Introduction

- Review nerve physiology/ anatomy
- Purpose of testing
- Study design
- Motor NCS
- Sensory NCS
- Mixed NCS
- Interpretation
- Technical considerations
- Summary
Anatomy

- Motor Neuron
  - Axon
    - Myelin
  - Neuromuscular Junction
  - Muscle fibers
Anatomy

- Dorsal Root ganglion: Bipolar Nerve cell
  - One projection central
    - Dorsal column
  - Other axon distal
    - Sensory end organ
  - Myelinated: different degrees
Anatomy

- Neurons
  - AHC
  - DRG
- Roots
- Rami
  - Ventral Rami:
    - Plexus
  - Dorsal Rami:
    - Paraspinals
Anatomy

- Certain nerves are routinely studied
  - Location
  - Size
  - Important pathology
  - Ease of evaluation

- Some are less often studied

- Some are rarely studied
Study Design

- Answer the clinical question
  - Not just routine

- Specifically choose nerve evaluation needed
  - Motor NCS
  - Sensory NCS
  - Repetitive stimulation
  - Other (mixed study)

- Least number of NCS needed to answer the clinical question
  - I.e.. CTS
Purpose of testing

Neuropathy

- Focal
  - Carpal Tunnel Syndrome (CTS)
  - Peroneal neuropathy
  - Ulnar neuropathy

- Generalized
  - Diabetic Neuropathy
  - Guillain Barre syndrome (GBS)

- Axonal
  - Diabetic Neuropathy
  - Nerve transection

- Demyelinating
  - GBS
  - CTS

Other conditions

- Radiculopathy
- Neuromuscular junction defects
  - Myasthenia Gravis
  - LEMS
- Motor Neuron Disease
  - ALS
- Sensory Neuronopathy
  - Sjogren’s disease
Motor nerve conduction studies

- Larger
- More reproducible
- Troubleshooting is easier
Why?

- Compound Muscle Action Potential
- Muscle amplifies the response
  - Stimulate nerve axons
    - Causes muscle to contract
  - Recording the muscle contraction
  - Response is in millivolts
    - (1000X larger than SNAP)
  - Few anatomic variations
    - Large motor axons tend to be affected late in disease states
Motor NCS

- Belly-Tendon montage
  - G1: active
  - G2: reference

- Stimulate proximal
  - Measure site (s)
  - Consistent

- 0-60mAmps stimulation
  - 0.1ms duration
  - May need to adjust
Motor NCS parameters

- Latency
  - Onset
  - Time (mS)
- Amplitude
  - Baseline to peak
  - Electrical signal (mV)
    - Muscle contraction
Conduction velocity: two points in time
- Rate = distance/ time
  - So 2 points are needed
    - i.e. CV = 20cm/4ms
- Cannot record a distal conduction
- Why?
  - Neuromuscular junction
    - Cannot accurately calculate time
Conduction Velocity

- Rate = distance/ time
- E.g., Median Nerve:
  - Distal latency: 4 ms
  - Proximal latency: 8 ms
  - Measure:
    - 20 cm between 2 sites

- CV = d/ t
- CV = 20 cm/ 8 ms - 4 ms
- CV = 20 cm/ 4 ms
- CV = 200 mm/ 4 ms
- CV = 200 m/ 4 s
- CV = 50 m/ s
Motor NCS parameters

- Area
  - Not used frequently
  - Used when considering conduction block
    - Often calculated automatically by modern machines

- Duration of waveform
  - Temporal dispersion
    - Demyelinating disease
    - Or with severe axonal loss
Sensory Nerve conduction studies

- Summation of all sensory nerve fiber action potentials
  - SNAP (sensory nerve action potential)
  - Fibers are of mixed type:
    - Large/ small
    - Myelinated/ unmyelinated
- Small
  - μVolts
DRG

- External to the spinal cord
- May be located in intervertebral foramen
  - Lesions may be proximal to DRG
- Important consideration
  - Distal axon and DRG may be spared
    - Therefore Sensory NCS may be normal
    - Despite symptoms!
Sensory NCS parameters

- Latency (ms)
  - Onset
  - Peak: more commonly used
    - More reproducible/consistent

- Amplitude (µV)
  - Baseline to peak
  - Peak to peak

- Duration

- Conduction velocity
  - Can calculate a distal velocity
  - Use onset latency for CV
    - Fastest fibers
Sensory NCS

- Antidromic
  - Anti: “against” or opposite
  - I.e.: Against natural conduction
    - Stimulate proximal, record distal

- Orthodromic
  - Ortho: “right” or correct
  - I.e.: Natural direction of sensation
    - Stimulate distal; record proximal
Antidromic SNCS

- More common
  - Why?

