Electroencephalograph (EEG)

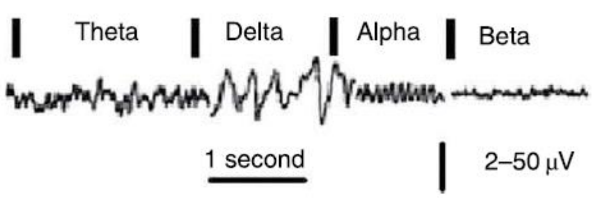
Electroencephalograph (EEG) is an instrument for recording the electrical activity of the brain, by suitably placing surface electrodes on the scalp. EEG machines are used for diagnosing a variety of neurologic diseases, such as epilepsy, convulsive disorders, brain death, cerebrovascular lesions, ischaemia, and problems associated with trauma. They can also be used to evaluate psychiatric disorders and differentiate among various psy- chiatric and neurologic conditions. It is also effectively used in the operating room to facilitate anaesthetics to establish the integrity of the anaesthetized patient's nervous system. In addition, routine EEG monitoring in the operating room and intensive care units is also becoming popular. This has become possible with the advent of small, computer-based EEG analysers.

Principle

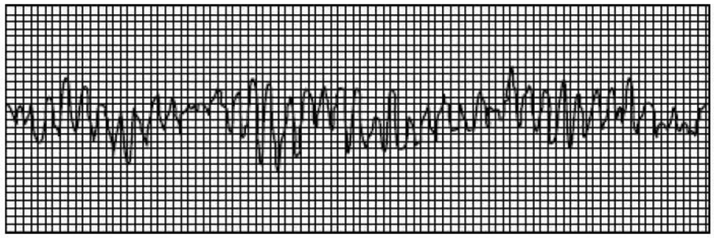
The brain generates rhythmical potentials, which originate in the individual neurons of the brain. These potentials are summated as millions of cells discharge synchronously and appear as a surface waveform, the recording of which is known as the electroen- cephalogram. The EEG signals are of great diagnostic value both in terms of their amplitude and frequency as shown in Table.

Table The basic frequency of the EEG range

Delta (δ)	0.5-4 Hz
Theta (θ)	4-8 Hz
Alpha (α)	8-13 Hz
Beta (β)	13-22 Hz
Gamma (γ)	22-30 Hz



Typical EEG waveform with classification in different frequency components.

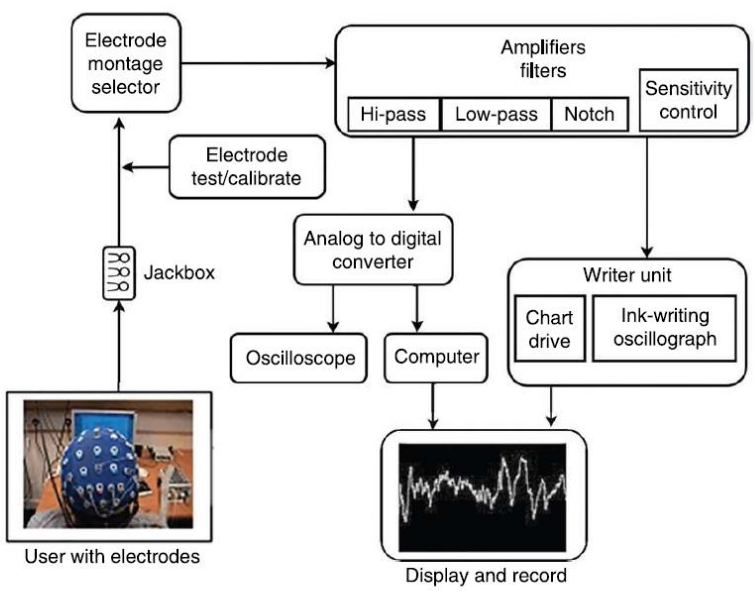


Typical EEG signal waveform

EEG signals picked up by the surface electrodes are usually small as compared with the ECG signals. Their amplitude varies from 10 μV to over several hundreds of microvolts, but 50 μV peak to peak is the most typical. The brain waves, unlike the electrical activity of the heart, do not represent the same pattern over and over again. Therefore, brain recordings are made over a much longer interval of time in order to be able to detect any kind of abnormalities. The EEG signal bandwidth is from below 1 Hz to over 100 Hz.

Block Diagram

EEG machines employ electrodes placed on a patient's scalp to measure, amplify, display in graphic form, and record the weak electrical signals generated by the brain. The processed EEG signals are usually recorded in graphic form over a period of time so that waveform and pattern changes can be readily studied for possible diagnosis. Modern EEG monitors use computers to analyse and generate large amounts of electroencephalographic data, which are processed and displayed in various formats. Most systems produce and display certain types of event-related EEG signals that occur in response to can a periodically applied external stimulus. The basic block diagram of an EEG machine with both analog and digital The subsystems is shown in Figure below



Block diagram of a typical EEG machine.

