Electroencephalogram (EEG)

- Graphical depiction of cortical electrical activity, usually recorded from the scalp.
- Advantage of high temporal resolution but poor spatial resolution of cortical disorders.
- EEG is the most important neurophysiological study for the diagnosis, prognosis, and treatment of epilepsy.

10/20 System of EEG Electrode Placement
**Physiological Basis of the EEG**

- Extracellular dipole generated by excitatory post-synaptic potential at apical dendrite of pyramidal cell

**Physiological Basis of the EEG (cont.)**

- Electrical field generated by similarly oriented pyramidal cells in cortex (layer 5) and detected by scalp electrode
**Electroencephalogram (EEG)**

- Clinical applications
  - Seizures/epilepsy
  - Sleep
  - Altered consciousness
  - Focal and diffuse disturbances in cerebral functioning

**EEG Frequencies**

- Gamma: 30-60 Hz
- Beta: 13-30 Hz
- Alpha: 8 to \( \leq 13 \) Hz
- Theta: 4 to under 8 Hz
- Delta: \(< 4 \) Hz
**EEG Frequencies**

- **Awake - eyes open** - beta - 18-25 cycles per second (cps)
- **Relaxed - eyes closed** - alpha - 8-13 cps
- **Stage 1 - theta** - 4-8 cps
- **Stage 2 - 12-14 cps - sleep spindles and K complexes**

**EEG Frequencies**

- **Stages 3 and 4 - delta (or slow wave sleep)** waves 1-4 cps > 75uV
- **REM sleep** - 3-7 cps (like theta or stage 1)
EEG Abnormalities

- Background activity abnormalities
  - Slowing not consistent with behavioral state
    - May be focal, lateralized, or generalized
  - Significant asymmetry
- Transient abnormalities / Discharges
  - Spikes
  - Sharp waves
  - Spike and slow wave complexes
  - May be focal, lateralized, or generalized

Focal seizure generation

- Seizure initiation
  - Burst of action potentials, i.e. paroxysmal depolarizing shift
  - Hypersynchronization of neighboring cells
- Propagation
  - Activation of nearby neurons
  - Loss of surrounding inhibition
**Sharp Waves**

- An example of a left temporal lobe sharp wave (arrow)

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**The “Interictal Spike and Paroxysmal Depolarization Shift”**

Intracellular and extracellular events of the paroxysmal depolarizing shift underlying the interictal epileptiform spike detected by surface EEG

Ayala et al., 1973

American Epilepsy Society 2008
Generalized Spike Wave Discharge

EEG: Absence Seizure
EMG and Nerve Conduction Studies

- An extension of the Physical Examination
- Quantitates nerve and/or muscle injury
- Provides Useful Data Regarding Nerve Injury
  - Site
  - Type
  - Severity
  - Duration
  - Prognosis

Importance of EDX Studies

- Diagnosis
- Localization
- Assist in further testing (i.e. identify potential biopsy sites, imaging studies, spinal fluid analysis, blood work)
- Prognosis
- Use in Research
Goals of EDX Testing

Localization Severity

Muscle NMJ Nerve Anterior Horn

Fiber type Pathology Temporal course

Adapted from fig 1-2, Preston and Shapiro

When to order NCSs and EMG

- Mononeuropathy
- Mononeuropathy Multiplex
- Radiculopathy
- Plexopathy (Brachial or Lumbosacral)
- Anterior Horn Cell Disorders
- Diffuse neuropathies
- Cranial neuropathies
- Neuromuscular Junction Disorders
- Myopathy
Types of nerve conduction studies

- Sensory: typically antidromic
- Typical nerves examined: Sural, ulnar, median, occasionally radial or superficial peroneal

Sensory NCS Parameters

- Onset and peak latencies
- Conduction velocity
  - determined by velocity of a very few fast fibers
- Amplitude
  - determined by the number of large sensory fibers activated
Normal Median Sensory Study

Latency  CV      Amp  
(msec) (m/s) (uV)

Wrist-D2  2.2 58  44.1

Motor NCS Parameters

- Distal Latency  
  - determined by conduction velocity of the nerve, neuromuscular junction & muscle

- Amplitude  
  - determined by number of muscle fibers activated

- Proximal conduction velocity  
  - determined by conduction velocity of the fastest fibers
Motor Nerve Conductions

- Vital part of EDX as this is important for identifying demyelination, compression
- Need to do proximal and distal studies to evaluate for conduction velocity, conduction block, temporal dispersion
- Typical nerves: ulnar, median, peroneal, tibial.
- Less common: radial, femoral, phrenic, spinal accessory, facial

<table>
<thead>
<tr>
<th></th>
<th>DL (msec)</th>
<th>CV (m/s)</th>
<th>Amp (mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wrist-APB</td>
<td>3.2</td>
<td>15.0</td>
<td></td>
</tr>
<tr>
<td>Elbow-Wrist</td>
<td>55</td>
<td>14.8</td>
<td></td>
</tr>
</tbody>
</table>
What is Peripheral Neuropathy?

