

## Abnormal Levels of Consciousness and their Electroencephalogram Correlation: A Review

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**Received:** December 03, 2016; **Published:** December 13, 2016

### Abstract

Consciousness is a state of awareness of self and the interaction with the surrounding environment and the components of the environment. The term also has other uses such as collective consciousness (set of shared beliefs, ideas and morality that unifies as a force within a society), specific consciousness (that gives a conscious state the particular phenomenal quality) and general consciousness (that makes a state conscious at all).

Electroencephalogram records brain's electrical activity via metal electrodes attached to skin on the head. The waves are transmitted to a recording device and the process routinely takes 30-90 minutes on an average. It is a grossly under utilised tool with prominent and often the only known use being in seizure disorders and epilepsy.

The disorders of consciousness are acute and chronic. Electroencephalogram is known to be effective in detecting these disorders, monitoring them and prognosticating them. However, very few non-neurologists are aware of this use as a tool for disorders of consciousness.

**Keywords:** *Consciousness; Electroencephalogram; Acute Disorders of Consciousness; Clouding of Consciousness; Delirium; Obtundation; Stupor; Locked in State; Coma; Chronic Disorders of Consciousness; Dementia; Hypersomnia; Abulia; Akinetic Mutism; Minimal Conscious State; Vegetative State Brain Death*

### Introduction

Electroencephalogram (EEG) is a valuable tool and is grossly underutilized. Most non-neurologists use it only for seizures and epilepsy. This is a very valuable tool in other spectrum of the diseases as well including abnormal levels of consciousness where EEG can not only provide a diagnosis, but may also help prognosticate cases and monitor therapy. We hereby discuss the EEG features of the various disorders of consciousness.

### Article Proper

Consciousness is a state of awareness of self and the interaction with the surrounding environment and the components of the environment. The two major components of consciousness are content and arousal. The content includes all the functions that are maintained by cortical functions inclusive of cognition and affective response. There may be associated loss of recognition of the type of stimuli. Re-

duced level of consciousness may be due to reduction of the behavioural responses. It may occur due to abnormality of cortical function as well as specific brainstem injuries. The acute disorders of consciousness are clouding of consciousness, delirium, obtundation, stupor, locked in state and coma. The sub-acute or chronic forms of disorders of consciousness are dementia, hypersomnia, abulia, akinetic mutism, minimal conscious state, vegetative state and brain death [1].

Clouding of consciousness or brain fog is an abnormal regulation of consciousness. Clouding of consciousness is a very mild form of altered mental status in which the patient has inattention and reduced wakefulness. This is the mildest form of altered consciousness and is usually seen with delirium being one of the features noted with delirium. There is minimally reduced wakefulness or awareness. There may be hyperexcitability and irritability. The orientation is affected, more commonly to time and place. The patients are inattentive and have poor backward repetition. Cerebral oxygen consumption is usually reduced by at least 20% [1,2].

Electroencephalogram (EEG) changes may be characteristic or may be associated to the associated abnormality and may provide confirmatory evidence in cases where establishing diagnosis is difficult on clinical basis. This is more so if a prior EEG is available because the first change observed is the slowing of the alpha rhythm wherein the slowed rhythm may still lie within normal range but is slow for the individual. Retrospective diagnosis may be made by repeating EEG once the patients has been stabilised. As the confusion and impairment of consciousness becomes more prominent, activity at lower frequency can be seen [3].

Delirium is a disorder of consciousness with decreased ability to focus, sustain or shift attention. There is change in cognition or development of a perceptual disturbance not otherwise accounted for. The disturbance usually develops suddenly over a short period of time and there are fluctuations in the course of the day. The patients are disoriented to time, place and rarely to person. The delirium may be of three type-hyperactive delirium, hypoactive delirium and mixed delirium [4].

In delirium, the EEG may show slowing or dropout of posterior dominant rhythm, generalized slow wave activity-theta wave or delta waves may be seen. The background activity is poorly organized. There may be loss of reaction to eye opening and closing. There is a reduced ratio of fast to slow band power. There is reduced peak frequency of occipital leads. Eye closed activity of two electrodes yielding a frontoparietal derivation may help identify delirium and differentiate it from those without delirium. However, the specificity of EEG in delirium is circumspect [5].

Obtundation is a state of sluggish responsiveness, with increased somnolence, and reduced interaction and interest in the environment. The correlation between severity of EEG and cognitive dysfunction is seen well in obtundation compared to other forms of dysfunction. This is especially true for subcortical dementia. A number of abnormal EEG patterns are seen and suggest the mechanism underlying obtundation. These include burst suppression pattern, alpha coma pattern, spindle coma pattern, triphasic waves and periodic lateralized epileptiform discharges. EEG changes usually seen in non-convulsive status epilepticus (periodic lateralized epileptiform discharges, bilateral independent periodic lateralized epileptiform discharges, generalized periodic epileptiform discharges) may also be seen [6].

