Nerve Conduction Study [NCS] -n- Needle Electromyography [EMG] 

DISTAL ENTRAPMENTS

David Hutchinson PT, DSc, MS, ECS
Objectives

Knowledge
- Testing procedure
- Purpose of testing
- Abnormalities

Application
- Clinical Utility
- Case review(s)
Background

**Neuropathic**
- Focal Neuropathies
- Polyneuropathies
- Motor neuron conditions

**Myopathic**
- Muscular Dystrophy

**Neuromuscular Junction Disorders**
- Lambert Eaton
- Myasthenia Gravis
- Botulism
NCS/EMG: Focal Neuropathy

- Assess electrophysiology of the somatic sensory and motor components of the peripheral nerve system (fast fibers)

- **Nature**
  - Demyelination
  - Conduction Block
  - Axonopathy

- **Location**
  - Proximal
  - Distal
  - Mixed
  - Generalized

- **Severity**
  - Mild
  - Moderate
  - Severe

- **Duration**
  - Acute
  - Subacute
  - Chronic
NCS Technique

• A supramaximal electrical stimulus is applied to the nerve at key sites (Palm, Wrist, Elbow, Axilla, etc.)

• A wave of depolarization (ionic discharge) travels along the nerve activating the sensory & motor fibers supplied by that nerve

• The desired response is recorded with special electrodes.
  – As shown, the bar electrode D2
NCS Measures

- Tabular Data are organized by nerve, site of stimulation, distance between segments, and normative values

<table>
<thead>
<tr>
<th>Site</th>
<th>NR</th>
<th>Peak (ms)</th>
<th>Norm Peak (ms)</th>
<th>O-P Amp (µV)</th>
<th>Norm O-P Amp</th>
<th>Neg Dur (ms)</th>
<th>Neg Area (µV·ms)</th>
<th>Site1</th>
<th>Site2</th>
<th>Delta-P (ms)</th>
<th>Dist (cm)</th>
<th>Vel (m/s)</th>
<th>Norm Vel (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left Median Anti Sensory (3rd Digit)</td>
<td>31.9°C</td>
<td>3.5</td>
<td>&lt;3.6</td>
<td>1.8</td>
<td>13.1</td>
<td>1.69</td>
<td>12.59</td>
<td>Wrist</td>
<td>3rd Digit</td>
<td>3.5</td>
<td>14.0</td>
<td>40</td>
<td>&gt;38</td>
</tr>
<tr>
<td>Palm</td>
<td>1.5</td>
<td>33.8</td>
<td>&gt;10</td>
<td>2.09</td>
<td>30.43</td>
<td>1.75</td>
<td>24.29</td>
<td>Wrist</td>
<td>Palm</td>
<td>1.7</td>
<td>7.0</td>
<td>41</td>
<td>&gt;48</td>
</tr>
<tr>
<td>Wrist</td>
<td>3.5</td>
<td>27.0</td>
<td>&gt;10</td>
<td>1.75</td>
<td>24.29</td>
<td>1.69</td>
<td>12.59</td>
<td>Wrist</td>
<td>Wrist</td>
<td>4.6</td>
<td>25.5</td>
<td>55</td>
<td>&gt;55</td>
</tr>
</tbody>
</table>

- Waveform parameters include:
  - **Latency (ms)** – time from stimulus to wave onset or peak (x-axis)
  - **Conduction Velocity (m/sec)** – the latency factored by distance between segments
  - **Amplitude (mV or microV)** – strength of sensory or motor response to the supramaximal stimulus (y-axis)
Focal Neuropathy: Value of NCS Findings
### NCS Response: Healthy Nerve

#### Anti Sensory Summary Table

<table>
<thead>
<tr>
<th>Site</th>
<th>NR</th>
<th>Onset (ms)</th>
<th>Norm Onset (ms)</th>
<th>O-P Amp (mV)</th>
<th>Norm O-P Amp</th>
<th>Site1</th>
<th>Site2</th>
<th>Delta-0 (ms)</th>
<th>Dist (cm)</th>
<th>Vel (m/s)</th>
<th>Norm Vel (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right Median Motor (Abd Poll Brev) 35.5°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palm</td>
<td></td>
<td>1.6</td>
<td></td>
<td>14.3</td>
<td>&gt;5</td>
<td>Wrist Abd Poll Brev</td>
<td></td>
<td>3.8</td>
<td>8.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrist</td>
<td></td>
<td>3.8</td>
<td>&lt;4.2</td>
<td>10.1</td>
<td>&gt;5</td>
<td>Wrist Palm</td>
<td></td>
<td>2.2</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elbow</td>
<td></td>
<td>7.7</td>
<td></td>
<td>9.8</td>
<td></td>
<td>Elbow Wrist</td>
<td></td>
<td>3.9</td>
<td>19.8</td>
<td>51</td>
<td>&gt;48</td>
</tr>
</tbody>
</table>

**S1 [Palm]: Nml Response**

**S2 [Wrist]: Nml Response**

**S3 [Elbow]: Nml Response**
Pathology

Healthy Nerve

Demyelination

Conduction Block

Axonopathy – non-localizing

Conduction Block Changes – Immediate
Demyelinating and Axonal Changes – time dependent
Pathologic Findings

- **Demyelination** [localized to wrist]—slowed Latency and Conduction Velocity

<table>
<thead>
<tr>
<th>Site</th>
<th>NR</th>
<th>Peak (ms)</th>
<th>Norm Peak (ms)</th>
<th>O-P Amp (µV)</th>
<th>Norm O-P Amp</th>
<th>Neg Dur (ms)</th>
<th>Neg Area (µV·ms)</th>
<th>Site1</th>
<th>Site2</th>
<th>Delta-P (ms)</th>
<th>Dist (cm)</th>
<th>Vel (m/s)</th>
<th>Norm Vel (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right Median Anti Sensory (3rd Digit)</td>
<td>32°C</td>
<td>Palm</td>
<td>2.2</td>
<td>28.9</td>
<td>&gt;10</td>
<td>1.91</td>
<td>29.10</td>
<td>Wrist</td>
<td>3rd Digit</td>
<td>4.1</td>
<td>14.0</td>
<td>34</td>
<td>&gt;38</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wrist</td>
<td>4.1</td>
<td>&lt;3.6</td>
<td>&lt;10</td>
<td>2.09</td>
<td>23.87</td>
<td>Wrist</td>
<td>Palm</td>
<td>1.9</td>
<td>7.0</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Elbow</td>
<td>9.1</td>
<td>17.5</td>
<td>&gt;10</td>
<td>2.75</td>
<td>22.71</td>
<td>Elbow</td>
<td>Wrist</td>
<td>5.0</td>
<td>24.0</td>
<td>48</td>
<td>&gt;48</td>
</tr>
</tbody>
</table>

