Is EEG a useful test in adult psychiatry?

BACKGROUND We present a brief review of the use of EEG in psychiatry, with particular emphasis on differential diagnostic assessment of acute psychiatric conditions.

METHOD This article is based on a literature search in PubMed and on the authors' own clinical experience and collections of papers.

RESULTS Epilepsy, encephalitis or other brain disease may first present with psychiatric and cognitive symptoms. Slow EEG activity can be a non-specific sign of brain disease. Psychiatric patients also have an increased risk of developing epilepsy. Where there are seizure symptoms such as muscle cramps or conditions characterised by rapid changes in mood or behaviour, epileptiform activity on the EEG is a specific sign of epileptic aetiology or comorbidity. Quantitative frequency analysis of EEG data (QEEG) is useful in research and exceptionally as a supplement to diagnosis in clinical settings. To date, no QEEG methods have been accepted as reliable independent markers for psychiatric disorders or treatment response.

INTERPRETATION An EEG test should be performed in patients with new-onset psychosis and conditions characterised by fluctuating or progressive loss of cognitive function. Adult psychiatric patients with seizure symptoms or conditions featuring rapid changes in mood or behaviour should also be referred for EEG.

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Electroencephalography (EEG) is primarily of use in diagnosing epilepsy and other brain diseases (1), but there are other reasons why EEG is also an important diagnostic test in psychiatric practice. Firstly, there is comorbidity between severe psychiatric disorder and epilepsy. Many patients with epilepsy suffer from depression (2, 3). At the same time, patients with depression have been shown to have a three-to-seven times greater risk of developing epilepsy (4). A corresponding relationship has also been identified between schizophrenia and epilepsy (5). Epileptic seizures can also mimic psychiatric disorders or trigger episodes with psychiatric symptoms.

Secondly, a number of acute and subacute brain diseases may produce emotional or cognitive core symptoms. For example, frontal lobe brain tumours, autoimmune encephalitis and Lewy Body dementia in patients with Parkinson's disease may first present with psychiatric symptoms and the patient will thus be referred initially for psychiatric assessment.

The third and final problem is associated with the classification of psychiatric disorders. Can a quantitative analysis of the frequency content of EEG waves (QEEG) contribute to psychiatric diagnosis and treatment? This question has exercised the minds of researchers and clinicians for many years (6, 7).

The purpose of this article is to provide a brief review of research into and practical clinical use of EEG in adult psychiatry.

Method

This article is based on a literature search in PubMed using the search word «EEG» in combination with, respectively, «depression», «bipolar disorder» and «schizophrenia». In addition, the article is based on the authors' own collections of papers and experience of EEG in clinical neurophysiology, neurology and psychiatry. We have made a point of reviewing papers on controlled original studies from the last 25 years, as well as review articles from benchmark research communities.

EEG and Quantitative EEG (QEEG)

The EEG signal is composed of synchronised synaptic potentials in the cerebral cortex and appears as wave forms made up of different frequencies and rhythms. In the EEG of healthy adults and adults in a waking state, the activity consists mainly of alpha waves in the 8–13 Hz frequency range and some beta waves in the 14–30 Hz frequency range, while there are few theta waves in the 4–7 Hz frequency range and almost no visible delta waves in the 0.5–3 Hz frequency range. Table 1 shows in which neural networks the different frequencies can be found (8). During drowsiness and sleep, an EEG will show more slow waves. Drugs that affect the brain can also change the speed of the EEG rhythms.

Epileptiform activity consists of sharp waves or a «spike-and-wave» pattern. This is a specific sign of epilepsy if the patient also has seizure symptoms which can fit the diagnosis. The probability of finding epileptiform activity in a patient with epilepsy increases if the EEG is recorded while the patient is sleeping (9).

