Entrapment Neuropathies and Nerve Conduction Studies

Hans L. Carlson, M.D.
Assistant Professor, Dept. of Orthopaedics & Rehabilitation
Physical Medicine & Rehabilitation
Oregon Health & Science University

No financial interest or other relationship with the manufacture(s) or provider(s) of products or services presented.

Entrapment Neuropathy

- Mononeuropathy caused by direct pressure resulting in motor and/or sensory deficits in single nerve distribution. (Deficits may involve several nerve roots.)
  - Compression neuropathy, Nerve compression syndrome.

Diagnostic Tools

- History
- Physical Exam
- Electrodiagnostic Studies
  - Nerve Conduction Studies
  - Electromyography (EMG)

Review the timing of ordering electrodiagnostic studies.
Assess whether the study conclusions are consistent with the clinical assessment.
Discuss management options based on outcomes.
Timing
Timing of the test in relation to the onset of symptoms is critical!

Timing of the Electrodiagnostic Study
Ideal time to test following an acute injury is after 4-6 weeks.

Timing of the Electrodiagnostic Study
Testing early
Study may be unremarkable even with significant nerve injury and abnormal exam.
Potential for some useful information depending on clinical situation.

Timing of the Electrodiagnostic Study
Entrapment Neuropathies
Commonly chronic at the time of presentation.
Test may help with prognosis for acute compression neuropathies.

Assess whether the study conclusions are consistent with the clinical assessment.
Review the timing of ordering electrodiagnostic studies.
Discuss management options based on outcomes.

Overview of Electrodiagnostic Studies
Hand Pain

- 44 y.o. female with a 9 month history of progressive right hand/thumb numbness.
- Complaints of grip weakness.
- Intermittent pain radiating to the elbow and shoulder.

Hand Pain

- Mild left APB weakness. No intrinsic atrophy. Normal interossei and finger flexor strength.
- Normal sensation.
- Equivocal Tinel’s at wrist and Phalen’s maneuvers.

Hand Pain

- Electrodiagnostic studies

Hand Pain

- Electrodiagnostic studies

Nerve Conduction Study

Supramaximal stimulation

Nerve Conduction Study

Sensory Nerve Action Potential (SNAP) Ulnar
Nerve Conduction Study
Compound Motor Action Potential
Ulnar

Nerve Conduction Study
Late Responses: F-Waves
Ulnar

Nerve Conduction Study
Sensory Nerve Action Potential
Median

Nerve Conduction Study
Compound Motor Action Potential
Median

CTS Internal Comparisons
Mixed Nerve: Palmar Study
Median vs. Ulnar latency
Preston & Shapero 1998
CTS Internal Comparisons
Lumbral-Interosseous Study
Median vs. Ulnar Latency
Brannegan, K. Barn: 2007

EMG
Evaluate for denervation and abnormal motor unit characteristics.
Selection of muscle representing nerves and nerve roots relevant to clinical query.

Electromyography

FDI
1. Spontaneous Activity
   ** Normal (No activity)

Electromyography

FDI
1. Spontaneous Activity
   ** Normal (No activity)

Electromyography

FDI
1. Spontaneous Activity (Denervation) - Normal findings

Electromyography

FDI
1. Motor Unit Action Potential (MUAP)
   ** Morphology Analysis
Electromyography

FDI

Motor Unit Action Potential (MUAP)

Morphology Analysis

Electromyography

FDI

Motor Unit Action Potential (MUAP)

Morphology Analysis

VIDEO

Electromyography

FDI

MUAP Recruitment -Normal findings

Electromyography

FDI

MUAP Recruitment - Normal findings

Electromyography

FDI

MUAP Recruitment - Normal findings
Electromyography

APB (Median C8-T1)
Spontaneous Activity

Electromyography

APB
\^ Spontaneous Activity
\* 1+ Fibrillations

Electromyography

APB
\^ Spontaneous Activity
\* 1+ Fibrillations

Electromyography

APB
\^ Spontaneous Activity
\* 1+ Fibrillations

Electromyography

APB
\^ Spontaneous Activity
\* 1+ Fibrillations

Electromyography

APB
\^ Spontaneous Activity
\* 1+ Fibrillations

Electromyography

APB
\^ Spontaneous Activity
\* 1+ Fibrillations

Electromyography

APB
\^ Spontaneous Activity
\* 1+ Fibrillations

Spontaneous Activity - Abnormal findings
Electromyography

- APB
  - Motor Unit Action Potential (MUAP)
    - Morphology Analysis
    - 2-3+ Polyphasia

