# Nerve conduction study in medical practice

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# Introduction

- **Nerve conduction studies (NCS**) and **needle electromyography (EMG)** provide objective physiologic assessment of peripheral nerve and muscles. These two parts of the examination are performed sequentially.

- Electrodiagnostic evaluation includes both nerve conduction studies (NCS) and EMG.

- Nerve conduction studies are performed on motor and sensory nerves, but only large myelinated fibers can be evaluated

# Nerve Conduction Study (NCS)

- NCS is a test commonly used to evaluate the function of the motor and sensory nerves of the human body.

- mainly for peripheral nerves

Peripheral nerves are stimulated with an controlled electrical stimulus

Responses recorded

# Nerve conduction velocity (NCV)

- Nerve conduction velocity (NCV) is a common measurement made during nerve conduction study (NCS).

- The term NCV often is used to mean the actual test , but this may be misleading since velocity is only one measurement in NCS.

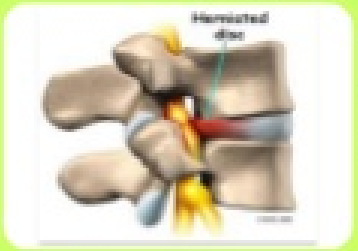
# Common disorders diagnosed by NCS

## Peripheral neuropathy

- Mononeuropathy (ex: carpal tunnel syndrome)
- Mononeuritis multiplex (ex: vasculitides, rheumatoid arthritis, lupus erythematosus [SLE], sarcoidosis, leprosy, Lyme disease, amyloidosis)
- Polyneuropathy (ex: diabetic neuropathy,)

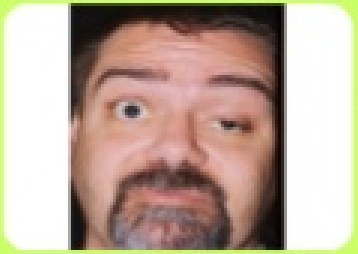
## Myopathy

- Muscular dystrophies (ex: Facioscapulohumeral muscular dystrophy)
- Myotonia
- Congenital myopathies
- Metabolic myopathies




## Radiculopathy (problem in which one or more nerves are affected with emphasis on the nerve root; Radix = "root")

- Nerve damage from herniated discs



## Diseases of neuromuscular junction

- Myasthenia gravis

# Other uses of NCS in medical practices

- To distinguish peripheral neuropathy from myopathy and motor neuron disease.
- To detect plexopathy (Brachial or lumbosacral)
- To detect subclinical lesions (eg.Charcot-Marie-Tooth disease, carpal tunnel syndrome)
- To differentiate inherited, acquired, and autoimmune demyelinating polyneuropathy.

# Limitations:

- Routine motor and sensory conduction velocity and latency measurements are from the largest and fastest fibers.

- Large-diameter fibers have the most myelin and the least electrical resistance, both of which result in faster conduction velocities.

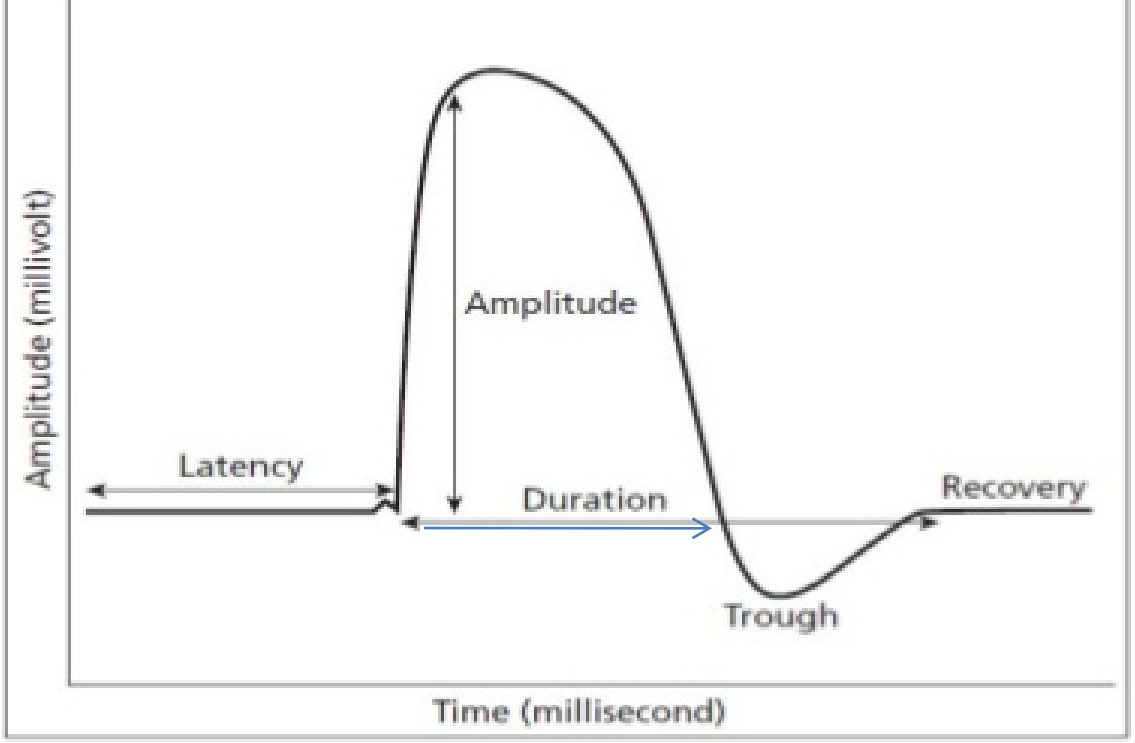
- Thus, neuropathies that preferentially affect only small fibers may not reveal any abnormalities on NCSs.

# Electrodiagnostic data

Components that are evaluated in nerve conduction studies include

- Latency
- Conduction velocity
- Amplitude
- Duration

# CMAP




- **Latency** – time interval between the onset of a stimulus and the onset of a response
- **Amplitude** – the maximal height of the action potential.
- **Conduction velocity** – how fast the fastest part of the impulse travels

**Duration** - refers to the total duration of an evoked response measured in milliseconds.

# Procedure

- **Active recording electrode** placed on the center of the muscle belly (over the motor endplate)
- **Reference electrode** placed distally about 3-4 cm from active electrode.
- **Stimulator** placed over the nerve that supplies the muscle, cathode closest to the recording electrode.
- Current needed