With the development of modern computer technology, frequency analysis based on

MAIN POINTS

Patients with new-onset psychosis should undergo clinical examination for pathological changes in the brain using a standard EEG test

Psychiatric patients with sudden or stereotypical seizure episodes accompanied by changes in consciousness, behaviour or mood should also be assessed for epilepsy using EEG

A quantitative EEG analysis (QEEG) has no certain clinical usefulness in patients with depression or schizophrenia and must be interpreted by a clinical neurophysiologist in connection with a standard EEG test

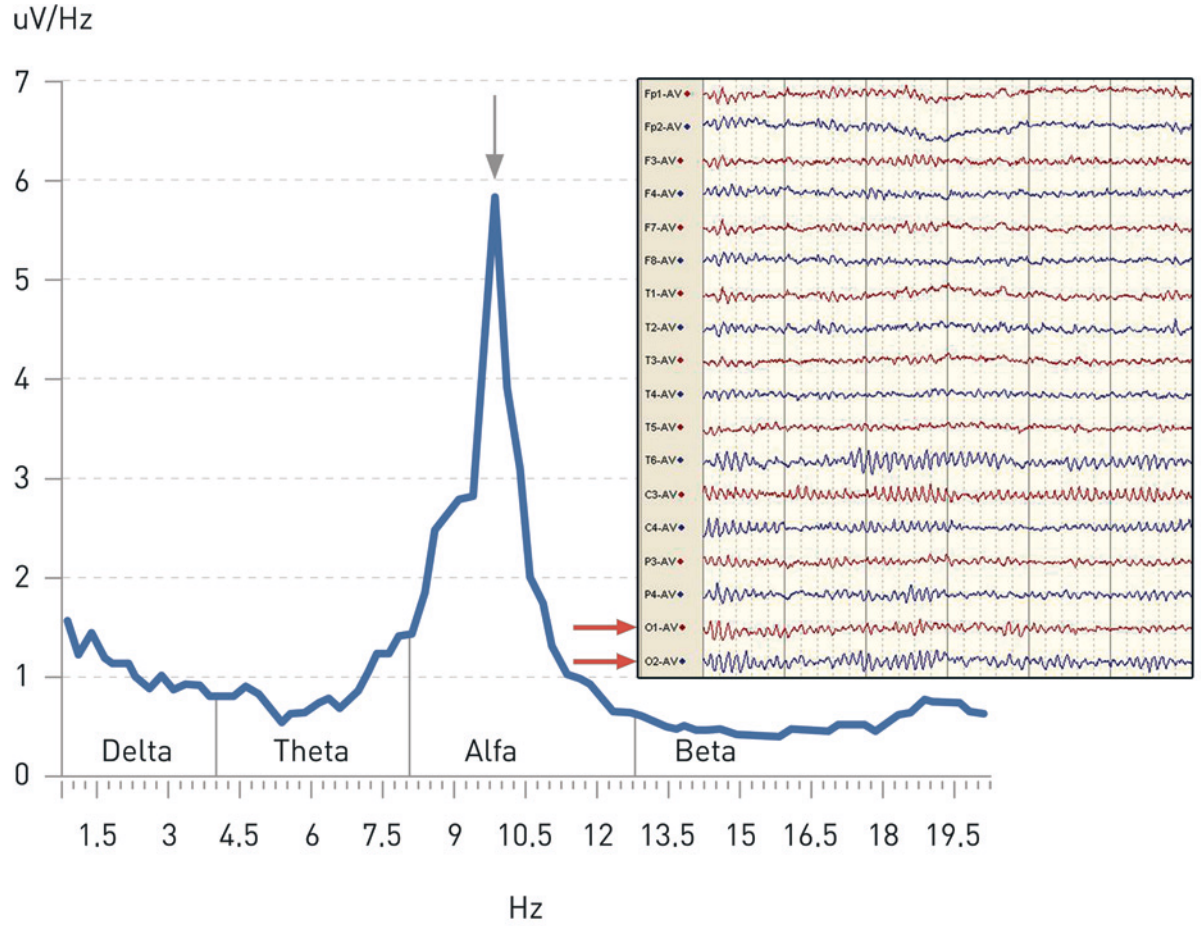

Fig. 1 *Normal EEG of a waking adult, eyes closed, is shown accompanied by the associated frequency-distribution curve. The blue curve is the result of a QEEG analysis of the visual cortex based on 103 seconds of artifact-free EEG and shows the average curve from electrodes O1 and O2 (red horizontal arrows). The curve shows amplitude per Hz (y-axis) as a function of EEG frequency (x-axis). The amplitude per Hz is a measure of how frequent and energy-rich the EEG activity is as a function of the frequency content. Delta, theta, alpha and beta activity can also be calculated as the area under the curve (in μV) between the vertical lines that mark the boundaries between the frequency ranges. The alpha rhythm frequency (black arrow – the peak of the curve) is normal = 9.75 Hz. Note that there is relatively low theta amplitude (between 4 and 7.75 Hz) and delta amplitude (between 0.75 and 3.75 Hz) in a normal EEG.*

