EEG and Brain Imaging in Psychiatry

Electroencephalography

Electrode placement

- usually according to the International 10-20 System which entails measurements from:
  - the nasion
  - the inion
  - the right auricular depression
  - the left auricular depression

- sphenoidal electrodes (between the mandibular coronoid notch and the zygoma) can be used to obtain readings from the inferior temporal lobe
- nasopharyngeal leads (in the superior part of the nasopharynx) can be used to get readings from the inferior and medial temporal lobe

Wave characteristics

- amplitudes range from 5-150 $\mu$V
- frequencies range from 1-40 Hz
- spikes are transient high peaks that last less than 80 ms
- sharp waves are sharply-defined waves that rise rapidly, fall more slowly, and last more than 80 ms

Frequency ranges

1. **Delta ($< 4$ Hz):**
   a) diffusely distributed across scalp in sleeping adults and in children
   b) abnormal in non-sleeping adults

2. **Theta (4-7 Hz):**
   a) transient theta components found in 15% of the normal population

3. **Alpha (8-13 Hz):**
   a) prominent over occipital region
   b) accentuated by eye closure and attenuated by attention
   c) a consistent difference of 1 Hz or more between hemispheres is pathological
   d) slowing is seen in early PHENYTOIN toxicity

4. **Beta (14 Hz and above):**
   a) principally frontolateral
   b) may be enhanced by anxiety, alcohol, and drugs (barbiturates, benzodiazepines)

5. **Mu (arch-like 7-11 Hz waves):**
   a) over precentral areas
   b) occurs over the motor cortex and is related to motor activity
   c) attenuated by contralateral limb movements

6. **Lambda:**
   a) single sharp waves in occipital region
b) usually associated with visual ‘scanning’ and is related to ocular movements during visual attention
c) occurs when eyes are open

7. **Vertex waves:**  
a) electronegative sharp wave over vertex  
b) evoked by auditory stimulus

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**The Normal EEG**

- infants have slower and usually higher amplitude rhythms  
- asynchronous at first, and easily disturbed – mature rhythms develop between 2 and 6 years  
- adults usually show either alpha posteriorly and beta anteriorly, but generalized low-amplitude beta may be present – established by puberty  
- when subject is drowsy, alpha becomes intermittent and theta appears  
- in old age:  
  - alpha frequency slows  
  - delta activity is decreased

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**Changes in EEG patterns**

**Diffuse lesions**

- rhythmic slowing  
- occasionally periodic discharges

**Focal lesions**

- polymorphic, arrhythmic, unreactive delta  
- periodic lateralized epileptiform discharges

**Epilepsy**

1. initial interictal EEG is abnormal in 50-75 \%  
2. with repeated recordings, 90-95 \% will show abnormalities  
3. 2 \% of normal population have abnormalities considered to be epileptiform  
4. **Absence seizures:**  
   a) 3 Hz spike and wave  
   b) 4 Hz spike and wave in juvenile

5. **Primary generalized tonic-clonic seizures:**  
   a) interictal : bursts of spike and wave  
   b) ictal :  
      i) 10 Hz fast activity during tonic phase  
      ii) lower-frequency spike and wave complexes during clonic phase  
   c) postictal : generalized slowing delta range

6. **Myoclonic epilepsy:**  
   a) polyspike and wave

7. **Partial (focal) epilepsy:**  
   a) interictal : focal spikes or sharp waves  
   b) ictal : focal rhythmic discharge
Periodic complexes
- Herpes simplex encephalitis
- CJD (in late stages)
- Subacute sclerosing panencephalitis

Triphasic waves
- Liver, renal hypoxia, or metabolic encephalopathies

Frontal intermittent rhythmic delta activity (FIRDA)
- Metabolic encephalopathy
- Brain stem dysfunction

Alpha coma
- Widespread, non-reactive alpha-range activity
- Generalized encephalopathy

Burst-suppression
- High-voltage bursts, followed by periods of extreme suppression
- Occurs within bihemispheric insult and deep anaesthesia

Drugs
- Chlorpromazine
  - Increased delta
  - Decreased beta
  - I.e. increases slow wave activity
- Phenytoin
  - Slowing of alpha
- Benzodiazepines
  - Increased fast wave (beta) activity
- Alcohol
  - Increased beta (i.e. fast wave)
- Carbamazepine
  - Increased fast wave
- Antidepressants (both TCAs and SSRIs):
  - Slowing of alpha
  - Increased slow wave (delta) activity

