The value of seizure semiology in lateralizing and localizing partially originating seizures

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ABSTRACT

Diagnosing epilepsy depends heavily on a detailed, and accurate description of the abnormal transient neurological manifestations. Observing the seizures yields important semiologic features that characterize epilepsy. Video-EEG monitoring allows the identification of important lateralizing (left versus right), and localizing (involved brain region) semiologic features. This information is vital for identifying the seizure origin for possible surgical interventions. The aim of this review is to present a summary of important semiologic characteristics of various seizures that are important for accurate seizure lateralization and localization. This would most likely help during reviewing video-EEG recorded seizures of intractable patients for possible epilepsy surgery. Semiologic features of partial and secondarily generalized seizures can be grouped into one of 4 categories including; automatism, speech, motor, and autonomic features. These features will be discussed in detail in this review. However, seizure semiology should be correlated with EEG and MRI findings. Accurate identification of the seizure origin is more likely if focal EEG onset and MRI findings were concordant with the clinical semiology.

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Diagnosing epilepsy depends heavily on detailed and accurate history of the abnormal transient neurological signs and symptoms.[1] In other words, epilepsy is a clinical diagnosis. There is no single test that can accurately exclude or diagnose epilepsy.[2] Observing the seizures would yield important semiologic features that characterize partially originating seizures. These observations help in lateralizing (left versus right) and localizing (involved brain region) the seizure onset. Therefore, this information is vital not only for seizure classification, but more so for identification of surgical candidates. The EEG and neuroimaging, particularly MRI, are needed to identify focal physiological and pathological brain abnormalities.[3-5] The development of video-EEG monitoring has allowed careful correlation of semiologic features with simultaneous EEG recordings.[6] As a result, clinical semiology gained greater reliability in diagnosing specific seizure types and localizing their onset.[7] The aim of this review is to present a summary of important semiologic characteristics of various seizures that are needed for accurate lateralization and localization. This would most likely help during reviewing video-EEG recorded seizures of intractable patients for possible epilepsy surgery.

History taking. Careful and detailed history is the cornerstone of an accurate epilepsy diagnosis. A previous diagnosis of epilepsy should not be accepted without a confirmatory history. A timed description of the patient's behavior during the event is needed for accurate classification and localization.[1] The first encounter may require a follow-up visit or phone call to other witnesses, such as a family member or a friend. The physician should remember to include the younger patient in the conversation, who may provide valuable additional information. If the description is not clear, the physician can ask the witness to mimic the event, or the physician may mimic different seizures to find a match for the patient's events. Asking the parents or relatives to videotape the events, whenever possible, can be diagnostic. The history of each event should be divided in 4 stages including pre-ictal, seizure onset, ictal, and postictal phase (**Table 1**). In the pre-ictal phase, provoking or precipitating factors should be sought, such as fever, illness, ingestion, compliance, and head injury. The time of the seizure is important as some occur predominantly in sleep (benign rolandic seizures, tonic seizures in Lennox Gastaut syndrome, and frontal lobe seizures). History of any brief focal signs or symptoms (aura) at the beginning of the

more dramatic seizure should be obtained. Anxious relatives tend to describe the most dramatic part of the seizure and ignore the more subtle initial focal signs. Rising abdominal (epigastric) sensation suggests mesial temporal lobe localization. Psychic symptoms, particularly fear, suggest seizures originating from the amygdala of the temporal lobe. Visual aura can be positive (for example flickering lights, spots, lines) or negative (field defects) and localizes to the occipital lobe. However, more complex visual hallucinations (for example, person, animal, or object) suggest involvement of the visual association cortex in the posterior temporal lobe. Epileptic visual aura should be distinguished from migraine aura, which develops gradually over 5 minutes and lasts for a longer period of time with no disruption in the level of consciousness. In this situation, headache usually occurs during or within 60 minutes of the visual aura. Olfactory aura usually involves smelling foul odors (uncal fits) and is localizable to the uncus of the temporal lobe, while auditory aura, usually originates from the temporal neocortex.[8] Sensory features can be positive (for example, pins and needles) or negative (numbness), and suggests parietal lobe origin. Aura symptoms should not be confused with prodromal symptoms, which may precede generalized tonic clonic seizures by several hours to a day. Prodromal symptoms include headache, irritability, and personality changes; all are rare in children and are not part of the ictus. During the seizure, the exact description of the clinical manifestations, their evolution and duration is termed "seizure semiology" (**Tables 2-4**). These features will be discussed in detail in the next sections.