**Abnormal findings**
Markedly decreased recruitment
Electromyography

**APB**
MUAP Recruitment - Abnormal findings

---

**EMG**
APB (Median C8-T1)
FDI (Ulnar C8-T1)
EIP (Radial C7)
PT (Median C6-T)
FCU (Ulnar C7-T)
Bicep (Musculocutaneous C5-6)
Tricep (Radial C6-7)
Deltoid (Axillary C5-6)
Cervical PS (C5-T1)

---

Assess whether the study conclusions are consistent with the clinical assessment.

Review the timing of ordering electrodagnostic studies.

Discuss management options based on outcomes.

---

Clinical Assessment
Patterns of Neurologic Deficits

- Mononeuropathy
- Radiculopathy
- Plexopathy

---

Patterns of Neurologic Deficits
Mononeuropathy
*Single nerve, multiple nerve roots.*

Radiculopathy
*Single nerve root, multiple nerves.*
Patterns of Neurologic Deficits
Plexopathy
Multiple nerves, multiple nerve roots.

Carpal Tunnel Syndrome
Median Neuropathy at the Wrist
Paresthesias with repetitive or forceful activity, rest, etc.
Weakness thenar activities/dexterity.
Radiation from shoulder to hand occasionally.

Carpal Tunnel Syndrome
Examination:
Median sensory and/or motor deficits
CTS provocative maneuvers
Phalen's, Tinel's
Atrophy of thenar eminence

Carpal Tunnel Syndrome
Single study results dependent on technical issues and have surgical implications.
CTS comparisons best with uninvolved nerve of the ipsilateral hand (internal comparison).
CSI-C: Combined Sensory Indexing: Sum of latency differences.

Combined Sensory Index
Sum of latency differences
Normal ≤ 0.9 ms
Superior sensitivity and specificity
Superior test/retest reliability
Robinson, Micklesen, Wing, Muscle & Nerve 1998
Lee, Wing, Robinson, Muscle & Nerve 2000

Carpal Tunnel Syndrome
Electrodiagnostic Evaluation
Two abnormal median studies
Motor, sensory, internal comparison
One abnormal internal comparison study
Mixed Phalen, Lumbotarsal/Intersenous, Sensory Dpt 1 or 4
EMG
ABP and C6-7 muscles
Rule out proximal neuropathy
**Proximal Median Neuropathies**

*Median Neuropathy at the Elbow - Pronator Syndrome*

- Sensory and/or motor deficits.
- Elbow symptoms.
- Anterior Intersosseous Neuropathy
- Kiloh-Nevin Syndrome
- Motor deficit.
- "OK Sign".

**Cubital Tunnel Syndrome**

*Ulnar Neuropathy at the Elbow*

- Paresthesias at night, with pressure or repetitive flexion of the elbow.
- Weakness with digit spread or grip or wrist flexion.
- Sensory symptoms may not isolate to ulnar distribution.

**Cubital Tunnel Syndrome**

*Examination*

- Ulnar sensory and/or motor deficits.
- Provocative maneuvers:
  - Tinel’s at elbow
  - Elbow flexion
  - Ulnar claw (hand)
  - Wartenberg’s sign
  - Froment’s test
- Wasting FDI muscle.

**Cubital Tunnel Syndrome**

*Electrodiagnostic Evaluation*

- Two abnormal ulnar studies
  - Motor (FDI, ADM, inching)
  - Sensory, F-waves
- Localizable to elbow
  - Motor, inching
- EMG
  - FDI and FDP (uln) or FCU
  - C8-T1 muscles
- Rule out median neuropathy

**Distal Ulnar Neuropathy**

*Cyclist’s Palsy*

- Ulnar nerve entrapment at Guyon’s canal.
- Intrinsic hand muscle weakness.
- Sensory loss only in palmar ulnar distribution.