- **Conduction Block**—[localized to wrist] reduced or absent amplitude at or proximal to lesion

<table>
<thead>
<tr>
<th>Site</th>
<th>NR</th>
<th>Peak (ms)</th>
<th>Norm Peak (ms)</th>
<th>O-P Amp (µV)</th>
<th>Norm O-P Amp</th>
<th>Neg Dur (ms)</th>
<th>Neg Area (µV·ms)</th>
<th>Site1</th>
<th>Site2</th>
<th>Delta-P (ms)</th>
<th>Dist (cm)</th>
<th>Vel (m/s)</th>
<th>Norm Vel (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left Median Anti Sensory (3rd Digit)</td>
<td>32.8°C</td>
<td>Palm</td>
<td>1.9</td>
<td>42.8</td>
<td>&gt;10</td>
<td>1.50</td>
<td>28.19</td>
<td>Wrist</td>
<td>3rd Digit</td>
<td>3.2</td>
<td>14.0</td>
<td>44</td>
<td>&gt;38</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wrist</td>
<td>3.2</td>
<td>&lt;3.6</td>
<td>&lt;10</td>
<td>1.09</td>
<td>16.60</td>
<td>Wrist</td>
<td>Palm</td>
<td>1.3</td>
<td>7.0</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Elbow</td>
<td>6.6</td>
<td>8.8</td>
<td>&gt;10</td>
<td>1.00</td>
<td>17.12</td>
<td>Elbow</td>
<td>Wrist</td>
<td>3.4</td>
<td>19.0</td>
<td>56</td>
<td>&gt;48</td>
</tr>
</tbody>
</table>

- **Axonopathy with Slowing** at wrist [localized to wrist] - reduced amplitudes all sites with latency slowing across wrist

<table>
<thead>
<tr>
<th>Site</th>
<th>NR</th>
<th>Peak (ms)</th>
<th>Norm Peak (ms)</th>
<th>O-P Amp (µV)</th>
<th>Norm O-P Amp</th>
<th>Neg Dur (ms)</th>
<th>Neg Area (µV·ms)</th>
<th>Site1</th>
<th>Site2</th>
<th>Delta-P (ms)</th>
<th>Dist (cm)</th>
<th>Vel (m/s)</th>
<th>Norm Vel (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right Median Anti Sensory (3rd Digit)</td>
<td>31.3°C</td>
<td>Palm</td>
<td>1.9</td>
<td>6.6</td>
<td>&gt;10</td>
<td>1.91</td>
<td>4.46</td>
<td>Wrist</td>
<td>3rd Digit</td>
<td>6.5</td>
<td>14.0</td>
<td>22</td>
<td>&gt;38</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wrist</td>
<td>6.5</td>
<td>&lt;3.6</td>
<td>&lt;10</td>
<td>6.41</td>
<td>20.62</td>
<td>Wrist</td>
<td>Palm</td>
<td>4.6</td>
<td>7.0</td>
<td>15</td>
<td></td>
</tr>
</tbody>
</table>
Pathologic Findings

- Axonopathy [non-localizing] - generalized amplitude reduction t/o nerve but we do not know where the problem originates based on limited data furnished
  - further testing needed
  - This leads to the next part of our discussion.

<table>
<thead>
<tr>
<th>Motor Summary Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site</td>
</tr>
<tr>
<td>-------------------------------------</td>
</tr>
<tr>
<td>Left Radial Motor (Ext Ind Prop)</td>
</tr>
<tr>
<td>Forearm</td>
</tr>
<tr>
<td>Elbow</td>
</tr>
<tr>
<td>Spiral Groove</td>
</tr>
</tbody>
</table>
Electromyography Technique
Normal vs Pathologic Findings
Nerve study findings ≠ Causation

Intrinsic (e.g. virus) vs extrinsic (e.g. pressure source)

- **WALLERIAN DEGENERATION = AXONAL LOSS**
- **CHANGES ARE TIME DEPENDENT**
- Nerve study findings ≠ Causation
### EMG Changes Correlate to Axonal Timeline

<table>
<thead>
<tr>
<th>Time Frame</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-4 Weeks</td>
<td>Muscle Membrane Instability</td>
</tr>
<tr>
<td>3-4 Months</td>
<td>Collateral Sprouts</td>
</tr>
<tr>
<td>9-12 Months</td>
<td>Maturation</td>
</tr>
<tr>
<td>1 inch/month</td>
<td>Axonal Regrowth</td>
</tr>
</tbody>
</table>

- **Muscle Membrane Instability**
  - Occurs 3-4 weeks after injury
  - Characterized by instability of muscle membrane
  - Likely due to axonal damage

- **Collateral Sprouts**
  - Occurs 3-4 months after injury
  - Growth of new axons alongside damaged ones
  - Essential for functional recovery

- **Maturation**
  - Occurs 9-12 months after injury
  - Process of refining and stabilizing axonal sprouts
  - Leads to improved neural function

- **Axonal Regrowth**
  - Occurs at a rate of 1 inch/month
  - Continuous growth of axons over time
  - Key to long-term recovery and regeneration
## EMG: TYPICAL TABLE OF FINDINGS