Table 2 - Differentiating staring due to absence from that of complex partial seizures.

Features	Absence	Complex partial
Sleep activation	None	Common
Hyperventilation	Results in seizure induction	No activating effect
Seizure frequency	Frequent, many per day	Less frequent
Seizure onset	Abrupt	Slow
Aura	None	If preceded by a simple partial seizure
Automatism	Rare	Common
Progression	Minimal	Evolution of features
Cyanosis	None	Common
Motor signs	Rare, or minimal	Common
Seizure duration	Brief (usually <30 seconds)	Minutes
Postictal confusion or sleep	None	Common
Postictal dysphasia	None	Common in seizures originating from the dominant hemisphere

Table 1 - Important aspects of seizure history and their significance.

Features	Significance
1. Preictal phase	
Prodrome	Precedes generalized tonic clonic seizures
Environment of occurrence	To exclude syncope or pseudoseizures
Time of the day (for example upon awakening)	Myoclonic epilepsy or primary generalized
Precipitants or triggers	Reflex or photosensitive epilepsy
Association with sleep	Rolandic or frontal lobe epilepsy
2. Ictal onset	
Aura	Lobe of origin (for example occipital if visual)
Focal onset	Lateralization and localization (Table 4)
3. Ictal phase	
Progression	Identify involved brain regions
Aphasia	Dominant hemisphere
Awareness and consciousness	Simple versus complex partial or generalized
Duration	Status epilepticus
4. Postictal phase	
Confusion/amnesia	Suggests complex partial or generalized
Unilateral headache	Ipsilateral seizure origin
Weakness (Todd's paresis)	Contralateral hemispheric origin
Visual field defect	Occipital lobe involvement
Dysphasia	Dominant hemispheric involvement

Semiology. Seizures are stereotyped and random events. Semiologic features are needed in order to accurately lateralize and localize the seizure origin. These features may only be identified accurately by using video-EEG recording. In addition to MRI and EEG, the semiologic characteristics play an important role in the decision for possible epilepsy surgery in intractable patients. Concordance between the semiologic, MRI, and EEG findings are usually necessary for successful epilepsy surgery.[5,9] However, some patients have several seizure types with different semiology. Different seizures may be due to varying cortical involvement or propagation to neighboring cortex. A seizure may be characterized by flashing lights in one visual field (occipital), followed by eye deviation away from the side of onset (spread to association cortex), followed by loss of awareness and automatic behavior (spread to the temporal lobe), and then culminates in a generalized tonic-clonic seizure

(secondarily generalized). Facial twitching followed by speech arrest supports the diagnosis of a partial seizure originating from the dominant hemisphere.[10] During complex partial seizures, the patient may have simple oral-buccal automatisms (chewing, swallowing, sucking), or complex motor phenomena (bicycling, flailing, walking). Staring due to complex partial seizures should not be confused with that of absence seizures. Hyperventilation for 3 minutes can induce absence and lead to quick diagnosis during the clinic visit. Additionally, helpful differentiating features are summarized in **Table 2**. Identification of the focal features of partial and secondary generalized seizures is the key for accurate seizure lateralization and localization. On some occasions, the patient may experience only the first stage of the seizure with absence of the later stages. Only close questioning and careful observations will uncover this valuable localizing information, which will be discussed in detail in the following sections.

Table 3 - Differentiating features of frontal and temporal lobe seizures.