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Electrodes

The electroencephalogram is typically recorded by picking up the voltage difference between an active electrode on the scalp and a reference electrode on the ear lobe or any other part of the body. This type of recording is called 'monopolar' recording. However, 'bipolar' recording is more popular wherein the voltage difference between two scalp electrodes is recorded. Such recordings are done with multi- channel EEGs.

Several types of electrodes may be used to record EEG. They are usually smaller in size than ECG electrodes and include peel and stick electrodes, silver-plated cup electrodes, and needle electrodes. In general, needle electrodes provide greater signal clarity because they are injected directly into the body. For surface electrodes, there are disposable models such as the tab, ring, and bar electrodes. There are also reusable discs that may be combined into an electrode cap that is placed directly on the head. EEG surface electrodes are smaller in size than ECG electrodes. They may be applied sepa- rately to the scalp or may be mounted in special bands, which can be placed on the patient's head. In either case, electrode jelly or paste is used to improve the electrical contact by minimizing skin-electrode impedance. مهمة أنواع الالكترود التي تستخدم في EEG

EEG electrodes give high skin contact impedance as compared with ECG electrodes. Good electrode impedance should be generally below 5 k.Q. Impedance between a pair of electrodes must also be balanced or the difference between them should be less than 1 k.Q. Before measurement, contact impedance should be measured, and EEG trace should be observed while recording. EEG preamplifiers are generally designed to have a very high value of input impedance to take care of high electrode impedance. Using today's technology, high input impedance (1G) amplifier chips and active electrode approaches decrease dependency of the contact impedance.

Montages

EEG machines are multi-channel machines and they require many electrodes to pick the EEG signal. Many systems typically use electrodes, each of which is attached to an individual wire. However, some systems use caps or nets into which electrodes are embedded. This system is particularly common when high-density arrays of electrodes are used. In this case, there are several ways of choosing the electrode pairs according to specific montages. A pattern of electrodes on the head and the channels they are connected to is called a montage. The reference electrode is generally placed on a nonactive site such as the forehead or earlobe. EEG electrodes are arranged on the scalp for most clinical and research applications according to a standard known as the 10/20 system, adopted by the American EEG Society. This system ensures that the naming of electrodes is consistent among laboratories. Conventionally, there are 21

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electrode (19 recording electrodes plus ground and system reference) locations in the 10/20 system. This system involves placement of electrodes at distances of 10 and 20% of measured coronal, sagittal, and circumferential arcs between landmarks on the cranium. Electrodes are identified according to their position on the head: Fp for frontal polar, F for frontal, C for central, P for parietal, T for temporal, and O for occipital. One electrode is labelled isoground and placed at a relatively neutral site on the head, usually the midline forehead or a metal clip on the earlobe. A new montage convention has been introduced in which electrodes are spaced at 5% distances along the cranium. These electrodes are closely spaced and have their own naming convention.

يتم وضع القطبين على الرأس Fp: للقطب الجبهي، F للجبهي، C للمركزي، Pللجداري، T للصدغي، و O للقذالي . يتم وضع علامة على أحد الأقطاب الكهربائية على أنه أرضي متساوي ويتم وضعه في مكان محايد نسبيًا على الرأس، عادةً الجبهة الوسطى أو مشبك معدني على شحمة الأذن. تم تقديم اتفاقية مونتاج جديدة حيث يتم وضع الأقطاب الكهربائية على مسافات 5٪ على طول الجمجمة. هذه الأقطاب الكهربائية متقاربة ولديها اتفاقية تسمية خاصة بها.

Amplifiers

Every EEG channel is provided with individual, multistage amplifier with differential input and adjustable gain in a wide dynamic range. A typical adult human EEG signal is about 10-100 V in amplitude when measured from the scalp and is about 10-20 mV when measured from subdural electrodes. The preamplifier used in EEGs must have high gain and low noise characteristics as the EEG potentials are small in amplitude. In addition, the amplifier must have a very high common mode rejection to minimize stray interference signals from power lines and other electrical equipment. The input impedance should be greater than 20MQ. The common mode rejection ratio (CMRR) should be at least 100dB for each input. The amplifier must be free from drift so as to prevent the slow movement of the recording pen from its centre position as a result of changes in temperature. EEG amplifiers must have high gain in the presence of unbalanced source resistances and DC skin potentials at least up to 100mV. Noise performance is crucial in EEG work because skin electrodes couple brain waves of only a few microvolts to the amplifier.

Each individual EEG signal is preferably amplified at the bedside. Therefore, a specially designed connector box, which can be mounted near the patient, is generally employed with EEG machines. This results in the avoidance of cable or switching arte facts and also eliminates undesirable crosstalk effects of the individual electrode potentials. The section of the amplifiers, which receive direct signals from the patient, uses optical isolators to separate the main power circuitry from the patient to separate the possibility of accidental electric shock. The connector box also carries a circuit arrangement for measuring the skin contact impedance of electrodes. Thus, poor electrode-to-skin contacts above a predetermined level can be easily observed. The preamplifier is followed by a high gain amplifier in which the analog signal is converted to a digital signal, which is more suitable for output. These amplifiers together amplify the voltage between the active electrode and the reference, typically 1000-100 000 times, or 60-100 dB of voltage gain. A typical value of the calibration signal is 50 uV/cm

