Summary - Abnormal EEG

- Focality due to structural changes
- Diffuse changes due to encephalopathy/delirium
- Morphology, frequency, amplitude, reactivity, variability
- Correlate with the clinical picture and imaging
- Assess need for cVEEG? Evolution, variability, seizures
Focal slowing with only focal slow activity

Focal slow activity also with fallout of faster frequencies

- Pierre Gloor - cat experiments. Neil Schaul

- De-afferenting cortex, but sparing overlying mantle – i.e. white matter disease produces polymorphic (arrhythmic) delta activity

- Focal cortical and subcortical lesions: both cortex and white matter – produce combined slowing and loss of fast activity

- Pure cortical – focal slowing, or attenuation of fast activity - alpha/theta
Left polymorphic delta and fast activity: both cortical and white matter, e.g. stroke
Bi-frontal ischemia – anterior slow activity sparing posterior alpha rhythm
Right subcortical GBM – slow activity preserving some overlying fast activity
Cortical atrophy – slowing of background alpha frequencies
The slowing is variable - “reverses” with arousal/stimulation - $\uparrow$ CO2
Encephalopathy –
Often multiple simultaneous causes
Multimorbidity in encephalopathy

EEG severity in Encephalopathy

- **Mild**: slowing posterior waking rhythm [<8.5 Hz]. Sleep and waking still different.

- **Moderate**: Alpha replaced by theta activity [4-7 Hz] - diffusely distributed. EEG is reactive.

- **Moderately Severe**: delta activity [<4 Hz] - loss of fast frequencies. EEG less variable. Reactivity less.

- **Severe**: low voltage delta activity - minimal variability/reactivity. Eventually flat (<2uV) - unreactive.
Classification System for Coma

- **Grade I**: regular alpha, some theta
- **Grade II**: predominant theta
- **Grade III**: widespread delta (reactive or non-reactive), or spindle coma
- **Grade IV**: burst-suppression pattern; alpha coma pattern, theta coma pattern or delta (<20uV).
- **Grade V**: Flat (<2uV)

Synek 1988
EEG patterns in coma
Grade I – alpha with some theta – 79%
Grade I I – theta  ~ 50 %
Grade III – delta
reactive/unreactive ~ 25 %
EEG Grading for Good Outcome after CRA

Good Outcome

Grade 1  48/61  (79%)
Grade 2  45/88  (51%)
Grade 3  11/43  (26%)
Grade 4  0/138  (0%)
Grade 5  0/70  (0%)
The following EEG patterns were predictive of a poor outcome:

- Low-voltage invariable EEG
- Electro-cerebral inactivity - FLAT
Alpha Coma

- First described by Loeb and Poggio (1953) in a patient with brainstem hemorrhage.
- Consists of alpha frequency activity
- Unlike waking alpha rhythm, it is
  - Diffusely distributed
  - Anteriorly dominant
  - May be invariable and unreactive
Overall mortality for the group was 256/335 (76%)

Etiology predicted outcome (% mortality)

- Anoxia: 88%
- Brainstem infarct: 90%
- Drug intoxication: 8%
Spindle Coma

- First described by Jasper and Van Buren (1953) in a patient neoplasia of the midbrain near the 3rd ventricle
- Consists of sleep-like activity with 9-14 Hz spindles
- Activity may occur on routine or prolonged EEG recordings, may be reactive to noxious stimuli, but not with awakening
Spindle Coma: What Features Predict Outcome?

- Mortality for all spindle coma causes 56/242 (23%)
- **Etiology predicted outcome** (% mortality)
  - Structural/brainstem path 73%
  - Hypoxia 33%
  - Trauma 15%
  - Drugs/seizures/encephalopathy 0%

Kaplan et al, 2000
Patients >2 weeks after CRA in coma patients ~ permanently disabled.

Late recovery - 17-37 days after CRA who reached independent status.

PSA during burst-suppression patterns (BSP).

