ELECTROENCEPHALOGRAPHY

1. DEFINITION
   Electroencephalography (EEG) represents the graphic record method of the electrical cerebral activity with the help of electrodes placed on the scalp or with deep microelectrodes, being the most important method of functional cerebral exploration.

2. THEORETICAL BASIS
   The nerve cells in the brain produce signals that are called action potentials. These action potentials move from one cell to another across a gap called the synapse. Special chemicals called neurotransmitters help the signals to move across the gap. There are two types of neurotransmitters, one will help the action potential to move to the next cell, the other will stop it moving to another nerve cell. The brain normally works hard to keep an equal amount of each of these neurotransmitters in the brain.
   EEG activity is quite small, measured in microvolts (µV) with the main frequencies of interest up to approximately 30 Hertz (Hz). Electrical cerebral activity stems from the activity of cortical pyramidal neurons, modulated by sub-cortical structures and being closely connected to the modifications of membrane potential. These modifications can be represented by:
   - the action potential - the total and brief depolarisation (nervous impulse) which is transmitted unaltered along the axon.
   - the post-synaptic potentials (PSP) - form sub-synaptically and spread decrementally (electrotonically) in dendrites in the following manner:
     - if the modification results in depolarisation, it will have an excitation effect = the post-synaptic excitation potential (PSEP),
     - if it acts in a hyperpolarising manner, it will have an inhibitory effect = the postsynaptic inhibition potential (PSIP)
   Cortical electrical fields form at the level of the pyramidal neuron group with the same cytoarchitectonics and functional state, the group being able to synchronize their electrical activity. The fields spread through heterogeneous media such as the meninx, LCR, skullcap, subcutaneous tissue, which is why they surface reduced and distorted. Caught by nonpolarisable electrodes, amplified almost 1 million times, cortical electrical fields are graphically represented by quasi-sinusoidal oscillations whose frequency and amplitude varies from a cortical region to another, maintaining their inter-hemispheric symmetry.

3. INDICATIONS
   - neurology – epilepsy, meningoencephalitis, degenerative processes;
   - neurosurgery – craniocerebral traumas, expansive neoplastic processes, benign tumours, vascular malformations;
   - psychiatry – psychic diseases, neuroses;
   - intensive care – assessing the depth of coma and the diagnosis of clinical death.

4. MATERIALS, TECHNIQUE
electroencephalograph, electrodes (small metal discs called electrodes are placed on the scalp in special positions). These positions are identified by the recordist who measures the head using the International 10/20 System. This relies on taking measurements between certain fixed points on the head. The electrodes are then placed at points that are 10% and 20% of these distances. Each electrode site is labelled with a letter and a number. The letter refers to the area of brain underlying the electrode e.g. F - Frontal lobe and T - Temporal lobe. Even numbers denote the right side of the head and odd numbers the left side of the head.

Placing and attaching the electrodes on scalp is done after having degreased the skin with alcohol and having applied some saturated saline solution or electrolytic paste on the electrodes, the patient being allowed to remain seated or lying on his back having a supporting device under the cervical region. The perfect contact between skin and electrode is one of the essential conditions for obtaining a quality EEG.

-Calibrating system: it records amplitude - the 5 mm vertical movement of the recording stylus corresponds to 50 µV amplitude, and the speed at which the paper moves – 15 mm/sec.

EEG RECORDING STAGES
- Reference diagram – wakefulness, eyes closed, physical and psychical relaxation;
- Diagram on opening eyes;
- Diagram on eyes closed and activation through hyperpnea;
- Intermittent light stimulation with 6 Hz and 12 Hz;
- Supplementary activations.

METHODS OF EEG ACTIVATION
The EEG diagram must be recorded both at rest and on activation of the evoked electrical cortical activity. The methods of cortical activation through various stimuli aim at triggering electrical pathological manifestations, which are absent on a spontaneous EEG diagram.

• Hyperpnea. Voluntarily taking 25-30 breaths/ min during 3 minutes determines a respiratory alkalosis (hypocapnia) secondary to hyperventilation which physiologically induces the increase of cortical excitability and the amplification of the synchronising effects of subcortical structures. In pathological conditions, hyperventilation can determine vasoconstriction, cerebral spasms, ischemia and cerebral hypoxia.
• Intermittent light stimulation (ILS). It is done with the help of the stroboscope which generates intermittent light stimuli, with the frequency of 4-30 flashes/sec. (Hz). The most used frequencies are those of 6 Hz and 12 Hz, applied for 2-3 minutes.
• Supplementary activations. They refer to methods of activating the EEG diagram done with the aim of diagnosing epilepsy, done only with the help of the specialist neurologist physician, there existing the possibility of offering first aid in the case of the start of an epileptic seizure:
  - sound activation – for diagnosing of audiogenic reflex epilepsy;
  - medicinal activation – for establishing of the convulsion threshold;
  - medicinal sleep activation – is done only in children as the irritative manifestations appear on falling asleep and waking up, or activation through sleep privation for 36-48 hours – which is useful for all forms of epilepsy.

