

# Online brainmapping

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## INTRODUCTION

Until the past 3 decades, localization of brain tumors and other focal lesions was difficult. Neuroimaging techniques consisted of skull x-rays, which were usually negative, and pneumoencephalograms, which were invasive, painful, and often uninformative. In 1936, Walter, who introduced the term "delta waves," first identified the association between localized slow waves on EEG and tumors of the cerebral hemispheres. This established EEG as an important tool for localizing brain tumors. For the next 4 decades electroencephalographers mounted an enormous effort to improve accuracy of localization and to seek clues to underlying pathologic processes.

Experience has shown EEG to be somewhat reliable in localizing lesions involving superficial accessible portions of the cerebral hemispheres, though it is of limited value in deep-seated lesions, especially posterior fossa tumors. The role of EEG in detecting focal cerebral disturbances has undergone a significant change since the development of CT scan and MRI. Today EEG is primarily complementary to these studies and is used mainly for evaluating functional changes in the patient's condition. It demonstrates aspects of brain physiology that are not reflected in structural neuroimaging. Functional neuroimaging techniques, such as positron emission tomography (PET), single-photon emission computed tomography (SPECT), and functional MRI (fMRI), can exhibit physiologic changes but not with the temporal resolution of EEG. Furthermore, EEG provides the only continuous measure of cerebral function over time.

This article reviews the major EEG changes that occur with different brain tumors, as determined by location, histologic type, associated complications, and surgical and nonsurgical treatments.

## TYPES OF EEG ABNORMALITIES ASSOCIATED WITH BRAIN TUMORS

EEG abnormalities in brain tumors depend on the stage at which the patient presents for evaluation. EEG changes observed with tumors result mainly from disturbances in bordering brain parenchyma, since tumor tissue is electrically silent (with the possible exception of tumors containing neuronal elements, such as gangliogliomas). For this reason, EEG localization often is misleading, although lateralization is generally reliable.

The following are common findings:

- Polymorphic delta activity (PDA)
- Intermittent rhythmic delta activity (IRDA)
- Diffuse or localized theta activity
- Localized loss of activity over the area of the tumor
- Asymmetric beta activity
- Disturbance of the alpha rhythm
- Spikes, sharp waves, or spike-wave discharges

Activation procedures are usually of limited value in patients with tumors, although hyperventilation occasionally can accentuate focal slowing. Asymmetries of photic driving can be useful at times, although they also can be misleading.

- [Slow Wave Activity](#)

Focal delta activity is the classic electrographic sign of a local disturbance in cerebral function. A structural lesion is strongly suggested if the delta activity is continuously present; shows variability in waveform amplitude, duration, and morphology (polymorphic); and persists during changes in physiologic states, such as sleep or alerting procedures. When focal delta is found without a corresponding imaging abnormality, it is usually in the setting of acute seizures (especially postictally), nonhemorrhagic infarction, or trauma.

Clinical and experimental observations indicate that PDA results primarily from lesions affecting cerebral white matter; involvement of superficial cortex is not essential, and lesions restricted to the cortical mantle generally do not produce significant delta activity. Functional deafferentation of cortex likely is critical.

Delta activity that fails to persist into sleep or attenuates significantly with arousal or eye opening is less indicative of structural pathology, as is rhythmic or sinusoidal delta. The latter usually occurs intermittently and is termed IRDA. It is usually bilateral and of high amplitude and is

typically maximal occipitally (OIRDA) in children and frontally (FIRDA) in adults. Unlike PDA, IRDA increases in drowsiness and attenuates with arousal. IRDA often is observed without structural pathology, as in metabolic encephalopathies, but it also can occur with diencephalic or other deep lesions; in this situation, an amplitude asymmetry can be present, with higher amplitude ipsilateral to the lesion. As in other clinical settings, theta activity is indicative of less severe localized or diffuse dysfunction than delta activity and is observed more commonly with functional disturbances than with structural disturbances. When unaccompanied by delta activity, theta is less likely to indicate a lesion that produces a focal neurologic deficit or seizures.

- **Localized Loss and Asymmetries of Background Activity**

Since tumor tissue probably does not generate electrical activity detectable with conventional recording techniques, electrical silence is the best localizing sign of a cerebral tumor. However, it is a rare finding, occurring only when the tumor involves significant cortical areas with minimal subcortical disruption. Incomplete loss of activity, especially faster normal rhythms, is observed more commonly and is diagnostically helpful.

- **Alpha rhythm**

By the time the patient presents with focal or diffuse neurologic symptoms and signs, disturbance of the alpha rhythm may be present. Slowing of the alpha rhythm ipsilateral to a tumor is more common and significant than asymmetry of amplitude. However, disturbance of alpha rhythm depends on the site of the tumor. The more posterior the location, the more the alpha tends to be slowed, impersistent, or disturbed by admixed theta waves. The alpha rhythm also may fail to block to eye opening on the side of the neoplasm (ie, Bancaud phenomenon).

