NORMAL EEG AND THE RANGE OF NORMAL

John Stern, MD
Geffen School of Medicine at UCLA
Los Angeles, CA

Introduction

One truism for EEG is that there are more ways of being normal than abnormal. That is, normal variants are numerous, EEGs are not required to include all of the normal features to be considered normal, and an EEG that does not include a clearly abnormal feature can be considered normal by default. Moreover, some abnormal patterns have features that are similar to normal patterns, so every potentially abnormal finding should be scrutinized as a possible normal variant. Familiarity with the range of normal is clearly critical to accurate interpretation of EEG.

Background Rhythms

The ongoing activity during EEG is a combination of frequencies and often manifests as a narrow frequency band with fluctuations in amplitude and intermittent mixing with other frequency bands. This variation typically takes place over seconds and may transition to an entirely different background over minutes. With knowledge of this, the first step in the review of an EEG is the assessment of the rhythmic activity across the recording with attention to the frequencies, amplitude, symmetry, and transitions. This assessment will indicate the patient's behavioral state (awake, drowsy, asleep, encephalopathic) and whether focal dysfunction is present. However, the behavioral state assessment cannot rely entirely on the cerebrally generated rhythms because level of alertness and response to external stimuli is needed to interpret whether diffuse slow activity represents normal sleep or encephalopathy. Attention to the technologist's notation about behavioral state and recognition of muscle, eye movement, and head movement artifact is needed to accurately interpret the background activity.

State Change

Progression from full wakefulness into non-REM sleep is common during outpatient, sleep-deprived EEGs. Wakefulness is evident in vertical eye movements (blinks), muscle artifact, a frequency gradient with beta frequencies anteriorly and alpha frequencies posteriorly, and an alpha rhythm across the occipital region that blocks (attenuates) with eye opening. However, an alpha rhythm is not required in normal wakefulness. Its presence depends on relaxed wakefulness, so excessive vigilance or cognitive activity can attenuate it. It also may be absent as a normal variant. With drowsiness, the alpha rhythm may disappear or slow in frequency and the frontal beta activity may become more prominent or be replaced by central or temporal theta activity. Artifacts also may change with a decrease in muscle activity and the development of slow, lateral eye movements. With greater drowsiness and transition into sleep, vertex sharp transients and then sleep spindles and K complexes may occur. Identifying wakefulness and the level of drowsiness or sleep depends on the combination of all of these features and recognition that not all have to be present for a specific state.

Normal Asymmetry

Focal dysfunction is reflected in a significant asymmetry in the amplitude or frequency of background activity, and the key to recognizing the abnormality is knowledge of the normal variation in symmetry. This partly relies on an awareness of the impact of montage on the appearance of a rhythm and also the intermittent nature of symmetry. The montage is important because the appearance and localization of a focal finding when using a bipolar montage is influenced by the spatial extent of the underlying activity. The essential problem is greatest when the two electrodes producing the output channel are closer together than the expanse of the activity. This situation reduces the amplitude and sometimes eliminates the rhythm because of the differential amplification (subtraction) that produces one channel from two electrode inputs. Considered from a topographic perspective, the amplitude in a channel is a slope and the slope at the top of a plateau is minimal, regardless of the plateau's altitude. In practice, amplitude is optimally assessed with a

distant reference electrode because such an electrode is more likely to be beyond the local field. As such, the distance between the two electrodes is more important than their locations. One common approach is the use of a common reference electrode montage. The Cz electrode is especially helpful because of its midline, central location. Cz's equal and greater distance from each lateral region increases its likelihood of being beyond the lateral activity's field. However, a Cz reference would not be as useful when considering parasagittal slowing because it is more likely to be influenced (contaminated) by the adjacent activity. A bipolar montage is more reliable when the focal slowing is not broadly distributed.

After accurately determining the amplitude, asymmetric low amplitude is identified by a relative difference between contralateral, homotopic regions and not by a specific voltage value. For the posterior dominant rhythm, an amplitude asymmetry is expected and the right side is more often larger in amplitude. This asymmetry is normal unless the right's amplitude is more than 2 times the amplitude of the left. The left alpha rhythm is not typically larger in amplitude, and its allowable asymmetry is 1.5 times the amplitude of the right. For frontal-central beta activity, asymmetry is less common and the maximum normal relative asymmetry is 1.5 times.

The intermittent nature of symmetry can produce asymmetry that is present on one side at one time and then on the other side at another time with equivalent occurrences of each side's slowing. This is called a shifting asymmetry and is a normal variant because the asymmetry is not present over an averaged longer time frame. Recognizing shifting asymmetry requires a conscious awareness of each occurrence of asymmetric slowing in the context of a recollection of the prior occurrences of slowing. Essentially, the EEG reader mentally averages the changes through the tracing. Stated differently, recognizing shifting asymmetry requires actively thinking about shifting asymmetry.

Focal slowing typically refers to a frequency difference that is beyond a frequency band. This can be the occurrence of theta activity in a region producing alpha activity, the occurrence of delta activity in a region producing theta activity, or the loss of beta activity in a region producing a combination of both beta and alpha activity. Nevertheless, focal slowing within the posterior dominant rhythm can be due to a smaller frequency difference. The standard definition of normal has the posterior dominant rhythm's asymmetry as less than or equal to 1 Hz.

References

Ebersole JS, Pedley TA. Current Practice of Clinical Electroencephalography, 3rd Ed. Lippincott Williams & Wilkins, 2003.

Fisch B. Fisch and Spehlman's EEG Primer, 3rd Ed. Elsevier, 1999.

Krauss GL, Fisher RS, Kaplan PW. Johns Hopkins Atlas of Digital EEG, 2nd Ed. Johns Hopkins University Press, 2010.

Stern JM. Atlas of EEG Patterns, 2nd Ed. Lippincott Williams & Wilkins, 2013.