The EEG of Status Epilepticus

Peter W. Kaplan

Summary: Gastaut noted that there are as many forms of status epilepticus (SE) as there are seizure types. The pleomorphic EEG patterns reflect this wide variety of clinical types. The different electroclinical types of status epilepticus share EEG characteristics including rhythmic activity, epileptiform discharges, and often a waxing and waning evolution. Gray zones of interpretation exist in the form of runs of epileptiform periodic discharges, typically of lower frequency, and lesser temporal variability. In diagnosing SE, clinical correlation and response to parenteral anti-epileptic drugs (AEDs) are of particular importance. Accurate diagnosis of electroclinical type is essential, because it determines prognosis and dictates the intensity of therapeutic management. Some patients with benign forms of SE may benefit from nonparenteral treatment, and be followed up clinically and by spot EEGs. Conversely, intensive care unit management with anesthesia and continuous monitoring, and parenteral AEDs may be required for refractory convulsive SE.

Key Words: Nonconvulsive status epilepticus, Encephalopathy, EEG, Triphasic waves, Periodic waves, PLEDs, BiPLED, GPEDs, Electrographic seizures, Periodic discharges.

As noted by Gastaut, “there can be as many forms of status epilepticus as there are seizure types” (Gastaut, 1983). The EEG of status epilepticus (SE), therefore, encompasses a great variety of EEG seizure patterns. Nonetheless, particular similarities are present among the various types. In discussing the EEG of SE, there is also the need to understand the usefulness and the uncertainties of interpreting the EEG. To address some of these issues, this article will review the patterns of epileptiform activity typical of SE, and those that are controversial in the diagnosis or misdiagnosis of SE. Typical and atypical cases of SE will be used to illustrate these themes.

Status epilepticus remains an important subject, because of the significant morbidity and mortality that attends some types of SE. Such potential morbidity represents a medical emergency, and engenders the need for rapid and accurate diagnosis and for effective and safe treatments.

Obtaining good-quality EEGs or prolonged monitoring in either the emergency room or in intensive care units (ICUs) presents significant technical challenges. The recording environment may be plagued with artifact produced by movement around the patient, nursing of the patient, intrusion of the effects of machinery such as respirators, intravenous drip artifact and any machine that propagates 50 or 60 Hz electromagnetic noise. The patient’s movement, vibrating beds, and muscle artifact can even produce tracings that may highly resemble SE (Hirsch, 2005).

In a particular patient in an ICU, obtaining an EEG may be difficult, because of the patient’s attendant needs for sterility; the presence of significant burns or open wounds (in the burn unit); limited access created by bandages, or open wounds of the skull and scalp. There is also competition for access to the patient who needs to be nursed, changed, wounds dressed or may be sent off for other tests such as MRI or computed tomography.

DEFINITIONS

Status epilepticus was characterized by Gastaut in 1983 as being present “when an epileptic seizure is so frequently repeated or so prolonged as to create a fixed and lasting condition” (Gastaut, 1983). Shorvon (2001, 2005) more recently enlarged on this definition, describing SE as “a term used to denote a range of conditions in which electrographic seizure activity is prolonged for 30 minutes or more and results in nonconvulsive clinical symptoms.” The determination of nonconvulsive status epilepticus (NCSE), however, presents other challenges. Because, by definition, convulsive movements must be absent for this diagnosis to be present, there is the need to identify whether a state of ongoing seizure activity is present. Defining NCSE mandates the use of an EEG to establish the presence of ongoing seizures. Much ambiguity remains, however, in what an electroencephalographer would identify as seizures. Seizures are not merely the presence of epileptiform activity lasting for 30 minutes, because there are a number of states with confusion and obtundation that may have an EEG correlate showing epileptiform morphologies. Some such states are triphasic waves (TWs), the presence of profuse interictal activity, and some patterns of epileptiform activity without ictal significance (rhythmic midtemporal theta of drowsiness or wicket-spikes). A convenient formulation of NCSE is the alteration of consciousness or behavior from baseline state for at least 30...
minutes without convulsive movements, and the presence of one or more of the following epileptiform patterns:

1. Repetitive focal or generalized epileptiform activity (spikes, sharp waves, spike-and-wave, sharp-and-slow wave complexes) or rhythmic theta or delta activity at more than two per second.
2. The above EEG patterns at less than one per second, but with improvement or resolution of epileptic activity and improvement in the clinical state following intravenous injection of a rapidly acting antiepileptic drug, such as a benzodiazepine.
3. A temporal evolution of epileptiform or rhythmic activity at more than one per second with change in location or frequency over time.

