Electricity and so much more!

- Recording membrane potentials
  - Can only measure activity
  - Implications made from absence of activity!
- Know where things are!
- Settings on instrument prepared for what you might record.
- Vary settings when response not apparent
  - Small, late, etc?
Describe these potentials.
Muscle at rest.

- Several different spikes?
- Duration?
- Regular firing?
- Amplitude?

Sweep = 10 ms/div
Gain = 200 µV/div
What is the size of the important signals here?

Ans: 20µV; so use a 50µV/cm Gain
Describe these potentials. Muscle at rest.

- Several different spikes?
- Duration?
- Regular firing?
- Amplitude?

Irregular End-plate Potentials

Sweep = 10 ms/div
Gain = 100 µV/div
Nerve Action Potential Recording

- The traveling action potential wave of SNAP is not symmetrical
- Distant portions are recorded by both electrodes
- Negative peak recorded under E1
Instrumentation

- Be prepared to record the signals related to your differential diagnosis!
- Amplitude/Gain
- Frequency & Duration/Sweep speed
- Hear it/Audio volume
  - Keep it on during Nerve Conduction Testing
    - This will not harm the amplifier
- Frequency/Analog to digital conversion rate
What is error in settings?

Cannot measure the 2nd sensory amplitude?

Median sensory to D3
Top-wrist stim
Bottom-palm stim

20 µV
1 ms
Correct settings! Able to measure amplitude. What are amplitudes?

Now we see the 50% SNAP conduction block!
NCV Vocabulary: Measurements

- Distal Latency (A)
- Conduction Velocity
  - distance/time
- Amplitude (B)
  - Baseline-to-peak
- Duration (C)
  - Negative potential
- Supra-maximal Stimulation = the stimulus that is 10% above that which produces the maximum response amplitude
Case: Paraspinal Muscle at rest
Describe the Findings

- Regular, 1.3 Hz
- 2 spikes, short duration
- Pacemaker spikes
Interference EMG

- A: Fluorescent lights + EMG
- B: Fluorescent lights
- C: Fluorescent lights + 60 Hz (power line)
  - (You can have fluorescent lights fixed!)
Interference EMG

- D: 60 Hz, power line signal
- E: 60 Hz “notch” filter applied to D

But this causes loss of signal in this frequency band as well.
Differential Amplifier

- Powerline interference affects all electrodes equally.
- Subtraction at differential amplifier results in near Zero output.
- This is the preferred way to eliminate 60 Hz interference.
Filters-Electronic

- The range of frequencies permitted to the output is the Bandwidth.
- The filter limits (“cut off”) are at 50% power reduction. About 70% amplitude (V).
Filters
Positive sharp waves

Left-Positive waves recorded with filters
20 Hz to 10kHz

Right-Positive waves recorded with filters
100 Hz to 10kHz

Sharper peak on negative phase
Looks like positive waves seen in end-plate zones.
**CMAP: Effect of Low Frequency Filter**

<table>
<thead>
<tr>
<th>Case</th>
<th>Lat. ms</th>
<th>Amp. mV</th>
<th>Dur. ms</th>
<th>Low freq.</th>
<th>Stim. mA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Wrist</td>
<td>3.85</td>
<td>10.4</td>
<td>6.20</td>
<td>3 Hz</td>
<td>14 mA</td>
</tr>
<tr>
<td>2. Elbow</td>
<td>3.85</td>
<td>8.9</td>
<td>6.65</td>
<td>20 Hz</td>
<td>15 mA</td>
</tr>
<tr>
<td>3. Axilla</td>
<td>3.85</td>
<td>5.5</td>
<td>4.80</td>
<td>100 Hz</td>
<td>15 mA</td>
</tr>
<tr>
<td>4.</td>
<td>3.65</td>
<td>10.5</td>
<td>6.45</td>
<td>3 Hz</td>
<td>15 mA</td>
</tr>
</tbody>
</table>

**Median Motor Latency**

- 100%
- 85%
- 55%
Filters; Sensory NCV

- High frequency filter change.
- 10 kHz vs. 2 kHz (smooth)
- Use the correct reference values for your filter settings!
The peak is the high frequency content.