1. 20-50 mA for motor NCS
2. 5-30 mA for sensory NCS

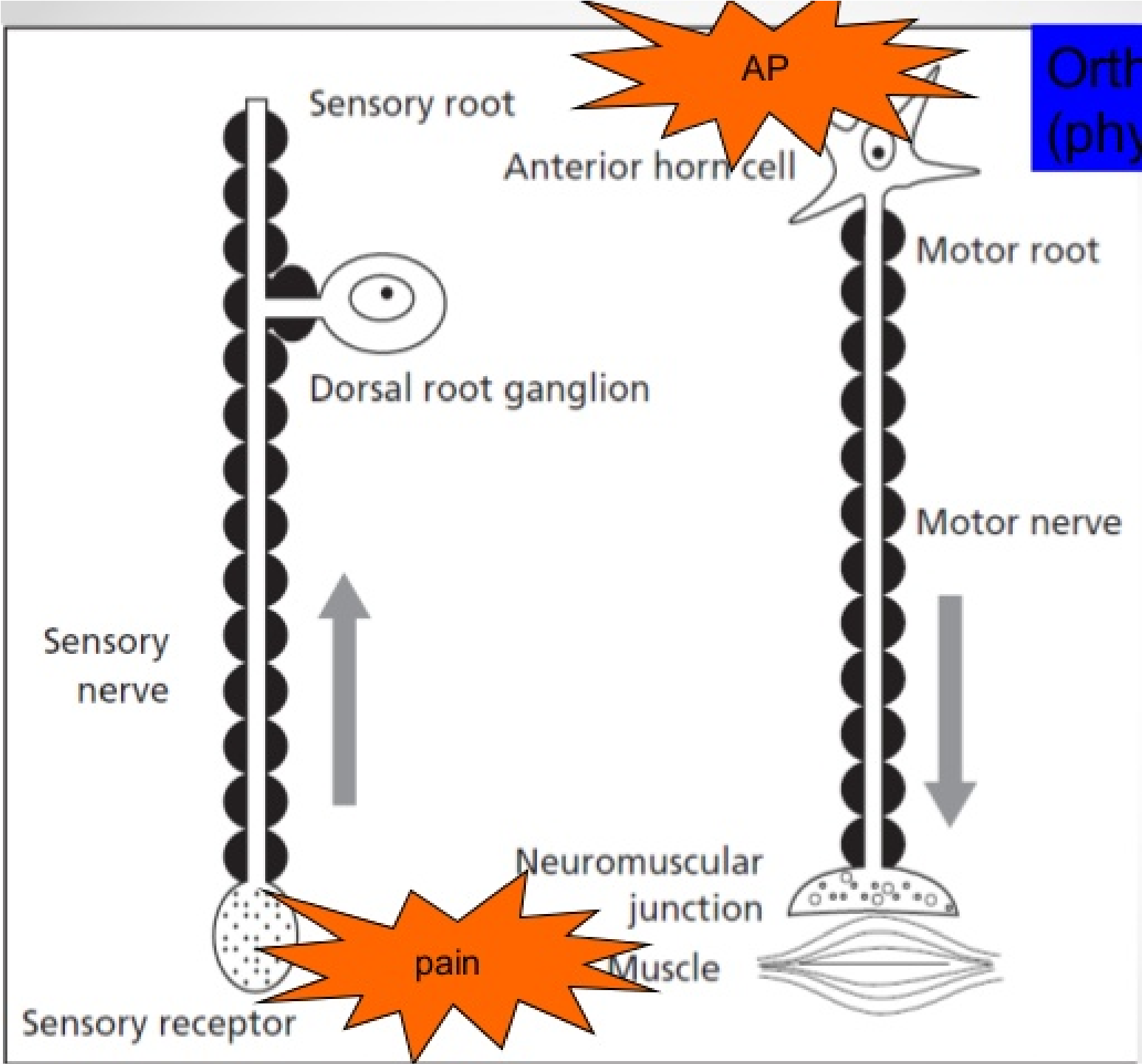
- Supramaximal stimulation is given.

# DIRECTION OF CONDUCTION

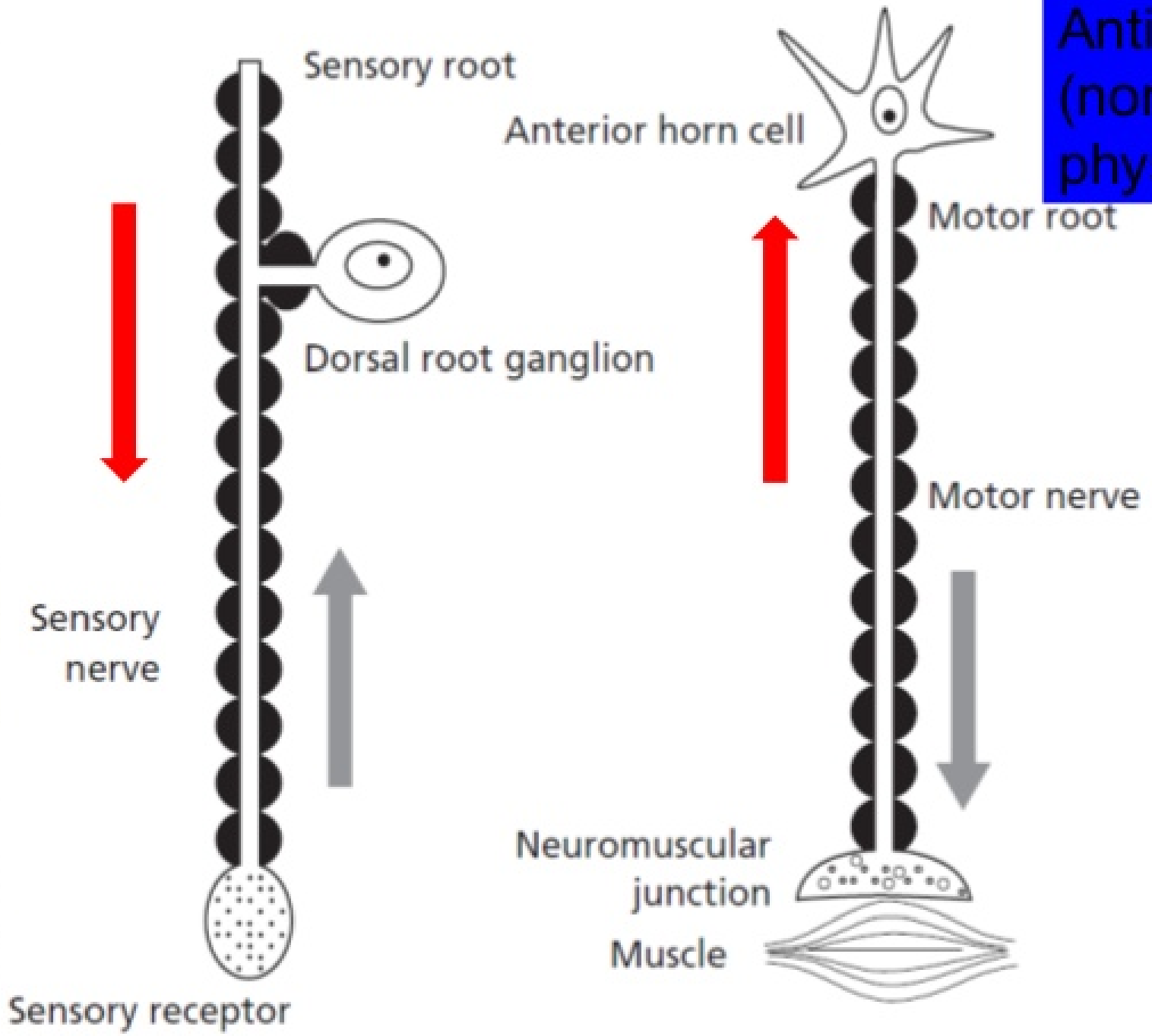
- Orthodromic conduction
- Antidromic conduction

- **Orthodromic – when the electrical impulse travels in the same direction as normal physiologic conduction**
- **Antidromic – when the electrical impulse travels in the opposite direction of normal physiologic conduction**

# Orthodromic (physiological)



Antidromic (non-physiological)