Nerve conduction responses after injury
F-waves and H-reflex

- Useful for identifying proximal segmental demyelination
- Can only be done when motor amplitude is > 1 mV
- Extremely height-dependent

F Waves: Normal Median
Needle Electromyography: Techniques

- Needle electrode is inserted into the muscle
  - Needle is disposable, single use
- Multiple muscles are accessible for examination
- Combination of muscles tested
  - Dependent upon clinical question
- Level of discomfort is mild

Needle Electromyography: Data

- Insertional Activity
- Spontaneous Activity
- Motor Unit Configuration
- Motor Unit Recruitment
- Interference Pattern
Needle Electromyography: Data

- **Motor Unit Configuration**
  - Single motor unit: A motor axon and all its muscle fibers
  - Motor Unit Configuration: Amplitude, Duration, Morphology
  - Muscle is volitionally activated at different force levels
  - Needle recording properties enable assessment of single MUs

- **Motor Unit Recruitment**
  - Pattern of motor unit activation with increasing volitional activation

- **Interference Patterns**
  - Motor unit pattern with full voluntary activation

**EMG: Spontaneous Activity**

- **Fibrillation Potentials**
- **Positive Sharp Waves**
EMG: Spontaneous Activity

Fasciculation Potential

EMG: Neurogenic Motor Unit

10 msec/div, timebase
2MV/vertical segment
EMG
Motor Unit Changes

Common Mononeuropathies

- Median at the Wrist (CTS)
- Ulnar at the Elbow (Tardy Ulnar Palsy)
- Peroneal Palsy at the Fibular Head

Figure 44-4
Single voluntary motor unit potentials. A. Normal. B. Prolonged polyphasic potential seen with reinnervation. C. "Burst unit"—nearly shaped but of much greater amplitude than normal. D. Brief, low-amplitude "hypogalvanic" units. Calibrations: 5 ms/shorten 0.8 and 1 mV in A and B; 5 mV in C. 100 μV in D (overnight).

Adams and Victor, 1961
Case 1

- 63 year old woman
- Numbness, tingling, pain of entire right hand X 4 months
- Awakens her at night.
- Drops objects from right hand
- Works as sander in furniture factory.
- Borderline diabetic
- Examination: Decreased cold entire right hand, normal strength, positive Tinel’s right wrist, normal reflexes in the RUE

Carpal Tunnel Syndrome

Atrophy of APB Muscle

Dawson, Hallett, Millender, 1990
Median Nerve Innervation of the Hand and Sensory Loss

Carpal Tunnel Syndrome X-Section View of Wrist

Kopell, Thompson, 1963
Ulnar Neuropathy
Claw Hand

Haymaker, Woodhall, 1953

Ulnar Neuropathy
Sensory Loss, Nerve Innervation

Kopell, Thompson, 1963
Common Peroneal Injury
Right Foot Drop and Sensory Loss

Haymaker, Woodhall, 1953

Length Dependent Motor and Sensory Polyneuropathy
Plexopathy: Selected Etiologies

- Compression (CABG)
- Inflammatory (Parsonage-Turner Syndrome)
- Radiation Injury (Radiotherapy)
- Traumatic Injury (Traction, laceration, missile)
- Ischemia (Diabetic amyotrophy)

Guillain-Barre Syndrome
Conduction Block
Model of Neuromuscular Junction

Myasthenia Gravis (MG)

Repetitive Nerve Stimulation

Myasthenia Gravis
Repetitive Nerve Stimulation

2 Hz
Single Fiber EMG
Myasthenia Gravis

Lambert-Eaton Syndrome
Repetitive Nerve Stimulation
Dermatomyositis

Hand Rash

Dermatomyositis

Eyelid and Facial Rash
Summary: Utility of EMG/ NCS

- Highly sensitive indicator of early nerve injury
- Detects dynamic and functional injury missed by MRI
- Provides information regarding chronicity of nerve injury
- Provides prognostic data
- Highly localizing
- Clarifies clinical scenarios when one disorder mimics another
- Identifies combined multi-site injury, avoiding missed diagnoses
- Identifies more global neuromuscular injury with focal onset
- Provides longitudinal data for charting course, response to therapy
- **All dependent on a reliable laboratory with full repertoire of techniques**