5. NORMAL CEREBRAL BIOELECTRICAL RHYTHMS

The EEG rhythm is defined as a succession of waves with the same characteristics – frequency, amplitude, duration, morphology, regional topography and reactivity to stimuli. EEG activity can be broken down into 4 distinct frequency bands:
- Beta activity > 13 Hz
- Alpha activity 8 Hz-13 Hz
- Theta activity 4 Hz-7 Hz
- Delta activity < 4 Hz

Beta activity represents the dominant rhythm in adults in the state of wakefulness, eyes open, expressing the state of cortical excitation. It tends to be seen in the channels recorded from the centre or front of the head. Some drugs will increase the amount of beta activity in the EEG. The characteristic amplitude of this rhythm is 5-30 μV and the frequency of 13-30 Hz. Unlike the alpha rhythm, beta waves are very irregular and indicate the desynchronising of the neuronal activity in the anterior frontal and parietal cortex.

Alpha activity (rhythm) is also a normal activity when present in adults during the state of wakefulness, with eyes closed, in conditions of physical and psychical relaxation. It is mainly seen in the channels recorded from the back of the head. It is fairly symmetrical and are low amplitude oscillations, of approximately 50 μV and of medium frequency, 8-13 Hz (cycles per second) slower in children and old people and more rapid in states of cortical hyperexcitability. Between the two hemispheres there is a difference in amplitude which does not exceed 5-10 μV, the amplitude being reduced in the dominant hemisphere. Under the impulse of the light stimuli (opening eyes) and on focusing attention, a rhythm will be replaced by beta rhythm, a blocking reaction, or will decrease in amplitude with over 50% of the initial value, the desynchronising reaction. The same phenomenon is produced in the case of cortical activity, emotive state, etc. These waves reflect the synchronic electrical activity of the neurons in the occipital cortex.
Theta activity can be classed as both a normal and abnormal activity depending on the age and state of the patient. It is the dominant rhythm in adults during the first stages of sleep (superficial sleep) and in children aged between 2 and 7. Theta (θ) waves are waves with a frequency of 4-7 Hz (under 8 c/s) and a maximum amplitude of 20 μV. Although they are normal in children, their presence in adults, during the state of wakefulness, is considered pathological. In adults it is normal if the patient is drowsy. However it can also indicate brain dysfunction if it is seen in a patient who is alert and awake.

![Theta activity](image)

**Theta activity**

Reactivity to stimuli:
1. Rhythm completely blocked by the light stimuli is described,
2. Which is amplified along with the intensification of mental processes and
3. Only influenced by the affective-emotional state.

Delta activity is only normal in an adult patient during profound sleep, being also encountered in anaesthesia states, during which the ascendant reticulated activating system is inhibited. These waves have the highest amplitude 50-200 μV and a low frequency: 0.5-3.5, of maximum 4 Hz. The presence of delta waves in the state of wakefulness of adults indicates the existence of some cerebral lesions, cerebral tumours, hypoglycemia, hypocalcemia, cerebral hypoxemia, barbiturate coma, etc. Reactivity to stimuli: the lack of response to any stimuli.

![Delta activity](image)

**Delta activity**

**Gamma rhythm**

Gamma waves have a high frequency, around 30-100 Hz. These are recorded on the electroencephalogram in conditions of intense, superior cortical activity, as for example: perception, solving of complex problems, fear, conscience, etc.

![Gamma activity](image)

There are a number of other waveforms which tend to be a little more specific to certain conditions. For example spike and wave activity indicates a seizure disorder and may be seen in the EEG even if the patient is not having an epileptic seizure. Other epileptic
conditions may be diagnosed if spikes or sharp waves are seen. Triphasic waves are sometimes seen if the patient has severe liver or kidney disease that is affecting brain function.

Spike and wave activity

**EEG PHYSIOLOGICAL DIAGRAMS**

An EEG normal diagram is characterised by the existence of a dominant rhythm, of 10 Hz and medium amplitude of 20-100 μV. The amplitude reflects the number of neurons which function synchronically and not the degree of activity of each neuron. When the brain is active (state of wakefulness) low amplitude waves predominate; when the brain is inactive (during profound sleep) high amplitude and low frequency waves predominate because neurons tend to function synchronically.