<table>
<thead>
<tr>
<th>Side</th>
<th>Muscle</th>
<th>Nerve</th>
<th>Root</th>
<th>Ins Act</th>
<th>Fibs</th>
<th>Psw</th>
<th>Amp</th>
<th>Dur</th>
<th>Poly</th>
<th>Recrt</th>
<th>Int Pat</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right</td>
<td>Abd Poll Brev</td>
<td>Median</td>
<td>C8-T1</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>0</td>
<td>Nml</td>
<td>Nml</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>ABD DigMinimi</td>
<td>Ulnar</td>
<td>C8-T1</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>0</td>
<td>Nml</td>
<td>Nml</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>FlexDigProf</td>
<td>Ulnar</td>
<td>C8, T1</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>0</td>
<td>Nml</td>
<td>Nml</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>FlexCarRad</td>
<td>Median</td>
<td>C6-7</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>0</td>
<td>Nml</td>
<td>Nml</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>ExtIndicis</td>
<td>Radial (Post Int)</td>
<td>C7-8</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>0</td>
<td>Nml</td>
<td>Nml</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>BrachioRad</td>
<td>Radial</td>
<td>C5-6</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>0</td>
<td>Nml</td>
<td>Nml</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>Triceps</td>
<td>Radial</td>
<td>C6-7-8</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>0</td>
<td>Nml</td>
<td>Nml</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>Deltoid</td>
<td>Axillary</td>
<td>C5-6</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>0</td>
<td>Nml</td>
<td>Nml</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>Parasp</td>
<td>Rami</td>
<td>C5</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>0</td>
<td>Nml</td>
<td>Nml</td>
<td></td>
</tr>
</tbody>
</table>
EMG Assessment: Abnormal Findings

**NORMAL STATE**

**Rest**

- mV
- msec

**Voluntary Contraction**

- mV
- msec

---

### Rest: Excitable Membrane

- mV vs msec

### Voluntary Contraction: Sprouting or Axonal Regrowth

- mV vs msec

### Voluntary Contraction: Matured Sprouts

- mV vs msec

---

<table>
<thead>
<tr>
<th>Side</th>
<th>Muscle</th>
<th>Nerve</th>
<th>Root</th>
<th>Ins Act</th>
<th>Fibs</th>
<th>Psw</th>
<th>Amp</th>
<th>Dur</th>
<th>Poly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right</td>
<td>Abd Poll Brev</td>
<td>Median</td>
<td>C8-T1</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>0</td>
</tr>
<tr>
<td>Right</td>
<td>ABD DigMinimi</td>
<td>Ulnar</td>
<td>C8-T1</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>0</td>
</tr>
<tr>
<td>Right</td>
<td>FlexDigProf</td>
<td>Ulnar</td>
<td>C8, T1</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>0</td>
</tr>
<tr>
<td>Right</td>
<td>FlexCarRad</td>
<td>Median</td>
<td>C6-7</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>0</td>
</tr>
<tr>
<td>Right</td>
<td>ExtIndicies</td>
<td>Radial (Post Int)</td>
<td>C7-8</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>0</td>
</tr>
<tr>
<td>Right</td>
<td>BrachioRad</td>
<td>Radial</td>
<td>C5-6</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>0</td>
</tr>
<tr>
<td>Right</td>
<td>Triceps</td>
<td>Radial</td>
<td>C6-7-8</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>0</td>
</tr>
<tr>
<td>Right</td>
<td>Deltoid</td>
<td>Axillary</td>
<td>C5-6</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>0</td>
</tr>
<tr>
<td>Right</td>
<td>Parasp</td>
<td>Rami</td>
<td>C5</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>Nml</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recrt</th>
<th>Int Pat</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nml</td>
<td>Nml</td>
<td></td>
</tr>
<tr>
<td>Nml</td>
<td>Nml</td>
<td></td>
</tr>
<tr>
<td>Nml</td>
<td>Nml</td>
<td></td>
</tr>
<tr>
<td>Nml</td>
<td>Nml</td>
<td></td>
</tr>
<tr>
<td>Nml</td>
<td>Nml</td>
<td></td>
</tr>
<tr>
<td>Nml</td>
<td>Nml</td>
<td></td>
</tr>
<tr>
<td>Nml</td>
<td>Nml</td>
<td></td>
</tr>
<tr>
<td>Nml</td>
<td>Nml</td>
<td></td>
</tr>
<tr>
<td>Nml</td>
<td>Nml</td>
<td></td>
</tr>
<tr>
<td>Nml</td>
<td>Nml</td>
<td></td>
</tr>
<tr>
<td>Nml</td>
<td>Nml</td>
<td></td>
</tr>
<tr>
<td>Nml</td>
<td>Nml</td>
<td></td>
</tr>
</tbody>
</table>
EMG Approach

• So far we discussed
  – EMG to define Severity and Duration of axonal pathology
  – NCS
    • Localizing: demyelination and conduction block
    • Non-localizing: axonopathy

• How do we determine the pattern of axonal loss changes?
  – Needle EMG into muscles distal to the lesion and then proximal. Then assure non-affected nerves to assure they are normal
    • Muscles innervated downstream [distal] from site of potential entrapment show abnormalities
    • Extra caution when see pure axonal loss without focal slowing

• Lets look at an example
Suspect PT Entrapment: AIN

1. Map potential abnormalities at/distal to compression site?
   - Assess PQ, FPL, FDP (median)

2. Define normal muscles?
   - PT, FCR
   - Check Ulnar FDI, radial EIP
   - C8 multifidus
   - Check rostral/caudal areas

Remember: Findings ≠ Causation
Publications on Testing Methodology

• Carpal Tunnel Syndrome\textsuperscript{1, 6-9}
  – Median sensory and motor NCSs are valid and reproducible clinical laboratory studies.
  – Confirm a clinical diagnosis of CTS with a high degree of sensitivity (>85%) and specificity (>95%).

• Cubital Tunnel Syndrome\textsuperscript{2, 6-9}
  – Guidelines for testing proposed. Optimal elbow position (70-90 deg) and stimulus site recommendations
  – Sensitivity and specificity studies needed
  – Operator rigor and experience critical.