FFT (Fast Fourier Transformation) was researched in psychiatry and neurology (9, 10). Frequency analysis provides numerical values for the quantity of delta, theta, alpha and beta activity and the distribution can be shown in an x/y (frequency/quantity) graph (Fig. 1). Frequency analysis (QEEG) is built into several commercial EEG systems used in Norway today. Unqualified overuse of QEEG in clinical settings in the 1990s was criticised by the American Academy of Neurology, who stated that QEEG should always be used in conjunction with a standard EEG test interpreted by a neurophysiologist (6). The reason for this is that there are many sources of error which must be eliminated before it is possible to rely on a QEEG analysis giving the correct result. QEEG is a useful research tool, however. With the development of analytical programs with user-friendly interfaces and larger data processors, there is now rapid growth in research into the use of QEEG in psychiatric conditions (7).

EEG and cognitive processes – biological background

Can EEG rhythms tell us anything about our cognitive abilities or emotional stability? New research shows that rhythmic activation of neural networks, particularly within the theta frequency range, is very important for memory and other functions of the basal ganglia in the brain (11) (Table 1). Especially fast 31–100 Hz gamma waves (12), in interplay with theta rhythms, are assumed to reflect the basic neurobiological mechanisms whose function is to link new experiences to old memories (association) and to transfer relevant new experience to the long-term memory (13). On the other hand, there is no certain connection between alpha rhythm frequency and intelligence as long as the alpha rhythm remains within the normal range of 9–13 Hz (14).

Other new QEEG methods such as low-resolution electromagnetic tomography (LORETA) (15) provide information about sources of EEG rhythms in deeper parts of the brain. Analysis of covariance (coherence or concordance analysis) (16) shows which

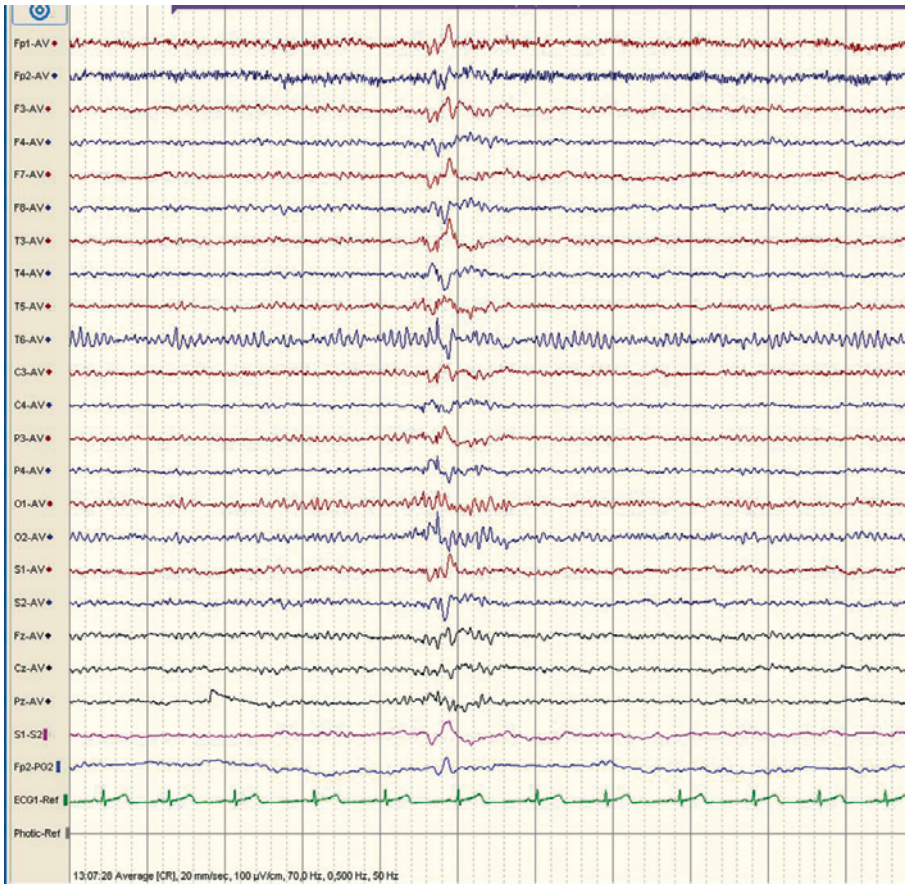

Fig. 2 *EEG of a subject with acute depressive periods. Normal background activity. One single brief, generalised asymmetrical discharge with atypical spikes can be seen.*

parts of the brain cooperate while executing various tasks. In this way, QEEG can supplement functional MRI of the brain and can be used to map the brain's «functional network» in healthy and sick individuals.

