Value and Limitations of Seizure Semiology in Localizing Seizure Onset

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Summary: Seizure semiology has been the foundation of clinical diagnosis of seizure disorders. This article discusses the value and the limitations of behavioral features of seizure episodes in localizing seizure onset. Studies have shown that some semiologic features of seizures are highly accurate in the hemispheric lateralization and lobar localization of seizures. There is good agreement between blinded reviewers in lateralizing video-recorded seizures in temporal lobe and extratemporal lobe epilepsies. However, seizure semiology alone should not be used to determine the site of seizure onset. Each semiologic feature may falsely localize seizure onset. Seizure semiology in some patients may signify the site of seizure propagation rather than origination. Moreover, seizure semiology may not be as reliable in multifocal epilepsies as it is in unifocal epilepsies. Many semiologic features of seizures of adults are often missing in seizures of children. Seizure semiology should be analyzed and integrated with EEG and neuroimaging data to localize the seizure focus. A sample of the recorded seizures should be shown to the patient’s relatives or friends to verify that it is representative of habitual seizures.

Key Words: Epilepsy, Semiology, Seizures, Video-EEG

The diagnosis of epileptic seizure disorder has depended historically on the recognition of behavioral features of seizure episodes. Since ancient times, keen observations of seizure episodes by physicians have yielded a wealth of semiologic features that characterize epileptic seizures. These observations led eventually to the classification of different types of seizures, even before EEG became available.

The advent of video-EEG monitoring has permitted careful analysis of the semiologic features of seizures for their correlation with simultaneous EEG activities (Goldensohn, 1966; Penry et al., 1975). As a result, semiology gained greater reliability in diagnosing specific types of seizures and in localizing their EEG onsets (French et al., 1993). The objective of this discussion is to identify the value and the limitations of seizure semiology in localizing seizure onset and to assess the usefulness of seizure semiology in patient evaluation for epilepsy surgery. Although subjective features and witnesses’ descriptions of seizure episodes are clinically important, the discussion of seizure semiology in this article focuses on visually observable features of seizures that can be recorded on video. Therefore, the emphasis of this article is on the interpretation of the visual appearance of seizure episodes that are recorded on video for the purpose of correlation with EEG to localize seizure onset for epilepsy surgery.

VALUE OF SEIZURE SEMIOLOGY

Video recordings of seizures often clarify the seizure description obtained from the patient history. Historical descriptions of seizures have a number of limitations. Impairment of consciousness or memory by seizure activity deprives patients of their ability to recall features of their own seizures. Witnesses may not have had the opportunity to observe seizure episodes in their entirety, or the observation may have been too emotionally upsetting for the witnesses to remember details of their observations. The ability of patients’ relatives and friends to recall features of seizures is poor (Rugg–Gunn et al., 2001). After viewing video recordings of seizures, the accuracy of recall was only 45% for convulsive seizures and 70% for nonconvulsive seizures. The limitations of witnesses in accurately and fully describing seizures may be a reason for the low specificity of expert clinicians in correctly identifying types of seizures on the basis of the history. In one study, the specificity of epileptologists who were relying on the history to identify temporal lobe seizures was only 50% (Deacon et al., 2003).

Semiologic features of seizures can be grouped into motor signs (positive and negative), automatisms, autonomic signs, and peri-ictal speech signs. Tables 1 and 2 summarize the semiologic features observed during and after partial seizures. (A full discussion of each semiologic feature is beyond the scope of this presentation. The reader is referred to the syllabus of the 2005 American Academy of Neurology Annual Course number 8AC.001.) Most features are useful for lateralizing seizure onset to a hemisphere (hemispheric lateralization), whereas few features help in localizing seizure onset to a lobe in the hemisphere (lobar localization). For example, dystonic limb posture is more useful for hemispheric lateralization than for lobar localization because of its high predictive value in lateralizing seizure activity to the hemisphere contralateral to the limb. But then, dystonic limb posture can be observed with seizures arising from either the temporal lobe or the frontal lobe. In contrast, the feature of
bipedal automatism such as bicycling behavior is usually seen with seizures of frontal lobe origin, but it does not suggest right or left hemisphere seizure onset. Semiological features of seizures also have varying "sensitivity" in that the observed rate is variable between features. However, Tables 1 and 2 show that most features have high positive predictive values.

Semiological features of seizures have high reliability in lateralizing seizure onset. One study showed good agreement between blinded reviewers in lateralizing video-recorded seizures in 27 patients with temporal lobe epilepsy and 11 patients with extratemporal lobe epilepsy (k score of 0.68) (Chee et al., 1993). Seizure semiology could be lateralized in 80% of these patients, and 94% of the lateralization was correct. In another study, blinded analysis of video-recorded seizure semiology showed that 82% of temporal lobe seizures and 87% of frontal lobe seizures could be lateralized (O’Brien et al., 1998). The lateralization was correct in 90% of the temporal lobe seizures and in 95% of the frontal lobe seizures. A separate study showed that the concordance between seizure semiology and ictal scalp EEG was 96% in patients with temporal lobe epilepsy (Serles et al., 2000). Concordant localizing findings in the video-EEG recording may be used to help obviate intracranial electrode implantation, especially when there is also a related epileptogenic lesion apparent on MRI. This is often the case in candidates for temporal lobe epilepsy surgery (Cambier et al., 2001).