Some such patterns will be reviewed under a classification of NCSE into 1) complex partial status epilepticus (CPSE), and 2) generalized nonconvulsive status epilepticus (GNSE). A list of the different types of partial onset SE and primary generalized SE is given in Tables 1 and 2.

### Simple Partial Status Epilepticus

Simple partial status epilepticus (SPSE) involves identifying a focal, subjectively perceived or visible, behavioral change without mental status change. This may involve motor activity, for example, nystagmus (Fig. 1), jerking of half the face or the limbs on one side; sensory disturbance (e.g., with numbness, a burning sensation, or alteration in sensory awareness of part of the body), “special sensory” alteration (e.g., visual, auditory, olfactory), autonomic (e.g., sweating, salivation, pallor or pupillary dilatation); or psychic alteration (e.g., visual, auditory, olfactory), autonomic (e.g., anger, fear, happiness, illusions, hallucinations). The EEG correlates of such states vary from no perceptible change on the EEG (largely because the seizure focus is too focal, correlates of such states vary from no perceptible change on the EEG (largely because the seizure focus is too focal, circumscribed or too distant from the recording electrode) to ictal patterns with combinations of spikes, spike and waves, polyspikes and rhythmic slow activity. Recordings with depth electrodes have revealed that seizure activity is, indeed, circumscribed or too distant from the recording electrode) to ictal patterns with combinations of spikes, spike and waves, polyspikes and rhythmic slow activity. Recordings with depth electrodes have revealed that seizure activity is, indeed, present even while the scalp (surface) EEG remains normal (Kaplan, 1992). Many of these states clearly go unrecognized both because the clinical symptomatology is not thought to be epileptic and/or the EEG remains uninformative. In some cases, ictal single photon emission computed tomography (SPECT) scanning can reveal the focal, ictal nature of the disorder (Fig. 3) (Kaplan, 1999).

The most common and arguably the most morbid type of status is secondarily generalized convulsive status epilepticus (SGCSE). It may be accompanied by coma and lead to death, often in a third of cases. There are many etiologies, ranging from trauma, to infection, to malignancy, to underlying epilepsy, and it may occur at any age. As clearly demonstrated by Treiman et al. (1990), the EEG correlate of this dynamic condition often reflects a progression from overt to subtle clinical and subtle EEG manifestations (Treiman et al., 1990).

### Primary Generalized Convulsive Status Epilepticus

This rare entity is usually seen in patients with genetic epilepsies manifesting as convulsive seizures, who are non-compliant with their medication. In summary, the clinical and EEG progression are those of SGCSE with the exception that there is no progression to a state of “subtle status.”

### Atonic Status Epilepticus

Atonic SE predominantly affects infants. Clinical manifestations can be relatively subtle with revulsion of the eyes, minor jerks, usually with coma. The EEG typically shows bilateral synchronous spike and slow-wave activity. Prognosis is generally good.

### Generalized Myoclonic Status Epilepticus

Generalized myoclonic SE as part of the myoclonic epilepsies is extremely rare. It may affect children or adolescents, typically with idiopathic generalized epilepsies in which the myoclonus is irregular, bilateral, and with preserved consciousness. Alternately, it may be seen in secondary generalized epilepsies in which there is asymmetric, asynchronous, milder myoclonic movements, often with clouding of consciousness. The EEG may show bilateral, synchronous polyspikes (with a clinical myoclonus). Arrhythmic bursts of spiked waves, delta activity, or so-called recruiting rhythms have been described.

A continuous state of myoclonic movements in coma is frequently seen after cardiac arrest. It is also referred to as status myoclonicus or status myoclonic. This common con-

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**TABLE 1. Types of Status Epilepticus (Partial Onset)**

<table>
<thead>
<tr>
<th>Simple partial status epilepticus (SPSE)</th>
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</thead>
<tbody>
<tr>
<td>Complex partial status epilepticus (CPSE)</td>
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<tr>
<td>Secondarily generalized convulsive status epilepticus (SGCSE)</td>
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</tbody>
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**TABLE 2. Types of Status Epilepticus (Primary Generalized)**

<table>
<thead>
<tr>
<th>Generalized convulsive status epilepticus (GCSE)</th>
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<tbody>
<tr>
<td>Absence status epilepticus (ASE)</td>
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<tr>
<td>Atypical absence status epilepticus (AASE)</td>
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<tr>
<td>Generalized atonic status epilepticus (GASE)</td>
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<tr>
<td>Generalized myoclonic SE</td>
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<td>Generalized clonic SE</td>
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<tr>
<td>Generalized tonic SE</td>
</tr>
<tr>
<td>Electrical status epilepticus of sleep (ESES)</td>
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(Kaplan, 1993). Many of these states clearly go unrecognized both because the clinical symptomatology is not thought to be epileptic and/or the EEG remains uninformative. In some cases, ictal single photon emission computed tomography (SPECT) scanning can reveal the focal, ictal nature of the disorder (Fig. 3) (Kaplan, 1999).