Features	Frontal Lobe	Temporal Lobe
Seizure frequency	Frequent, often daily	Less frequent
Sleep activation	Characteristic	Less common
Seizure onset	Abrupt, explosive	Slower
Progression	Rapid	Slower
Initial motionless staring	Less common	Common
Automatisms	Less common	More common and longer
Bipedal automatism	Characteristic	Rare
Complex postures	Early, frequent, and prominent	Late, less frequent and less prominent
Hyperkinetic motor signs	Common	Rare
Somatosensory symptoms	Common	Rare
Speech	Loud vocalization (grunting, screaming, moaning)	Verbalization speech in non-dominant temporal lobe seizures
Seizure duration	Brief	Longer
Postictal confusion	Less prominent or short	More prominent and longer
Postictal dysphasia	Rare, unless it spreads to the dominant temporal lobe	Common in dominant temporal lobe seizures

Table 4 - Value of various semiologic characteristics in lateralizing or localizing the onset of partial seizures.

Semiologic characteristic	Lateralization or localization
1. Automatism	
Oral automatism	Temporal lobe, typically hippocampal
Unilateral limb automatism	Ipsilateral to seizure origin
Unilateral eye blinks	Ipsilateral to seizure origin
Bipedal automatisms	Frontal lobe seizures
Ictal spitting or drinking	Right temporal seizures
Ictal laughter (Gelastic)	Hypothalamic, mesial temporal or frontal cingulate origin
Postictal nose wiping	Ipsilateral temporal lobe seizures
Postictal cough	Temporal lobe seizures
2. Speech dysfunction	
Ictal speech arrest	Temporal lobe seizures, usually dominant hemisphere
Ictal speech preservation	Temporal lobe seizures, usually non-dominant hemisphere
Postictal dysphasia	Dominant hemisphere involvement
3. Motor signs	
Early non forced head turn	Ipsilateral to seizure origin
Late forced head turn	Contralateral to seizure origin
Eye deviation	Contralateral to seizure origin
Focal clonic jerking	Contralateral to seizure origin, peri-rolandic
Asymmetric clonic ending	Ipsilateral to seizure origin
Dystonic limb posturing	Contralateral to seizure origin
Tonic limb posturing	Contralateral to seizure origin
Fencing posture	Contralateral frontal lobe (supplementary motor) seizures
Figure of 4 sign	Contralateral to the extended limb, usually temporal lobe
Unilateral ictal paresis	Contralateral to seizure origin
Postictal Todd's paresis	Contralateral to seizure origin
4. Autonomic features	
Ictus emeticus	Right temporal seizures
Ictal urinary urge	Right temporal seizures
Piloerection (goose bumps)	Left temporal seizures

Frontal versus temporal lobe seizures. The frontal and temporal lobes are 2 regions most frequently affected by partial epilepsy. Distinguishing between the 2 is important in evaluating medically intractable patients for possible resective epilepsy surgery. **Table 3** lists some important differentiating features. Using these features, seizures were accurately localizable to the frontal or temporal lobes in the majority of patients.[11,12]

Specific lateralizing and localizing semiologic features. Lateralizing and localizing semiologic features of partial and secondarily generalized seizures are summarized in **Table 4**.[12] They can be grouped into one of the following 4 categories, 1) automatism, 2) speech, 3) motor, and 4) autonomic features.

Table 5 - Examination of patients during the seizure for semiologic features.

Examination	Significance
Response to communication	Level of awareness
Speech (naming, reading)	Dominant hemispheric involvement
Memory, by presenting phrases or words for later recall	Temporal lobe involvement
Distractibility	Frontal lobe involvement
Response to passive eye opening	To exclude pseudoseizure (tight closure)
Response to physical stimulation	Attention, motor dysfunction
Weakness or lack of motor control	Contralateral seizure origin
Plantar extensor response	Post-ictal paresis