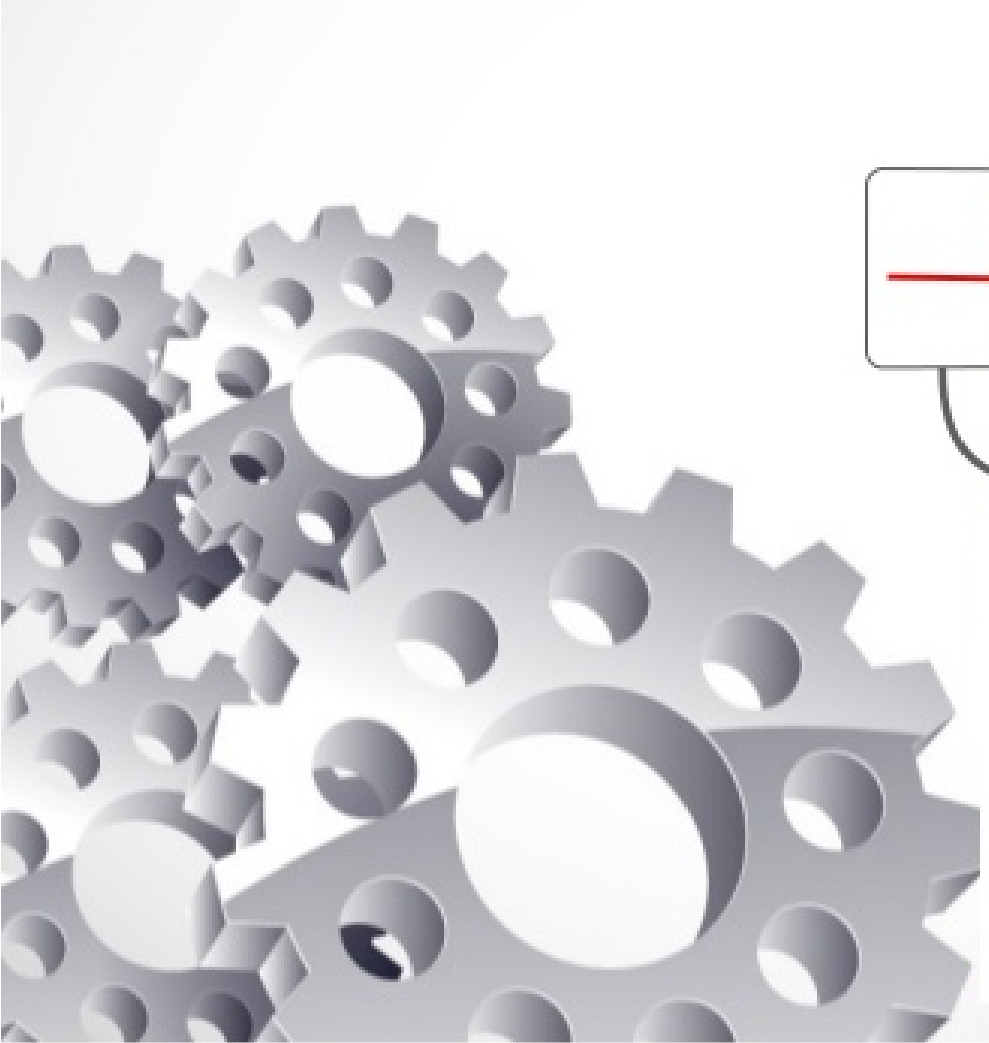


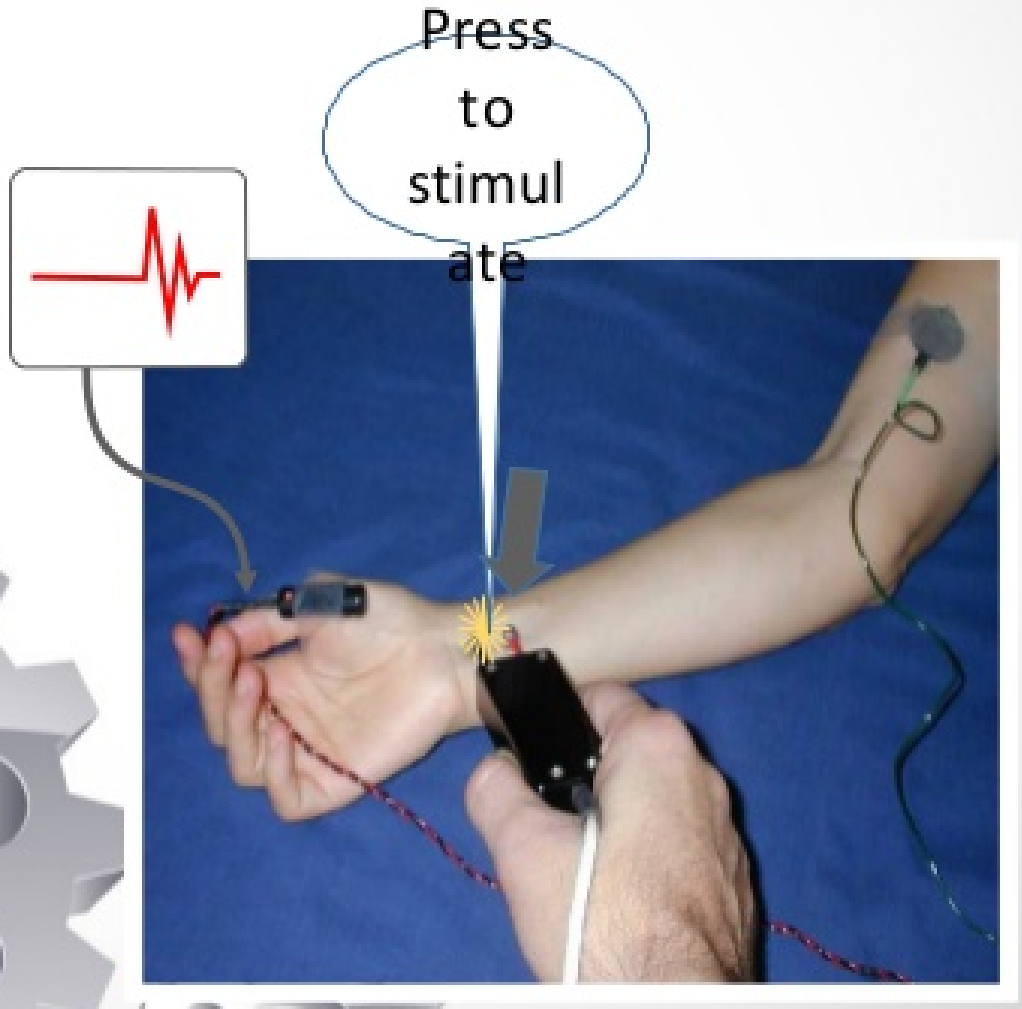
# Components of NCS

- The NCS consists of the following components:
  - Compound Motor Action Potential (CMAP); *also called Motor nerve conduction study*
  - Sensory Nerve Action Potential (SNAP); *also called Sensory nerve conduction study*
  - F-wave study
  - H-reflex study
  - Repetitive nerve study
  - A-(Axon) wave study
  - Blink Reflex study
  - Direct Facial Nerve Study

*will not be discussed…*

# Motor nerve conduction



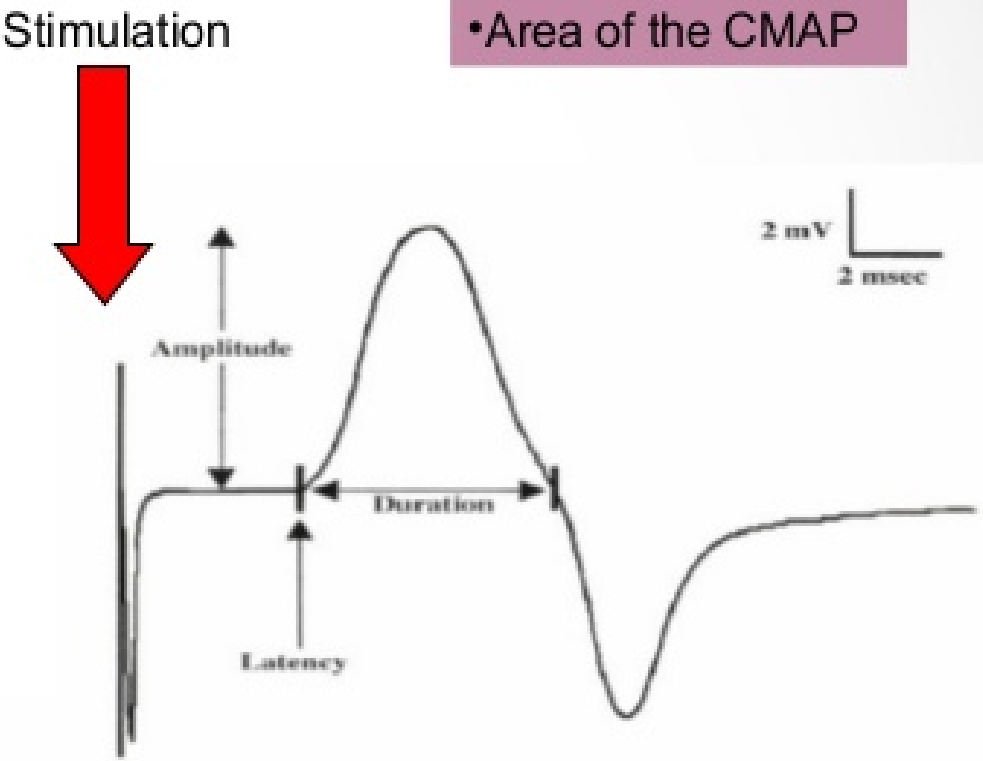


# Compound muscle action potential (CMAP)

- Compound term represents the summation of all underlying individual muscle fiber action potentials.

- Biphasic potential with an initial negativity, or upward deflection from the baseline.