- In general, easier

- Higher amplitude responses
  - Sensory nerve is more superficial in distal skin
    - Easier to obtain and record
Antidromic Sensory NCS
Orthodromic Sensory NCS

![Graph showing Orthodromic and Antidromic NCS data]

<table>
<thead>
<tr>
<th>Method</th>
<th>Peak latency (ms)</th>
<th>Amplitude (mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Orthodromic</td>
<td>2.8</td>
</tr>
<tr>
<td>B</td>
<td>Antidromic</td>
<td>2.9</td>
</tr>
</tbody>
</table>
“Mixed” nerve studies

- Motor is pure motor: belly-tendon montage
  - Recording muscle

- Sensory NCS should record only sensory fibers
  - Record over skin
  - Evaluate SNAP

- But, some nerves recorded are mixed
  - Both sensory and motor fibers present
    - Stimulation
    - Recording site
“Mixed” nerve studies

- Palmar studies
- Tarsal Tunnel studies (plantar nerve)
- Specialized studies
  - Evaluating one specific lesion
    - Carpal tunnel syndrome
    - Tarsal tunnel syndrome
  - Not pure sensory potentials
    - Cannot assess integrity of sensory nerve/DRG
Mixed NCS

- Palmar record over wrist
  - Median and ulnar
    - Both motor and sensory fibers present
  - Stimulate in palm
    - Both motor and sensory fibers present
- Comparison of latencies
  - Amplitude is less relevant
Other considerations in NCS

- Physiologic temporal dispersion
  - Not all dispersion is pathologic
  - Proximal amplitudes are lower than distal
    - Double check your results!
  - Why?
    - Loss of synchrony over longer distances
    - Proximal nerves are deeper and more difficult to stimulate
Averaging

- Used for low amplitude sensory nerve potentials
  - Additive waveforms confirm + presence of SNAP
  - Subtracts out artifact

- Lateral antebrachial cutaneous sensory responses
  - Effect of averaging: 1, 2, 6, 10 responses
Routinely evaluated nerves

- **Motor:**
  - Tibial, Fibular (peroneal)
  - Median, Ulnar

- **Sensory**
  - Sural
  - Median, Ulnar

- **Mixed**
  - Palmars
    - Carpal Tunnel syndrome only
Commonly evaluated nerves

- Motor:
  - Radial

- Sensory:
  - Superficial Fibular (Peroneal)
  - Radial
  - Medial antebrachial cutaneous
  - Lateral antebrachial cutaneous
  - Dorsal Ulnar cutaneous

- Mixed:
  - Medial and Lateral plantars (tarsal tunnel)
Late Responses: F waves/ H reflexes

- Both are used to answer a specific clinical question
  - F waves: primarily used to evaluate proximal demyelination
    - GBS/ CIDP
    - Radiculopathy
  - H reflex: used to evaluate radiculopathy
    - S1 nerve root
F waves

- Electrical signal travelling up to anterior horn cell
  - “bounces” back
  - NOT a reflex
- Wave traveling up and back down motor axons
- Proportion of axons
  - Differs with each stimulus
  - So each waveform varies
- Reflects speed of conduction
F-wave utility

- Radiculopathy
  - Demyelinating (ie nerve root compression)
    - May be prolonged
  - Axonal
    - May disappear

- Demyelinating disease
  - Early: may have no change
  - Mid-course: delay in F-wave latency
  - Late/ severe: loss of F-wave

- F-wave absent/ not recorded
  - Can be normal occurrence
    - Especially in median and radial nerves
F wave parameters