- **Beta activity**

Abnormalities of beta activity usually are limited to voltage asymmetries. To be considered unequivocally abnormal, a persistent amplitude difference of one third or greater (expressed as a fraction of the higher voltage) should be present. Diminished beta activity results either from cortical dysfunction, as in parenchymal tumors, or from an increase in resistance of the medium-separating cortex from scalp-recording electrodes, as in meningiomas or subdural collections. Focally increased beta activity usually is associated with a skull defect.

- **Interictal Epileptiform Discharges**

- **Isolated discharges**

Spikes, sharp waves, or spike-wave complexes occurring with consistent localization are observed uncommonly early in the course of brain tumors. In one study predating the CT scan era, such discharges appeared with only 3% of gliomas and metastatic tumors at the time of craniotomy. However, they were more common either as early findings of slowly growing neoplasms associated with seizures or later after focal slowing had developed.

- **Periodic lateralized epileptiform discharges**

Patients with tumors may exhibit periodic lateralized epileptiform discharges (PLEDs) at times, particularly after a series of seizures. In a study of 282 patients with typical PLEDs, tumor was present in 18%. Most patients with this EEG finding have had or will have seizures, if they are observed sufficiently closely and persistently; the pattern likely represents a transitional state between ictal and interictal epileptiform discharges. Aggressiveness of treatment depends in part on whether the discharges are resolving (becoming less sharp, more localized, and further apart) or the opposite.

- **Seizure patterns**

When electrographic seizures are recorded during a routine EEG, suspect status epilepticus. Clinical accompaniments may be subtle, as in aphasic or other forms of nonconvulsive status, particularly when the patient's baseline condition has been compromised by the tumor, its treatment, or complications.

## EEG CHANGES IN TUMORS BY LOCATION

Since EEG reflects activity of cortical neurons, hemispheric tumors affect EEG most consistently and prominently. In older studies, a normal EEG occurred in approximately 5% of hemispheric, 25% of deep or basal, and 25% of infratentorial tumors. The overall figure now may be 50% or higher, given the earlier diagnosis allowed by modern neuroimaging. Location is an important determinant of the likelihood and nature of EEG abnormalities.

- **Frontal Lobe Tumors**

Frontal lobe tumors characteristically cause focal PDA, which accurately localizes the lesion.

In approximately one third of patients, slow waves are bilateral and may be IRDA rather than PDA. This occurs most often when deep structures such as the corpus callosum are involved (butterfly glioma).

- IRDA is more frequent with frontal tumors than with tumors in other hemispheric locations, even in children in whom the IRDA is often maximal occipitally (OIRDA).
- The slow wave abnormality may be only in the theta range, particularly in small, slowly growing tumors.
- The alpha rhythm usually is preserved, although it may be disrupted with large lesions.
- Parasagittal tumors, particularly meningiomas, may cause decreased beta activity on the side of the tumor or runs of ipsilateral alpha and theta activity.
- Sharp waves and spikes are most likely in slow-growing neoplasms and may be bilateral; occasionally, frontally predominant spike-wave complexes mimicking those of idiopathic epilepsies may be produced.
- **Temporal Lobe Tumors**

Temporal gliomas are generally the easiest to localize on EEG, since PDA occurs over the tumor site in more than 80% of patients. Tumors in other locations, such as the thalamus, also may produce temporal delta; however, focal delta is more reliably localizing when background rhythms also are attenuated.

- **Anterior temporal**
  - When tumors are in this location, a well-preserved alpha rhythm occurs.
  - PDA is well localized.
  - EEG from the contralateral hemisphere is often virtually normal.
  - Since these tumors often are associated with seizures, they may demonstrate interictal epileptiform discharges. These may be identical to those associated with nonneoplastic lesions such as mesial temporal sclerosis, especially when the tumor is located medially, as is often the case with very slow-growing tumors, such as gangliogliomas and dysembryoplastic neuroepithelial tumors.
- **Posterior temporal**
  - Tumors in this location are characterized by PDA and usually disturbance of the ipsilateral alpha rhythm.
  - Slowing or disorganization of the alpha rhythm with intermixed theta is present.
  - Occasionally, alpha amplitude is decreased markedly rather than slowed.
- **Parietal Lobe Tumors**
  - Tumors in this region less often produce localized slowing; PDA usually is lateralized but often not clearly localized. When phase reversals are present, they may be temporal or frontal rather than parietal.
  - PDA is often slow (<2 Hz), but it is usually of lower amplitude than with frontal or temporal tumors.
  - The alpha background generally is disturbed either ipsilaterally or bilaterally.
  - Theta rather than delta activity may occur in meningiomas, low-grade gliomas, and small metastases.
  - In centroparietal tumors, mu rhythms may be attenuated ipsilaterally but occasionally may be more persistent and of higher amplitude.
  - Since seizures are common in patients with tumors in perirolandic areas, ipsilateral epileptiform discharges may be present; at times they may be difficult to distinguish from mu, especially after craniotomy.
- **Occipital Lobe Tumors**
  - Most occipital gliomas produce focal changes, especially PDA, which spreads variably to more anterior and contralateral locations. Occipital meningiomas, mainly of the tentorium, can cause more focal EEG changes.
  - The background alpha rhythm is rarely normal and may be impaired either ipsilaterally or bilaterally.
  - Interictal epileptiform discharges are rare.
- **Deep Hemispheric Tumors**
  - Deep hemispheric tumors include tumors impinging on the lateral and third ventricle and surrounding structures, including the diencephalon, basal ganglia, and corpus callosum. Neuroimaging has led to earlier diagnosis of smaller tumors that may be associated with normal EEGs. When abnormalities are observed, the following apply:
  - The typical EEG finding is IRDA. This finding classically has been associated with hydrocephalus or increased intracranial pressure, but this assumption may be incorrect, since IRDA is uncommon in hydrocephalus of nonneoplastic origin and is not present in benign intracranial hypertension.
  - PDA typically does not occur, although asymmetric IRDA is relatively common.
  - Especially in older patients, rhythmic delta may be more continuous than intermittent.
  - Alpha rhythm and sleep spindles may be disrupted ipsilateral to the lesion.
  - Epileptiform discharges are very rare