Acute psychiatric symptoms

Neurological brain diseases may first present with psychiatric symptoms, for example in the form of new-onset psychosis or fluctuating or progressive loss of cognitive function (17, 18). EEG is therefore a useful tool in clinical examination and may, for example, help to distinguish between «bipolar disorder» and «organic disorder with bipolar symptoms» (19).

We sometimes find a clear increase in slow theta and delta waves. The clinical neurophysiologist who interprets EEG will first consider whether an increase in slow theta activity may have been caused by treatment with antipsychotic or antiepileptic drugs (20) or by drowsiness. Slow delta waves are as a rule a non-specific sign of brain disease, such as brain tumour, infection/abscess, limbic encephalitis, cerebrovascular disease, degenerative, inflammatory or demyelinating brain disease or a toxic/metabolic encephalopathy. In patients with acute psychiatric symptoms without any known underlying cerebral pathological changes and in whom slow EEG activity is detected, an EEG test should as a rule be performed, supplemented with a CT or MRI brain scan (21).

Psychiatric disorders increase the risk of epilepsy

Patients with psychotic or affective disorders will have an increased risk of developing epilepsy (5, 6). The causal connection is complex and probably includes neurobiological, psychosocial and/or iatrogenic mechanisms (2). A sub-group of patients with recurrent brief unstable depressive episodes often have an abnormal EEG (Fig. 2), and have more frequent comorbid epilepsy than patients with classic depressive or bipolar disorders (22, 23).

In a retrospective observational study of clinical EEG in acute psychiatry from 2006, abnormal EEG was identified in 17 % of the patients (24). A little less than half had known epilepsy, but the EEG results changed the therapy in only 1–2 % (24). This study was retrospective and involved few EEG tests. In our experience, the real significance of EEG may be greater, however, because we now have better access to MRI scans and use more antiepileptic drugs in psychiatry. Even though most EEGs are normal, the results may be extremely important for those patients whose tests reveal findings. EEG should therefore be carried out on patients with conditions characterised by rapid changes in mood or behaviour, muscle cramps or other brief, stereotypical seizure-like symptoms.

Psychiatric symptoms may be caused by epilepsy

Epileptic seizures can resemble psychiatric disorders. Prolonged epileptic seizures such as in complex partial status epilepticus (CPSE, non-convulsive status) can give rise to long-term impaired consciousness, automatisms, affective changes, confusion, amnesia, fear or schizophreniform disorder symptoms (25). Temporal lobe epilepsy can cause sudden, temporary anxiety or deep despair (3, 25). Frontal lobe epilepsy can manifest itself in seizures with bizarre behaviour. Important differential diagnoses are, among others, panic disorder, parasomnia and psychogenic seizures.

Table 1 EEG wave frequencies found in neural networks. Simplified from Table 1 in Uhlhaas & Singer (8). Reproduced with the permission of Macmillan Publishers Ltd: Nature Reviews Neuroscience © 2010

EEG rhythm	Anatomy	Function
Delta (0.5–3 Hz)	Thalamus, cortex	Sensory gating. Deep non-REM sleep. Memory.
Theta (4–7 Hz)[1]	Hippocampus, sensory cortex, prefrontal cortex	Memory, synaptic plasticity
Alpha (8–13 Hz)[1]	Thalamus, hippocampus, sensory and motor cortex	Alertness, consciousness
Beta (14–30 Hz)[1]	Whole cortex, basal ganglia	Sensory gating, alertness, motor control
Gamma (31–100 Hz)	All brain structures	Sensory function, alertness, memory, consciousness, synaptic plasticity

[1] Also involved in synchronisation between brain regions

Depressive or psychotic episodes can also be time-related to an epilepsy seizure. Many patients with epilepsy report prodromal mood changes 1–3 days prior to a seizure. Epileptic seizures can also be followed by temporary psychiatric symptoms, such as postictal psychosis or postictal depression. There is typically a symptom-free interval of up to one week (3, 25).

Since, as we have seen, it can be difficult to distinguish between epilepsy and psychiatric disorders, patients with acute psychiatric symptoms should generally be examined by both a psychiatrist and a neurologist, and an EEG test should be performed whether the patient has known epilepsy or not.

