Epileptiform Electroencephalographic Patterns

BARBARA F. WESTMORELAND, M.D.

Electroencephalography (EEG) is the most useful test for assessment of patients with epilepsy. It can help establish the diagnosis of epilepsy and determine the type of seizure disorder and its site of origin. Epileptiform abnormalities in the EEG tracing may be focal or generalized. The main types of focal epileptiform discharges arise from the temporal, frontal, occipital, centroparietal, centrotemporal, and midline regions of the brain. Generalized epileptiform discharges consist of the 3-Hz spike-and-wave, slow spike-and-wave, atypical spike-and-wave, paroxysmal fast activity, and hypersarrrhythmic patterns. Status epilepticus is manifested by continuous epileptiform discharges or recurrent seizure activity without interim recovery, which can occur in a generalized or focal manner. Benign epileptiform variants unassociated with seizures can also be present in the EEG. Included in this category are the “14 & 6” positive bursts, small sharp spikes, wicket waves, 6-Hz spike-and-wave discharges, and rhythmic temporal theta activity. The EEG findings should be interpreted in the context of the overall clinical picture.

FOCAL EPILEPTIFORM ACTIVITY

Focal epileptiform discharges arise from a localized area of the brain, and the site of origin depends on (1) the degree of epileptogenicity of the area of the brain involved, (2) the type and location of the lesion, and (3) the age of the patient. The area of the brain most prone to seizures is the hippocampus (in the temporal lobe), followed by the sensorimotor strip adjacent to the central sulcus and the frontal lobe. These areas have the lowest threshold and greatest susceptibility for developing seizures. The parietal and occipital lobes are less epileptogenic. The type of lesion is important in the development of seizures. Certain types of vascular lesions, such as arteriovenous malformations, are more likely to be associated with epileptiform activity than are other types. Similarly, slow-growing tumors are more likely to be associated with seizures than are rapidly progressive ones. The severity, type, and site of head trauma determine the likelihood of development of focal epileptiform abnormalities.

Infants, children, and adults have different susceptibilities and patterns of seizures, and characteristic age-related expression and distribution of spikes have been noted at certain ages. For example, generalized 3-Hz spike-and-wave discharges and rolandic spikes are seen primarily in children, whereas temporal discharges are more common in adults. The main types of focal epileptiform activity are those arising from the temporal, frontal, occipital, centroparietal, midtemporal, and central midline areas of the brain.

Temporal Discharges.—Temporal discharges, the most frequent type of focal epileptiform abnormality, are associated with complex partial seizures (Fig. 3). Complex partial seizures are manifested by alterations in consciousness,
automatisms, various motor and sensory accompaniments, cognitive and affective symptoms, speech disturbances, or some combination of these findings. Temporal discharges have a high correlation with the presence of seizures. This high frequency of development of seizures is related to the epileptogenic proclivity of the hippocampus. In addition, the temporal lobe constitutes a major portion of the cerebral hemispheres and is susceptible to various types of...
lesions, including trauma, vascular insults, tumors, and encephalitis.

Temporal discharges are often activated during drowsiness and sleep and occur more than twice as frequently during sleep as during the awake state. Therefore, in a patient thought to have seizures that originate in the temporal lobe, an EEG study should include a sleep recording.

Temporal discharges may be associated with slowing of EEG activity. A characteristic finding in patients with seizures arising from the temporal lobe is temporal intermittent rhythmic delta activity (Fig. 3). This pattern consists of rhythmic slow-wave activity occurring intermittently and represents the surface reflection of the underlying epileptogenic focus.

During a recorded seizure, the EEG may show ictal discharges consisting of repetitive and incremental sharp waves, spikes, rhythmic slow waves, or sinusoidal waveforms. After the seizure, some degree of postictal (post-seizure) slowing may be evident over the involved area. Although temporal epileptiform abnormalities can occur in persons of any age, they are seen most frequently in adolescents and adults.

**Frontal Discharges.**—Epileptiform discharges arising from the frontal region may include spikes, sharp waves, spike-and-wave discharges, multiple spike-and-wave discharges, or paroxysmal fast activity consisting of "trains" of repetitive spikes. Frontal discharges are also highly epileptogenic, and a large percentage of patients with frontal discharges have seizures. Moreover, seizures can rapidly generalize from a frontal focus. Frequently, vascular lesions, tumors, or head trauma and associated scarring produce a frontal epileptogenic focus. Seizures arising from the frontal lobe can manifest as focal motor seizures, deviation of the eyes or head to one side, tonic posturing, drop attacks, absence seizures, complex partial seizures, or secondarily generalized seizures. Frontal discharges have been noted in all age-groups.

