

In Clinical Practice

Abdul Qayyum Rana · Ali T. Ghouse  
Raghav Govindarajan

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# Neurophysiology in Clinical Practice

 Springer

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# Neurophysiology in Clinical Practice

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*To our beloved families, colleagues, students, and,  
most important, our patients who have inspired us  
to complete this work.*

# Preface

Neurophysiology rotations can be challenging for beginners, and they may require several weeks to become familiar with various aspects of neurophysiology. Even after residency and fellowship training, the practitioner may feel they still don't have mastery of the field. This handbook is designed to provide a basic introduction to neurophysiology for practicing physicians, advanced care providers, fellows, and residents, as well as medical students doing their neurophysiology rotation. This guide is meant to help the reader to understand the basics of neurophysiology and its clinical applications, but it is not a comprehensive review.

The handbook is divided into two sections. Part I (Chaps. 1, 2, 3) describes electroencephalography and Part II (Chaps. 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, and 23) discusses electromyography and nerve conduction studies. All of the information presented in this manual has been reviewed for accuracy and practice; however, the authors/editors and publisher are not responsible for any errors, omissions, or consequences arising from the application of this information, and they make no expressed or implied warranty of the contents of this publication. Suggestions to improve this publication are welcome and should be directed to the authors.

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**Part I**  
**Electroencephalography**

# Chapter 1

## Basics of Electroencephalography (EEG)

### Physiology

Electroencephalography (EEG) is the noninvasive recording and measuring of the electrical activity of the cerebral cortex, with surface EEG performed via electrodes placed on the scalp. The recorded voltage activity is the net difference between ionic current flows within the brain, controlled by N-methyl-D-aspartate (NMDA) glutamate receptors becoming permeable to calcium ions. An EEG recording is a summation of numerous different frequencies. The depolarization and synchronous activation of many neurons generates epileptiform activity. The spike and wave activity seen in epilepsy is likely caused by cyclic depolarization and repolarization. The inhibiting feedback of the neurons results in the ultimate cessation of the epileptiform activity. The thalamus is considered to be the main site for the origin of cortical excitability. A minimum of 6 cm<sup>2</sup> of cortical synchronous activity is needed to create a recordable scalp potential on surface EEG.

This short review of the basic principles of EEG recording and interpretation, while by no means exhaustive, should assist the reader in becoming competent in requesting and interpreting an EEG report.

## EEG Recording

Biological signals consist of various different sequences. Filters are used to exclude frequencies that are less useful. EEG machines have a 60-Hz filter, which removes activity in the 60-Hz range and helps in eliminating artifacts from the line voltage that affect physiological recordings. The use of different montages, that is, different organizations of scalp electrodes, allows for different methodologies to be used in reading the EEG recording. With these montages, the same event will vary because of the different electrode pairings.

The following are the frequencies of different waves seen in a routine EEG recording:

Delta waves have a frequency of 1–3.99 Hz.

Theta waves have a frequency of 4–7.99 Hz.

Alpha waves have a frequency of 8–12.99 Hz.

Beta waves have a frequency above 13 Hz.

TABLE 1.1 Electroencephalographic waves

Wave	Frequency	Normal	Abnormal
Alpha	8–12.99 Hz	Dominant rhythm during wakefulness. May be identified by its reactivity and suppression by eye opening. Maximally seen over occipital deviations	Diffuse alpha pattern seen in coma
Beta	above 13 Hz	Normal sleep rhythm in young children. May become more prominent in adults when changing from wakefulness to drowsiness	Amplitudes >50 seen with barbiturate and benzodiazepine use. Lower unilateral voltage may represent cerebral edema or dural fluid collections. Loss of beta activity implies cortical injury

TABLE 1.1 (continued)

<b>Wave</b>	<b>Frequency</b>	<b>Normal</b>	<b>Abnormal</b>
Delta	1–3.99 Hz	Normal sleep rhythm. Delta waves may be induced by hyperventilation. Found in one-third of adults within the frontocentral regions during eye-closed wakefulness	Intermittent rhythmic delta activity with polymorphic delta activity in focal lesions
Theta	4–7.99 Hz	Normal in sleep and drowsiness, may be present in posterior slow waves of youth	Temporal theta pattern in the elderly or focal theta activity over a structural lesion

Amplifiers are used to magnify the signal for its display. Electrodes are an integral part of the circuit, which consists of the patient and the recording equipment.

Electrode gel provides a contact between the skin and the electrodes and is considered an extension of the electrode. High electrode impedance and loose electrodes can result in electrode “pops,” which are spike-like potentials that occur randomly.

Epileptiform activity consists mainly of spikes and sharp waves. Spikes have a duration of less than 70 ms, whereas the sharp waves have a duration of 70–200 ms.

TABLE 1.2 Epileptiform rhythms

<b>Description</b>	<b>Normal</b>	<b>Abnormal</b>
<i>Spikes</i> : up to 70 ms	Vertex waves, positive occipital sharp transients of sleep	Focal and generalized epileptiform activity
<i>Sharp waves</i> : 70–200 ms	Benign epileptiform transients of sleep 6/s phantom spike and wave 14-and-6 positive spikes	

TABLE 1.3 10–20 electrode placement system

F	Frontal
Fp	Frontopolar
C	Central
T	Temporal
P	Parietal
O	Occipital
A	Auricular

Sixteen channels are typically used for a routine scalp EEG. The seventeenth channel is used for electrocardiography (ECG).

Electrodes are placed according to the International 10- to 20-electrode placement system.

The following letters stand for the following electrodes:

As shown in Fig. 1.1, the odd numbers are on the left side of the head, whereas the even numbers are on the right side. The lower numbers are on the anterior side of the head and the higher numbers are on the posterior side. The midline electrodes are indicated by “z” instead of a number.

The electrodes are arranged in montages (arrays), of which there are several, the two most common being the referential (Fig. 1.2) and the bipolar (Figs. 1.3 and 1.4) montages. Changing the montage in an EEG recording will affect the waveforms present due to the change in electrode pairing.

A common referential montage indicates that the reference for each electrode is common; for example, each electrode may be referred to the ipsilateral ear. A bipolar montage means that the reference for one channel is active for the next channel, e.g., F7-T3 means that F7 is the active electrode and T3 is the reference, whereas T3-T5 means T3 is the active electrode and T5 is the reference electrode.

EEG negativity can represent a superficial excitation or a deep cortical inhibition. The upward deflection of a recording is negative, whereas the downward deflection is positive. Spikes originate in the electrode common to a phase reversal. When EEG data was acquired in the analogue mode, a routine EEG recording typically used referential, longitudinal