Clinical neurophysiology

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Abstract

The electroencephalogram (EEG) is a simple, non-invasive test of brain function that is mostly used for the diagnosis and classification of epilepsy. Bilateral 3/second spike and slow wave complexes are seen in primary generalized epilepsy and localized spike discharges occur in partial seizures. Prolonged recordings of seizures, allowing a clinical and electrographic correlation, are helpful for precise diagnosis. The EEG may show characteristic waveforms (slow waves, triphasic or repetitive complexes) that help in the management of other brain diseases such as encephalitis and encephalopathy. Evoked potentials are used to confirm the presence of central nervous system demyelination in suspected multiple sclerosis where imaging changes are equivocal. Operative or intensive care unit monitoring of central nervous system function with evoked potentials or EEG are used in spinal surgery and for patients with status epilepticus or head injury. Nerve conduction and needle electromyography (EMG) are used to investigate peripheral neuromuscular disorders, especially to confirm the presence and assess the severity of peripheral nerve disease. Clinical neurophysiologists are often asked to investigate patients with undiagnosed neurological symptoms, and in these patients the tests provide objective information as an extension to the clinical examination. Measurement of sensory nerve action potentials helps locate lesions in sensory pathways. A combination of motor nerve conduction and needle EMG is particularly useful when investigating patients with weakness. Specialized computer-based EMG studies help quantify abnormalities in myasthenia, motor neurone diseases and primary myopathy.

Keywords electroencephalogram; electromyography; epilepsy; evoked potentials; motor neurone disease; myopathy; nerve conduction; peripheral neuropathy

In clinical neurophysiology, electrical potentials recorded in the resting state or following an external stimulus are used to determine the function of the central or peripheral nervous system. The three main groups of tests are:

- electroencephalogram (EEG) (recordings of spontaneous activity from the brain)
- evoked potentials recorded from the central nervous system (CNS) following an external sensory stimulus
- nerve conduction studies/electromyography (EMG) (used to investigate peripheral neuromuscular structures).

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What's new?

- Most EEG recordings now have a linked video, allowing more precise electroclinical evaluation of epilepsy syndromes and sporadic symptoms
- The electrophysiological features of acquired demyelinating peripheral neuropathies are being better defined, and treatment modified depending on the presence of conduction block.
- Evoked potentials remain useful to diagnose some patients with multiple sclerosis.
- Long-term EEG monitoring for epilepsy and on intensive treatment unit (ITU) are becoming more widely available

Electroencephalogram

Electrodes attached to the scalp with conductive paste are most often used to record electrical potentials originating in the cerebral cortex. The signals vary in frequency and amplitude between different regions of the head; the most consistently observed activity is at 8–12 cycles/second over the occipital region when the subject's eyes are closed (the alpha rhythm). The mechanism that generates EEG rhythms is not fully understood but is thought to involve diffusely projecting neuronal circuits connecting the thalamus and cerebral cortex. The normal EEG changes in appearance with the subject's state of alertness and with development from birth to adulthood. A wide range of patterns are seen in normal individuals. These factors can make diagnosis of cerebral disease difficult, but three types of electrical discharges are strongly associated with disorders of cortex function (Figure 1).

Excessive slow-wave discharges (< 8Hz), when generalized, indicate a diffuse disorder such as metabolic, endocrine or ischaemic encephalopathy, or neurodegenerative dementia. When localized, they indicate focal or multifocal structural cortical disease – imaging procedures are required to show the anatomical basis for these EEG changes.

Spike and slow-wave complexes are the hallmark of epilepsy and may be seen during seizures (ictal discharges) or, more often, subclinically between attacks (interictal epileptic discharges, IEDs). Generalized spike and slow-wave complexes occur in primary generalized epilepsy, in which they are bilaterally synchronous, maximal over the front of the head and repeat at a rate of about 3 per second. In some photosensitive patients, these discharges can be provoked by a light flickering at a rate of about 18 flashes per second. Focal spike and slow-wave discharges are characteristic of partial epilepsy and are localized to the region of the cortex where the seizures are likely to originate (most commonly the temporal or frontal lobes).

Complex discharges have diverse waveforms, but typically exhibit a periodic discharge pattern, appearing rhythmically at