**Occipital Spikes.**—Occipital spikes are an age-related EEG finding; they occur unilaterally or bilaterally in children younger than 6 years of age and then subsequently disappear. They are not highly epileptogenic; approximately half of the children with this type of spike discharge will not have seizures. Many of the children, however, have amblyopia, strabismus, or problems with vision. "Needle sharp spikes," consisting of a brief spike discharge, occur in congenitally blind children and do not have a high association with seizures. Although occipital spikes in young children may be a relatively benign finding, their
presence in older children or adults is often associated with such lesions as vascular malformation, tumor, trauma, or cerebral dysgenesis. If seizures are present, they usually are associated with visual symptoms such as scintillating scotomas, unformed visual hallucinations, flashing lights, or a dimming of vision in the contralateral visual field. 

Benign epilepsy of childhood with occipital paroxysms consists of unilateral or bilateral high-voltage spike-and-wave discharges that occur over the occipital regions after eye closure. Such discharges have been seen in children with migraine headaches. 

**Centroparietal (Rolandic) Spikes.**—Centroparietal (rolandic) spike discharges are also an age-related finding, occurring mainly in children between 4 and 10 years old. 

These discharges are not highly epileptogenic; only about half of the children with such spikes have seizures. The episodes usually consist of focal motor or sensory seizures that can become secondarily generalized. Some patients with centroparietal spikes may have some type of motor dysfunction, mental retardation, or cerebral palsy with or without an associated seizure disorder. The EEG abnormality usually is a blunt spike-and-wave discharge or low-amplitude monophasic spikes.

**Centrotemporal Spike Discharge of Childhood.**—Centrotemporal spikes occur preponderantly in children 4 to 14 years old. 

The spike discharge is maximal (that is, has the highest amplitude) in the central and midtemporal electrodes; however, if additional electrodes are used, the spike is maximal over the lower rolandic area, immediately superior to the sylvian fissure. Characteristically, the discharge consists of a diphasic blunt spike, followed by a slow-wave component. The discharge may be present unilaterally or bilaterally, or it may alternate from side to side on subsequent EEG recordings. Occasionally, the side of the spike discharge may not correspond to the hemisphere giving rise to the seizures or ictal symptoms. Sleep potentiates the occurrence of the spike discharge, and at times, these discharges may be detected only during a sleep recording. The centrotemporal spikes often manifest as a transverse dipole in the EEG, with peak positivity over the anterior head regions and peak negativity over the central and temporal regions. This feature is unique to centrotemporal spikes.

Approximately 60 to 80% of children with centrotemporal spikes have seizures. Centrotemporal spikes seen in children with seizures have been referred to as “sylvian seizures,” “benign rolandic epilepsy of childhood,” or “benign seizures of childhood.” These seizures often have a focal sensory or motor onset that consists of paresthesias or twitching of the side of the face or hand. During such seizures, patients may be unable to speak because of motor speech arrest, and they may have excessive salivation or drooling because of difficulty with swallowing. The seizure may spread and become secondarily generalized, with clonic or tonic movements of the body. The seizures often occur during sleep or as the child awakens from sleep. Most patients with benign rolandic epilepsy have no evidence of cerebral lesions, and the seizures and spike discharges usually disappear spontaneously during adolescence. Centrotemporal spikes as well as centroparietal spikes may also be seen in children who are asymptomatic and do not have seizures.

**Midline Epileptiform Discharges.**—Midline epileptiform discharges arise from the midline region, most commonly over the central vertex area. The discharges occur as either spikes or sharp waves, and they may have some reflection to the adjacent parasagittal region. The seizures consist of various motor and sensory phenomena, with onset in the leg. One type of seizure that arises in the supplementary motor area of the mesial frontal region is characterized by elevation and abduction of the arm on one side in conjunction with deviation of the head and eyes to the elevated arm. In addition, the patient may have rhythmic movements of other parts of the body, motor or speech arrest, and generalized body sensation.

**Periodic Lateralized Epileptiform Discharges.**—Periodic lateralized epileptiform discharges (PLEDs) are focal or lateralized epileptiform EEG discharges that occur periodically. They may consist of spikes, sharp waves, slow waves, or complex waveforms recurring every 1 to 3 seconds (Fig. 4). PLEDs may be associated with electrographic seizure discharges consisting of repetitive trains of spikes or sharp waves or rhythmic activity over the involved area. PLEDs are often seen in association with an acute or subacute disturbance of cerebral function, such as a vascular insult, encephalitis, rapidly growing tumor, abscess, head trauma, or subdural hematoma, and they may appear after an intracranial operation.

