an unusual muscle movements, sensory experiences, speech problems, emotional experiences or distorted perceptions.

**Simple Partial Seizures:**

In this type of seizure, people will not lose their consciousness.

**Complex Partial Seizures:**

In this type, the affected person will lose their consciousness. The persons affected by this type are not able to recall the things during the occurrence of seizure and may be very confused and exhausted with the impact of abnormality in their behavior manner. Simple partial seizures may be developed into complex partial seizures and complex partial seizures may be recharged into generalized seizures when more number of neurons is activated.

**Generalized seizures:**
It is also referred as mal”dnarg“' seizure because in this condition, neurons are forced in both the hemisphere (http://brain.oxfordjournals.org/ content/129/5/1281.long). The initial symptom of this disease will be a weaken consciousness.

**Absence Seizure:**

When the weakened consciousness is enormously concised, it is classified as a absence seizure.

**Tonic-Clonic Seizure:**

If the changes in the level of the consciousness are coupled with specific movements, it is classified under tonic-clonic seizures. During a tonic-clonic seizure, the person can feel two different types of movements. During the **tonic phase**, the body becomes rigid whereas during a **clonic phase**, the individual suffers from rhythmic jerking movements (Lima & Coelhob 2011).

**Atonic seizure:**

The person affected by this type of seizures will suddenly lose their muscle tone and may fall on the ground abruptly or may fall in a rhythmic step-by-step fashion or display sleepy of the head or drooping of the body.

**Myoclonic seizure:**

In case of myoclonic seizure, the person feels sudden muscle jerks and it amy generally takes place in the arms and legs (Arzimanoglou, Guerrini, and Aicardi, 2004; DeLorenzo, 1991; Porter, 1993).


2.6 DIAGNOSIS AND PROGNOSIS

A person affected by the seizures should be diagnosed properly in order to prevent from epilepsy. Reduction of Seizure is the ultimate goal of medical world. Despite of invention of good drug, people still continue to have seizures. A division of the corpus callosum was seldom carried out to prevent seizure discharges (Heaton 2008, ibeyli 2010). Stimulation of the cerebellum was introduced to suppress seizures, but it was not successful. The ketogenic diet, a high-fat, adequate-protein, low-carbohydrate diet have been implemented to manage the stubborn epilepsy according to the Wilder's original report in 1921. But it was not much so effective (Pradhan & Dutt 1994, Qin et al. 2004).

2.7 FACTORS CAUSING SEIZURES

There are large number of factors that have been identified and are the major reasons for occurrence of seizures among the people. Some of the more common reasons are include stress, sleep deprivation and tiredness, alcohol and alcohol withdrawal, toxins and drugs, metabolic disturbances, caffeine etc. In case of women, it may be due to the menstrual cycle (Siuly et al. 2014). Furthermore, an epilepsy can also be triggered by interaction of stress with some others effects. (Übeyli 2010). All people are unique in nature and people affected with epilepsy will have identifiable features. The averting of such kind of triggers may result in greater seizure control but it leads to various lifestyle restrictions. The possibility for supporting injuries when having a seizure can increase the anxiety of both affected individuals and their family (Cincotti et al. 2000, Cincotti et al. 2003).

Epilepsy is a potentially life-threatening condition and when people with epilepsy focus on the view of death, it may lead to increased
anxiety and depression. Researchers have constantly stated that people affected by epilepsy, even though they intake a good medicines for seizure control, they may have a increased risk of unfortunate death when compared with those people who are affected by seizures.

Thus the recording of electrical signals originate from human brain can be collected from the scalp of the head using a device called Electroencephalogram (EEG) (Fabiani et al. 2004). These measured signal's parameters and patterns indicate the health of the brain. With the help of these Digital Signal Processing functions, EEG signals can be analyzed to properly diagnose the patient (Cheng et al. 2014, Kubler et al. 2005, Babiloni et al. 2000).

The manual analysis made by a small team of professionals after EEG recording necessitates the automated seizure analysis (Garrett et al. 2003a, Garrett et al. 2003b).

2.8 BASIC CONCEPTS OF SOFT COMPUTING

EEG systems can be analyzed with the help of Digital System Processing functions to diagnose the patient affected by seizures (Teplan 2002, Aurlien et al. 2004, Roberts et al. 1998, Subha et al. 2010). The various analytic methods utilized to extract feature from EEG signals are as follows:

- Spectral estimation
- Transfer function based method
- AR method
- ARMA method
- Wavelet analysis
Spectral estimation:

Spectral estimation helps in finding the pulse rhythms present in the EEG system. The short segment of EEG data is examined for spectral parameters such as location and amount of spectral energy (Lemm et al. 2002). For this purpose, Wave shaping filters are used in this technique. Wave shaping filters generates the desired output according to the given input (Towle et al. 2003, Inouye et al. 1991, Pincus et al. 1991, Saa & Gutierrez 2010).

Transfer function based method:

An estimate amount of the spectral density of a system is known as the periodogram. This periodogram is often computed using the fast Fourier transform (FFT). This can be also be achieved using estimated correlation function (Hjorth 1970, Welch 1967).