**Comprises of :**
- Latency,
- Amplitude,
- Duration, and
- Area of the CMAP




Motor conduction velocity can be calculated after 2 sites (proximal & distal) stimulated

# Compound muscle action potential (CMAP)

- Measure of the speed of the fastest conducting motor axons.

- Conduction velocity (m/s) calculated as:

$$\frac{\text{distance between 2 stimulus sites (m)}}{\text{difference between 2 latency (s)}}$$

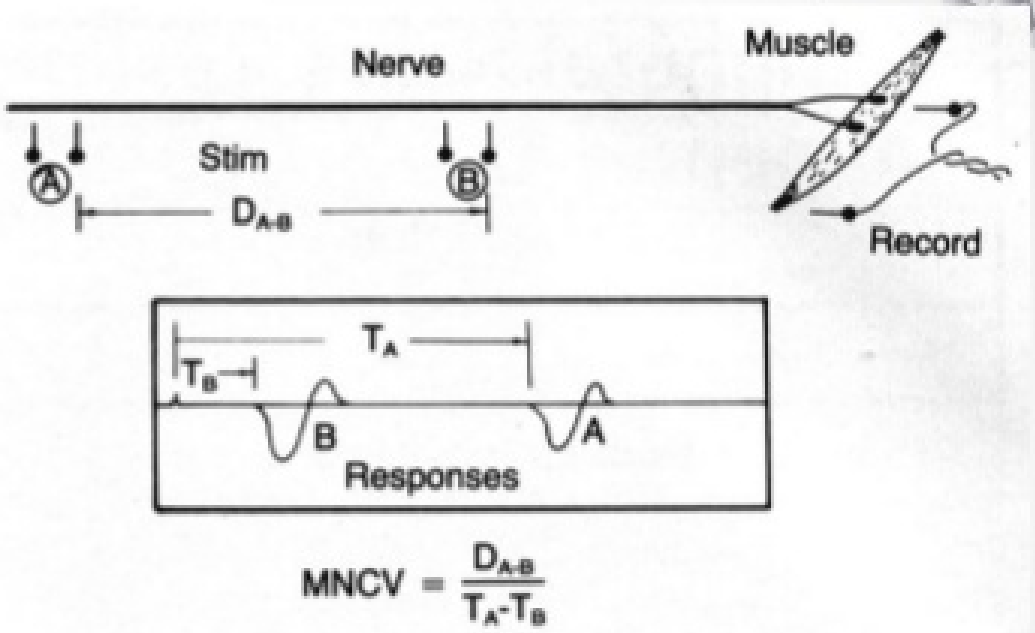
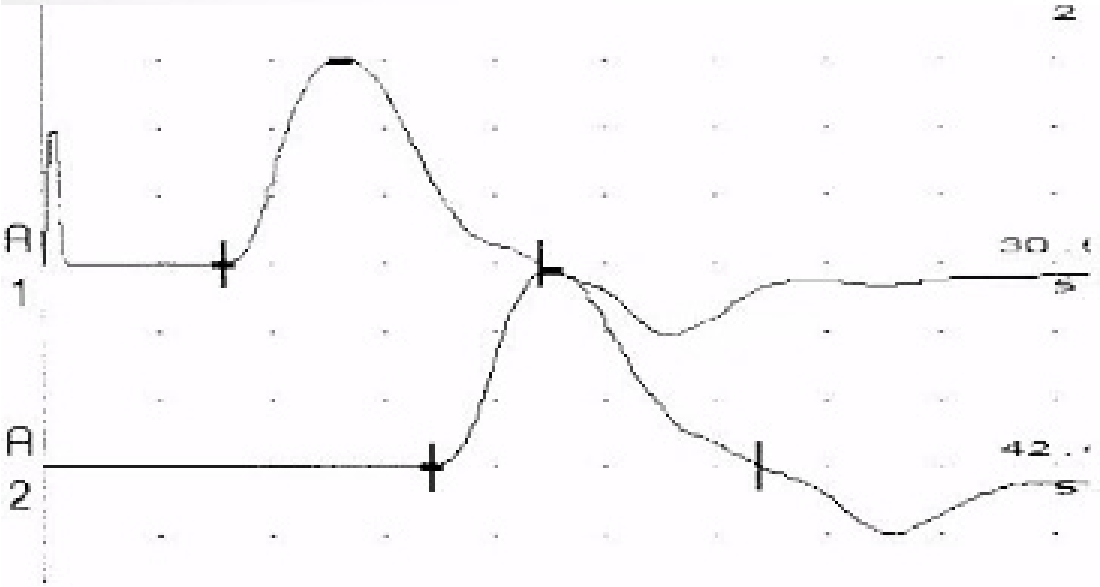
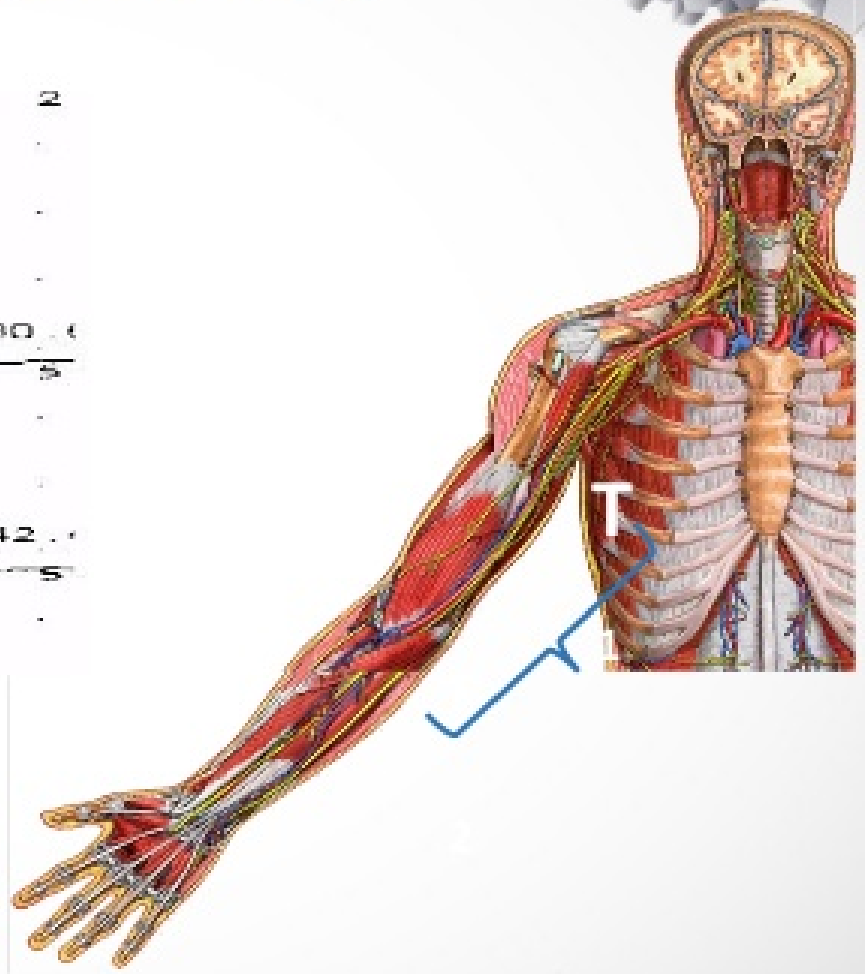



**FIG. D-2** Schematic diagram of motor nerve conduction velocity (MNCV) estimation. The nerve is stimulated at two sites, and recording is done from the muscle.