In stupor, the patient demonstrates behavioural unresponsiveness and deep sleep. They can be aroused by vigorous and continuous stimulation but the patient, even with maximum stimulation such as pain, bright light, and loud noise shows impaired response. A condition affecting the ascending reticular activation system is usually implicated in stupor. In stuporous patients, in addition to generalized slowing- delta and theta rhythm, the EEG also shows triphasic waves. The complex has two electronegative waves separated by an electronegative wave that has higher amplitude. The waves may sometimes resemble a myoclonic discharge. Bilateral independent periodic lateralized epileptiform discharges, generalized periodic epileptiform discharges may also be seen. Occasionally, epileptiform discharges have also been noted [3,7].

Coma is a state of unresponsiveness where the patient's eyes are closed and the examiner fails to elicit arousal or response to even vigorous stimulation. There may be grimacing or withdrawal response. No defensive or localising movement occurs [8].

EEG is a supplemental investigation in coma. It allows documentation of thalamocortical dysfunction. EEGs may help prognosticate the patient especially when a complete generalized suppression is noted of less than 10 micro volts e.g. in cases of cardiac arrest. Other forms of activities that may be seen include periodic complexes, marked suppression, epileptiform activity, burst suppression, alpha theta coma patterns etc. While a single EEG may help with the diagnosis, serial EEG can monitor unstable patients and can reflect on response to therapy in treatable causes of coma. Testing of reactivity and multiple variables may be of role in this role. EEG may show beta coma intermingled with alpha or delta activity. Alpha coma may be seen. This may be diffuse or monomorphic and posterior. Theta coma usually predicts a poor prognosis. Diffuse, focal, unilateral or anterior predominant high voltage delta activity is seen most frequently in metabolic encephalopathy. In others, low voltage delta coma may be seen. Spindle coma may be seen with traumatic brain injury. Burst suppression pattern with or without interruption may suggest intoxication. Finally, electro-cerebral inactivity may be said to be present if there is no spontaneous neuronal activity detectable [8].

Locked in syndrome is a condition where there is a complete paralysis of all voluntary muscles except for ocular movements while the patient is aware and conscious, and results usually from brainstem lesions. EEG may be normal or it can show alpha coma pattern with or without unreactive alpha rhythm to multimodal stimuli. In another study, EEGs showed a reactive alpha rhythm most of the time or a theta rhythm that suggests consciousness. Minor focal or bilateral disturbances may be noted in theta or fast delta range. In a truly comatose patient, alpha rhythm, if present, is unresponsive to stimulus. Relatively normal EEG with reactivity in a patient who otherwise appears unconscious may suggest the possibility of Locked in Syndrome. EEG may also show abnormal desynchronous, poorly organized background activity. So, EEG may provide a simple, non-invasive quick test of diagnosing Locked in State at bedside [9-11].

Hypersomnia is a state of excessive but normal appearing sleep. The person awakens readily when stimulated. The duration of the 'awake' period may be brief. Some suggest that the symptom should be present for at least 3 months before being significant. But this may not be the case in acute settings. In a truly hypersomnia patient, sleep is normal and cognition is intact while awake. In pathological state, the patient has clouded consciousness when awake. Many acute and chronic conditions are associated with hypersomnia as a symptom. Hypothalamic dysfunction is implicated with the condition [12,13].

The EEG may be normal or may show slight slowing, with slow activity record intermittently especially theta activity on 'awake' EEG. Epileptiform discharges have been seen in some cases. Minimum weighted average instantaneous frequency might be an intrinsic character. The EEG changes specific to the cause of hypersomnia may be seen [14-16].

Abulia is a syndrome of diminished motivation. In abulia, the patient looks away, stares emptily, and seems to be in a daze. However, there may be sudden expression of concern on subjects with a complete grammatical language and animation. Patient refuses to cooperate for formal testing despite an intact ability to do so. There is reduced dopaminergic activity in bilateral centromedial core of the brain. Cases are also known to occur due to damage to basal ganglia, capsular genu, caudate nucleus and anterior cingulate circuit. Abulia shows bifrontal or generalized slowing with lack of desynchronization following any external stimuli. Slowing may be focal or unilateral. Slow alpha activity may be seen in some [17,18].

Minimally conscious state is a disorder of severely impaired consciousness where there is a partial minimal preservation of the awareness. They demonstrate behavioural evidence of self and perform some activities that suggest this awareness of self and the environment such as following objects and reacting to questions and commands even if appropriate. There is usually continuous but incomplete improvement. Others have a good recovery sufficient for independent activities. It may be an intermediate state that arises during recovery from coma or alternatively while worsening of the neurological status [19].

The type of EEG abnormality observed may vary with the location of the lesion. EEG shows diffuse or focal slowing- theta and delta waves. There is disorganization in the more severely injured hemisphere with decreased reactivity of posterior dominant rhythm. While changes are ipsilesional, bilateral changes may be seen. Slowing is most apparent in the electrodes closest to the lesion. EEG may suggest cortical dysfunction. They may identify occult seizure activities. Asleep EEG shows continuous polymorphic slowing especially near the lesion. Sleep spindles are attenuated [20].

