Nerve Conduction Studies
Nerve Conduction Studies

Nerve conduction studies are an essential part of an EMG examination.

The clinical usefulness of NCS in the diagnosis of diffuse and local neuropathies has been thoroughly validated since the 1940’s.

The findings reflect the functional state of the myelinated motor nerves, the neuromuscular transmission and the muscle fibers.
Figure 2. Pathways Leading to Pain in Peripheral Neuropathy and Potential Sites of Pharmacologic Interventions.

After peripheral nerve injury, a cascade of events up-regulates expression of membrane channels in the nociceptive neurons of the dorsal-root ganglion. Potential inhibitors of the sodium channel include tricyclic antidepressants, carbamazepine, oxcarbazepine, phenytoin, topiramate, lamotrigine, mefloquine, and lidocaine; a potential inhibitor of the potassium channel is gabapentin; and potential inhibitors of the calcium channel are gabapentin and lamotrigine. Sprouting sympathetic axons form interwoven baskets around cell bodies, causing exaggerated pain, which may be inhibited by tricyclic antidepressants, bupropion, or venlafaxine. At the site of peripheral-nerve damage (inset), sodium channels (which may be inhibited by the agents listed above) spread along the axon, resulting in ectopic neural discharges. Projections from nociceptive neurons in the dorsal-root ganglion to spinal interneurons enhance excitation by release of substance P, calcitonin gene-related protein (CGRP), and glutamate. The second-order neuron in the spinal cord, which is normally activated by glutamate through the α-amino-3-hydroxy-5-methyl-4-isoxazolepropionic acid (AMPA) receptors (orange triangle), is induced to fire spontaneously (central sensitization) through activation of the N-methyl-D-aspartate (NMDA) receptor (green triangle). Excitation of the second-order neuron leads to an increase in intracellular calcium and activation of protein kinases (PK) that phosphorylate intracellular proteins such as NMDA receptors. Potential inhibitors include gabapentin, lamotrigine, oxcarbazepine, topiramate, dexmedetomidine, tramadol, opioids, selective serotonin-reuptake inhibitors, and venlafaxine. Dynorphin, an opioid neuropeptide whose levels are elevated in chronic pain syndromes, can also contribute to ectopic excitation of the second-order neuron through activation of NMDA receptors. There is loss of inhibition of second-order neurons by reduction of input from γ-aminobutyric acid (GABA) through down-regulation of GABA<sub>A</sub> receptors (pink oval). Sprouts of central terminals of nonnociceptive neurons in the dorsal-root ganglion (Aβ neurons) express nociceptive substances (potentially inhibited by levodopa) in the dorsal horn, contributing to hyperalgesia and tactile allodynia.
Two motor units
Stimulation

A nerve is a Chain of Polarized Cells (Myelin Action). Stimulation in one point generates a depolarization.

A nerve could be depolarized by:
- Electrical Chock
- Mechanical Compression
- Magnetic Field
median nerve

anastomosis of ulnar nerve to median nerve

or pollicis brevis

len pollicis

carpo pollicis brevis

carpo pollicis brevis

carpo pollicis brevis
carpal head;
carpal head often

to uln
Stimulation Points

Upper Extremities

- Plexus Axillary
- Median Elbow
- Ulnar Elbow
- Radial Elbow
- Median Wrist
- Ulnar Wrist
- Median - Ulnar Palmer
- Above Elbow Ulnar
- Below Elbow Ulnar
Stimulation Points

Lower Extremities

- Crural
- Peroneal
- Sural
- Popliteal fossa
- Posterior Tibial
- Tibial
- Sciatic
Current Stimulation

NERVE

Supramaximal Stimuli
Min. 3 Times Sensory Threshold
Once a nerve is depolarized at some point, a wave of depolarization passes in both directions from that point.
Propagation - Refractory Period

NERVE

Propagation by Successive Depolarization followed by Repolarization. Time before Repolarization is called the Refractory Period.
Motor Latency

Motor Latency

Motor Response

**MOTOR LATENCY**

in ms = Propagation Time from S to M
Motor Response

Stimulation
Artifact

Peak Latency
Onset Latency

Duration

Area

Amplitudes
Negative Deflection
Peak to Peak
Motor Conduction  Median Nerve

Recording: Surface Electrodes  
Stimulation: Handgrip or Bipolar

Latency

Distance mm: 240  
C.V.: 51 m/s

Wrist  3.5 ms

Elbow  8.2 ms

Diff.: 4.7 ms

Distance  mm: 240
**Stimulation & Recording**

**RULE**

To reduce Stimulation Artifact as much as possible, Ground must be placed between Stim. & Rec.

Stimulation Polarity: NEGATIVE

- Anode (Red) → Cathode (Black)
- Nerve

**STIMULATION**

- Anode
- Cathode

**RECORDING**

- Active
- Reference

**GROUND**

BLACK TO BLACK

Stimulation Polarity: NEGATIVE
Motor & Sensory

General Remarks

MOTOR

- Amplitude 0.5 mV to 5 mV - Direct response
- Normally biphasic
- Duration 1 to 3 ms - Latency depends on stimulation site
- Stimulation Current depends on nerve and site, 15 - 30 mA

SENSORY

- Amplitude 5 µV to 35 µV
- Direct response for high amplitude potentials - otherwise Averager is needed
- Normally biphasic
- Duration 1 to 3 ms - Latency depends on stimulation site
- Stimulation Current depends on nerve and site, 5 - 15 mA
Pathologic Responses