**Radial Neuropathy**

*Saturday Night Palsy, Honeymoon Palsy*

- Acute weakness with wrist and finger extension.
- Paresthesias at back of hand.
### Radial Neuropathy

**Examination:**
- Wrist and finger drop.
- Sensory deficits at the superficial radial nerve.
- May have tenderness at the spiral groove.
- Elbow extension preserved.

**Electrodiagnostic Evaluation**
- Abnormal radial studies
  - Motor
  - Sensory
- Localizable to spiral groove
- EMG
  - Radial muscle distal and proximal, Triceps 
  - C5-8 muscles
  - Rule out radiculopathy, brachial plexopathy

### Radial Neuropathy

**Superficial sensory radial neuropathy**
- Hand-Off Palsy
- claw-hand Phenomenon
- Wartenberg’s Syndrome

**Sensory deficits only.**

**Posterior Interosseous Neuropathy**
- Supinator Syndrome
- Radial Tunnel Syndrome

**Motor deficits with finger and some wrist extension.**

**Sensation in radial distribution preserved.**

### Peroneal Neuropathy

**Examination:**
- Ankle dorsiflexion, eversion weakness.
- Sensory deficits at the superficial and or deep peroneal nerve.
- May have positive Tinel’s at knee.
- Plantar flexion preserved.
- Steppage, circumduction or foot slap gait.

**Electrodiagnostic Evaluation**
- Peroneal Motor and Sensory Studies
  - Peroneal (EDB, TA), Fovea Superficial Peroneal
  - EMG
    - Deep Peroneal (2)
    - Sup. Peroneal (1)
    - SHBF
    - Tibial distal and proximal muscles
  - Rule out tibial, sciatic neuropathy

**Peroneal Neuropathy**

**Trauma**, masses, fractures, compartment syndromes, braces, prolonged or repetitive flexion.

**Generally acute weakness of ankle dorsiflexion and/or eversion.**

**Paresthesias** at dorsum of foot.
Radiculopathy
Patterns of neurologic deficits
Single nerve root, multiple nerves.

Discuss management options based on outcomes.

Electrodiagnostic Studies
an extension of the clinical exam.

Radiculopathy
Electrodiagnostic Evaluation
Motor and Sensory Studies
In distribution of suspected radiculopathy
Sensory studies may be normal with radiculopathy
Late Responses
Fwaves, Hreflex
EMG (Mandatory)
At least 2 muscles with same myotomes/different nerves
Proximal and distal muscles
Paraspinals
Rule out mononeuropathy, plexopathy

Prognostic value of electrodiagnostic studies
Limited

Entrapment neuropathies
multiple treatment options...
Severity of entrapment
Monitor for progressive neurologic deficits.

Severity of electrodiagnostic findings does not necessarily correlate with symptoms.

Acute nerve injuries
Electrodiagnostic studies... is there axonal continuity!

Electrophysiologic Evidence
Needs to correlate with clinical findings.

Is there more than one piece of evidence to support the finding?
Is there denervation vs. abnormal motor unit morphology?
Are the diagnostic criteria met?
Foot Drop

- 65 y.o. female
- 6 month history of right leg pain and numbness/foot drop.

Foot Drop

- Weakness of ankle evertors and dorsiflexors on right leg.
- Normal knee extension, flexion and ankle plantar flexion strength.
- Normal and symmetric Achilles and patellar reflexes.
- Decreased sensation top of foot.

Electrodiagnostic studies

Foot Drop

Electrodiagnostic studies

Foot Drop

Electrodiagnostic studies

Foot Drop

Electrodiagnostic studies
Foot Drop

- Electrodiagnostic studies
  - Tibial CMAP

Foot Drop

- Electrodiagnostic studies
  - Sural Sensory Nerve Action Potentials

Foot Drop

- Electrodiagnostic studies
  - Superficial Peroneal SNAP

Foot Drop

- Electrodiagnostic studies

Summary

This is an abnormal study. There are electrophysiologic findings consistent with a right peroneal neuropathy distal to the innervation of the short head of the biceps femoris.
Arm Weakness

- 27 y.o. male with a history of multiple right upper extremity fractures three months ago.
- Symptoms of right arm weakness and numbness.

Arm Weakness

- Weakness of the right upper extremity with wrist and digit extension.
- Normal strength of finger and wrist flexors and elbow and shoulder.
- Decreased sensation of right dorsal hand.
- Normal biceps and triceps reflexes, decreased brachioradialis reflex.