Velocity of conduction = $\frac{\text{Distance (cm)}}{\text{T1-T2 (millisecond)}} \times 100$

(Meter/sec)




| | DL (m/s) | CV (msec) | Amp(mV) |
|---|---|---|---|
| Wrist-APB | 3.2 | | 15.0 |
| Elbow-Wrist | | 55 | 14.8 |

# Motor nerve conduction study – sites

## Median nerves (R & L) at;

- Wrist
- Elbow

→ Abductor Pollicis Brevis

## Ulnar nerves (R & L) at;

- Wrist
- Elbow

→ First Dorsal Interosseous (FDI)
→ Abductor Digiti Minimi (ADM)

## Peroneal nerves (R & L) at;

- Ankle
- Head of fibula

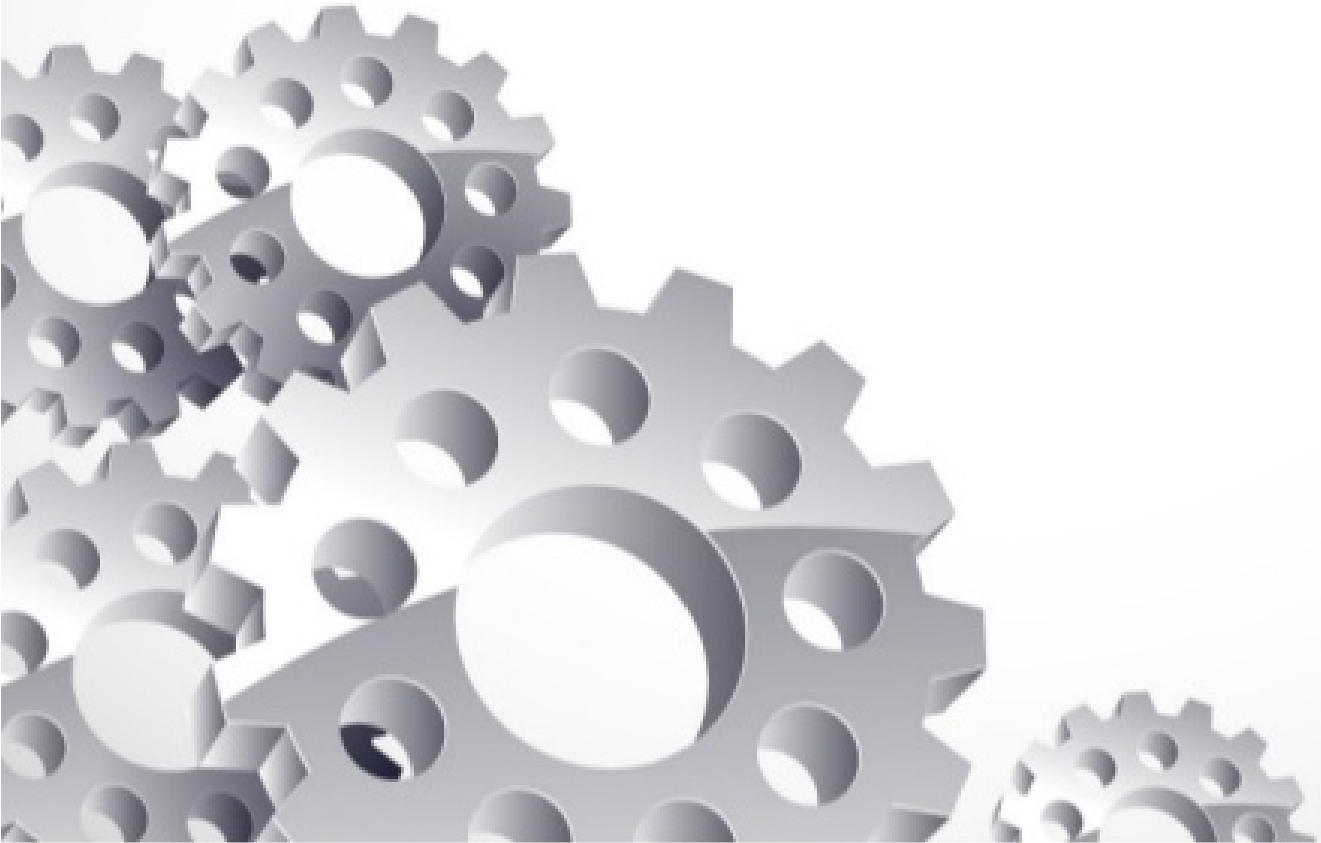
→ Extensor Digitorum Brevis
→ Tibialis Anterior

## Tibial nerves(R & L) at;

- Ankle

→ Abductor Hallucis
→ Abductor Digiti Quinti Pedis

# Sensory nerves conduction study



# Sensory nerve conduction study

- Sensory nerve conduction studies directly assess sensory axons by recording a sensory nerve action potential(SNAP) proximal or distal to the site of stimulation.

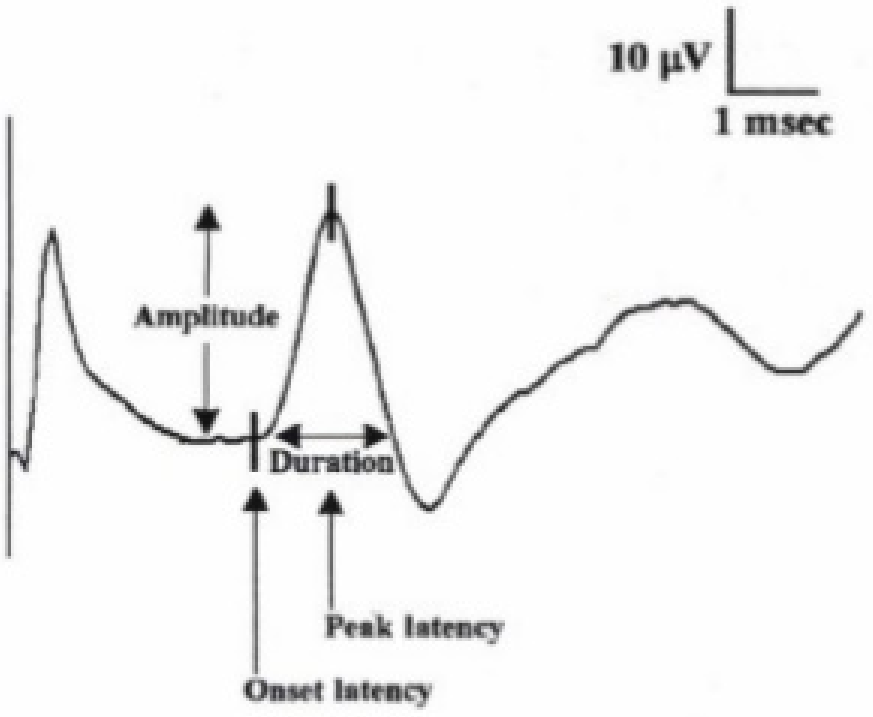
- If the stimulus site is distal and the recording site is proximal towards the spinal cord- orthodromic study and if stimulus is proximal and recording site is distal away from the spinal cord – antidromic study.

- SNAP are of much smaller amplitude than CMAP

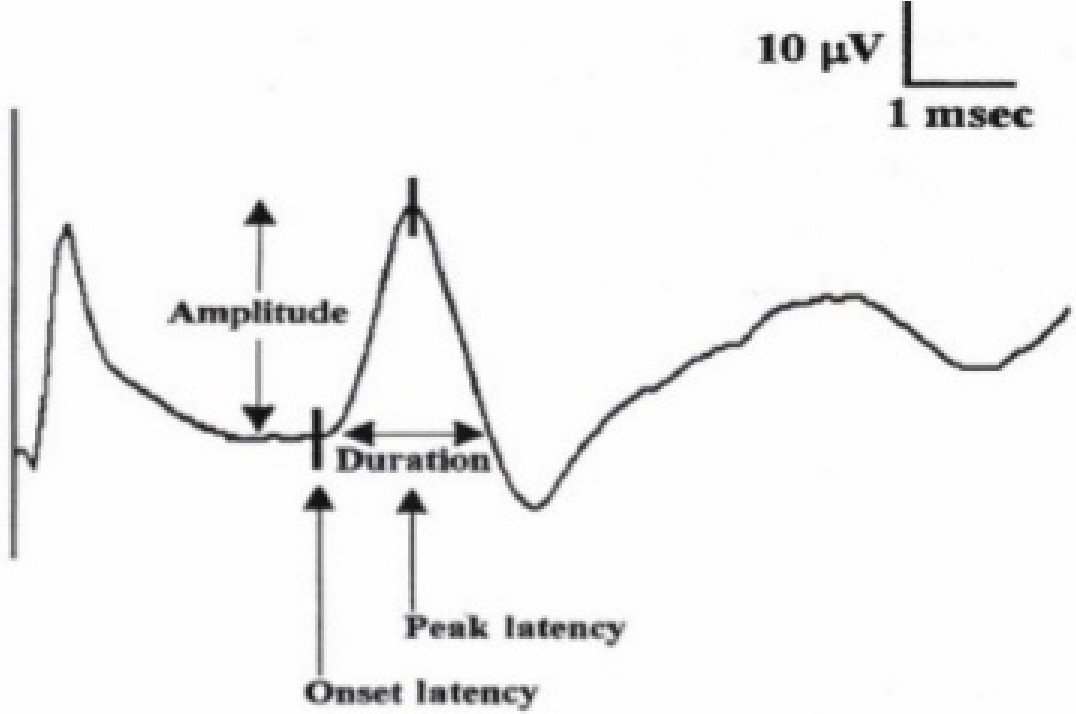
- SNCS are more sensitive than MNCS in detecting early and mild disorders