### High Frequency Filter Effects On SNAP

<table>
<thead>
<tr>
<th>Trace</th>
<th>High Frequency Filter (Hz)</th>
<th>Low Frequency Filter (Hz)</th>
<th>Peak Latency (ms)</th>
<th>Amplitude (μV)</th>
<th>Negative Spike Duration (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>10,000</td>
<td>0.5</td>
<td>3.4</td>
<td>34</td>
<td>1.1</td>
</tr>
<tr>
<td>B</td>
<td>3,000</td>
<td>0.5</td>
<td>3.4</td>
<td>31</td>
<td>1.1</td>
</tr>
<tr>
<td>C</td>
<td>2,000</td>
<td>0.5</td>
<td>3.5</td>
<td>29</td>
<td>1.2</td>
</tr>
<tr>
<td>D</td>
<td>1,000</td>
<td>0.5</td>
<td>3.7</td>
<td>28</td>
<td>1.2</td>
</tr>
<tr>
<td>E</td>
<td>500</td>
<td>0.5</td>
<td>3.8</td>
<td>24</td>
<td>1.3</td>
</tr>
</tbody>
</table>
Electrode Separation
Median Sensory Distal Latency (14cm)

Electrode separation

top = 4 cm

Lat=3.70
Amp=27.6

bottom = 2 cm

Lat=3.65
Amp=21.2
Effect of Temperature on NCV

- Sensory Nerve Action Potential (SNAP) recorded at 32°C and 27°C (lower)
- Slowing is approx. = 5%/°C
- Amplitude and duration will both increase!
  - Not seen in pathology!
Nerve Conduction: Supramaximal Stimulation

- Supramaximal stimulation is related to the size of the sensory or motor response!

Supramaximal stimulation is NOT the maximum shock that your stimulator can deliver!
Shock Artifact

- Obscures initial response and baseline “0”
- Impedes measure of amplitude and duration
Ground Electrode Placed Between the Stimulator and the Recording Electrodes

(It can also be placed on the dorsum of the hand.)

(The correct technique for many years!)
Shock Artifact: Rotation of the Anode (about the Cathode)

- Reduction of shock artifact can often be achieved by rotation of the anode
- Watch your stimulator wires—stay away from recording wires ( )
Rotation of the Anode
(about the Cathode)

- Variation in shock artifact with rotation of
  the anode about the cathode
Rotation of the Anode (about the Cathode)

- Shock artifact occurs when E1 and G2 are on different lines of electrical potential in the stimulator’s electrical fields.
- Rotation moves these fields and can re-orient the electrical fields so that E1 and G2 are on an equi-potential line.
Shock Artifact: Other Factors

- Dry skin thoroughly between stim and recording elect.
- Increase distance between stimulator and recording elect. (if possible)
- Check or replace skin surface electrodes
- Move ground closer to recording electrode
Shock Artifact: Troubleshooting

- Minimize use of electrode gel
- Avoid excessive stimulus
- Try needle stimulus
- Use constant-current, rather than constant-voltage stimulus
Nerve Conduction Set-up

- **Motor**
  - Sweep speed
    - 2 ms/cm
  - Gain (Amplifier)
    - 2-5 mV
  - Filters
    - L=2 Hz, H=10 kHz

- **Sensory**
  - Sweep speed
    - 1 ms/cm
  - Gain (Amplifier)
    - 10-20 µV
  - Filters
    - L=20 Hz, H=2 kHz

N.B. “Most of the time”
Adapt *prn* to see response clearly.
Analog to Digital Conversion and Back

Sampling frequency of digital conversion must be more than two (2) times the highest frequency of interest in the study.
Data Should be Consistent!