The most common and arguably the most morbid type of status is secondarily generalized convulsive status epilepticus (SGCSE). It may be accompanied by coma and lead to death, often in a third of cases. There are many etiologies, ranging from trauma, to infection, to malignancy, to underlying epilepsy, and it may occur at any age. As clearly demonstrated by Treiman et al. (1990), the EEG correlate of this dynamic condition often reflects a progression from overt to subtle clinical and subtle EEG manifestations (Treiman et al., 1990).
dition almost invariably has a fatal outcome. The EEG may show spiked, polyspike, or spike slow-wave at various intervals from several per second to one every several seconds.

**Generalized Clonic Status Epilepticus**

Generalized clonic SE predominantly occurs in children (50% to 80%). When it is seen with normal children, there is usually an intercurrent fever. It may also be seen with mental retardation usually in the setting of Lennox-Gastaut syndrome. The clinical correlate is of repeated, rhythmic, bilateral, small clonic jerks, although these may often be asymmetric or arrhythmic. The EEG is variable typically showing bilateral synchronous spikes, but may show spike bursts or recruiting rhythms that then progress to spike-waves.

**Generalized Tonic Status Epilepticus**

Generalized tonic SE is a rare condition that may occur in either children or adults, usually those with Lennox-Gastaut syndrome. The seizures consist of brief, frequent clonic contractions of the arms, often accompanied by eye revulsion; contraction of the face, neck, and throat; and extension of the legs, often without return to baseline between contractions and seen every few minutes. There may be significant autonomic changes. Flexion of the spine may produce vertebral collapse and para-
plegia (personal observation). Seizures may be precipitated by benzodiazepines. The EEG may show desynchronization, but more typically shows low-voltage fast activity at 20 to 30 Hz that gradually slows down to 10 to 20 Hz while increasing in voltage (Fig. 4). Polyspikes and slow waves may be seen. Despite being refractory to a number of parenteral antiepileptic drugs (personal observation), cognitive prognosis may be good.

Nonconvulsive Status Epilepticus

Complex Partial Status Epilepticus

The EEG patterns of complex partial status epilepticus (CPSE) are highly variable. The morphology may include isolated spikes, spike slow waves, and rhythmic theta or delta activity, with a frequency of 0.5 Hz to 1 Hz or upwards, largely lateralized to one side of the scalp. The patterns may be continuous, waxing and waning, and may occur in bursts without any typical diagnostic pattern, except that ictal lateralization predominates, or appears at onset. In some cases, lateralization is difficult to determine in that a mesiofrontal focus can be responsible, producing secondary bilateral synchrony (Fig. 5).

Another form of CPSE from deep temporal structures is limbic SE (Fig. 6), which may have a highly variable clinical state with fluctuations in the level of consciousness from wakefulness to catatonia, some with dream-like states. A patient may be fearful, agitated, confused, or anxious.

Aside from the patterns previously described with CPSE, the scalp EEG may appear normal or be misdiagnosed as an encephalopathy because of the presence of rhythmic delta activity or of disorganized TWs (Fig. 7). In the case presented, theta-delta activity can be seen to alternate over the frontal regions as the frequencies slightly accelerate and decelerate independently. Depth electrodes can sometimes reveal the ictal nature of the disorder (Wieser et al., 1985).

Generalized Nonconvulsive Status Epilepticus

Generalized nonconvulsive status epilepticus (GNSE) is highly variable, with morphologies that include generalized wave forms, spikes, spike-waves, polyspike-waves, and rhythmic theta or even delta activity. The frequency typically may vary from 0.5 to 1 Hz and upwards. The patterns are often continuous, but may occur in bursts or in a waxing and waning pattern. Again, no specific pattern is uniquely diagnostic, but there is a generalized distribution with no dominating focal features (Fig. 8).