- Latency
  - ms

- “Normal”
  - Upper limit of normal
  - Depends on height
    - Either for short or tall persons
    - Need a normogram
    - Calculate expected time
Late Response: H reflex

- True reflex
- Afferent loop: la sensory fibers
- Efferent loop: Motor axons
- Actual synapse
H reflex

- S1 nerve root
  - Tibial N. stim
    - recording from gastrocnemius

- Other H reflex responses are difficult to elicit

- H reflex largest with submaximal stimulation
  - As stimulation increases
    - H reflex diminishes
    - M-wave (motor response) increases
H reflex utility

- Proximal damage to either sensory or motor pathway
  - Radiculopathies
  - Avulsion
- Side to side comparison
- Tibial nerve studied most often
  - Upper limit of normal latency is 35 ms
NCS: Basic Interpretations

- **Amplitude:** related to the number of axons in a nerve
- **Latency:** a marker of time; therefore, most affected by demyelinating processes
- **Conduction velocity:** speed; can be affected by both axonal loss and demyelination
  - Large, fast conducting fibers are lost
    - Moderate slowing
  - Demyelination
    - Marked slowing
Normal Values

- Vary lab to lab
- No universal standards
- General principles apply
  - Side to side variability
    - < 50% difference
    - amplitude
  - Physiologic temporal dispersion
    - <20 % drop in amplitude
  - Comparison studies
    - < 0.2 or 0.3 ms difference
- In general
- Conduction velocities
  - Motor NCS
  - Legs > 40 M/s
  - Arms > 50 M/s
  - Sensory NCS
  - 10 M/s faster
Conduction Velocity

- Determined by the fastest conducting fibers

- Motor NCS
  - Legs: 40 M/s
  - Arms: 50 M/s
  - Sensory CV about 10 M/s faster

- Axonal loss can produce slowing
  - <2/3 LLN
    - Legs > 30 M/s
    - Arms > 40 M/s

- Demyelination
  - Produces significant slowing
  - > 2/3 LLN
    - Legs < 30 M/s
    - Arms < 40 M/s
Axonal Loss

- Most Neuropathies
  - LE > UE
  - Distal > proximal
  - Sensory > Motor

- So a NCS study in a patient with Neuropathy
  - Low amplitudes, more severe in the legs than arms
  - Loss of sensory responses in legs early on
  - CV slowing > 2/3 LLN
### Demyelinating Process

**Hereditary**

- Uniform slowing
  - Across all segments
- Uniform waveform shape
  - CMAPs
- Profound slowing

**Acquired**

- Non-uniform process
- Conduction block
  - Non-compressible segments
- Temporal dispersion
- Increased variability in range of velocities
- Some nerves affected more than others
  - MMN
Focal vs. Generalized

- **Focal lesion**
  - Either axonal or demyelinating
  - Compression
    - Demyelinating
      - CTS, ulnar neuropathy
    - Axonal
      - Mononeuritis multiplex
      - Nerve transection

- **Generalized**
  - More often due to systemic process
  - Axonal
    - Polyneuropathy
  - Demyelinating
    - GBS
    - CIDP
Safety Considerations

- For NCS
  - Generally very safe

- EMG/NCS machine electrically certified
  - Checked annually to rule out “leak”
  - Grounded outlet

- Do not create an electric circuit through patient
  - I.e. Bed unplugged, no other devices attached to pt
    - But, studies are done in ICUs routinely, with precautions
  - Pacemaker: not a problem if one stays distal and ground is near stimulator
  - Other devices: turn off if possible (artifact!)
Technical Problems

- Temperature
- Incorrect measurements
- Inter-electrode distance (too far or too close)
- Background interference/ noise
- Incomplete circuit
  - I.e.: check to make sure electrodes are plugged in!
Temperature

- Very important
  - Commonly ignored/missed
  - 0.2ms/degree centigrade

- Arms > 31 °C
- Legs > 30 °C
- Must check distal limb
  - Thermistor
  - Infrared temperature probe
Summary: NCS

- Easily tolerated, safe
- Must be consistent in technique
  - Intralab normal values
- Monitor for technical issues
- Very sensitive to axonal loss
- Very specific for demyelinating disease