Personality disorder
- Increased slow waves (theta) in 31-58% of psychopaths
- Changes more right sided
- ‘Positive spike’ seen in 40-45% of aggressive and impulsive psychopaths

Anxiety
- Increased beta activity

Hypnosis
- Similar to the normal relaxed, waking state
Neuroimaging techniques

Exposure to radioactive substances
- PET and SPECT

Exposure to ionizing radiation
- CT
- PET
- SPECT
- fMRI (not regular MRI)

Computerized Tomography

Schizophrenia
- enlarged lateral ventricles
- third ventricle enlargement
- cortical atrophy (CA)

Affective disorders
- similar to schizophrenia, but less marked
- late onset depressives show more abnormalities than early-onset patients
  - more association with cognitive impairment and higher mortality

Dementia
- ventricular enlargement (VE) is marked in AD
- ‘patchy’ atrophy and multiple lucencies in multi-infarct dementia
- atrophy of caudate and fronto-temporal region in Huntington’s chorea
- hypodensities in basal ganglia in Wilson’s disease
- severe bilateral atrophy of anterior frontal lobes in Pick’s disease
- cortical and subcortical atrophy in Parkinson’s disease

Alcoholism
- VE and CA seen in chronic alcoholics
- CA related to extent of cognitive impairment

Magnetic resonance imaging (MRI)

Principle
- strong magnetic fields cause proton spin axes to align, and when rf waves are administered, the protons jump to a higher quantum level and then return, emitting wave frequencies which can be measured
Applications

- MRI can be used to obtain information about:
  - high-resolution structural images
  - neuronal membrane phospholipid metabolism (using $^{31}\text{P}$ MRS)
  - concentration of fluorine-containing drugs and metabolites (using $^{19}\text{F}$ MRS)
  - lithium concentrations
  - regional blood flow (using fMRI)

Schizophrenia

- agenesis of corpus callosum, cavum septum pellucidum
- reduction in size of mesial temporal lobe and superior temporal gyrus (especially on the left)
- smaller frontal lobes
- larger basal ganglia structures

Affective disorders

- white matter hyperintensity lesions in bipolar patients and particularly in elderly depressives
- some reports of reduction in size of caudate and putamen nuclei in depression

Alzheimer’s disease

- selective loss of hippocampal tissue

Substance abuse

- reduction in cortical grey matter and $T_1$ changes correlate with cognitive impairment in alcoholics
- some reports of white matter hyperintensities in opiate addicts

Autism

- hypoplasia of 4th ventricle and cerebellar vermis

Gilles de la Tourette’s syndrome

- asymmetry and/ or reduction in basal ganglia structures

Multiple sclerosis

- especially useful for showing plaques and areas of demyelination

Functional MRI

- uses exogenous contrast agents, or the endogenous contrast agent effect of deoxyhaemoglobin in blood
- can achieve high spatial and temporal resolution images of brain activity
Single photon emission (computerized) tomography (SPET; SPECT)

Principle
• uses single photon (gamma ray) emitting isotopes, e.g. xenon 133, technetium 99
• given IV or inhaled
• the resolution is generally lower than PET

Applications
• SPET can give information about:
  • regional cerebral blood flow (rCBF)
  • ligand binding
• Clinical uses include:
  • Alzheimer’s disease
  • when the symptomatology (e.g. hallucinations, epilepsy) occurs at a time when the patient is not near a scanner; a suitable ligand (e.g. 99m-technetium) can be given at the material time and the patient scanned afterwards

Schizophrenia
• reduced rCBF in frontal regions – ‘hypofrontality’

Affective disorders
• as that in schizophrenia, with reversal after antidepressant therapy

Alzheimer’s disease
• decreased rCBF in posterior parietal and temporal regions

Xenon inhalation
• shows failure of activation of frontal lobes in schizophrenics performing the Wisconsin Card Sorting Test

Positron emission tomography (PET)
• unstable isotopes (oxygen 15, fluorine 18, carbon 11), generated from a cyclotron, emit gamma rays when penetrating tissue
• the radioactive substance can be given IV or inhaled

Applications
• PET can give information about:
  • metabolic changes
  • regional cerebral blood flow (rCBF)
  • ligand binding
• Clinical uses include:
  • cerebrovascular disease
  • Alzheimer’s disease
  • epilepsy, prior to neurosurgery
  • head injury
Panic disorder
• decreased activity in the right parahippocampus demonstrated

OCD
• hypermetabolism in orbitofrontal cortex and caudate nucleus; normalizes with treatment