EEG COURSE

Workshop 1

“Basic principles and interpretations of electroencephalography”

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Basic principles and interpretations of electroencephalography

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Objectives:

At the end of the workshop, the participant will be able to:

1. Understand the principles of EEG recording.
2. Identify commonly encountered EEG artifacts.
3. Recognize normal awake and sleep EEGs in children and adults.
4. Interpret some common abnormal EEG patterns.

Electroencephalography (EEG) is the science relating to the electrical activity of the brain. The background electrical activity of the human brain was first analyzed in a systematic fashion by the German Psychiatrist Hans Berger (1929). Since then, EEG has been used in clinical practice to disclose non-epileptiform and epileptiform cortical dysfunction.

EEG recording.

EEG is recorded with scalp electrodes. The recordings may be bipolar or unipolar. Bipolar records show fluctuations in potentials between 2 electrodes and the unipolar record show potential difference between cortical electrodes and theoretically indifferent electrodes. A digital EEG machine allows any section of the record to be completely reformatted namely, viewed with any Montage, Gain, Filter or Timebase. The standard placement recommended by the American EEG society for use in the International 10-20% system is for 21 electrodes (Figure 1). The standard numbering system in the 10-20 system places odd-numbered electrodes on the left and even numbered electrodes on the right, with the letter designating the anatomic area.

Montage.

The term montage refers to the particular combination of electrodes examined at a particular point of time. In most instances, multiple montages are more useful than a single montage for long periods. The function of the montage is to record from all areas of the scalp and also to record activity in such a manner that it is easily perceived by the reader. The principal montages are longitudinal bipolar "Double Banana", coronal bipolar, circumferential bipolar, laplacian, common average referencial and ear (A1, A2) referential. It should be mentioned here that bipolar runs provide better localized focal or regional features, while the morphology of the widespread phenomena appear best on referential montages.

Physiological basis of EEG (EEG generator).

The activity recorded in the EEG is mostly that of the most superficial layers of the cortical gray matter. The potential changes in the cortical EEG are due to current flow in the fluctuating dipoles formed on the dendrites of the cortical cells and the cell bodies (Figure 2) namely current to flow through the volume conductor between "source" at the soma and basal dendrites and the "sink" at the apical dendrites sustaining excitatory postsynaptic potential (EPSPs). Figure 2 illustrates current paths taking increasingly remote curving routes. The zero potential surface is located halfway between the positive and negative poles of the dipole. To understand how electrical potentials are recordable on the scalp generated by populations of the pyramidal neurons, it can be easily understandable by the solid angle concept of the volume conduction theory. In this, the potential generated by a dipole layer in a volume conductor (brain and its environs) is proportional to the solid angle subtended by the dipole layer at the point of the measurement (Figure 3).
EEG interpretations. EEG interpretation requires a structured approach to ensure that important information is not lost or data misinterpreted. Prior to the interpretation, the only clinical data known to the reader should be the age of the patient. In evaluating an EEG pattern or event, one should answer the following: Is it an artifact? Is it a normal pattern? Hypothesis building about the possible abnormality (ies) during the analysis.

EEG analysis. The initial analysis of EEG includes the frequency or wave length of the background activity (Delta below 3.5/sec, Theta 4-7/sec, Alpha 8-13/sec, Beta above 13/sec and Gamma above 30 – unlimited range/sec), its voltage (micro-volts), waveform, manner of occurrence, locus, reactivity on eye opening or sensory stimuli, interhemispheric coherence (Symmetry and synchrony). (Figure 4 and Figure 5). A continuous waveform recorded from living tissue are usually sinusoidal. Sine waves of several frequencies usually appear together in clinical EEG to produce complex waveforms (Figure 6). This feature should be recognized in assessing such phenomena.

Epileptic and paroxysmal pattern. The term "Epileptic discharge" has been attacked and condemned on the ground that such discharges may occur in the absence of the clinical seizure. The same is true for the term "seizure discharge" or even "Paroxysmal discharge". However, in interpreting interictal paroxysmal pattern, the interpretator will frequently encounter abnormal waves like apikes (pointed peak with 20-<70 msec duration), sharp waves (pointed peak with 70-200 msec duration), polyspikes or multiple spikes (mostly bilateral/generalized synchronous discharges encounter in myoclonus, primary generalized epilepsy, photosensitive individual and children with LGS), runs of rapid spikes, spike wave complex (classical 3 Hz), slow spike wave (1-2.5 Hz) and periodic or quasiperiodic discharges.