1) Automatism. Automatisms are repetitive semi-purposeful movements that simulate some normal movements. Oral automatisms (chewing, swallowing, sucking, lip smacking) occurring at the beginning of a seizure are suggestive of temporal lobe epilepsy of hippocampal origin. They occur in around 70% of these patients as compared to 10% of patients with extra-hippocampal seizures.[13] However, oral automatism has no lateralizing value. Unilateral limb automatisms are repetitive non-rhythmic hand and finger movements, usually associated with ipsilateral seizure onset.[14] As the seizure progresses, the contralateral limb may develop a dystonic posture. This can be confusing to the observer who may assume that the repetitive movements are the result of a seizure originating from the contralateral hemisphere. Unilateral eye blinking (winks) is a rare phenomenon that occurs ipsilateral to the seizure onset.[15] It should not be confused with hemi-facial clonic jerking causing rhythmic facial contractions associated with contralateral seizure onset. Bipedal automatisms, such as bicycling movements, take the form of symmetric bicycling or kicking movements and are suggestive of frontal lobe seizures.[16] Prominent leg movements favor involvement of the supplementary motor area.[17] Postictal nose rubbing or wiping is an uncommon form of unilateral limb automatism resulting from parasympathetic overactivity.[18] It is usually associated with ipsilateral temporal lobe seizures. Postictal coughing is also associated with temporal lobe seizures.

2) Speech disturbances. Speech disturbances during seizures include receptive, expressive, or global dysphasia. The lateralizing value of ictal speech preservation or arrest is shown in **Table 4**. Ictal verbalization (verbal phrases or sentences) should be distinguished from vocalizations (moaning, grunting, or screaming). Vocalizations have no lateralizing value, however, are more commonly seen in frontal lobe seizures as shown in **Table 3**.[19,20] Naming defects (dysnomia) and paraphasic errors are easily demonstrable during seizures.[21] Postictal dysphasia (inability to talk normally despite being able to follow simple commands) suggests a seizure originating from the dominant hemisphere. However, it may not be detected to the observer unless the patient is asked to read a statement after the seizure (**Table 5**). Postictal dysphasia is more likely observed with dominant temporal lobe seizures than with dominant frontal lobe seizures.[22] However, note that non-dominant hemisphere seizures can interfere with speech simply on the basis of postictal mental confusion.[23]

3) Motor signs. Motor signs can be positive, such as clonic, or tonic movements, abnormal posturing, dystonia, head or eye deviation. Negative motor signs include muscle weakness or paralysis. Positive motor signs should be distinguished from automatisms, which were described in section 1. One should look carefully for asymmetry of motor signs. Early asymmetric motor activity correlates with the seizure origin, while late asymmetry suggests seizure propagation.[12] Early non-forced head turn is a voluntary-like head turn that appears early and often associated with ipsilateral hand automatisms.[24] The head turn is usually toward the hemisphere of seizure origin. Note that initial head turn may be a response to an external stimulus in a partially responsive patient. Late forced head turn is due to seizures arising from the contralateral hemisphere. It is more common in temporal that frontal lobe seizures, and occurs in a later stage of temporal lobe seizures.[25] Eye deviation is usually associated with forced head turning, and occurs in the same direction. Early eye deviation is also associated with contralateral occipital lobe seizures.[26] Focal clonic jerking is suggestive of contralateral peri-rolandic seizure origin. Many patients with temporal lobe seizures have delayed focal clonic activity as a result of seizure spread.[27] Asymmetric clonic ending refers to unilateral clonic jerking occurring in a later phase of generalized seizures, namely, as they terminate.[28] This jerking occurs ipsilateral to the seizure onset due to spread and termination in the contralateral hemisphere. Dystonic limb posturing is characterized by sustained posturing of the contralateral limbs due to spread to the basal ganglia.[29] Typical hand posture involves wrist flexion, finger flexion at the metacarpo-phalangeal joints, finger extension at the inter-phalangeal joints, and thumb adduction. Unilateral tonic limb posturing is suggestive of contralateral hemispheric seizure origin. Fencing posture is frequently associated with contralateral frontal lobe seizures, particularly of

the supplementary motor area.[30] This complex posture is characterized by lateral abduction and external rotation of the arm at the shoulder with head deviation towards the same side. Occasionally, the upper limb is also flexed at the elbow with the hand raised to the face that has turned forcefully towards it. Asymmetric tonic limb posturing (figure of 4 sign) is usually observed during the early tonic phase of partial seizures as they become secondary generalized.[31] One arm is extended at the elbow while the other is flexed at the elbow, giving the appearance of a figure of 4. Both arms are slightly raised in front of the chest. The seizure onset is contralateral to the extended limb, and is usually temporal lobe in origin. Unilateral ictal limb paresis may or may not persist into the postictal phase and is associated with contralateral hemispheric origin.[32] Postictal weakness (Todd's paresis) has a lateralizing value indicating a contralateral hemispheric origin. The weakness may not be obvious to the observer; therefore, power should be specifically tested during and after seizures (**Table 5**). Asking the patient to point to the ceiling with each hand would test for weakness, as well as, for the level of awareness by following the command.