Average amplitude of Median Sensory response at the thumb is 4 times the radial.
Mild Carpal Tunnel Syndrome

Top = Radial stim
Middle = Median stim
Bottom = Midpoint stim (Bactrian Sign)  (           )

Antidromic 10cm Technique To Digit I
Troubleshooting Example
Data Inconsistent

Median stim, Dig 1 rec
Radial stim, Dig 1 rec
Troubleshooting Example
Data Inconsistent

Median stim, Dig 1 rec
Radial stim, Dig 1 rec

“Missing” nerve causes us to increase stimulation intensity until we see something (anything)!
In this case, partial activation of distant nerve.
Common Errors

- Missing severe disease
  - Absent response is replaced by alternate response (e.g. ulnar motor rather than median motor response in CTS, or radial rather than median sensory response at thumb)
- Review data for inconsistencies, assume that inconsistent data contains technical errors!
Sural Sensory Nerve Conduction

Sweep=1 ms/div, gain=10 µV/div.

A:14cm

Pathologic SNAP with duration >1.5 and < 3.0 ms. If duration is > 3 ms, then it is not a sensory potential.
Not Sure It’s a Potential?

- Markers appear on this signal.
- But there are other waves, too.

➢ Can you reproduce it?
Peroneal Motor NCV
What is inconsistent?

- Is it accessory peroneal?
- Popliteal stim is largest (P)
- Too little stim at ankle (A) and fibula (F)

(Pseudo-accessory peroneal)
Median Motor NCV

- E1 off of Motor point (but has negative initiation)
- E1-G2 short circuit
- Correct

All stimulations at the wrist
Median Motor NCV Inconsistency

Stimulate at:
1. Palm (P)
2. Wrist (W)
3. Elbow (E)
Median Motor NCV

- Stimulation at the wrist (W1) Excessive!
- Elbow stim (E)
Distance Measurement Problems

- 1. Excessive stimulation changes the point of activation
  - depth affects accuracy (needle)
- 2. Tape measure errors
  - Skin contours
Motor Nerve Recording

**ERRORS - Altering E1 position**

-20%

1 cm lateral

-47%

1 cm distal

Median Motor Nerve Latency
Progressive Weakness
Possible AIDP (GBS)

- No response is seen after a high intensity stimulation;
- What do you do next?
Demyelinating Neuropathy

- Anticipate the possible pathology of severe slowing and small amplitude!
- Change:
  - Sweep = 5 ms/cm (slower) &
  - Gain = 1 mV/cm (greater amplification)
Median Motor Conduction

- Median motor conduction velocity?
- A2 Latency wrist stim
- A3 Elbow stim
  - Sweep 5 ms/div
  - Gain 5 mV/div
Monopolar vs. Concentric: Are They Different?

Of Course They Are!

When Does It Matter?
Needle Electromyography

- **Purpose of Study**
  - Acquire qualitative and quantitative information regarding the electrical property of muscle

- **Requirements:**
  - Accurate
  - Efficient
  - Minimal risk
Recording Volume in the Muscle

- Concentric has a hemispheric space.
- Monopolar has a spherical space.
- Monopolar needle may be able to record from more fibers, although closest fibers have greatest influence.
Monopolar Needles

**Advantages**
- Lower impedance
- Larger recording volume
- Lower Cost
- Less Painful
- Location in muscle does not affect results
- Non-directional

**Disadvantages**
- Greater noise
- Surface reference electrode required
- More wear when re-used
Recording Surfaces

- Monopolar needle records only from its intramuscular tip
- Reference electrode is on the skin
Recording Surfaces

- Concentric needle has two intra-muscular recording surfaces.
- Electrical potentials are recorded with both of them, and may be inverted.
- When deep in the muscle, the outer shaft averages most signals and reduces them.
Resting Activity

- Sherman, Walker, Donofrio ’90
- Fibrillation Potentials more frequently seen with concentrics
- Gain settings:
  50 µV for concentrics, 100 µV for monopolars
- Suggested that the concentric needle causes more trauma, hence more fibs.
Resting Activity

- Kohara, Kimura ’93
- Fibrillations counted were $\geq 20 \, \mu V$
- Monopolar
  - 15.3 / 0.5 s
- Concentric
  - 7.3 / 0.5 s
## MUAP Amplitude Recording in Needle Electromyography