All patients with late recovery from coma had prominent BSP on EEG

Prominent theta (4-7 Hz) dominated the bursts and between bursts
Encephalopathy patterns by anatomic origin
Anatomical localization of EEG pattern

- **Cortical**
  - Decreased alpha amplitude
  - Slowing of posterior alpha background frequency

- **Subcortical/white matter/thalamus**
  - Increased polymorphic or arrhythmic delta activity (ADA)
  - Triphasic waves (TWs)
  - Frontal intermittent delta activity (FIRDA)

- **Cortical and subcortical**

- **Brainstem**
  - Arrhythmic delta activity; rhythmic delta activity
  - Impaired arousal patterns
  - Sleep spindle activity
  - Alpha frequency patterns
Encephalopathy patterns by frequency
Excess Beta Activity

- Benzodiazepines or barbiturates
- Anxiety
- Alcohol withdrawal
Diffuse theta activity

- Mild metabolic problems – hypoglycemia
- Excess medication/toxicity
- Degenerative Cortical problems – Alzheimer
- Static encephalopathy
Polymorphic Delta Activity

- Polymorphic delta activity (PDA): dysfunction of the subcortical white matter
- Lesions which partially deafferent subcortical white matter (Schaul et al, 1977)
- PDA generated in pyramidal neurons layers II, III and V
- Encephalopathies - metabolic, toxic or infectious (Schaul et al, 1986).
Continuous Rhythmic Delta Activity (RDA)

- Deep-seated epileptic foci
- Limbic encephalitis
- Limbic status epilepticus
- Types of toxic-metabolic encephalopathies
Intermittent Rhythmic Delta Activity (IRDA)

- Non-specific; seen in various encephalopathies (Schaul et al, 1981)
- IRDA correlates with structural lesions affecting both the cortical gray matter and the deep nuclei (Gloor, 1968)
- Initially, IRDA was associated with deep midline lesions and increased ICP (Daly, 1953)
Bursts of frontal intermittent rhythmic delta activity (FIRDA)
Encephalopathy patterns - reactivity
Slowing “reverses” with arousal/stimulation - ↑ CO2
Metabolic encephalopathy – CO2 Narcosis
[pCO2 - 107 mmHg]
Favorable prognosis after CRA

- Spontaneous variability
- Reactivity
- Continuous patterns
- No GPDs; no identical bursts

Michel van Putten
Encephalopathy – structural, clinical and imaging correlates
5580 EEG recordings from 2007 to 2012

181 EEGs performed due to altered mental status

Exclusion criteria:
- 22 without brain imaging
- 5 with insufficient clinical data

n=27

n=154

Indications for EEG:
- Altered mental status (154; 100%)
  In addition:
  - Suspected seizures (38; 25%)
  - Delirium (21; 14%)
  - Suspected status epilepticus (4; 3%)

Theta (22%)
Theta-delta (21%)
Delta (18%)
TWs (22%)
FIRDA (17%)
Clinical and imaging correlates of encephalopathic patterns in EEG

Predefined particular EEG patterns

Objective
To investigate the association and interplay of structural (on brain MRI or CT), and non-structural pathological conditions with particular EEG patterns in encephalopathic patients.

→ Categorization of encephalopathic patients according to predefined EEG patterns.
A 60-year-old, confused man after **profound hypoglycemia** from **acute** insulin excess.
Excess slow background and diffuse slow activity (theta-delta)
MRI midline/posterior fossa (rhombencephalic changes)
Affects arousal pathways/stimulation
Limbic encephalopathy
Generalized rhythmic delta activity (GRDA)
The EEG - Slow background activity and intrusion of polymorphic slow activity.
TWs with atrophy, renal and cardiac failure, urosepsis and metabolic acidosis
An 18-year-old has encephalitis and acute disseminated encephalomyelitis (ADEM) – raised ICP
Structural abnormalities with different EEG patterns
Encephalopathy
EEG morphology
GPDs with triphasic morphology TWs