Arm Weakness

- Electrodiagnostic Studies

Arm Weakness

- Electrodiagnostic Studies
  - Median SNAP

Arm Weakness

- Electrodiagnostic Studies
  - Ulnar SNAP
Arm Weakness

Electrodiagnostic Studies
- Radial SNAP

Arm Weakness

Electrodiagnostic Studies
- Median CMAP

Arm Weakness

Electrodiagnostic Studies
- Ulnar CMAP

Arm Weakness

Electrodiagnostic Studies
- Radial CMAP

Arm Weakness

Electrodiagnostic Studies
Arm Weakness

- Summary
  - This is an abnormal study. The electrophysiologic findings are consistent with a right radial neuropathy at or above the innervation of the right brachioradialis. There is no electrophysiologic evidence of a right median neuropathy or right ulnar neuropathy.

Elbow Pain

- 36 y.o. male with a 10 month history of right upper weakness and medial hand numbness.
- Symptoms aggravated with work (construction) and at night.

- Weakness of the right upper extremity with 4 and 5 digit grip and digit spread.
- Normal strength of finger and wrist extensors, no intrinsic hand muscle atrophy.
- Decreased sensation of right medial hand.
- Normal biceps, triceps and brachioradialis reflex.

Elbow Pain

- Electrodiagnostic Studies
- Median SNAP
Elbow Pain

Summary

This is an abnormal study. The electrophysiologic findings are consistent with a right ulnar neuropathy at the elbow. There is no electrophysiologic evidence of a right median neuropathy at the wrist (carpal tunnel syndrome).

The prolonged right median CMAP and SNAP latency by themselves are of uncertain clinical significance but may be suggestive of a non-localized median neuropathy.

Electrodiagnostic Studies

Ulnar CMAP Conduction Block

Sciatica

- 47 y.o. male with a 6 month history of low back pain and leg pain s/p lifting injury at work.

- Right-sided low back pain and leg pain, numbness and weakness aggravated with bending, lifting and sneezing.
Sciatica

- Electrodiagnostic Studies
  - Sural SNAP

Sciatica

- Electrodiagnostic Studies
  - Superficial Peroneal SNAP

Sciatica

- Electrodiagnostic Studies
  - Tibial CMAP

Sciatica

- Electrodiagnostic Studies
  - Peroneal CMAP
Sciatica

Summary
This is an abnormal study. The electrophysiologic findings are most consistent with a right L5 lumbosacral radiculopathy.

Left Arm Pain/Weakness

76 y.o. male 12 months s/p C6-7, C8-T1 left cervical decompression / laminectomy

Continued significant left upper extremity and neck pain and intrinsic hand weakness.

Left Arm Pain/Weakness

- Left intrinsic hand muscle atrophy with interossei, APB weakness
- Decreased sensation digit 5 and medial digit 4
- Mildly decreased left triceps reflex

Electrodiagnostic studies
Left Arm Pain/Weakness

- Electrodiagnostic studies
  - Median SNAP

Left Arm Pain/Weakness

- Electrodiagnostic studies
  - Ulnar SNAP

Left Arm Pain/Weakness

- Electrodiagnostic studies
  - Radial SNAP

Left Arm Pain/Weakness

- Electrodiagnostic studies
  - Median CMAP

Left Arm Pain/Weakness

- Electrodiagnostic studies
  - Median F-waves

Left Arm Pain/Weakness

- Electrodiagnostic studies
  - Ulnar CMAP
Left Arm Pain/Weakness

- Electrodiagnostic studies
  - Ulnar F waves

Left Arm Pain/Weakness

- Electrodiagnostic studies
  - Ulnar (FDI) CMAP

Left Arm Pain/Weakness

- Electrodiagnostic studies
  - Mixed Palmar Comparison

Left Arm Pain/Weakness

- Electrodiagnostic studies
  - Lumbrical/Interosseous Comparison

Left Arm Pain/Weakness

- Electrodiagnostic studies
Left Arm Pain/Weakness

Summary

This is an abnormal and complex study. There are electrophysiologic findings consistent with a left median neuropathy at the wrist (carpal tunnel syndrome). The electrophysiologic findings are also suggestive of a left non-localized ulnar neuropathy vs. a left C8-T1 cervical radiculopathy.