<table>
<thead>
<tr>
<th></th>
<th>Concentric</th>
<th>Monopolar</th>
<th>Comment Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nandedkar ‘91</td>
<td>436 (±269) μV</td>
<td>585 (±315) μV</td>
<td>Sharp rise time</td>
</tr>
<tr>
<td>Pease ’88</td>
<td>912 (±315)</td>
<td>1038 (±369)</td>
<td>Max amplitude</td>
</tr>
<tr>
<td>Dumitru ’97</td>
<td>340 (±181)</td>
<td>557 (±466)</td>
<td>Simultaneous recording of MUPs</td>
</tr>
<tr>
<td>Kohara ‘93</td>
<td>1460 (±570)</td>
<td>1830 (±670)</td>
<td>Max amplitude</td>
</tr>
</tbody>
</table>
MUAP Duration Recording in Needle Electromyography

- Similar results in all of the comparative studies
- Considered best reflection of local fiber density
When Does It Matter?

- **Monopolar Needle**
  - All routine studies!
  - First cases for a new trainee
  - Nerve stimulation in deep location

- **Concentric Needle**
  - Electrically noisy locations (e.g. ICU)
  - Allowing residents the comparative experience
Needle EMG Set-up

- **Sweep speed**
  - 10 ms/cm
  - (= 0.1 sec screen)
- **Gain (Amplifier)**
  - 50 µV for insertion and rest
  - 200-500 µV for MUPs

- **Recruitment**
- **Sweep speed**
- 10-50 ms/cm
- **Gain**
  - 500-1,000 µV
- **Filters**
  - L=20 Hz
  - H=10 kHz

N.B. “Most of the time”
Adjust *prn* to see response clearly.
Safety in EDX Medicine:

- **Infectious**
  - Universal Precautions – GLOVES with needles
  - Needles Disposed after use (do not recap, or if you must, then do “one-handed recapping”)

- **Electrical**
  - Current Leak and Ground Inspection by Engr.
  - Avoid Extension Cords
  - One ground on patient (Only!)
  - Common ground for other equipment (all on same circuit)
Leakage current
A greater risk
When two devices
Are in play. Avoid
The current path!
Paraspinal muscle hematoma

Filter Recommendations

- **Needle EMG**
  - 20 Hz
  - 10,000 Hz

- **SFEMG**
  - 500 Hz
  - 30,000 Hz

- **Motor NCV**
  - 2 Hz
  - 10,000 Hz

- **Sensory NCV**
  - 20 Hz
  - 2,000 Hz
Troubleshooting Noise

- Fluorescent Light Noise
  - Turn off, use incandescents
  - Replace starters with new, solid-state designs
- 60 Hz Power Noise
  - Un-plug other devices at wall
  - Re-arrange power cord locations
- Check all plug connections at amplifier and devices
Troubleshooting Noise

- **Next Steps - Differential Diagnosis**
  - Proper electrode positions

- **Electrode impedance**
  - Replace all surface and needle electrodes sequentially, clean and/or abrade skin

- **Bad wires** (damage may be hidden)
  - Wiggle or tug wires to test stability
  - Replace all wires and connectors
  - Avoid long lead wires
Troubleshooting Noise

- Amplifier or computer malfunction
  - Reboot system*, possible software malfunction/instability.

*ALWAYS unplug electrodes and patient connections before shutting down computer or unplugging equipment (can cause capacitor discharge)!
Troubleshooting Noise-Other Steps

- Make skin-to-skin contact with patient
  - “Ground yourself”
- Move instrument and amplifier locations and orientation
  - Wires and housings act as “antennas”
- Have instrument inspected for electrical problems and current leaks
Analog to Digital Signal Transfer
(ref: John Cadwell, in Aminoff text 1998)

Analog signal original

Digital sampling at 32 Hx A to D

Analog signal “reconstructed”
Differential Amplifier
(ref: Rogoff and Reiner, in Licht 1961)

Fig. 17. Block diagram of an electromyograph.
Differential Amplifier
(ref: Rogoff and Reiner, in Licht 1961)

Fig. 16. Action potential distortion due to limited frequency response. Upper line, normal; middle line, poor high frequency response; lower line, poor low frequency response.
Differential Amplifier
(ref: Rogoff and Reiner, in Licht 1961)
References