# Sensory nerve conduction (SNC)

- a compound potential that represents the summation of all the individual sensory fiber action potentials.
- Usually are biphasic or triphasic potentials.
- For each stimulation site, the onset **latency**, **peak latency**, **duration**, and **amplitude** are measured
- A sensory CV can be calculated wi one stimulation alone



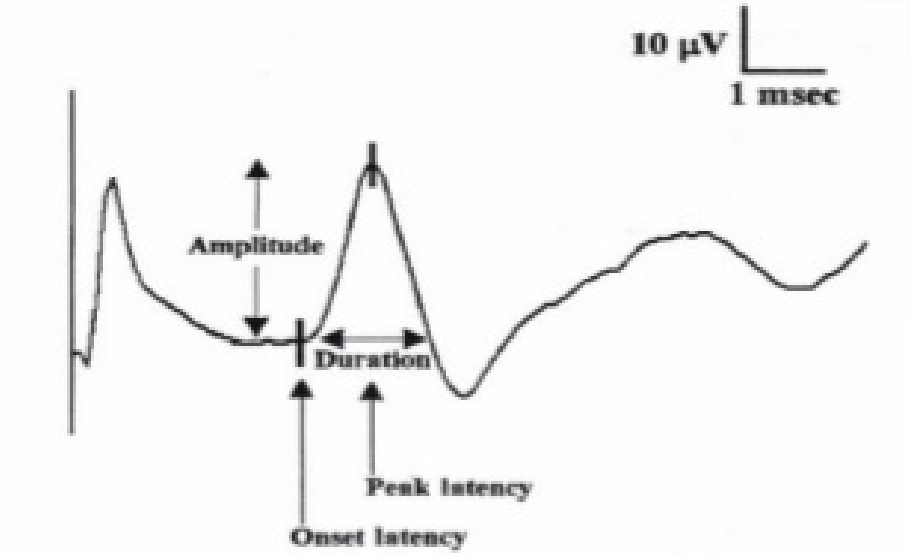
# Sensory nerve action potential (SNAP)




- **Onset Latency:**
  - is the time from the stimulus to the first deflection from baseline
  - represents nerve conduction time from the stimulus site to the recording electrodes for the largest cutaneous sensory fibers
  - used to calculate conduction velocity.

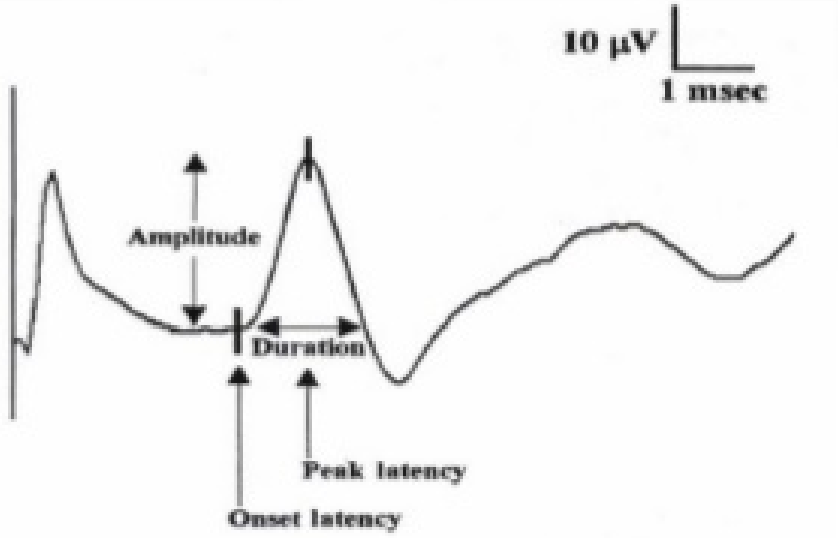
- **Peak Latency:**
  - is measured at the midpoint of the first negative peak.
  - Inter examiner variation is less (marking).

# Sensory nerve action potential (SNAP)




- Duration:
  - measured from the onset of the potential to the firstbaseline crossing (i.e., negative peak duration).
  - The SNAP duration typically is much shorter than the CMAP duration (typically 1.5 ms vs 5-6 ms).

# Sensory nerve action potential (SNAP)




- Amplitude:
  - commonly measured from baseline to negative peak.
  - Low SNAP amplitudes indicate a definite disorder of peripheral nerve.

# Sensory nerve conduction velocity

- Sensory conduction velocity represents the speed of the fastest, myelinated cutaneous sensory fibers.

- Sensory conduction velocity can be determined with one stimulation, by dividing the distance traveled by the onset latency

**Sensory conduction velocity=**
**Distance between R - S / Onset latency=m/s**

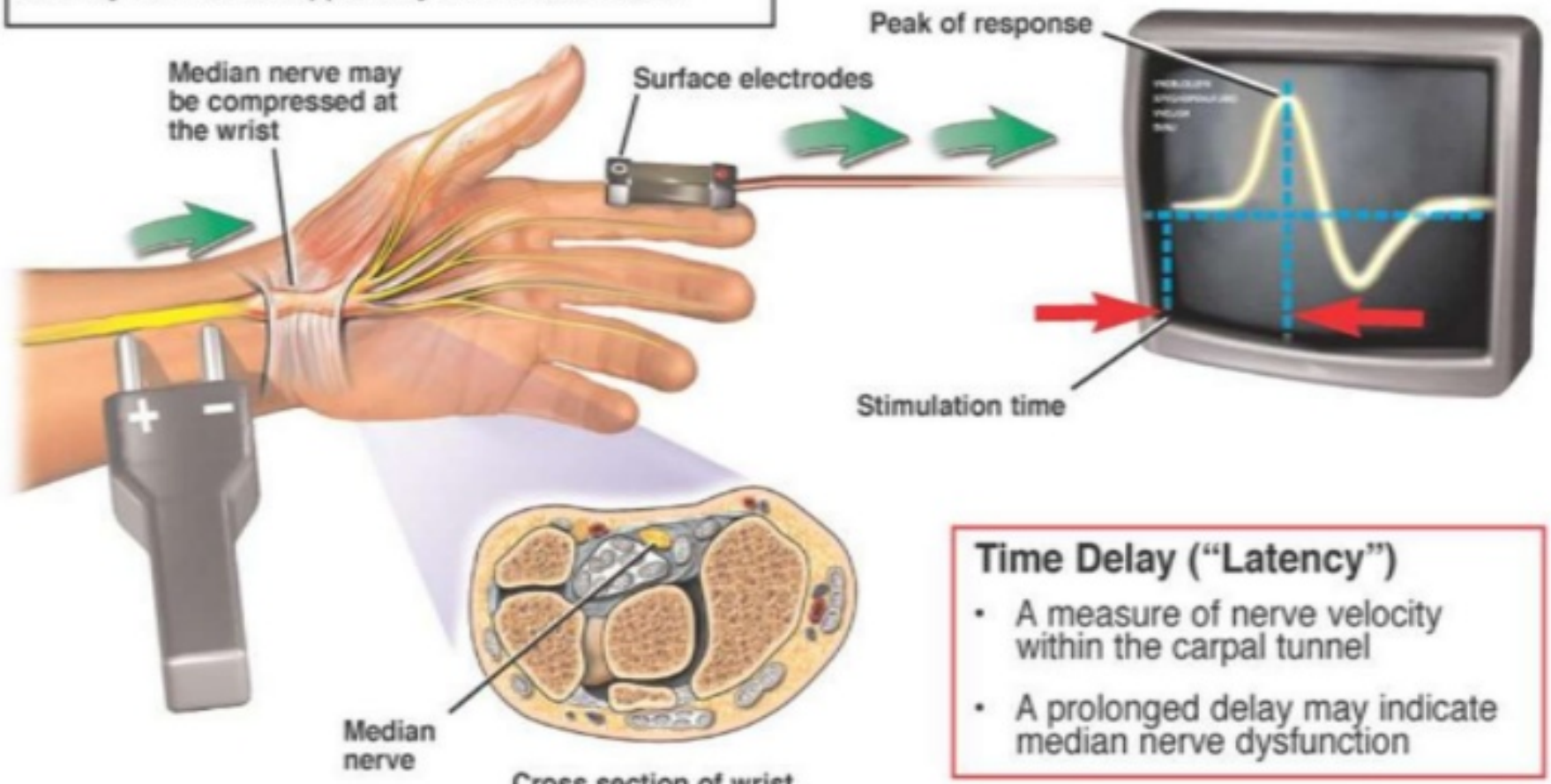
# Sensory nerve conduction study (cont..)

