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

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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 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)

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
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

<table>
<thead>
<tr>
<th>Latency (msec)</th>
<th>CV (m/s)</th>
<th>Amp (uV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wrist-D2</td>
<td>2.2</td>
<td>58</td>
</tr>
</tbody>
</table>
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 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

Normal Median Motor Study

<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?

F-waves and H-reflex

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

Median Nerve
Innervation of the Hand and Sensory Loss

Dawson, Hallett, Millender, 1990

Kapell, Thompson, 1963
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
Repetitive Nerve Stimulation
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**