• Radial Sensory, Ulnar Tunnel, Anterior and Posterior Interosseous Neuropathies\textsuperscript{6-9}
  – Guidelines for testing proposed
  – Sensitivity and specificity studies needed
  – Operator rigor and experience critical
NCS: Considerations

- Temperature: cool hand = decreased latency, increased amplitude
- Age: <5 and >65-70 = decreased latency, decreased amplitude
- Anomalies: Martin Gruber, Riche Cannei’, Pre vs post fixed plexus
- Time from reported onset
- Height – adjust with certain parts of test
- Concurrent Issues – consider multiple overlapping issues (CTS vs C6-7 radiculopathy/plexopathy, CTS with underlying poly)
Normal Values: Sensory NCS

<table>
<thead>
<tr>
<th>Nerve</th>
<th>Rcdg</th>
<th>Site</th>
<th>Dist (cm)</th>
<th>Peak Lat (msec)</th>
<th>O-P Amp</th>
<th>Normal CV</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Median</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digit 2 or D3</td>
<td></td>
<td>Wrist</td>
<td>14</td>
<td>&lt;3.6</td>
<td>&gt;38</td>
<td></td>
<td>1. W-P transcarpal lat &lt; 17 ms @ 7-cm distance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Elbow</td>
<td>n/a</td>
<td></td>
<td>&gt;48</td>
<td></td>
<td>2. W-P no &gt; 50% reduction</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3. Side - side ampl no &gt; 50% difference for all test sites</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4. &lt; 3.0 ms if using onset</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Med-Ulnar</strong></td>
<td>D4</td>
<td>Wrist</td>
<td>14</td>
<td>&lt;3.6</td>
<td></td>
<td></td>
<td>1. No &gt; 0.5 msecond difference</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Med-Radial</strong></td>
<td>D1</td>
<td>Wrist/forearm</td>
<td>14</td>
<td>&lt;3.6</td>
<td></td>
<td></td>
<td>1. No &gt; 0.5 msecond difference</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ulnar</strong></td>
<td>D5</td>
<td>Wrist</td>
<td>14</td>
<td>&lt;3.7</td>
<td>&gt;38</td>
<td></td>
<td>1. M d SDL to Uln SDL no &gt; 0.5.</td>
</tr>
<tr>
<td></td>
<td>BE</td>
<td></td>
<td></td>
<td></td>
<td>&gt;48</td>
<td></td>
<td>2. W-P transcarpal lat &lt; 17 ms @ 7-cm distance</td>
</tr>
<tr>
<td></td>
<td>AE</td>
<td></td>
<td></td>
<td></td>
<td>&gt;50</td>
<td></td>
<td>3. W to P no &gt; 50% reduction</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4. &lt; 3.0 ms if using onset</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DUC</strong></td>
<td></td>
<td>4th web</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4. Side to side ampl no &gt; 50% difference.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DUC</td>
<td></td>
<td></td>
<td>&gt;40</td>
<td></td>
<td>1. Amp no &gt; 50% reduction side to side</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>LAC</strong></td>
<td>Lat Frm</td>
<td>Arm</td>
<td>14</td>
<td>&lt;3.2 (peak)</td>
<td>&gt;45</td>
<td></td>
<td>1. A SNAP amp &gt; 50% is significant.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5micro V (p to p)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MAC</strong></td>
<td>Mdl Frm</td>
<td>5cm up from Cubital Crease</td>
<td>14</td>
<td>10micro V</td>
<td>&gt;45</td>
<td></td>
<td>1. A SNAP amp &gt; 50% is significant.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sup Radial</strong></td>
<td>D1</td>
<td>Lat Forearm</td>
<td>14</td>
<td></td>
<td>&gt;38</td>
<td></td>
<td>1. Ampl are greater with recording using nn over EPL vs Thumb.</td>
</tr>
<tr>
<td></td>
<td>EPL</td>
<td>Dorsolat radius</td>
<td>12</td>
<td></td>
<td>&gt;40</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Normal Values: Motor NCS

<table>
<thead>
<tr>
<th>Nerve</th>
<th>Recording</th>
<th>Site</th>
<th>Dist</th>
<th>Onset Lat (msec)</th>
<th>Amp (mV)</th>
<th>Normal CV</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median</td>
<td>APB</td>
<td>Wrist</td>
<td>8cm</td>
<td>&lt;4.0 to 4.5 ms</td>
<td>5.00</td>
<td>n/a</td>
<td>MDL: ipsi or contral ulnar no &gt;1.0 msec Nml: Wrist to palm &lt;2.2 msec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Elbow</td>
<td></td>
<td>&gt;48 (some use 50)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Axilla</td>
<td></td>
<td>&gt;55</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Erbs</td>
<td></td>
<td>&gt;60</td>
<td></td>
<td></td>
<td>Across upper and lower trunks &lt;1.2 or 1.3 msec for nml latency</td>
</tr>
<tr>
<td></td>
<td>2nd web space</td>
<td>wrist</td>
<td>8cm</td>
<td></td>
<td></td>
<td></td>
<td>lum to interosseous comparision. Diff &gt;0.5 is meaningful</td>
</tr>
<tr>
<td>Ulnar</td>
<td>ADM (ADQ)</td>
<td>wrist</td>
<td>8.00</td>
<td>&lt;3.6</td>
<td>3.00</td>
<td></td>
<td>1. MDL to ADM no &gt;1.0msec than MDL to APB 2. MDL to ADM no &gt;2.0msec than MDL to FDI 3. definitive abnl &gt;4 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BE</td>
<td></td>
<td></td>
<td></td>
<td>50</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>AE</td>
<td></td>
<td></td>
<td></td>
<td>50</td>
<td>1. Greater 20%ampl reduction with BE and AE is significant. 2. Change in morphology may be significant. 3. A &gt;10m/sec reduction compared to forearm segment is abnormal. Some use &gt;15 m/sec side to side or compared to forearm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Axilla</td>
<td></td>
<td>&gt;55</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Erb's</td>
<td></td>
<td>&gt;60</td>
<td></td>
<td></td>
<td>Across upper and lower trunks &lt;1.2 or 1.3 msec for nml latency</td>
</tr>
<tr>
<td></td>
<td>FDI</td>
<td>Wrist</td>
<td></td>
<td>&lt;4.5</td>
<td></td>
<td></td>
<td>no &gt;15 ms compared to ADM value</td>
</tr>
<tr>
<td>Axillary</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deltoid</td>
<td>Erb's</td>
<td></td>
<td>&lt;4.9</td>
<td>&gt;20% side to side</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suprascapular</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Supraspinatus (needle)</td>
<td>Erb's</td>
<td></td>
<td>&lt;3.7</td>
<td></td>
<td></td>
<td>Across upper and lower trunks &lt;1.2 or 1.3 msec for nml latency</td>
</tr>
<tr>
<td></td>
<td>Infraspinatus (tab)</td>
<td></td>
<td></td>
<td>&lt;4.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radial</td>
<td>EIP</td>
<td>Frm</td>
<td>4.5cm</td>
<td>&lt;2.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>AE</td>
<td></td>
<td></td>
<td></td>
<td>&gt;50</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Axilla</td>
<td></td>
<td></td>
<td></td>
<td>&gt;55</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Erb's</td>
<td></td>
<td></td>
<td></td>
<td>&gt;60</td>
<td></td>
</tr>
</tbody>
</table>