- It can also be useful in localizing a lesion in relation to the dorsal root ganglion (DRG).
- The DRG is located in the neural foramen and contains the sensory cell body. Lesions proximal to it (root, spinal cord) preserve the SNAP despite clinical sensory abnormalities.
- This is because axonal transport from the cell body to the axon continues to remain intact.
- SNAPs are typically considered more sensitive than CMAPs in the detection of an incomplete peripheral nerve injury.
- Antidromic Studies;
  - Are easier to record a response than orthodromic studies
  - Are less uncomfortable when orthodromic studies secondary to less stimulation required
  - Have larger amplitudes due to the nerve being more superficial at the distal recording sites

# Sensory Nerve Conduction Studies (Electrodiagnosis) of the Median Nerve Across the Carpal Tunnel

Surface stimulation of the median nerve at the wrist. This sends a nerve impulse through the carpal tunnel into the hand and activates the specific muscles and sensory structures supplied by the median nerve.

Recorded sensory nerve response at the index finger from the median nerve stimulation at the wrist




## Time Delay ("Latency")

- A measure of nerve velocity within the carpal tunnel
- A prolonged delay may indicate median nerve dysfunction

# Sensory nerve conduction study – sites

## Median nerves (R & L) at;

- index finger
- thumb

## Ulnar nerves (R & L) at;

- little finger
- ring finger

## Sural nerves (R & L) at;

- behind the Lateral Malleolus

## Saphenous nerves(R & L) at;

- anterior to the Medial Malleolus

# Findings in NCS

- **Axonal neuropathy**
  - **CMAP and SNAP show low amplitudes , with conduction velocity either preserved or only mildly slowed.**

- **Demyelinating neuropathy**
  - **CMAP and SNAP amplitude can be normal with distal stimulation**

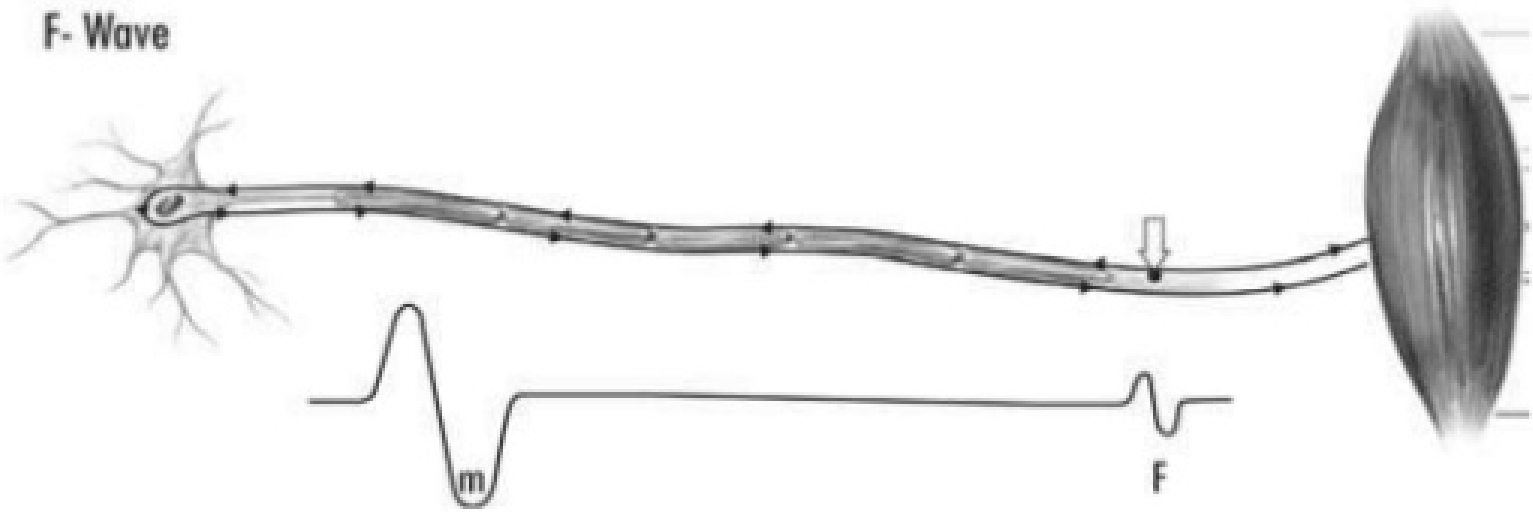
  - **If there is focal demyelination, the CMAP amplitude can be markedly reduced on proximal stimulation due to conduction failure across the demyelinating segment.**

  - **Significant slowing of conduction velocity suggests impaired saltatory conduction due to peripheral nerve demyelination. Such changes in NCS may be diffuse(in hereditary demyelinating peripheral neuropathy), focal(in pressure palsies) or multifocal ( in GBS,MNM)**

# Late response (F wave & H reflexes)

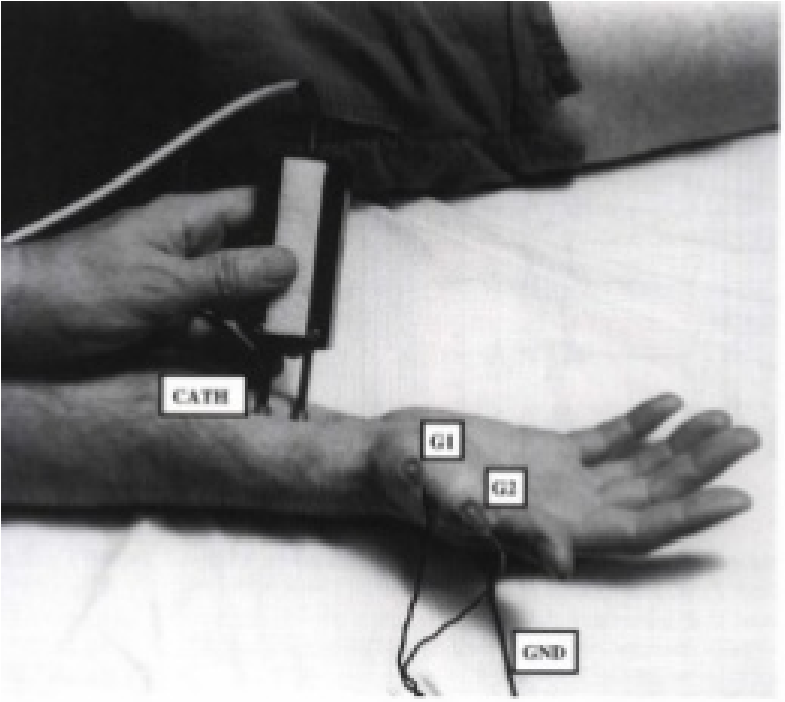
•Routine nerve conduction studies can evaluate only distal segments of the nerve.

• Late responses **F wave** and **H-reflexes** are used to evaluate the less –assessable proximal portions of the nerve.