4) Autonomic signs. Postictal vomiting has no lateralizing value; however, early ictal vomiting (ictus emeticus) usually suggests right temporal lobe origin.[33] Ictal vomiting can also be seen in benign occipital epilepsies. Ictal urinary urge, and piloerection (goose bumps) are rare and usually associated with temporal lobe seizures as shown in **Table 4**.[34,35]

Limitations of seizure semiology. Seizure semiology has some limitations in lateralizing and localizing the seizure origin. Many semiologic features have high positive predictive values, however, each feature has some potential to falsely localize the seizure onset.[12] Seizure semiology is determined by the pathway of seizure propagation. Therefore, seizure spread into adjacent brain regions accounts for the false localization. Another possible pitfall of seizure semiology is multifocal epilepsy.[36] Several seizures have to be recorded to overcome this possibility. Rathke et al,[37] showed that seizure semiology localized the seizure onset in only 2/3 of patients with multifocal epilepsy. Another issue is that seizure semiology is mainly based on data obtained from video-EEG monitored patients with intractable epilepsy. These patients may have semiologic differences when compared to patients with non-intractable epilepsy.[12] As well, some seizures of monitored patients are precipitated by antiepileptic drug withdrawal. In this situation, the seizure duration, and intensity, as well as the likelihood of secondary generalization, are increased.[38] However, available evidence indicates that seizure onset characteristics are not substantially altered and therefore appears to be the same as that of habitual seizures.[39] Finally, most literature descriptions of seizure semiology have been based on adult patients. Temporal lobe epilepsy is more difficult to recognize in children with less obvious features.[40] They are less stereotyped and have prominent tonic posturing or myoclonic jerks.[41] These motor components become less prominent with increasing age. Likewise, frontal lobe seizures in children appear different from those in adults.[42] Hypermotor activity, complex motor automatisms, and secondary generalizations were rarely encountered in children. In general, some semiologic features increase with age such as, automatism, unresponsiveness, dystonic posturing, and secondary generalizations. Other features decrease with age such as, asymmetric clonic movements and symmetric tonic posturing.[43]

In summary, seizure history and video recordings should be reviewed carefully to detect as many useful semiologic features as possible. It is essential to record multiple seizures in intractable patients to establish consistent semiologic features, particularly if surgery is considered. A representative seizure should also be shown to the patient's parents or relatives to confirm that habitual seizures were captured. Most of the semiologic features that were summarized in **Table 4** are useful for seizure lateralization, whereas fewer features are useful for localization.[44] For example, dystonic limb posturing is more helpful for hemispheric lateralization because of its high predictive value, however, it can be observed in seizures arising from either the frontal or temporal lobes. In contrast, bipedal automatisms, such as bicycling movements, are usually observed with frontal lobe seizures, but it does not suggest the side of seizure onset. Therefore, 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 (**Table 4**). Analysis of the development and sequence of multiple semiologic features can identify the seizure initiation and propagation. However, the seizure origin is identified more accurately if ictal EEG onset was concordant with seizure semiology. This concordance reached 96% in patients with temporal lobe epilepsy.[45] False localization should be suspected if the clinical onset occurred earlier than the ictal EEG onset. The EEG onset should either precede or coincide with the clinical seizure onset.

In conclusion, the clinical implications of recorded seizures should be assessed in parallel with information obtained from the clinical history, video-EEG, and imaging studies. Accurate identification of the seizure origin is enhanced when the diagnosis is based on integration of all available clinical, electrophysiological, and radiological data.

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