A combination of semiologic features also helps in lobar localization of seizures (Manford et al., 1996; Kramer et al., 1997) (Table 3). The temporal lobes and the frontal lobes are the two most common sites where partial seizures originate. It is crucial to distinguish reliably these two types of seizures, because many epileptogenic lesions involve both temporal and frontal lobes, and EEG discharges of frontal origin may appear more prominent at the ipsilateral anterior temporal lobe region. Blinded analysis of video-recorded seizures shows that semiology provided localizing information in all temporal lobe seizures and in 83% of frontal lobe seizures (O’Brien et al., 1998). The lobar localization was correct in all temporal lobe seizures and in 74% of frontal lobe seizures.

The value of seizure semiology is better appreciated when EEG does not provide information sufficient for localizing seizures. Scalp EEG fails to detect seizure onset in many patients, especially patients with extratemporal epilepsy. About 25% of seizures in patients with unilateral mesial temporal lobe epilepsy could not be lateralized by scalp EEG (Pataraia et al., 1998). The rate of inadequate scalp EEG lateralization is even higher in extratemporal lobe seizures. A third to a half of these seizures could not be lateralized by scalp EEG (Walczak et al., 1992; Mosewich et al., 2000). The limitations of ictal scalp EEG can be lessened when seizure semiology is also used for determining seizure onset. It has been shown that ictal scalp EEG alone lateralized seizure onset in 65% of patients with temporal lobe epilepsy, but the addition of semiologic data improved the lateralization to 95% (Serles et al., 2000). In patients whose focus of seizure onset could not be confidently localized with noninvasive video-EEG recording, clearly localizing seizure semiology may still help determine the location and limit the extent of intracranial electrode implantation.

**LIMITATIONS OF SEIZURE SEMIOLOGY**

Seizure semiology has several potential limitations in localizing seizure onset. Although many semiologic features have high positive predictive values, each feature has some potential to falsely localize seizure onset. Seizure semiology is often dictated by the pathway of electrical seizure propagation. For example, semiology and EEG of partial seizures in patients with hypothalamic hamartomas are often localized.
TABLE 2. Importance of Automatisms, Autonomic Signs, and Peri-ictal Speech Signs in Hemispheric Lateralization or Lobar Localization of Partial Seizures

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Location*</th>
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<tbody>
<tr>
<td>Unilateral limb automatism</td>
<td>Ipsilateral to seizure focus; 90% PPV</td>
</tr>
<tr>
<td>Unilateral eye blinks</td>
<td>Ipsilateral to focus; 83% PPV</td>
</tr>
<tr>
<td>Postictal cough</td>
<td>40% of temporal lobe seizure patients, 0% of pseudoseizure or frontal lobe seizure patients</td>
</tr>
<tr>
<td>Postictal nose wiping</td>
<td>50% of temporal and 10% of frontal lobe seizures; 90% PPV</td>
</tr>
<tr>
<td>Bipedal automatism</td>
<td>30% of frontal and 10% of temporal lobe seizure patients</td>
</tr>
<tr>
<td>Ictal spitting or drinking</td>
<td>Rare, but high association with right temporal seizures</td>
</tr>
<tr>
<td>Automatism with preserved responsiveness</td>
<td>Nondominant (usually right) temporal or extratemporal on either side</td>
</tr>
<tr>
<td>Gelastic seizure</td>
<td>Hypothalamic; sometimes mesial temporal or frontal cingulate origin</td>
</tr>
<tr>
<td>Autonomic signs</td>
<td>Mostly left temporal</td>
</tr>
<tr>
<td>Ictus emeticus</td>
<td>Rare, but usually right temporal</td>
</tr>
<tr>
<td>Ictal urinary urge</td>
<td>Rare (2%), but localizes to right temporal</td>
</tr>
<tr>
<td>Piloerection (goose bumps)</td>
<td>Mostly left temporal</td>
</tr>
<tr>
<td>Peri-ictal speech</td>
<td>Ictal speech arrest: Seen in 75% of temporal lobe seizure patients, but only 67% PPV for dominant hemisphere focus</td>
</tr>
<tr>
<td></td>
<td>Ictal speech preservation: Seen in only 15%, but PPV of 83% for non-dominant hemisphere focus in temporal lobe seizure patients</td>
</tr>
<tr>
<td></td>
<td>Postictal dysphasia: 90% dominant hemisphere involvement</td>
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PPV, positive predictive value.
*The PPV is the number of true positives divided by the sum of true positives and false positives.