<table>
<thead>
<tr>
<th>Pathologic Response</th>
<th>Amplitude</th>
<th>Duration</th>
<th>Latency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td>Axonal Degeneration</td>
<td>↓</td>
<td>↓</td>
<td>Normal+/-</td>
</tr>
<tr>
<td>Conduction Block</td>
<td>↓</td>
<td>↓</td>
<td>Normal+/-</td>
</tr>
<tr>
<td>Severe Demyelination</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Focal Slowing</td>
<td>Normal</td>
<td>Normal</td>
<td></td>
</tr>
<tr>
<td>Myelin Damaged</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\( Nl = \text{Normal} \)
## Carpal Tunnel CV General Application

### Motor Median Nerve

<table>
<thead>
<tr>
<th>Location</th>
<th>Latency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wrist</td>
<td>3.5 ms</td>
</tr>
<tr>
<td>Elbow</td>
<td>6.2 ms</td>
</tr>
</tbody>
</table>

### Sensory Median and Ulnar Nerves

<table>
<thead>
<tr>
<th>Location</th>
<th>Latency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digit 2</td>
<td>2.2 ms</td>
</tr>
<tr>
<td>Digit 3</td>
<td>2.4 ms</td>
</tr>
<tr>
<td>Digit 4</td>
<td>1.9 ms</td>
</tr>
</tbody>
</table>

**Diagram:**
- **Motor**: Stim. 1 and Stim. 2 with recording at Motor Median Nerve.
- **Sensory**: Stim. Digit 2, 3, 4 with recording at Ulnaris and Medianus.
F-Waves

Voluntary contralateral motor action to facilitate F Stim.

Rec.

Minimum F Latency is normally measured

Ulnaris Nerve

F-Latence 30 to 50 ms

block
As playing with this game

Shorter Distance Better Shoot!

F-Waves
**Refractory Period**

**CV General Application**

Double Stimulation Start with 4ms delay Decrease by steps of 0.05ms

Refractory period: 1.80 ms
**Sensory Conduction**  
*Ulnaris Nerve*

<table>
<thead>
<tr>
<th>Digit</th>
<th>Latency (ms)</th>
<th>Distance (mm)</th>
<th>CV (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>2.6</td>
<td>155</td>
<td>60</td>
</tr>
<tr>
<td>IV</td>
<td>3.1</td>
<td>175</td>
<td>56</td>
</tr>
</tbody>
</table>
Inching  

Ulnaris Nerve

1 inch dist. between Stim. Sites

No Stim.

Increased Latency

Other graphics with Amplitude and Duration

Latency

Inching

Palm

Wrist
<table>
<thead>
<tr>
<th>Settings</th>
<th>MNCS</th>
<th>SNCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rec. Sites Electrodes</td>
<td>All</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>Surface</td>
<td>Surface/Needle</td>
</tr>
<tr>
<td>High FQ (KHz)</td>
<td>2-5</td>
<td>2-5</td>
</tr>
<tr>
<td>Low FQ (Hz)</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Sensitivity Input</td>
<td>mV/Div</td>
<td>µV/Div</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>AVG</td>
<td>5-10</td>
</tr>
<tr>
<td>Sweep Speed ms/Div</td>
<td>Upper 2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Lower 5</td>
<td>2</td>
</tr>
<tr>
<td>Stim. Intensity Duration ms</td>
<td>Supramaxima 0.2</td>
<td>3x Threshold 0.2</td>
</tr>
<tr>
<td></td>
<td>Frequency c/s</td>
<td>1</td>
</tr>
</tbody>
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Normal Values

The results of NCS - Motor, Sensory must be compared to some normal values. These must be age-related as well.

Infants & young children:
Quite slow conduction rate.

Adults:
Amplitudes and conduction rate decrease with age.

The most sensitive normal value for a particular NCS is usually obtained by performing the same NCS on the corresponding nerve in the contra-lateral limb (assuming it is normal). A decrease of more than 50% in amplitude is considered abnormal.

Motor NCS  Sensory NCS

<table>
<thead>
<tr>
<th>Age 20-50</th>
<th>Amp. μV</th>
<th>Lat. mV</th>
<th>C.V. m/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nerve</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>&gt;20</td>
<td>&lt;3.4</td>
<td>&gt;50</td>
</tr>
<tr>
<td>Ulnar</td>
<td>&gt;15</td>
<td>&lt;3.1</td>
<td>&gt;50</td>
</tr>
<tr>
<td>Radial</td>
<td>&gt;18</td>
<td>&lt;2.7</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>&gt;6</td>
<td>&lt;4.0</td>
<td>&gt;50</td>
</tr>
<tr>
<td>Median (palm)</td>
<td>&lt;2.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ulnar (palm)</td>
<td>&lt;2.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sural</td>
<td>&gt;6</td>
<td>&lt;4.5</td>
<td>&gt;40</td>
</tr>
<tr>
<td>Peroneal</td>
<td>&lt;4.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peroneal</td>
<td>&gt;3</td>
<td>&lt;5.5</td>
<td>&gt;40</td>
</tr>
<tr>
<td>Tibial (post.)</td>
<td>&gt;8</td>
<td>&lt;6.0</td>
<td>&gt;40</td>
</tr>
</tbody>
</table>
Pitfalls

- High recording impedance electrode reducing amplitude
- Recording polarity inversion - incorrect onset latency
- Stimulation polarity inversion - increasing latency
- Unbalanced stimulation electrode - artifact
- Low stimulation intensity - impedance - infra stimulation
- Painful stimulation - movement artifact
- External interference (patient is an antenna)
- Incorrect setup - filters, sweep-speed...