Credits to:
Celia and Ella Hutchinson
Clinical Utility and Case Examples
Upper Limb Compression Neuropathies
Part 2

Mark T. Walsh PT, DPT, MS, CHT, ATC
APTA Combined Sections San Antonio

Disclosures
- No Disclosures

Key Learning Objectives
- Appreciate the importance of the Peripheral Nervous System as an Integral Organ of Life and Movement.
- Recognize the need for Examination and Evaluation of the Entire Upper Quarter.
- Understand the 5 components of a Neurodynamic Examination.
- Explore the Evidence of the Specific Special Tests of the Upper Extremity Nervous System.
- Interpret the findings of the Differential Nervous System Examination and Integrate the Results into a Working Diagnosis and Interventions Strategy.

Pathophysiology of Nerve Compression

Systemic and Metabolic Diseases Associated with Nerve Compression

<table>
<thead>
<tr>
<th>Disease</th>
<th>Disease</th>
<th>Disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA</td>
<td>Acromegaly</td>
<td>ETOH</td>
</tr>
<tr>
<td>DM</td>
<td>Pregnancy</td>
<td>Hemophilia</td>
</tr>
<tr>
<td>Gout</td>
<td>Hemodialysis</td>
<td>Neurofibromatosis</td>
</tr>
<tr>
<td>Hypothyroid</td>
<td>Myeloma</td>
<td></td>
</tr>
</tbody>
</table>

CLASSIFICATION OF NERVE INJURY

- Conduction Block [Sunderland 1st Degree]
  - Local Ischemia
  - Inhibits Nerve Impulse Transmission
  - Nerve Fibers Remain Intact
  - Immediate Return after Pressure Release
  - > 6-8 Hours Damage Irreversible

Systemic and Metabolic Diseases Associated with Nerve Compression:
- RA
- Acromegaly
- ETOH
- DM
- Pregnancy
- Hemophilia
- Gout
- Hemodialysis
- Neurofibromatosis
- Hypothyroid
- Myeloma
CLASSIFICATION OF NERVE INJURY

- Conduction Block [Sunderland 1st Degree]
  - Local Ischemia
  - Inhibits Nerve Impulse Transmission
  - Nerve Fibers Remain Intact
  - Immediate Return after Pressure Release
  - > 6-8 Hours Damage Irreversible

- Neuropraxia – Seddon [Sunderland 1]
  - Axon Preserved
  - Myelin Damage @ Nodes Ranvier (NR)
  - Block Remains until Myelin Re-Established
  - Compression/Traction
  - Recovery: Days/Months

- Axonotmesis – Seddon [Sunderland 2-3]
  - Loss Axon Continuity
  - “Endoneural” Tubes Intact
  - Wallerian Degeneration – Regeneration
  - Recovery Averaged 1 Month/Day
  - Traction/Compression

- Neurotmesis – Seddon [Sutherland 4-5]
  - Axon Endoneural Tube, Peri, Epineurium Disruption
  - Wallerian Degeneration
  - Recover 1 Month/Day – ?
  - Sunderland:
    - 3 – Endoneural Tubes Lost Perineurium Intact
    - 4 – Perineurium Lost – Epineurium Intact
    - 5 – Disruption of Epineurium

MACROANATOMY

- Epineurium – Outermost
  - Loose CT – Separates Fascicles
  - No Specific Layers
  - Characteristics
    - CT Arrangement Creates Undulations
    - Low Fiber Content
    - Compression Resister
    - # Fasciculi → Epineurium

- Perineurium – Defines a fascicular Bundle (Compartment)
  - THREE LAYERS
    - INNER
      - Mesothelial Cells/Tight Junctions
    - MIDDLE
      - Perineural Cells & Collagen Fibers
      - Concentric Lamellae
    - EXTERNAL
      - Fibroblasts
      - Junction Layer with Epineurium
MACROANATOMY

PERIPHERAL NERVE

- Endoneurium – Defines Axon Compartment
- TWO LAYERS
  - INNER: Reticular Fibers
  - Tightly Packed Cells
  - OUTER: Closely Packed Collagen Fibers
- Contents: Basement Membrane, Schwann Cell, Myelin Sheath, Axon (MN) or Central/Peripheral Process (SN)
- Undulating Course

PERIPHERAL NERVE

BLOOD SUPPLY

- Epineurium
  - Nutrient Vessels
  - Parallel:
    - Slack at Rest - Elongates
  - Epineural Vascular Plexus
  - Perineural Vascular Plexus
  - Oblique Course thru Perineurium
  - Endoneural Plexus

PERIPHERAL NERVE VASCULAR ANATOMY

Note that the vessel perforating the perineurium takes an oblique course. Why do you think this occurs? Hint: think about the primary mechanical function of the perineurium

COPRESSION/ENTRAPMENTS

NEUROPATHY

- Normal Pressure Gradient for Formulae [Sunderland]
  - PA > PC > PF > PV > PT
  - PA = Pressure Artial
  - PC = Pressure Capillary
  - PF = Pressure Fascicular
  - PV = Pressure Venous
  - PT = Pressure Tunnel

Disturbance of Pressure Gradient results in Pathological Sequence.