- First described as “blunt spike-wave activity” by Foley et al. (1950) in hepatic encephalopathy
- Bickford and Butt (1955) used the term “triphasic waves”
- Three phases, largest phase having surface positivity. Preceded and followed by smaller amplitude negative waves. Repeat at 2-3Hz
- Usually centro-anteriorly predominant, but diffuse.
- Reversible causes have a better prognosis. Still 30% mortality.
Figure showing TWs - travelling waves projected from the antero-posterior thalamic surface towards the cortex.
Clinical predispositions for GPDs - triphasic morphology (TWs)

- **Without** white matter disease/subcortical atrophy
  - Hepatic encephalopathy, hyperammonemia
  - Uremia, other marked electrolyte abnormalities
  - Anoxia
  - Toxins/medications (e.g. lithium, baclofen)

- **With** white matter disease/subcortical or diffuse atrophy
  - Mild infections (e.g. UTI, URTI)
  - Lesser degrees of electrolyte imbalance; Toxins
Hepatic Encephalopathy - ammonia at 92 umol/L
Anoxia - metronomic TWs
Cefepime – less regular; asymmetries - common
Lithium toxicity – can be sharper and asymmetric
Baclofen toxicity – sharper, variable, asymmetric
Pregabalin toxicity – can be sharper
Aztreonam – antibiotic toxicity – more anterior - fronto-polar
Significance of triphasic waves in patients with acute encephalopathy: A nine-year cohort study

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HIGHLIGHTS
- This study examined associations of clinical neurologic and EEG characteristics in encephalopathic patients with triphasic waves with outcome.
- Non-reactive EEG background activity was independently associated with death.
- Specific etiologies or underlying pathologies were not predictive for outcome.

ABSTRACT
Objective: Triphasic waves (TWs) are a frequent electroencephalography (EEG) finding in encephalopathy, yet their origin and prognostic significance are not well understood. The aim of this study was to determine the clinical and EEG characteristics in encephalopathic patients with TWs. We hypothesized that specific EEG characteristics are predictive of outcome.

Methods: Consecutive adult encephalopathic patients with TWs on EEG and neuroimaging were included. EEG analysis included semiquantitative evaluation of TWs, background activity, and EEG reactivity. The study endpoint was death.

Results: Over a nine-year period, 105 patients with TWs were included. Common abnormalities on neuroimaging were white matter lesions (40%) and cerebral atrophy (50%). Pathologic conditions included infections (56%), stroke (26%) and liver insufficiency (12%). Mortality was 20%. Absent EEG background reactivity and respiratory failure were independently associated with death (OR 3.79, 95% CI 1.08-12.80, p = 0.037 and OR 6.47, 95% CI 1.58-26.12, p = 0.02).

Conclusion: These results suggest that TWs are a marker of structural brain disease coupled with toxic-metabolic perturbations, and that etiologies or underlying pathologies were not predictive for outcome while non-reactive EEG was independently associated with death.

Significance: In contrast to clinical, EEG and neuroimaging findings, non-reactive EEG patterns predicted death in encephalopathic patients with TWs.

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Fig. 2. Proportional distribution of infections, metabolic derangements and structural brain abnormalities in encephalopathic patients with triphasic waves.
Prognostic significance of Triphasic Waves
(Sutter, Stevens and Kaplan 2013)

- 8 years - 105 patients. > 80% in ICUs
- Mortality 20%.
- White matter disease 60%; atrophy 55%; 23% ETOH
- 78% had 2 or 3 concurrent causes (infection, atrophy, tox/met – renal, hepatic)
- 32% had ALL THREE!
- Death associated with lack of EEG reactivity; ventilation
- Nothing else had prognostic significance
Summary

- **EEG** – look for focality, morphology, frequency, amplitude, variability and reactivity

- **Triage**: exclude seizures; provide prognosis

- Correlate with the clinical picture; imaging

- Assess need for cVEEG? Evolution, variability, seizures