Patients with PLEDs usually have an abrupt onset of seizures, obtundation, and a neurologic deficit referable to the area involved. The seizures may last for several days and be difficult to control with anticonvulsants. The clinical seizures and PLEDs usually resolve after 1 to 3 weeks. PLEDs represent an acute epileptic focus and occur in response to some acute or subacute insult to the cerebral hemispheres. Depending on the underlying process, they can evolve into other types of EEG abnormalities or resolve with neurologic recovery.

**GENERALIZED EPILEPTIFORM DISCHARGES**

The main types of generalized epileptiform patterns are the 3-Hz spike-and-wave discharges, slow spike-and-wave pattern, atypical spikes and waves, paroxysmal fast activity, and hypsarrhythmia.
**3-Hz Spike-and-Wave Discharges.**—3-Hz spike-and-wave discharges are associated with absence (petit mal) seizures. The typical EEG pattern consists of generalized stereotyped bisynchronous and symmetric spike and slow-wave bursts that recur at a rate of 3 Hz (Fig. 5). The discharges usually have a maximal amplitude over the anterior head regions. In addition, 3-Hz spike-and-wave discharges often occur in repetitive trains, and if the bursts last:

longer than 3 or 4 seconds, the patient often has a clinical accompaniment. Such clinical occurrences may consist of altered consciousness, staring, cessation of what the patient had been doing, or brief clonic movements such as blinking of the eyes or twitching of the eyelids. Hyperventilation often induces absence seizures and 3-Hz spike-and-wave bursts. Hypoglycemia can also enhance the presence of these discharges; however, alerting the patient attenuates the discharges.\textsuperscript{1,4} During sleep, the stereotypic pattern of 3-Hz spike-and-wave discharges assumes a more irregular or atypical spike-and-wave burst.

Absence seizures and the 3-Hz spike-and-wave pattern occur mainly in children and adolescents. The EEG pattern and seizures usually resolve after adolescence but can persist into adulthood.\textsuperscript{3,4}

**Slow Spike-and-Wave Pattern.**—The slow spike-and-wave discharges (also referred to as “generalized sharp-and-slow wave complexes”) have a frequency of 1.5 to 2.5 Hz, and the spike component has a blunter appearance than that of the 3-Hz spike and wave.\textsuperscript{1,5,20,21} The slow spike-and-wave discharges are usually generalized, but they can occur with a shifting emphasis from side to side or have more lateralized or focal expression. The discharges may occur as single spike-and-wave discharges or in repetitive trains that last several seconds. Often patients have no apparent clinical accompaniment. Drowsiness frequently enhances the presence of the spike-and-wave discharges. During sleep, generalized spikes, multiple spikes, or bursts of paroxysmal fast activity may occur. The intervening background activity is often abnormal, with focal or generalized slowing, asymmetry, or other types of epileptiform discharges. The slow spike-and-wave discharges are usually seen in young children who have some underlying organic disturbance of cerebral function; children with slow spike-and-wave discharges usually have severe seizure disorders with onset early in life. The seizures (tonic, tonic-clonic, clonic, atypical absence, akinetic, or myoclonic seizures) typically are generalized and may be difficult to control.\textsuperscript{3,4,20,22} Many patients with the slow spike-and-wave discharges also have signs of mental retardation and other neurologic deficits. The combination of frequent seizures, mental retardation, and the slow spike-and-wave EEG pattern constitutes the Lennox-Gastaut syndrome.\textsuperscript{21}

**Generalized Atypical (Irregular) Spikes and Waves.**—Atypical spike-and-wave discharges do not have the stereotypic appearance of the 3-Hz or slow spike-and-wave pattern. Instead, they consist of spike or multiple spike-and-wave components with frequencies that range from 2 to 5 Hz.\textsuperscript{1} The bursts are usually brief (less than 2 or 3 seconds) and may or may not have a clinical accompaniment (a brief absence seizure or myoclonic jerk). Sleep may help activate the spike-and-wave bursts, and sometimes photic stimulation may entrain bursts of atypical spikes and waves (a photoparoxysmal response) if the patient has light sensitivity. The atypical spike-and-wave pattern may be seen in patients of any age and with various types of generalized seizure disorders.\textsuperscript{1}