NORMAL PRESSURE GRADIENT

[Sunderland]

- Fascicle
- Capillary
- Artery
- Vein
- Tunnel

A Normal tunnel. For adequate nerve fibre nutrition, the pressure gradient must be: PA>PC>PF>PV>PT

COMPRESSION/ENTRAPMENT

HYPOXIA

- Increased Tunnel Pressure (P)
- Venule Collapses = Venous Stasis
- Hypoxic Axon
**COMPRESSION/ENTRAPMENT EDEMA**

- Venous Stasis
- Deterioration Capillary Endothelium
- Leakage Fluid into Fascicular Compartments
- Increase Intrafascicular Pressure ($P^+$)
  (Secondary “Mini” Compartment Syndrome)

**COMPRESSION/ENTRAPMENT INTRANEURAL FIBROSIS**

- Protein Rich Edema - Fibroblasts
- Fibrosis – Scar Tissue
- Cycle of Irritation
  Scar → ↑ Pressure - ↑ Hyporia - ↑ Fibrosis
- Demyelization

**Myelin Changes**

- Compression Progression Demyelination

**Connective Tissue Changes**

- Perineural Thickening

**CLINICAL CONSEQUENCES**

- Intraneural Fibrosis
- Extraneural Fibrosis/Tethering
  - Vascular
  - Mechanical

**Pathogenesis**
Pathogenesis and Clinical Correlation

NERVE COMPRESSION

Soft Tissue

Bone

Neural Tension Dysfunction
Carpal Tunnel Syndrome

- Tethered Median Nerve Test
  LeBar/Friedman 1986
- Carpal Tunnel Syndrome
  Nakamichi/Tachibana 1995, Valls-Sole et al 1995
- RSI & “Whiplash” Patients
  Greening et al 2005
  Reduced Longitudinal and Transverse Excursion
  Median Nerve

Double/Multiple Crush Syndrome

Evaluation Concepts and Pathogenesis

- Symptoms
- Sensory Changes
  Threshold
  Innervation Density
- Provocative Testing
- Motor Changes

Pathophysiologic

- Static Compression
- Dynamic Compression
**Radial Nerve (Radial Tunnel Syndrome)**

- **Prevalence**: <1%
- **Radial Nerve**
  - Differential Diagnoses:
    - Radiculopathy C5-C6
    - Elbow Arthropathy
    - Compartment Syndrome
    - Lateral Epicondylitis

**Primary Differential Diagnosis**

- **Lateral Epicondylitis**
  - **Clinical Features**: Pain
  - **Examination**:
    - Focal Tenderness
    - (+) Mills
    - (-) NDT-RN
  - Intra-rater Reliability ICC 63-88 (Peterson 09)
  - (+) Lift Off Test

**Lift off Test Lateral Epicondylitis**

- Cylindrical vs Spherical

**Radial Tunnel Syndrome**

- **Clinical Features**:
  - Motor/Sensory
  - **Pathophysiologic**:
    - Pain – (Wrist & Dorsal Hand)
    - Paresthesia?
    - Motor Weakness
  - **Pathomechanic**:
    - Neural Hyperalgesia
    - (+) NDT-RN
  - Intra-rater Reliability ICC 63-88 (Peterson 09)

**Radial Tunnel Syndrome**

- **Special Tests**:
  - Middle Finger Test
  - Resisted Supination in EE/WE
  - Repetitive Pronation/WF
  - (+) NDT – Radial Nerve

- Palpation Radial Head
- Palpation Pronator

- Lister 1979
  - Bolster 09
Radial Sensory Nerve

- Differential: Wartenberg’s Syndrome
- Cervical Radiculopathy C6
- LACN
- Radial Wrist Pathology
- Intersection Syndrome
- CMC-OA

- Clinical Features: Sensory
  - Pathophysiologic
  - Paresthesia
  - Sensory Loss
  - Pathomechanic
  - Focal Tenderness
  (+) NDT – Radial Nerve
  Include Thumb and Wrist
  (Gonzales-Iglesias 10)

Radial Sensory Nerve

- Special Tests
  - Tinel’s
  - Finkelstein’s
  (+) NDT – RN
  Include Wrist & Thumb

Pronator Syndrome

- Clinical Features:
  - 9%
  - Motor/Sensory?
    - Pathophysiologic:
      - Pain
      - Paresthesia?
      - Weakness
    - Pathomechanic:
      - Neural Hyperalgesia Pronator
      (+) NDT-MN

Ligament of Struthers/Lacertus Fibrosis

- Special Tests: NDT-MN High Intra-rater Reliability
  (Peterson et al 10, Talebi et al 12)

  - Resisted Elbow Flexion in Supinates
  - Rule of 9's

Pronator Syndrome

- Special Tests:
  - Resisted Pronation in EF
  - Resisted Middle Finger FDS
Pronator Syndrome

- Special Tests:
  - Palpation FDS
  - Palpation Pronator

Anterior Interosseous Nerve

- Clinical Features: Motor
  - Pathophysiologic:
    - Pain - Proximal Anterior FA
    - Volar Wrist and Proximal Palm
    - Weakness
  - Pathomechanic:
    - Neural Hyperalgesia
    - (+) NDT-MN?