Vegetative state is recovery of the arousal state and its cycling. It is usually identified initially by periods of eye opening in a previously unresponsive patient. The patients show no signs of awareness of the environment or self. However, they maintain their cardiopulmonary functions and autonomic functions because brainstem is usually preserved. A term persistent vegetative state may be used if the vegetative state lasts for at least 30 days. Usually it switches to coma by 10 to 30 days. A term permanent vegetative state may be used if the vegetative state lasts from three months to a year in non-traumatic and traumatic conditions respectively [19].

EEG may be normal. A multitude of 'awake' EEG patterns is known. There is a generalized slowing in theta and delta rhythms that may be continuous or intermittent. The background is attenuated and EEG is isoelectric. Periodic lateralized epileptiform discharges and triphasic waves are also seen. Same patient may show more than one type of waveforms at different times of testing. Epileptiform discharges may be seen such as focal sharp waves. Alpha-theta coma and spindle coma may be seen. A correlation may be seen between the clinical outcome and the initial EEG grade. Normal diurnal and nocturnal pattern may be preserved. EEG reactivity may be affected. Many sleep changes are not seen such as random eye movements, sleep spindles and vertex waves. Diminution or absence of EEG fluctuation during sleep-wake cycle serves as an indicator of brainstem dysfunction and its severity. EEG coherence serves as a better prognostic indicator for recovery after brain injury. High amplitude theta frequencies in these patients may be significant for favourable outcome [20,21].

First described by Cairns, *et al.* in 1941, akinetic mutism patients are silent and appear alert though immobile. They may have sleep wake cycles but mental activity is almost absent. Spontaneous motor activity is absent. Besides, motor activity, spontaneity and initiation of actions ideas, speech and emotion are completely or nearly completely lost. Attention may be passively drawn to environmental stimulus. Lesions may be in basal forebrain or hypothalamus. These patients are not paralyzed but do not have the will to move. They may occasionally whisper monosyllables. It is of 2 types- frontal and mesencephalic types [19].

EEG shows periodic sharp wave complexes. These usually occur after onset of myoclonus, but may occur prior to the myoclonus as well. Frontal intermittent rhythmic delta activity, frontal intermittent rhythmic triphasic slow waves are other waveforms that may be seen. These latter may herald the onset of periodic sharp wave complexes [22].

Brain death is irreversible loss of functions of the entire brain such that the body cannot maintain the respiratory and cardiovascular homeostasis. It eventually results into loss of systemic circulation. The cerebral hemispheres function depends on brainstem and therefore cerebral hemisphere functions cannot be tested accurately when brainstem is not functioning. Brainstem death is therefore identified as irreversible loss of capacity for consciousness, with irreversible loss of capacity to breathe. EEG in brain death demonstrates electrocortical silence. EEG is considered an optional test and therefore most consider that diagnosis of irreversible death of brainstem is sufficient to infer death, not needing the instrumentation [19,23-25].

Dementia is enduring and progressive decline in mental process due to organic processes. Arousal may not be affected. DSM-IV defines dementia as follows: A. The development of multiple cognitive defects manifested by both: (1) Memory impairment (impaired ability to learn new information or to recall previously learned information); (2) One (or more) of the following cognitive disturbances: aphasia (language disturbance), apraxia (impaired ability to carry out motor activities despite intact motor function), agnosia (failure to recognize or identify objects despite intact sensory function), disturbance in executive function (i.e., planning, organization, sequencing, abstracting). Patients are usually awake and alert. There are many types of dementia. Most common forms of dementia are Alzheimer's disease, vascular dementia, Lewy body dementia, frontotemporal dementia, normal pressure hydrocephalus, Parkinson's disease, Creutzfeldt Jakob disease etc. Dementia has three stages- early, middle and late [3].

EEG can diagnose the common dementias like Alzheimer's disease and vascular dementia. The former shows slow posterior rhythm frequency. There is increased diffuse slow frequency. And there is reduction of alpha and beta activities. In vascular dementia, occipital alpha rhythm is present while theta power increases. Delta power increase in both Alzheimer's disease and vascular dementia. Power ratio of alpha 3/alpha 2 is an early prognostic marker of Minimal Cognitive Impairment. Creutzfeldt Jacob disease shows bilateral sharp waves.

There may be sharp and slow waves. Background, normal initially, shows delta and theta waves as disease progresses. Alcohol dementias often show normal EEG patterns. Specific changes may vary with the type of dementia. Newer techniques like coherence analysis, evoked potentials, and event related potentials are bound to add to sensitivity of the EEG [3,26].

### Conclusion

EEG is a valuable tool in cases of abnormal levels of consciousness. And every EEG should be compared with prior EEGs to make out subtle changes. In expert hands, it is a useful tool.

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**Volume 4 Issue 1 December 2016**

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