Activation methods. Hyperventilation (HV), intermittent photic stimulation (IPS) or sleep are used in almost all clinical EEG laboratories to enhance pre-existing abnormalities or induce abnormal findings in an otherwise normal EEG. These methods are called activation procedures. Hyperventilation should be performed for a minimum of 3 minutes with continued recording for at least one minute after the cessation of over-breathing. Aside from diffuse slowing, it is effective in eliciting bilaterally synchronous spike wave discharges in a patient with generalized epilepsy. In IPS a strobe lamp is placed at a distance of 20-30 cm in front of the subject’s eyes. Flashes at frequencies of 1,3,6,9,10,15,20 and 40 Hz are given in trains of 5 second duration with eyes open and closed in a room with reduced illumination. The EEG changes induced by IPS are: photic driving (a physiological response consisting of rhythmic activity elicited over posterior region of the head), photomyoclonic response (brief repetitive muscle spikes over the anterior region of the head) and photoconvulsive response (characterized by spike-and-slow and multiple spike-and-slow wave complexes that are bilaterally synchronous, symmetrical and may out last the stimulus for a few seconds).

Localization and polarity. Localization of potentials plays a critical role in the clinical interpretations of EEGs. Accurate localization of an epileptiform discharge may help in identifying the epileptogenic zone. Most reviews of techniques of EEG localization have stressed the significance of a PHASE REVERSAL in bipolar montage and of AMPLITUDES in referential montages. Amplifiers for EEG recording are differential amplifiers namely, each channel records the difference in voltage between electrode selected for input 1 and that for input 2 (Figure 7). When the input 1 is more negative than input 2, the output "pen" deflects upwards. Other options of the pen deflections are shown in the figures (Figures 8, 9, 10, 11, 12, 13, 14, 15, 16, & 17). However, in referential recording an indifferent scalp electrode is connected to input 1 of each amplifier but a single common electrode is connected to input 2 of each amplifier.

Artifacts. Artifacts in EEG refers to any electrical signal that is not generated directly by the brain. Artifacts can mimic almost every kind of EEG pattern. The technologist and electroencephalographer need to be constantly alert to the possibility of artifact.

Clinical report consists of I) A technical description of the findings of the visual analysis. II) Technical Impression: Specifying general character of abnormality (focal, regional, diffuse, lateralized or combination of all). III) Clinical impression: Assess significance of EEG findings in terms of clinical history and findings.
Figure 1 - Electrode placement, according to the International 10-20% system.

Figure 4 - Shows the morphology and frequencies of the EEG waves.

Figure 2 - Demonstrate the source of scalp EEG. Note the distribution of current source (+) and current sink (-) fields around the isopotential line (0).

Figure 5 - Demonstrates the morphology of the paroxysmal wave forms.

Figure 3 - Shows the solid angles subtended by the P- and P+ electrodes.

Figure 6 - Shows effects of admixtures of the biological sine waves of different frequencies.
Figure 7 - Montage-bipolar longitudinal (double banana), the arrow indicates the connection of input 1 and input 2 to a differential amplifier.

Figure 10 - Shows the connection of input 1 and input 2 to the differential montage.

Figure 8 - Montage - referential/laplacian: individual input (input 1) is connected to the common average (input 2).

Figure 11 - Shows the rule of upward and downward movement of the recording pen.

Figure 9 - Montage-transverse connection (shown by arrows).

Figure 12 - Shows why the recording had negative and positive phase reversal.
Figure 13 - Describe the mechanisms involved in determining location of an epileptic focus.

Figure 14 - Shows the F3 negative.

Figure 15 - Shows the F3 positive.

Figure 16 - Shows the localization of the maximum negativity.

Figure 17 - Shown the bipolar montage with phase reversal.
In each of the following EEG indicate what the abnormalities are:

**EEG 1** - An 8-year-old male with history of nocturnal seizure. Transverse montage, sensitivity 100uv/cm. Note the potential shown by arrow.

**EEG 2** - A 24-year-old Saudi man with history of seizure. This is a longitudinal bipolar montage (double banana). Note the EEG changes shown by arrows.

**EEG 3** - A 24-year-old Saudi man with history of seizure: referential montage. Note the proximal events shown by the arrow.

**EEG 4** - A 13-year-old girl with the history of LOC (double banana montage). Note the EEG changes (arrows).

**EEG 5** - A 25-year-old, developed rigidity of the hands and rhythmic body movements and staring lasted for 8-10 minutes (doble banana montage). The recording was carried out during the above mentioned clinical seizure (arrow).

**EEG 6** - A 6-year-old girl with history of seizure. This is a laplacian montage. Note the events shown by the arrows.
EEG 7 - A 6-year-old girl with history of seizure. Laplacian montage. Note the change of the EEG event with the change of sensitivity (from 20μV to 30 μV/mm).

EEG 8 - A 17-year-old boy with history of dizziness. Double banana montage. Note the slow waves superimposed by muscle artifacts.

EEG 9 - A 12-year-old girl with history of headache. Laplacian montage. Note the change of the posterior alpha rhythm following a physiological maneuver (shown by arrows).

EEG 10 - A 4-year-old girl with history of GTCS. Laplacian montage. Note the paroxysmal events (shown by the arrow).

EEG 11 - A 12-year-old boy with history of sudden blindness for 10 minutes. Double banana montage. Note the posterior waves shown by the arrow.