Filters

Just like in an ECG, an EEG record may also contain muscle artefacts when recorded by surface electrodes. The artefacts could be large and sharp, in contrast to the ECG, causing great difficulty in both clinical and automated EEG interpretations. The most effective way to eliminate muscle artefact is to use low pass filters. In addition, high pass filters are employed, which typically filters out slow artefact, such as DC signals and movement artefact, whereas the low pass filter filters out high frequency artefacts, such as EMG signals. EEG machines also have a notch filter sharply tuned at 60 Hz so as to eliminate mains frequency interference. Typical settings for the high pass filter and a low pass filter are 0.5-1 Hz and 35-70 Hz, respectively. Selecting the proper filter band (at least bandwidth must be 0.5-70 Hz) is important to acquire proper signal. This is important for digitizing and data storage.

Recorder

In analog EEG machines, after the signal is filtered, it is given to the paper recorder. However, most EEG systems today are digital, and the amplified signal is digitized via an analog-to-digital converter. Analog-to-digital sampling typically occurs at 256-512Hz in clinical scalp EEG and sampling rates of up to 20 kHz are used in some research applications. The writing part of an EEG machine in older versions was direct writing thermal recorder. The best types of pen motors used in EEG machines have a frequency response of about 90 Hz. The modern PC-based machine can give a printout from a laser printer. In direct writing recorders, the paper drive is provided by a synchronous motor. An accurate and stable paper drive mechanism is necessary, and it is normal practice to have several paper speeds available for selection. Speeds of 15, 30, and 60mm/s are commonly used. A timescale is usually registered on the record by one or two time marker pens, which make a mark once per second. Timing pulses are preferably generated independently of the paper drive mechanism in order to avoid difference in timing marks due to changes in paper speed.

Channels

An electroencephalogram is recorded simultaneously from an array of many electrodes. Commercial EEG machines have up to 32 channels, although 8 or 16 channels are more common. Microprocessors are now employed in most of the commercially available EEG machines to permit customer programmable montage selection. These machines use a video monitor screen to display the selected pattern (montage) as well as the position of scalp sites with electrode-to-skin contact. Individual channel control settings for gain and filter positions can be displayed on the video monitor for immediate review.

Modern EEG machines are mostly PC based. The EEG is displayed on a large screen colour monitor with a resolution of 1280 x 1024 pixels. The user interface is through an ASCII keyboard and the output is available in the hard copy form through a laser printer. Specialized medical software is used to analyse, display, and provide special functions and options, which can be helpful in diagnosis of brain-related diseases.

Recording of Evoked Potentials

A special technique in electroencehlography is the recording of electrical potentials from the surface of the skull, when an external stimulus is applied to a sensory area of the brain. The electrical potentials generated as a result of the stimulus response are known as the 'evoked potentials' Evoked potential activity is distinct from spontaneous potentials as detected by EEG, EMG, or other electrophysiologic recording method. Evoked potential amplitudes are generally low as compared to the EEG signal. They are in the range of less than a microvolt to a few microvolts. The most frequently used evoked potentials for clinical testing include visual evoked responses, brainstem auditory evoked responses, and somatosensory evoked potentials.

Visual evoked potential (VEP): The VEP tests the function of the visual pathway from the retina to the occipital cortex and thus helps in diagnosis of problems with the optic nerves that affect sight. VEPs are usually evoked by light flashes or visual patterns such as a checkerboard or a patch. A healthcare professional places electrodes along the scalp to record the electrical signals as the patient watches a checkerboard pattern flash for several minutes on a screen. Brainstem auditory evoked potentials (BAEPs): The BAEP measures the functioning of the auditory nerve and auditory pathways in the brainstem. Auditory evoked potentials are usually elicited by tones or clicks. BAEPs are helpful in estimating the assessment of hearing ability and can point to possible brainstem tumours or multiple sclerosis. A healthcare professional places electrodes on the scalp and earlobes and delivers auditory stimuli, such as clicking noises and tones, to one ear. The frequency of stimulation is 50-70 Hz, and at least three different intensities are generally used.

Specifications

1- Number of channels: 32 channels
2- Frequency response: 0.1-70 Hz
3- Input impedance: >20 MQ
4- CMRR: 100 dB
5- Noise: < 1.5 V peak to peak
6- Input range: 5000 uV peak to peak
7- High pass filter for each channel: 15, 35, and 70 Hz
8- Low pass filter for each channel: 0.1, 0.3, 1.5, 3, and 5 Hz
9- Display: Split screen to compare the data of same time/different times with individual
10- selection of filters, sensitivity, and montages
11- Software: Standard software with patient annotation, create a map of the brain
12- Stimulator: Photic using LED or xenon flashlights

Applications

The main diagnostic application of EEG machine is for the diagnosis of epilepsy, which manifests itself as clear abnormalities on a standard EEG study. The other applications are in the diagnosis of coma, encephalopathies, and brain death. EEGs can also help to identify causes of other problems such as sleep disorders and a first-line method for the diagnosis of tumours, stroke, and other brain disorders.

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