There are exceptions to the localization provided by the profiles of seizure semiology of temporal lobe and frontal lobe epilepsies (Table 3). Although hypermotor activity and predominant nocturnal occurrence are features identified with frontal lobe seizures, seizures of temporal lobe origin have also been reported rarely to have the same features (Nobili et al., 2004). About 5% of patients with hypermotor seizures have temporal lobe epilepsy, rather than the expected frontal lobe epilepsy (Holthause and Hoppe, 2000). Conversely, in a blinded review of video-recorded seizures, the semiology characteristic of temporal lobe seizures was observed rarely in seizures of frontal lobe origin (O’Brien et al., 1998).

The localizing value of seizure semiology in patients with multifocal epilepsy may not be as good as that in patients with a single seizure focus. Our study showed that seizure semiology localized seizure onset in only 67% of the seizures in patients with multifocal epilepsy (Rathke et al., 2002). Moreover, the localized semiology agreed with intracranial EEG localization in only 62% of the seizures. Semiologic features in multifocal epilepsy were often of equivocal localizing value, to the extent that the agreement rate was only 41% between blinded review-
Seizure semiology derived from analyzing video-EEG monitoring recordings may not be the same as that of patients who did not undergo the monitoring. Most epilepsy patients who undergo video-EEG monitoring have intractable epilepsy. Therefore, there may be some semiologic differences between seizures in intractable epilepsy and seizures in non-intractable epilepsy. Nonetheless, our knowledge of the localizing value of seizure semiology is clinically most important in patients with intractable epilepsy, whose seizures need to be localized for resective epilepsy surgery. Questions have also been raised about whether the semiology of seizures precipitated by antiepileptic drug withdrawal is the same as the semiology of habitual seizures. Available evidence indicates that seizures precipitated by antiepileptic drug withdrawal appear to be the same as habitual seizures (So and Fisch, 1997). Antiepileptic drug withdrawal can increase the duration and intensity of seizures and also the likelihood of secondary generalization (Zhou et al., 2002). However, seizure-onset characteristics are not substantially altered. Nonetheless, antiepileptic drug withdrawal in some patients can rarely precipitate previously unrecognized seizures from an occult seizure focus. In a study that compared 71 baseline seizures and 89 withdrawal seizures of 18 patients, four patients were observed to have withdrawal seizures that were different from their baseline seizures (Spencer et al., 1981).

Descriptions in the literature of most semiologic features of seizures have been based on observations made in adult patients. Unlike temporal lobe seizures in adult patients, temporal lobe seizures in children younger than 42 months have prominent tonic posturing, myoclonic jerks, or epileptic spasms (Fogarasi et al., 2002). These motor components of temporal lobe seizures in children become less prominent with increasing age (Fig. 1). Likewise, frontal lobe seizures in children appear different from those in adults. A study of frontal lobe seizures in children younger than 7 years showed that epileptic spasms and subtle behavioral alteration were common (Fogarasi et al., 2001). Hypermotor activity, complex motor automatisms, and secondary generalized tonic-clonic seizures were either absent or rare in these children, although they are features often observed in frontal lobe seizures of adults. Another study demonstrated that some semiologic features of partial seizures in children increased with age, whereas others decreased with age (Nordli et al., 2001) (Fig. 2). Features that increased with age were automatism, dystonic posturing, secondary generalization, and unresponsiveness. Features that decreased with age were asymmetric clonus and symmetric tonic posturing.

**POINTERS IN ANALYZING SEIZURE SEMIOLOGY**

Video recordings of seizures should be reviewed carefully to detect as many useful semiologic features as possible. It is essential to record multiple seizures to establish the consistency of the features. Moreover, the value of recorded seizures is greater when their lateralization or localization is based on concordance of multiple semiologic features than when based on an isolated feature. Analysis of the sequence of development of multiple semiologic features often discloses the locations of seizure initiation and propagation. This sequence of semiologic features should be correlated in time with the EEG activity. Concordance between seizure semiology and EEG activity strengthens the value of recorded seizures in determining seizure onset and spread. The onset of clinical seizures that is substantially earlier than the onset of ictal EEG discharge may suggest that the EEG discharge is falsely localizing. Ideally, ictal EEG discharge onset should either precede or be simultaneous with the clinical seizure onset.

A seizure that is representative of the rest of recorded seizures should also be shown to the patient’s relatives or friends to verify that habitual seizures have been captured and analyzed. Finally, the clinical implications of recorded seizures should be assessed in parallel with information from the clinical history and imaging and neuropsychologic studies. In nearly all medical disorders, it is rare for a single source of information to be independently accurate and useful without correlation with other sources of information. The accuracy of medical diagnosis is enhanced when the diagnosis is based...
on integration of all available clinical and laboratory information regarding the patient.

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REFERENCES