Anterior Interosseous Nerve

- Differential
  - Cervical Radiculopathy C6-7
  - Thoracic Outlet Syndrome
  - Proximal Compression
  - Ulnar Nerve Involvement
  - Multi-Level Nerve Compression: (Double Crush)

Carpal Tunnel

- Clinical Features: History
  - Nocturnal Pain
  - Aggravating Factors
    - Isometric Pinching/Grasping
    - Repetitive Motion
  - Clumsiness
  - (+) Flick sign
  - Insidious Onset/Pregnancy
  - Symptom Severity Scale (Levine et. al. 93)

Carpal Tunnel

- Clinical Features:
  - Motor/Sensory
  - Pathophysiologic
  - Paresthesia
  - Sensory Loss
  - Weakness/Atrophy
  - Pathomechanic
  - (+) NDT-MN
  - Neural Hyperalgesia-Tinel's
Carpal Tunnel

- Special Tests
  - NDT-MN
  - Phalen’s
  - Reverse Phalen’s
  - Tinel’s
  - Carpal Tunnel Compression
    - Durkan’s  MacDermid 14,10
  - Scratch Collapse
    - Cheng 08, Makanji 13

- CTS Clinical Prediction Rule
  - (+) Flick Sign for Relief
  - Wrist Ratio > 67
  - Symptom Severity Scale > 19
  - Reduced Median Nerve Sensory Field in 1 Finger NCS
  - Age > 45
  - Likelihood Ratio 18.3 When all 5 Together

Carpal Tunnel

- Special Considerations
  - Triad Disease
  - CTS
  - Trigger Finger
dQuervains
  - Restricted Supination
    - Dr. Beasley Personal Communication

Ulnar Nerve
(Cubital Tunnel Syndrome)

- Ulnar Nerve: Differential
  - Radiculopathy C8-T1
  - TOS/Guyons
  - Medial Epicondylitis
  - Elbow Arthropathy

- Patient Rated UN Eval  MacDermid J 13

Ulnar Nerve
Primary Differential Diagnosis

- Medial Epicondylitis
  - Clinical Features:
    - Pain
  - Examination:
    - Focal Tenderness
    - (+) Passive Stretch-Flex/Pron
    - (+)RROM-Flex/Pron
    - (-)NDT-UN
Cubital Tunnel Syndrome

- **Clinical Features:**
  - Motor/Sensory
  - **Pathophysiologic:**
    - Pain
    - Paresthesia
    - Nocturnal
  - **Pathomechanic:**
    - Neural Hyperalgesia
    - (+)NDT-UN

- **Special Tests:**
  - Upper Limb Tension Test
  - Ulnar Nerve
  - Elbow Flexion Provocation Test

Guyon’s Canal (Ulnar Tunnel Syndrome)

- **Clinical Features:**
  - History
  - Insidious Onset
  - Trauma
  - Nocturnal Sx’s
  - Aggravating Factors:
    - Wrist Flexion/Extension

- **Anatomical Zones**
  - Zone 1 - Motor/Sensory
  - Zone 2 - Motor
  - Zone 3 - Sensory

- **Pathophysiologic**
  - Sensory – Volar
  - UPCN?
  - Motor – Claw

- **Pathomechanic**
  - Neural Hyperalgesia
  - Tinel's
  - (+)NDT-UN

Guyon’s Canal (Ulnar Tunnel Syndrome)

- **Differential**
  - Cervical Radiculopathy C8-T1
  - TOS
  - Cubital Tunnel Syndrome
  - Pisso-hamate OA
  - Hook Hamate Fracture

- **Tinel's – Cubital Tunnel**
  - Specificity
  - Peterson 10 (Reliability)
Guyon’s Canal (Ulnar Tunnel Syndrome)

- Special Tests
  - NDT – UN
  - Peterson 10 (Reliability)
  - Tinel’s
  - Phalen’s/Reverse Phalen’s
  - Compression Test

The demands on the Nervous System are no different than on any other tissues.

“Nerve Stretching for the Relief or Cure of Pain”
John Marshall Lancet 1883
Nervi Nevorum, SLR as Mobilization

Intervention Progression

High Irritability ➔ Low Irritability

Phase 1 ➔ Phase 2 ➔ Phase 3

Stop and Smell the Flowers
Strategies for Nerve Health

Jane Fedorczyk, PT, PhD, CHT
Tampa, FL

Peripheral Nerve Blood Supply

- 20-30% of the cardiac output used by nerves
- Minor compression impede blood flow

Maximize Nerve Health

<table>
<thead>
<tr>
<th>Increase Bloodflow</th>
<th>Increase Oxygen</th>
<th>Reduce Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce Caffeine</td>
<td>Hydration</td>
<td>Joint Protection</td>
</tr>
<tr>
<td>Stop Smoking</td>
<td>Focused Breathing</td>
<td>Activity Modification</td>
</tr>
<tr>
<td>Exercise</td>
<td></td>
<td>Mindfulness</td>
</tr>
</tbody>
</table>

Smoking is Bad for Nerves

Identified Risk Factor
- Nathan, 1996, 2002; Richardson, 2004
- Bartels, 2007; Pourmemari, 2014

Associated with Delayed Recovery

Smoking Cessation Education
Aerobic Exercise

ACSM Guidelines: Fact Sheets

Maximize Nerve Health

Increase Bloodflow | Increase Oxygen | Reduce Stress
--- | --- | ---
Reduce Caffeine | Hydration | Joint Protection
Stop Smoking | Focused Breathing | Activity Modification
Exercise | Mindfulness |

Hydrate

- Water increases oxygen perfusion in healing tissues
  - Arklie CT, 2003
- Water improves skin microcirculation; midlife adults tend to be dehydrated, but respond well to oral hydration
  - Deidre D, 2007

There’s an APP

BREATHE

Pranayama
Interventions for Nerve Compression
Jane Fedorczyk, PT, PhD, CHT

Guide to PT, 3.0
www.apta.org/Guide/PracticePatterns

The practice patterns have been deleted from Guide 3.0 and are available here for educational purposes only. They have been revised and adapted from Guide to Physical Therapist Practice, ed 2.