**Generalized Paroxysmal Fast Activity.**—Generalized paroxysmal fast activity consists of repetitive spike discharges between 8 and 20 Hz that occur in association with tonic seizures or at the onset of a generalized tonic-clonic (grand mal) seizure. The EEG accompaniment of a generalized tonic-clonic seizure consists of initially generalized paroxysmal fast activity, which is associated with tonic stiffening of the body (the tonic phase). The EEG activity then decelerates, at which time the patient has generalized shivering or trembling movements. Subsequently, the EEG shows generalized spike-and-slow wave discharges, during which time the patient has clonic jerks (the clonic phase). The clonic jerks coincide with the spikes, and the periods of relaxation between jerks coincide with the slow waves. The spike-and-slow wave discharges diminish in association with a decrease in the clonic jerks. Finally, the spike-and-wave discharges cease and are replaced by generalized slowing or attenuation of the EEG activity in the postictal phase (Fig. 6). During the postictal period, the patient is unresponsive. As the patient recovers, the EEG shows a return of background activity.

**Hypsarrhythmia.**—Hypsarrhythmia is a high-voltage arrhythmic pattern consisting of multifocal spikes and slow waves that occur almost continuously.\textsuperscript{3,5} Patients with this type of pattern often have infantile spasms or myoclonic jerks. The infantile spasms consist of flexion or extension movements of the body and last for several seconds.\textsuperscript{2,24} The EEG accompaniment of an infantile spasm consists of an initial high-voltage spike or sharp wave-and-slow wave complex, followed by an abrupt decrement or flattening of the EEG tracing (an electrodecremental pattern) that lasts for several seconds.\textsuperscript{2,24} Myoclonic jerks are brief and associated with a generalized high-voltage spike or spike-and-wave discharge in the EEG. The combination of the EEG pattern of hypsarrhythmia and infantile spasms has been termed “West syndrome.” This condition is an age-related epileptic entity seen in children younger than 1 or 2 years. It is a result of an insult or disease process that occurs at an early age, usually before 6 months.\textsuperscript{23} In half of the patients, this syndrome may result from prenatal, perinatal, or postnatal insults; infectious disease processes; congenital defects; tuberous sclerosis; or genetic, biochemical, or metabolic derangements seen in infants or young children. In the other half of the patients, the cause is unknown.\textsuperscript{3,4,23} In most patients, the presence of a hypsarrhythmic pattern indicates a poor prognosis; most children have mental retardation and persistent seizures.
**Status Epilepticus.**—Status epilepticus consists of recurrent or continuous seizure activity without recovery between the seizures. Convulsive status or generalized tonic-clonic status (grand mal status) consists of recurrent generalized tonic-clonic seizures in which the patient does not recover consciousness between the seizures. The EEG shows continuous or frequent repetitive generalized spikes, spike-and-wave discharges, or trains of repetitive spikes or paroxysmal fast activity (Fig. 7).

Nonconvulsive status or absence status (petit mal status) is associated with repetitive or continuous generalized spike-and-wave or multiple spike-and-wave discharges. Patients with nonconvulsive status may have altered consciousness, confusion, somnolence, myoclonic jerks of the body, blinking of the eyes, or automatic behavior, or they may appear to have a psychiatric or cognitive disturbance. Nonconvulsive status, which can be seen in any age-group, can occur in patients with seizures or in those with other underlying metabolic, medical, or neurologic disorders.

Focal status epilepticus, also called "epilepsia partialis continua," consists of recurrent or continuous focal spikes, sharp-wave discharges, or rhythmic activity in the EEG in association with continuous or repeated focal motor or sensory seizures.

Complex partial status occurs in association with continuous or repeated discharges over the temporal or frontal region. Patients with complex partial status usually have altered consciousness, confusion, automatic behavior, or apparent psychiatric or cognitive disturbances.

The EEG is helpful in determining the presence of status epilepticus or repeated seizures in patients with confusion or altered behavior at the time of assessment. Although status epilepticus often occurs in patients with seizures, it is also seen in patients who have other acute underlying neurologic
or medical problems, such as metabolic, toxic, or infectious processes; head trauma; vascular insults; or mass lesions.

**BENIGN EPILEPTIFORM VARIANTS**

Benign epileptiform variants are waveforms that have an epileptiform appearance but are not epileptogenic—that is, they are not associated with seizure disorders.29 The benign variants occur mainly during drowsiness and light sleep and disappear during deeper levels of sleep. They are seldom seen in patients in the fully alert state. Most of the waveforms of the benign variety occur diffusely or bilaterally, with a shifting emphasis from side to side. The benign variants include "14 & 6" positive bursts, small sharp spikes, wicket waves, 6-Hz spike and wave, and rhythmic temporal theta bursts of drowsiness.