- **Intraventricular and Sellar Tumors**

- Lateral ventricle (ependymoma, meningioma)

- EEG may exhibit PDA over the ipsilateral temporal lobe.
- Theta and sharp waves may be present temporally.

- Third ventricle (colloid cyst, epidermoid, craniopharyngioma)

- EEG is usually normal unless the lesion is large.
- Slowing may be bifrontal or diffuse.
- Runs of theta may be observed.

- Sellar region

- EEG is usually normal
- If present, slowing is usually bitemporal.

- **Infratentorial tumors**

- Brain stem and cerebellum

- EEG is more often abnormal in children.
- If present, slowing is most often posterior and bilateral.
- IRDA may be observed, especially if hydrocephalus is present.

- Cerebellopontine angle (acoustic neuroma)

- EEG is usually normal, especially with small tumors.
- When present, slowing is usually temporal or temporal occipital.
- Slowing is often intermittent and usually but not always ipsilateral; it may be bilateral or even predominantly contralateral.

## TUMOR TYPE AND EEG

EEG patterns are not specific for tumor pathology, but some general correlations exist.

- Slowly growing extra-axial tumors, such as meningiomas, produce the mildest EEG disturbances, whereas rapidly growing intraaxial tumors, such as glioblastomas, cause the most marked abnormalities.
- Benign intraaxial tumors, such as astrocytomas or oligodendrogliomas, are intermediate in their effects on the EEG.
- Interictal discharges most commonly are observed initially in slowly growing tumors and often are observed later in the course of higher grade lesions.

- **Meningiomas**

Being extraaxial, meningiomas compress the brain but cause little destruction of brain tissue. Therefore, meningiomas of the anterior or middle cranial fossa, unless large, infrequently alter EEGs. Convexity meningiomas are more likely to cause EEG changes. With rolandic or parasagittal meningiomas, common EEG changes include the following:

- Focal theta activity
- FIRDA
- Diminished, or less often, augmented beta activity
- Focal PDA that is usually low in amplitude (50-60 mV), intermittent, and misleadingly prominent in temporal derivations
- Epileptiform discharges observed in as many as 45% of patients

- **Gliomas**

Slowly growing gliomas such as oligodendrogliomas and fibrillary astrocytomas (excluding tumors of deep structures) often can be distinguished from the more rapidly growing anaplastic astrocytoma and glioblastoma multiforme.

- With the more benign tumors, which comparatively are circumscribed, the abnormalities tend to be localized and within the theta range.

- In the rapidly growing tumors, relatively more overall abnormality is present, and the background (particularly the alpha rhythm) is more impaired and disorganized.
- Glioblastomas produce the most widespread, slowest (often 1 Hz or less), and largest (100-200 mV) delta waves. These tumors cause prominent PDA, with marked alteration of background rhythms. Also, the high incidence of necrosis makes “flat PDA” (low-amplitude slow delta with diminished fast activity) more likely.
- Indolent gliomas commonly cause seizures, and epileptiform activity may appear before significant slowing occurs. Later, delta appears, often intermittently and at 2-3 Hz. Still later, focal PDA becomes persistent.
- [Metastases](#)

Metastatic tumors to the brain occur commonly with carcinomas of lung, kidney, and breast and with melanomas and chorionic carcinomas. When metastases are present bilaterally, slowing often appears diffuse, although it is often asymmetric; slowing from multiple bilateral lesions is often difficult to distinguish from a toxic-metabolic disturbance. Meningeal carcinomatosis usually causes changes that correlate with the clinical situation; when deposits are widespread and cause an encephalopathy, slowing is usually diffuse.

Isolated metastases usually cause less prominent abnormalities than gliomas of similar size and location. Slow waves show higher frequency, lower amplitude, and less persistence than with high-grade gliomas, and normal background rhythms are more likely to be preserved.

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