Atypical Absence Status Epilepticus

Atypical absence status epilepticus (AASE) is relatively rare, and is seen in infants or adolescents with mental retardation, usually with Lennox-Gastaut syndrome. Clinically, the patients are confused with a change from identifiable baseline despite their mental retardation. There may be subtle myoclonic movements, tonic and atonic seizures in the same patient. The EEG can show generalized spike wave activity typically varying from 1 to 2.5 Hz, often with generalized “recruiting rhythms” approaching 10 Hz. An example of AASE is given in Fig. 9.
Electrical Status Epilepticus and Slow Sleep

This nonconvulsive often generalized ictal state is rare and merges, in part, with the Landau-Kleffner syndrome. Typically it affects children with mental retardation, though they are usually normal before the onset of electrical status epilepticus and slow sleep (ESES). The clinical state is that of multiple seizure types (including partial seizures and atypical absence seizures). The EEG when awake may show diffuse multifocal or generalized spikes or spike waves which then pervade the recording during non–rapid eye movement (non-REM) sleep to occupy 85% of the record. There may be 1.5 to 2.0 Hz generalized spike waves. An example is given in Fig. 10.

FIGURE 5. This EEG (CPSE) shows continuous, left-hemisphere rhythmic 2 to 3 Hz delta activity with some waxing and waning evolution.

FIGURE 6. This EEG shows limbic status epilepticus with waxing and waning independent bifrontal 3 to 4 Hz activity (see text).
Periodic Discharges

Periodic discharges are stereotyped epileptiform discharges which occur at regularly spaced intervals. Morphologies may include spikes, polyspikes, sharp waves, sharply contoured slow-waves, or a mixture of spikes and slow-waves. The waves may be monophasic, biphasic, or triphasic, and are usually of high amplitude (100 to 300 μV). They typically occur at regular or almost regular intervals of 0.3 to several seconds (Fig. 11).
Several types of periodic EEG activity have been described. Periodic lateralized epileptiform discharges (PLEDs) are unilateral, and were first described in the early 1950s. Chatrian et al. (1963) introduced the term PLEDs and noted that they usually arose from structural or focal lesions, co-occurred with seizures, and represented a transient phenomenon lasting usually less than 2.5 weeks. A rarer form, PLEDs-plus, was described in association with fast rhythmic discharges with an even greater association with seizures. It was posited that these represented transitional patterns where seizures appeared after a rhythmic buildup of PLEDs-plus morphologies (Reiher et al., 1991).

**Bilateral Independent Pseudoperiodic Lateralized Epileptiform Discharges (BiPLEDs)**

With BiPLEDs, the lateralized periodic or pseudoperiodic discharges are seen independently over both hemispheres (Fig. 12). Usually representing a more morbid underlying condition than PLEDs alone, the most common etiologies are anoxic encephalopathy, CNS infections, and chronic seizure disorders, each representing about a quarter of the causes. Almost three quarters of patients are comatose and mortality is high (about 60%). Again, this pattern is highly associated with seizures (de la Paz and Brenner, 1981).

**Generalized Periodic Epileptiform Discharges**

Generalized periodic epileptiform discharges (GPEDs) are generalized synchronous epileptiform discharges, usually appearing in a comatose patient (Fig. 13). Frequent causes are anoxic-ischemic coma after cardiorespiratory arrest, but they may also be seen with metabolic encephalopathies or even Creutzfeldt-Jakob disease. Typical CNS infections include herpes simplex virus or following subacute sclerosing panencephalitis. Some forms of NCSE have largely a GPED appearance. Finally, the pattern may be seen in the final stages of the disease.

![Figure 9](image1.png)  

![Figure 10](image2.png)  
*FIGURE 10. This EEG shows diffuse multifocal or generalized spikes or spike waves that then pervade the recording during non-REM sleep, and 1.5 to 2.0 Hz generalized spike waves.*
stages of convulsive SE as it evolves toward subtle status (Husain et al., 1999).

One of the great challenges with periodic discharges is in deciding when they represent ictal (versus interictal) phenomena. Most electroencephalographers believe that PLEDs and BiPLEDs largely represent interictal discharges.

**SUMMARY**

The EEGs of SE typically show rhythmicity whether represented by epileptiform morphologies or theta or delta activity; whether generalized or lateralized; and usually waxing and waning (at least to some degree). When clinical signs of convulsions or movement are absent, there is the challenge
of differentiating impaired cognition or behavior with EEG changes as an encephalopathy versus NCSE. The evolving EEG picture, and clinical and EEG response to parenteral antiepileptic drugs may be pivotal. Finally, differentiating epileptiform morphologies appearing periodically or pseudoperiodically, with or without a motor clinical correlate, from an active state of seizures, represents one of the important gray zones of electroclinical diagnosis. Again, the pattern of EEG evolution, and response to medication, along with the expertise of the electroencephalographer and the “art” of EEG interpretation, are central to this process.

REFERENCES


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