**14 & 6 Positive Bursts.**—The 14 & 6 positive bursts consist of spike discharges that occur in rhythmic trains of 6 or 14 Hz.5,30 They have an arciform appearance with a spike component and a smooth-rounded waveform that resembles a "spiky spindle" (Fig. 8). The spike component appears as a surface positive waveform with an ear reference recording—hence, the term "positive spikes" or bursts. The 14 & 6 positive bursts are expressed maximally over the posterior temporal and parietal regions, and the bursts often occur independently over the two sides and may shift from side to side in predominance or may predominate over one side. The 14 & 6 positive bursts are seen most often in teenagers.29

**Small Sharp Spikes.**—Small sharp spikes are also referred to as "benign sporadic sleep spikes" and "benign epileptiform transients of sleep."29,31 Small sharp spikes are usually low-amplitude, short-duration, single spikes that occur as either a monophasic or a diphasic waveform with an abrupt ascending limb and a steep descending limb,29,32 which may be followed by a single short slow-wave component or decline in the background activity (Fig. 9). Small sharp spikes are seen predominantly in the temporal region and occur independently on the two sides. The following features distinguish small sharp spikes from more significant epileptiform abnormalities: small sharp spikes are not associated with a disturbance of the background or rhythmic slow-wave activity; they do not occur in repetitive trains; they are bilateral; and they disappear with deeper levels of sleep.29 Small sharp spikes are seen primarily in adults.29,31

**Wicket Waves.**—Wicket waves consist of monophasic arciform spikes that occur singly or in intermittent trains. Because of the arciform appearance, they look like wickets (Fig. 10).33 Wicket waves occur mainly over the temporal regions and may shift in prominence over the two sides or occur predominantly on one side. They usually have a frequency of 6 to 11 Hz and can be distinguished from more significant epileptogenic abnormalities by the absence of an aftercoming slow-wave component or distortion or slowing of the background activity. Wicket waves occur predominantly in adults.
6-Hz Spike and Wave.—The 6-Hz spike and wave (also known as the "phantom spike and wave") is a generalized spike discharge with a repetitive rate of 6 Hz (range, 5 to 7 Hz). The bursts are usually brief (less than 1 or 2 seconds) and consist of a low-amplitude spike, with an aftercoming slow-wave component that is more prominent and of higher amplitude. Because the presence of the spike may occasionally be difficult to appreciate, the label "phantom" was applied. The 6-Hz spike and wave has a diffuse distribution but may predominate over the anterior and posterior head regions. The atypical form of the 6-Hz spike and wave may be difficult to distinguish from a more significant spike-and-wave discharge. One distinction is that the benign 6-Hz spike and wave tends to disappear during sleep, whereas more significant spike-and-wave discharges persist and become more prominent in deeper levels of sleep.

Rhythmic Temporal Theta Bursts of Drowsiness.—Rhythmic temporal theta bursts of drowsiness (referred to previously as the "psychomotor variant pattern") consist of rhythmic activity in the theta range (from 5 to 7 Hz). The activity may have a sharp-contoured or notched appearance due to a mixture of faster and slower frequencies or harmonics of the background frequency. The rhythmic temporal theta bursts of drowsiness occur predominantly over the temporal regions, usually being maximal in the midtemporal area; the bursts may occur bilaterally or independently or shift from side to side over the two hemispheres. Because of its rhythmic nature, rhythmic temporal theta bursts of drowsiness may resemble a seizure-related discharge; however, it can be distinguished from a seizure discharge by its gradual onset and disappearance and by the monorhythmic pattern.
or monomorphic nature of the pattern, which does not 
evolve into other frequencies or waveforms. It occurs during 
relaxed wakefulness and drowsiness and is seen in adoles­
cents and adults.

CONCLUSION
The EEG is helpful in the assessment of patients with sei­
zures. It can confirm or establish the diagnosis of seizures, 
determine the type and site of origin of a seizure, and help 
distinguish between a seizure and a nonepileptic condition. In 
addition, other EEG findings may provide clues about the 
underlying disease process. A sleep recording is particularly 
useful for disclosing epileptiform abnormalities. Repeated 
EEGs or more prolonged recordings may be helpful in eliciting 
the epileptiform abnormalities. Normal EEG findings, 
however, do not exclude the diagnosis of seizures or epilep­
sy. Because the diagnosis of epilepsy is a clinical one, the 
EEG should be interpreted in the context of the entire clinical 
setting.

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