Movement System Classification = Dysfunction Due to Pain

Nerve Compression
Basic Etiology: PT > PA

Etiology of Carpal Tunnel Syndrome
- **Intrinsic** condition leading to increased content of the canal
- **Extrinsic** condition leading to change in the size of the canal
- **Combined effect**
  wrist posture, repetitive motions, finger loading

Etiology of Cubital Tunnel
Elbow Flexion Test
Typical Clinical Presentation

Primarily a neurogenic/neuropathic pain problem

- **Pain**
  - Within nerve distribution
  - Nerve entrapment location
  - Nocturnal pain associated with wrist compression

- **Paraesthesias**
  - Typically intermittent
  - Activity dependent
  - May be worse at night

- **Sensory loss**
  - Occurs before motor weakness

- **Motor weakness**
  - Longstanding condition
  - Clumsiness associated with Carpal Tunnel Syndrome

- **Regulatory Changes**
  - Not typical
  - More common in females

Intervention Guided by Differential Diagnosis of Sources of Neurogenic Pain

- Cervical Radiculopathy
- Brachial Plexopathy
- Thoracic Outlet Syndrome
- Other Nerve Entrapment
- Other Soft Tissue Pathology
  - Tendinopathy

Entrapment Points of Major Peripheral Nerves

<table>
<thead>
<tr>
<th>Median</th>
<th>Ulnar</th>
<th>Radial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ligament of Struthers</td>
<td>Arcade of Struthers</td>
<td>Spiral Groove of Humerus</td>
</tr>
<tr>
<td>Bicipital Aponeurosis</td>
<td>Posterior to Medial Epicondyle</td>
<td>Lateral Intramuscular Septum</td>
</tr>
<tr>
<td>Pronator Teres</td>
<td>Cubital Tunnel</td>
<td>Supinator</td>
</tr>
<tr>
<td>FDS Bridge</td>
<td>Guyon's Canal</td>
<td>Arcade of Froshe</td>
</tr>
<tr>
<td>Carpal Tunnel</td>
<td></td>
<td>Distal Lateral Forearm</td>
</tr>
</tbody>
</table>

Examination

- Patient History
- Appearance
- Tests and Measures
  - Sensation
  - Muscle Performance
  - Provocative Tests
  - EMG/NCV
  - Dexterity

Outcome Measures

- EMG/NCV
- Provocative testing (↓ symptoms)
- Grip and pinch (functional strength)

Patient-rated Outcomes

- Pain Scales: VAS and VRS
- Boston Carpal Tunnel Instrument
- Patient-rated ulnar tunnel evaluation (PRUNE)
- Neck Disability Index
- DASH
- PSFS

Typical Conservative Management

- Orthotic Use or Limb Positioning (especially at night)
  - TO ABATE ACUTE SYMPTOMS
- Patient Education
  - Avoid aggravating activity or position
- Ergonomic Changes/ Onsite Job Analysis
- Nerve Mobilization
- Tendon Gliding (wrist compression)
- “Global Tactics” or Lifestyle Modifications
  - Aerobic Exercise
- Strengthening (prn)
- Scapular & Trunk Stabilization Exercises (prn)
Limb Positioning (Elbow)
- Orthotic Use
- Avoid aggravating activity or position

Carpal Tunnel Pressures

<table>
<thead>
<tr>
<th>Position</th>
<th>Pressure (mm Hg)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral Wrist</td>
<td>2.5</td>
<td>Gelberman, 1981</td>
</tr>
<tr>
<td>Neutral Wrist w/ CTS</td>
<td>32</td>
<td>Werner, 1983</td>
</tr>
<tr>
<td>Wrist Flexion (normal)</td>
<td>31</td>
<td>Gelberman, 1981</td>
</tr>
<tr>
<td>Wrist Extension (max)</td>
<td>30</td>
<td>Gelberman, 1981</td>
</tr>
<tr>
<td>Supination w/ MCP flexion</td>
<td>55</td>
<td>Rempel, 1998</td>
</tr>
<tr>
<td>45° Pronation w/ MCP flex</td>
<td>12</td>
<td>Rempel, 1998</td>
</tr>
<tr>
<td>Finger Flexion (75-100%)</td>
<td>326-361</td>
<td>Cobb, 1995</td>
</tr>
</tbody>
</table>

Orthotic Intervention
- There is sufficient evidence for the use of a wrist orthosis with mild to moderate carpal tunnel syndrome
- Tunnel pressures are lowest with wrist near neutral
- The dorsal wrist orthosis (left image) may decrease pressure more than a volar wrist orthosis (right image)
- Symptom relief lasting up to 6 months after nocturnal splint use has been observed

Externally Applied Forces to the Palm
- Increase Carpal Tunnel Pressure

Restrict Lumbrical Incursion into Carpal Tunnel
- Recommended for:
  - Positive Berger test
  - Manual laborers
  - Compulsive gripper
  - Inflamed flexor tendon system
- Lumbrical blocking orthosis, MPs in 20°-45° flex, to reduce available composite flexion.
  - Brininger, 2007

Predicting Outcome with Conservative Management

1. Symptoms present for more than 10 months?  Y  N
2. Does patient have constant paraesthesias?  Y  N
3. Does patient of flexor tenosynovitis; triggering of digits?  Y  N
4. Is Phalen’s test positive within less than 30 seconds?  Y  N
5. Is the patient older than 50 years?  Y  N

1 point for yes
0 point for no

Predicting Outcome with Conservative Management

<table>
<thead>
<tr>
<th>Points</th>
<th>% Success Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>65</td>
</tr>
<tr>
<td>1</td>
<td>41.4</td>
</tr>
<tr>
<td>2</td>
<td>16.7</td>
</tr>
<tr>
<td>3</td>
<td>6.8</td>
</tr>
<tr>
<td>4 or 5</td>
<td>0</td>
</tr>
</tbody>
</table>

Conservative Management = NSAIDS and Wrist Orthosis

Effect of Wrist Position

- Measured CT pressure in healthy moving wrists.
- Determined that certain wrist postures produce pressure of 30mmHg in 75% of the study population:
  - extension at 32.7°
  - flexion at 48.6°
  - radial deviation at 21.8°
  - ulnar deviation at 14.5°


Reduce Tendon Loading

- Forceful gripping and pinching combined with provocative wrist and finger postures can greatly elevate CT pressures
- Even strong fisting (without added stressors) can elevate pressures >200 mmHg
- Caution against exercise programs that require these actions...PUTTY, GRIPPERS, HANDLES

Summary

- Treating primarily pain/sensory problem
- Emphasis on strengthening likely to aggravate symptoms
- Emphasis on activity modification
- Presence of true motor weakness 1° reason for immediate surgical decompression
- CTS – respond well to injection; respond well to surgery; if caught early
- Nerve originates in C-spine and ends in hand; make sure you investigate all points of entrapment