Consequences for treatment of epileptiform EEG activity

If epileptiform activity is found in an EEG, a neurologist should assess whether there is clinical epilepsy or not. Psychiatric disorders and symptoms caused by current epileptic activity should be treated with antiepileptic drugs. Treatment with such drugs may be necessary in exceptional cases even if an EEG does not show epileptiform activity, because ictal and postictal psychosis can be caused by deep-lying limbic epileptiform activity (20). Treatment with antiepileptic drugs may, however, be indicated for some non-epileptic patients, although a Cochrane Review has recommended that carbamazepine should not be used *routinely* to treat schizophrenia (26). Pathological EEG findings will increase the indication for administering antiepileptic drugs compared with other psychotropic drugs, irrespective of the psychiatric core symptoms (27, 28).

Is QEEG useful in practical neuropsychiatric diagnostics?

Severe depression and bipolar disorder

A well-known research group has used QEEG to identify unipolar and bipolar depression with sensitivity and specificity in excess of 83 % (6). However, the QEEG method used is not generally accepted as clinically useful. There are particularly scant findings in the literature on bipolar disorder, and in older studies bipolar disorder was frequently lumped together with severe depression in the analyses (29). Most patients with acute mania have a normal EEG (30). Varied findings have also been reported in patients with severe depression, including an increase in right-sided delta activity (31). Mania-like episodes in epilepsy patients are also associated with right-sided brain dysfunction (25). On the other hand, in one blinded study no increase was observed in either delta activity or asymmetry (32). The literature is not very consistent and QEEG is still most useful as a research tool for depressive disorders.

Schizophrenia

There are many reports of significant EEG deviations between patients with schizophrenia and control subjects. John et al. found right-sided preponderance in amplitude in all frequency bands in depressive and schizophrenic psychotic patients (33). In patients with schizophrenia, Gordon et al. found an increase in right-sided frontal lobe alpha wave preponderance (34). There is now a great deal of interest in research into gamma waves (35). An increase in the amount of slow EEG activity in medicated and non-medicated schizophrenia patients (36) may also be caused by drowsiness, as schizophrenia patients sleep less than healthy individuals (37) and have fewer sleep spindles (38). The quality of the literature is variable and the findings are not consistent. Consequently, we still have no robust QEEG method able to provide specific information about the schizophrenia diagnosis.

Can EEG/QEEG predict the response to psychiatric drug therapy?

The aim is to avoid weeks of «unnecessary» antidepressant treatment in patients who will not respond (39). Different QEEG markers correlate with the response to antidepressant treatment (40, 41), but it is impossible to predict the results in individual patients (30). Prognostic QEEG techniques cannot, therefore, be used yet in everyday clinical settings.

The research literature on the use of QEEG as a method to help diagnose depression, bipolar disorder and schizophrenia is unfortunately dominated by small-scale studies without blinded evaluation, and even in large-scale review papers there has been no attempt to assess the quality of the method (42, 43). QEEG is nevertheless a useful research tool because it is difficult to quantify normal limits in a visual EEG interpretation (44). We would stress how very important it is to blind all future studies and to include a sufficient number of healthy controls, patients and patient-controls if there is to be any hope of finding robust psychiatric QEEG markers in the future.

Conclusion

EEG is indicated in patients with new-onset psychosis, conditions characterised by rapid changes in mood or behaviour, or conditions characterised by fluctuating or progressive cognitive impairment. The purpose of using EEG is to examine whether the patient may have epileptic or slow EEG activity. Epileptiform activity is a specific sign of epileptic aetiology or comorbidity. Slow EEG activity may be a non-specific sign of brain disease, which should generally prompt further neurological examination. Where there are brief and stereotypical changes of behaviour in patients with psychiatric disorders, epilepsy should be suspected. Epileptic seizures may also manifest as, or trigger, psychiatric symptoms. Where underlying epilepsy is suspected, the general practitioner can also refer the patient for EEG.

Diagnostic EEG should be interpreted by a specialist in clinical neurophysiology. There are so many sources of error that must be identified and eliminated that any QEEG analysis should only be carried out as a supplement to a visual EEG interpretation (45, 46). Pathological EEG findings will increase the indication for use of antiepileptic drugs compared with other psychotropic drugs, irrespective of the psychiatric core symptoms.

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