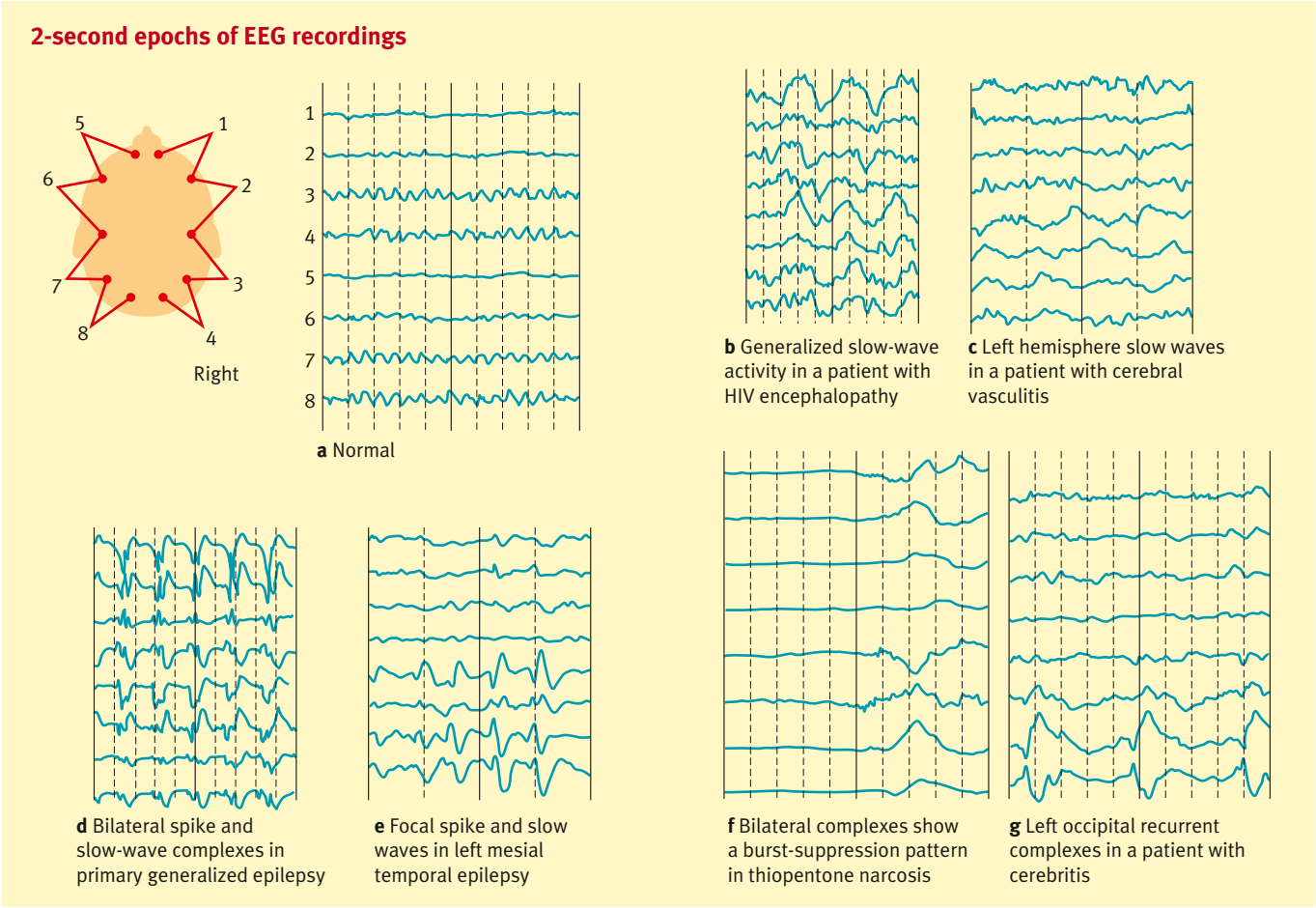

Figure 1

a rate of about 1–2 per second. Symmetrical complexes with a triphasic waveform are seen in sporadic Creutzfeldt–Jakob disease and in hepatic encephalopathy. Repetitive waves with a more complicated appearance are characteristic of the now rare subacute sclerosing panencephalitis. Lateralized discharges similar to IEDs occur in disorders causing acute necrosis of the cortex (e.g. infarction, herpes simplex encephalitis).

EEG in epilepsy

A single 20–60-minute EEG reveals IEDs in about 50% of patients with epilepsy. The sensitivity increases to more than 90% with repeated recordings using activating procedures (photic stimulation and over-breathing enhance electrical abnormalities in primary generalized epilepsy, and sleep or sleep deprivation can trigger IEDs in most types of epilepsy). In most patients with epilepsy, therefore, standard EEG can be used for diagnosis and syndromic classification. Conversely, because of the low sensitivity, a normal standard EEG cannot exclude the diagnosis of epilepsy. False-positive EEGs showing spike and slow-wave complexes in individuals who do not have epilepsy are obtained in less than 0.5% of the population.

Standard EEGs are usually recorded with a simultaneous video of the patient, which helps identify artefact and allows a correlation between electrical abnormalities and symptoms that may occur during the investigation. When doubt remains about the nature of the patient's symptoms it can be helpful to prolong the recording for up to 3 days using an ambulatory recorder. This has the advantage of recording in the patient's usual environment, and prolonging recordings during sleep helps detect IEDs, but attacks cannot be observed. Another method of prolonged EEG recording is videotelemetry, in which time-locked scalp EEG and video recordings (most often made in a confined ward environment) allow precise correlation of clinical and electrical changes during attacks. This technique is most useful in the preoperative assessment of candidates for surgical treatment of epilepsy and for those with intractable attacks that otherwise defy diagnosis.

Surgery is most often performed for the syndrome of mesial temporal epilepsy. This can often be sufficiently defined before surgery by a combination of interictal and scalp ictal EEG recordings, assuming they accord with imaging and neuropsychological data. In contrast, neocortical epilepsy without identifiable structural cortical disease usually requires evaluation by seizure recordings using intracranial electrodes to determine the safe extent of cortical excision.

EEG in intensive treatment unit (ITU) monitoring

Computer technology now allows long-term monitoring using a full set of scalp electrodes to facilitate management of patients with impaired consciousness from status epilepticus or