AR method:

When the frequency domain of the EEG signals has sharp peaks, Autoregressive (AR) is utilized for analysis. It is so popular because the accurate approximation of PSD can be easily achieved by solving linear equations (He sheng et al. 2003, He & Liu 2014).

Thus, AR model is called otherwise called as all pole method because each and every sample of the system can be expressed as a combination of previous samples and an error system. Levinision Durbin algorithm and Yule Waker equations are very much useful for the analysis of frequency content of input signal using parametric model (Pfurtscheller et al. 2001, Peng et al. 1995).
**ARMA (autoregressive moving average) method:**

This model is mainly used for modeling systems with sharp peaks in their frequency and also systems with severe noise (Babiloni et al. 2001).

**Wavelet analysis:**

A wavelet is a mathematical function. It is implemented by dividing a given function or continuous-time systems into different scale components. Generally frequency range is assigned to each component in a scale. Each scale component can then be examined with a resolution which matching to its scale (Yoon et al. 2005).

A wavelet transform is the nothing but a illustration of a function carried out the wavelets. The wavelets which are scaled and translated into many copies are known as “daughter wavelets” of a finite-length and the fast-decaying oscillating waveform are referred as the “mother wavelet” (Li et al. 2016, Tzallas et al. 2007).

The advantages of Wavelet transforms includes fast analysis for

(i) Functions which have discontinuities and sharp peaks

Its major computing components are fuzzy logic and neuro. The quality of fuzzy logic controller can be drastically affected by the choice of membership functions. So, tuning methods are required for fuzzy logic controllers to obtain more accuracy (Bashashati et al. 2005, Borisoff et al. 2004). Hence in order to overcome this, neural computing is adopted (Zhang & Lee 2009, Rabbi and Rezai 2012, Xu et al. 2004, Shoeb et al. 2011).

Advantages of soft computing methods

1) Resultant are obtained for solve non-linear problems, which do not possess mathematical model.

2) As the soft computing method considers the human Knowledge to the model systems it exploits the tolerance for approximation, uncertainty, and imprecision (Alexandre Teixeira et al. 2014, Majumdar 2011).

Neural Computing

Neural networks are nonlinear signal processing devices. They are interconnected by neurons. Neurons are responsible for processing information and the signals are transmitted by means of links. Thus the Interconnected 'nodes' has an 'activation function'. Patterns are given to the network via the 'input layer', and it will be communicated with one or more 'hidden layers'. These hidden layers then linked to an output layer (Walter et al. 2011, Yuan et al. 2011).

Bring the weight in the opposite direction of the gradient by subtracting a ratio of it from the weight (Gupta & McAvoy 2000, Gupta 2000). This ratio influences the quality and speed of learning; it is named as learning rate. The sign of the gradient of a weight specifies wherever the error is increasing; this is why the weight must be updated in the opposite direction (Guo et al. 2010, Jia 2011). Thus an epilepsy detection system using ANN highly depends on key factors which are described below:
Data:

The data acquired from EEG for seizure detection should be in valid and authentic.

Variables:

The variables used in the study mainly depends upon Minimum value of PSD, Maximum value of PSD, Mean of PSD and Standard Deviation of PSD which in turn are obtained from in each of the bands delta, theta, alpha and beta.

Dataset:

The data that are acquired for training plays a vital role in detecting the accuracy of seizures. Hence the volume of data acquired for training should be taken into consideration.

Training set:

The training set is the mainly important and it acts as the backbone for ANN based Seizure Detection system. It comprises of the input matrix and target matrix which is a collection of input and output for ANN. Hence, a better training set would result in better results (Mazurowski et al.2008).

Architecture of ANN:

The architecture of ANN is mainly depends on the number of layers, the number of neurons etc.
Types of Network:

Choosing an appropriate type of network plays a crucial role in faster detection of seizures. The training and detection is dependent on the types of the network (Riedmiller & Braun 1993, Guler et al. 2007). E.g. Multi Layer Perception (MLP), Multi Layer Feed Forward Network (MLFFN) etc. (Petrosian et al. 2000, Petrosian et al. 2001).

Feed forward Neural Network

Feed forward neural network is a widespread nonlinear modeling tool. It is so popular because it is particularly suitable for fine-tuning by optimization method and one to one mapping among input and output data (Übeyli 2009). This network makes use of back propagation algorithm. Thus the input-output relationship of the network is shown in the Figure 2.11.

![Feed forward neural network architecture](image)

**Figure 2.11  Feed forward neural network architecture**

In the figure 2.11,

\[ X_g \] - the total number of input data;
the node ‘$k$’ denotes the number of neurons present in the first hidden layer and

the node ‘$l$’ denotes the number of neurons present in the second hidden layer.

This hidden layer has a tan sigmoid (tan-sig) activation function and it is denoted as

$$\phi(z_i) = \tanh(v_i)$$  \hspace{1cm} (2.1)

The above said function is a hyperbolic tangent whose values varies from -1 to 1,

$z_i$ is the output of the $i^{th}$ node and

$v_i$ is the weighted sum of the input and the output layer.