**The EEG diagram of an adult in the state of wakefulness**

- on the reference diagram, there is a posterior a rhythm, with a tendency of forming spindles and presenting a discrete interhemispheric asymmetry (less ample in the dominant hemisphere), b rhythm in anterior derivations and isolated q waves in temporal derivations; a rhythm is “blocked” or “desynchronised” on opening eyes; Hyperpnea induces a rhythm a higher amplitude and a lower frequency;
- on ILS, the passive acquiring of the stimulation frequency by the occipital a rhythm can be noticed.

**The EEG diagram in child**

- the suckling presents a slow activity type d, polymorphous, generalised, with a frequency of 3 c/sec and an amplitude of de 30-40 μV;
- between the age of 2 and 4, the incidence of d rhythm drops and the incidence of q rhythm increases; between the ages of 4 and 8, q is the dominant rhythm;
- after the age of 8, a rhythm starts appearing, firstly unstable together with q rhythm which will progressively withdraw towards the temporal areas, while a rhythm occupies the posterior areas;
- after the age of 10, a rhythm becomes unstable and appears modulated in spindles, in the occipital derivations;
- between the ages of 12 and 14, the EEG rhythms of adults, a and b, appear. At puberty, cerebral rhythms are more labile and give a more ample answer to hyperpnea.

**The EEG diagram of an elderly subject**

The diagram presents reduced modifications compared to middle age and the modifications consist of:

- the decrease of the a rhythm incidence as the rhythm becomes slower and less ample,
- the increase of the q rhythm incidence with a tendency of anterior migration,
- decrease of reactivity to hyperpnea.

**EEG DIAGRAMS DURING SLEEP**

Judging by the morphological aspect of diagrams, slow sleep (telencephalic) or non-REM (non-Rapid Eye Movements) and fast (rhombencephalic), delirious, paradoxical sleep or REM are indicated.

1. **SLOW SLEEP = non-REM**

It takes 75-80% from the total duration of night sleep (6-6.5 hours). According to how
profound the sleep is, one can notice:

- **Stage I (A)** = the stage of passing from the state of wakefulness to the relaxation phase, being manifested through the decrease of incidence and frequency of a rhythm.
- **Stage II (B)** = of falling asleep, in which a rhythm is replaced by low amplitude q rhythm.
- **Stage III (C)** = is translated by the decrease in frequency of the diagram at 4-5 Hz because a slow q rhythm has appeared and an intermittent d activity.
- **Stage IV (D)** = profound sleep expressed through a polymorphous, generalised d activity, without the specific elements evoked by sleep.

2. **FAST SLEEP = REM**

In adults, it takes 20-25% of the night sleep duration and it takes place in stages II or III of slow sleep. In children, fast sleep represents 40% and, in the elderly, 10%. It appears discontinuously, in 5-6 cycles, at intervals of 70-90 minutes, the duration of each cycle being of 5-20 minutes. Fast sleep is characterised by:

- the appearing of a faster d or q rhythm, with frequencies between 2-6 Hz.
- slow waves indicated as “saw teeth” are characteristic and they appear in the derivations of the vertex and precede the rapid and ample movements of eye balls (REM) indicated on the oculogram.
- at the same time EMG is suddenly flat, and ECG records a more rapid and often irregular cardiac rhythm.

The fast sleep is dominated by dreams. Privation of fast sleep is conducive to concentration and memory disorders. The subject awaken during the stage of paradoxical sleep can tell almost 80% of a dream content.

**PATHOLOGICAL EEG CHARTS**

These are the EEG charts which show irritative (epileptic or non-epileptic) electrical or (superficial or profound) lesion manifestations which can be localized or generalised, spontaneous or evoked.

1. **EEG chart of an irritative type**

It has specific graphical elements which allow the setting of a diagnosis and the assessment of the seriousness of the irritative cortical event:

- the irritative manifestations are the peaks, the slow sharp waves, the peak/wave complexes, poly-peak/wave complexes and the typical periodical discharges.
- the irritative diagram is associated in children with cortical immaturity and the convulsive syndrome, and in adults with the affective-emotional disorders, endocrinal-metabolic disorders.

The main manifestation of cortical irritability is epilepsy or the epileptic crisis. The EEG petit mal epilepsy (pyknolepsy) is characterised by the appearing peak-wave complexes, with an amplitude of several hundreds μV and a frequency of 3 Hz.

2. **EEG lesion chart**

It comprises aspects of the electrical silence type, the flattening trajectory, pathologic q or d activity, particular aspects of the q or d rhythm. A trajectory indicating lesions brings important information regarding the modifications of the electrical cerebral activity in cranialcerebral traumas, cerebral tumours, vascular malformations, meningoencephalitis, degenerative processes, etc.