EEG 12 - A 24-year-old Saudi with history of GTCS. Double banana montage. Note the paroxysmal response following intermittent photic stimulation (9Hz) the discharges overlast the stimuli.
EEG 13 - A 19-year-old girl with history of GTCS. A 19-year-old girl with history of generalized seizure. Double banana montage. This 10 seconds EEG records was carried out after 120 seconds of HV. Note the changes.

EEG 16 - A 6-year-old girl with history of LOC. Double banana montage. Note the potentials shown by the arrow.

EEG 14 - A 9-year-old girl with history of dizziness. Double banana montage. Note the EEG rhythm shown by the arrow.

EEG 17 - A 25-year-old male with history of GTCS. Transverse bipolar montage. Note the sharp waves shown by the arrow.

EEG 15 - A 13-year-old girl with history of headache. Double banana montage. Note the paroxysmal event shown by the arrow.

EEG 18 - A 6-year-old boy with history of LOC. Double banana montage. Note the EEG event shown by the arrow.
EEG 19 - A 5-year-old male with history of seizure during sleep. Double banana montage. Note the epileptiform discharges shown by the arrows.

EEG 22 - A 9-year-old Saudi girl, developed history of sudden blindness for 10 minutes for the last 4 years. Laplacian montage. Note the runs of epileptiform discharges shown by the arrow.

EEG 20 - A 25-year-old male with history of GTCS. A 25-year-old Saudi female with a history of GTCS. Double banana montage. Note the morphology and location of the epileptiform discharges (shown by the arrows).

EEG 23 - An 8-year-old Saudi girl with the history of headache and moving of black spots in her visual field. Referential montage. Note the distribution of the dipole epileptic discharge shown by the arrows.

EEG 21 - A 27-year-old Saudi male with a history of jerking of right upper limb. Laplacian montage. Note the location of the sharp wave discharge shown by the arrow.

EEG 24 - A 6-year-old male with recurrent GTCS (2 times in a week). This is a laplacian montage. Note the distribution of the dipole of the sharp wave, discharges shown by arrows.
EEG 25 - A 43-year-old male with recurrent GTCS. This is a double banana montage. Note the morphology and distribution of the epileptiform discharges.

EEG 28 - A 6-year-old girl with history of seizure. Laplacian montage. Note the discharge shown by the arrow.

EEG 26 - A one-year and 7-month-old Saudi baby with the history of birth asphyxia and seizure. This is a double banana montage. Note the distribution of the epileptiform discharges.

EEG 29 - A 6-year-old girl with history of seizure. This is a transverse montage. Note the advantage of the use of O1 and O2 connection in focalizing occipital focus (phase reversal).

EEG 27 - A 6-year-old girl with history of seizure. This is a double banana montage. Note the potential shown by the arrows.

EEG 30 - This is a 9-year-old boy with staring spell. Absence. Double banana montage. Note the pattern of the epileptiform discharges. The discharges lasted for more than 30 seconds with LOC.
EEG 31 - Double banana montage. Note the frequency of discharges.

EEG 32 - A 13-year-old patient, mentally retarded with the history of seizure. Double banana montage. Note the runs epileptiform discharges.

EEG 33 - A 13-year-old patient, mentally retarded with the history of seizure. Double banana montage. This is the next 10 seconds record of the previous one.

EEG 34 - This is a one-year-old child with history of flexion spasm. Double banana montage. Note the events shown by arrows.

EEG 35 - A 25-year-old Saudi lady with history of JME. Double banana montage. Note the burst of the epileptic discharges shown by the arrow.

EEG 36 - This is a 14-year-old Saudi boy with tonic-clonic seizure. Referential montage. Note the discharge shown by the arrow.
EEG 37 - This is a 12-year-old boy with history of nocturnal seizure. Double banana montage. Note the paroxysmal discharges arising from the normal background rhythm.

EEG 39 - This is an 8 and half year old male with history of road traffic accident and left sided hemiplegia with partial seizure. Double banana montage. Note the background potentials shown by the arrow.

EEG 38 - A 10-year-old boy with left sided weakness after bone marrow transplant. Double banana montage. Note the EEG changes shown by the arrow.

EEG 40 - A 58-year-old female with DM, HTN, Renal failure, MVR on warfarin with the history of generalized weakness, fatigue and confusion. Double banana montage. Note the runs of potentials shown by the arrow.

EEG 41 - A 6-month-old boy with Ohtahara syndrome. Double banana montage. Note the pattern of the discharges shown by the arrow.
Concluding remarks. Paroxysmal discharges in the EEG are indicators of deviant neuronal behavior. A solid experience in clinical EEG and familiarity with the magnitude of epileptic seizure disorders are the indispensable pre-requisites for a truthful and clinically useful interpretation of paroxysmal EEG events. Moreover, detection and interpretation of the EEG data from visual analysis involve matter of judgement and experience which render clinical EEG as art as much as a science.