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 μV
- 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

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

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}P MRS)
  - concentration of fluorine-containing drugs and metabolites (using ^{19}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 4^{th} 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