Thus, the output of every layer can be denoted as

$$Y_{N \times 1} = f(W_{N \times M} X_{M \times 1} + b_{N \times 1})$$  \hspace{1cm} (2.2)

Where

$W$ is a matrix including the weights for each of M inputs for all N neurons,

$X$ is a vector including the inputs,

$b$ is a vector including the biases,

$f (~)$ is the activation function for both output layer and the hidden layer and

$Y$ is a vector including the output from each of the N neurons in each given layer.
The back propagation algorithm computes the error in the gradient descent and propagates it backwards to all neurons in the output layer, subsequently hidden layer. Then, the biases and weights are recalculated, and the outcome of the activated neurons is then transmitted forward i.e. the resultant is forwarded from the hidden layer to the output layer. The network is formulated with random biases and weights, and then it was trained by means of the Levinson-Marquardt algorithm. The weights and biases are updated according to the following equations

$$D_{n+1} = D_n - [J^T J + \mu I]^{-1} J^T e$$  \hspace{1cm} (2.3)

Where

- $D_{n+1}$ - a matrix including the new weights and biases,
- $D_n$ - a matrix including the current weights and biases,
- $e$ - network error,
- $\mu$ - a variable that decreases or increases depends on the performance function,
- $I$ - identity matrix and
- $J$ - Jacobian matrix.

In common, the Jacobian matrix consists of first order partial derivatives of a vector valued function. In case of the neural network, it is given by K-by-L matrix, where K is the number of inputs in the training set and L is the total number of parameters (biases + weights) present in the network. It can be calculated by taking the partial derivatives of each output with respect to each weight, and it form is represented below:
where $F(x_i, w)$ is the network function estimated for the $i$-th input vector of the training set with the weight vector $w$ and $w_j$ is the $j$-th element of the weight vector $w$ of the network. In conventional Levenberg-Marquardt implementations, the Jacobian is evaluated by utilizing finite differences. However, in neural networks, it is calculated using the first derivatives of the activation functions and the chain rule of calculus and it can be approximated by applying the Jacobian matrix with the formula:

$$H = J^T J$$

The gradient of the error surface is denoted by ‘$g$’ and is equivalent to $J^T e$.

**Feed Forward Neural Network Training**

The back propagation algorithm consists of two kinds of training modes namely batch mode and sequential mode.

In sequential training, a given input data is propagated forwardly and error is resolved and is back propagated. According the training, the weights are updated.

In the Batch mode of training, weights are updated only after the total set of training network are presented. Hence the weight update is only...
performed after every epoch. Thus the back propagation training algorithm is separated into two stages such as propagation and weight update.

**Propagation**

Each propagation encloses the following steps:

(i) In Forward propagation, the training pattern's is considered as inputs and if fed into neural network to create the propagation's output activations.

(ii) In Backward propagation, the propagation’s output activations of the neural network is used to generate the delta of all output and hidden neurons.

**Weight Update**

Each weight is updated by multiplying the input activation with that of the delta to obtain the gradient of the weight.

**No of hidden layers:**

The number of hidden layers also improves the accuracy of the system. A single layer network is enough for solving any problem with ease and rapidity, but it results in less accuracy. Hence a multilayer network is adopted in order to produce better results.

**Algorithms:**

Number of training algorithms are available. Hence an appropriate selection of training algorithms should be performed, to achieve fast and accurate results.
Weights/Bias:

Proper initialization of weights and bias would lead the network in a proper direction.

Learning Rate:

Higher the learning rate faster is the conversion and vice versa. A small learning rate may lead to a smooth conversion for better results with slow convergence whereas a high learning rate tends to a faster but less accurate results.

Threshold:

If an output is needed based on any particular condition than the threshold value has to be set.

Momentum:

For a smooth conversion of network, momentum factor should be less than 1.

Advantages of ANN model are:

(a) Has capability to train the network based on the optimization process.

(b) It produces an accurate estimation for nonlinear functions. Thus the performance of the neural networks is robust and efficient.

2.9 CLASSIFICATION METRICS OF THE CLASSIFIERS

Thus the performance of the classifier is measured by different statistical measurements such as Sensitivity (Sen), Specificity (Spec), Classification Accuracy (CA) and Receiving Operating Characteristic (ROC) curve.

Sensitivity:
It is the ratio of number of true positive (TP) decisions divided by the number of actual positive cases.

\[
\text{Sensitivity} = \frac{TP}{TP + FN}
\]

Where

TP- True Positive
FN- False Negative

Specificity:

It is the ratio of the number of true negative (TN) decisions divided by the number of actual negative cases.

\[
\text{Specificity} = \frac{TN}{TN + FP}
\]

Where

TN- True Negative
FP- False Positive

Classifications Accuracy:

It is the ratio of the number of correct decisions divided by the total number of applied cases.

\[
\text{Accuracy} = \frac{TN + TP}{\text{No. of applied cases}}
\]

2.10 SUMMARY

A panoramic view related to EEG and Epilepsy and the methods adopted for automatic epilepsy detection is elucidated in this chapter.