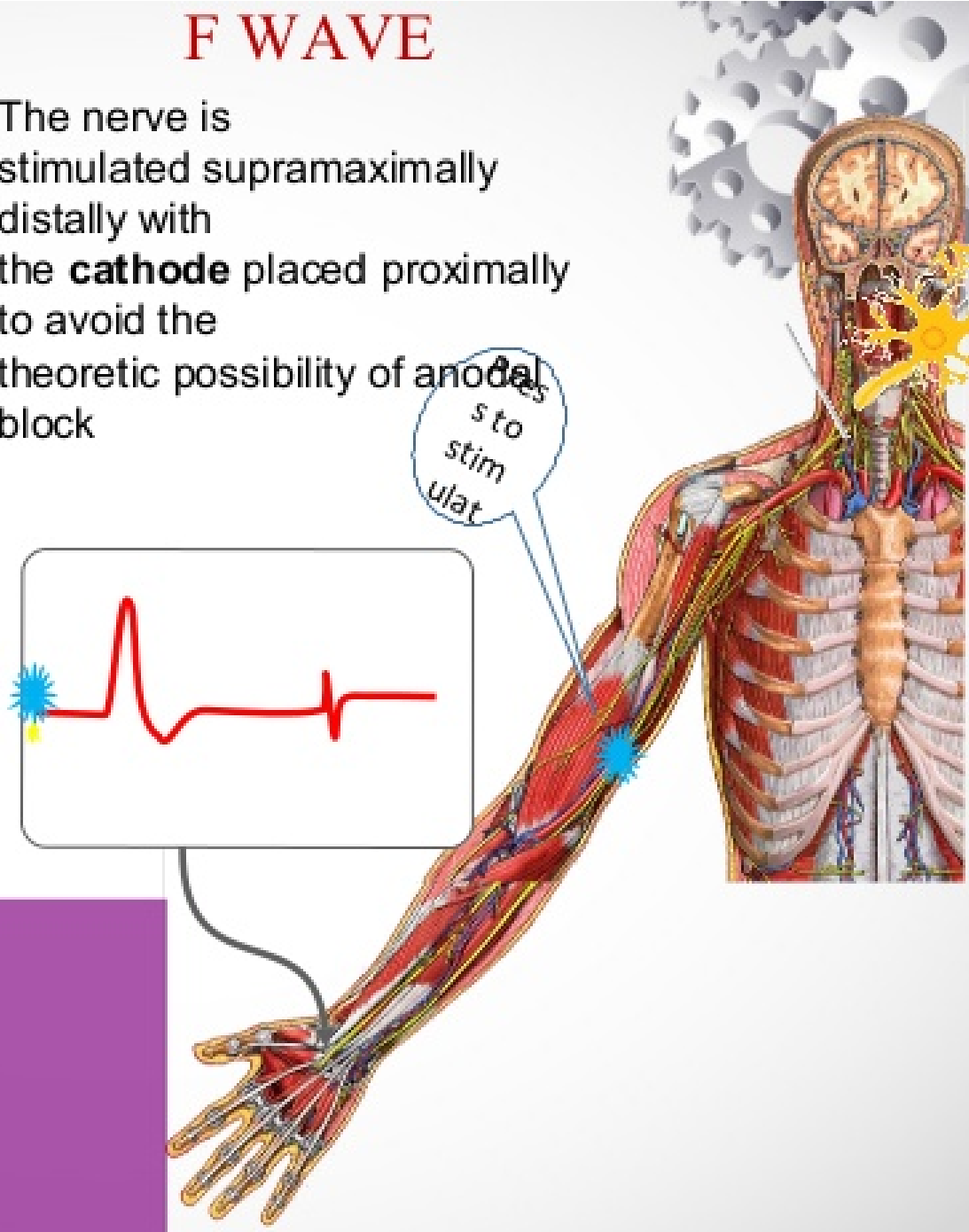



Stimulation is followed by depolarization which travels in both directions: first directly to the muscle fiber producing the M response, and retrograde up to the motor axon and to anterior horn, where it is re propogated back through the axons to produce the delayed F response.

# F WAVE




The nerve is stimulated supramaximally distally with the **cathode** placed proximally to avoid the theoretic possibility of anodal block

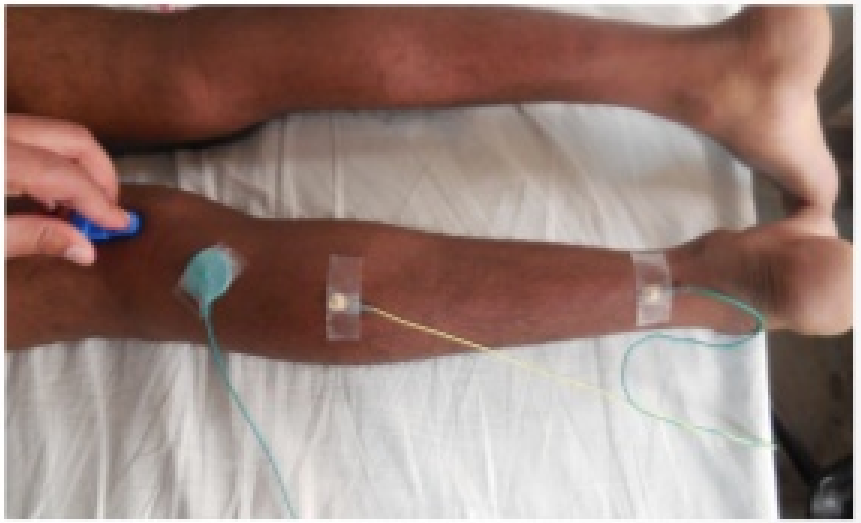



Uses:

- Early GBS
- C8-T1, LS-S1 radiculopathy
- Polyneuropathy
- Internal control (entrapment neuropathy)

# H - REFLEX

- The H reflex derives its name from Hoffmann, who first evoked the response in 1918.
- It is a true reflex with a sensory afferent, a synapse, and a motor efferent segment.
- stimulating the tibial nerve in the popliteal fossa, recording the gastroc-soleus muscle.



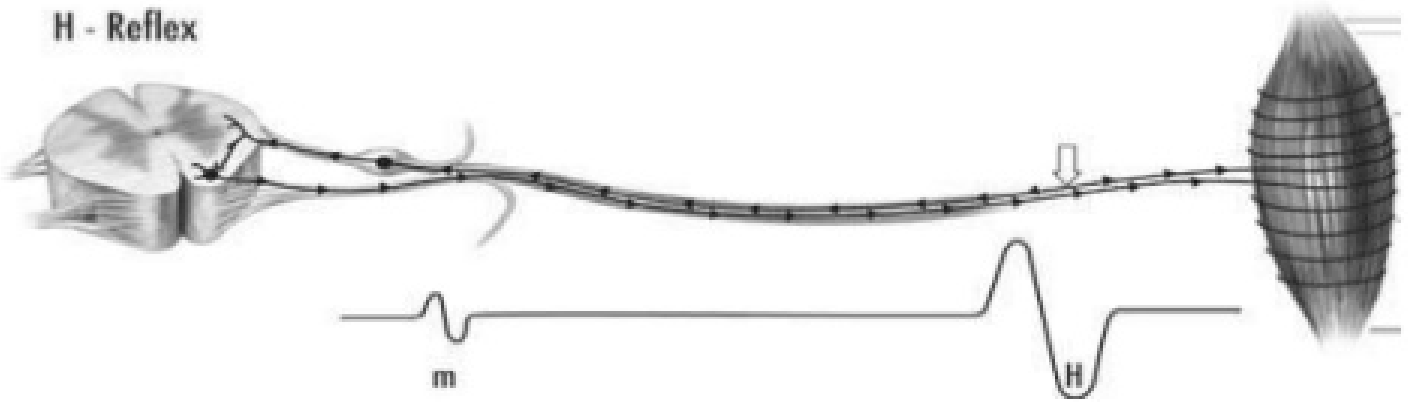
# H - REFLEX

- Start at very low stimulus intensities.
- latency: 25 to 34 ms
- Enhancement:
  - Jendrassik maneuver
  - Plantaflexion (ankle)
- Do not stimulate faster than 2 seconds (avoid effect of previous stimulation)

## Optimal location

This location over the soleus is approximately two to three fingerbreadths distal to where the soleus meets the two bellies of the

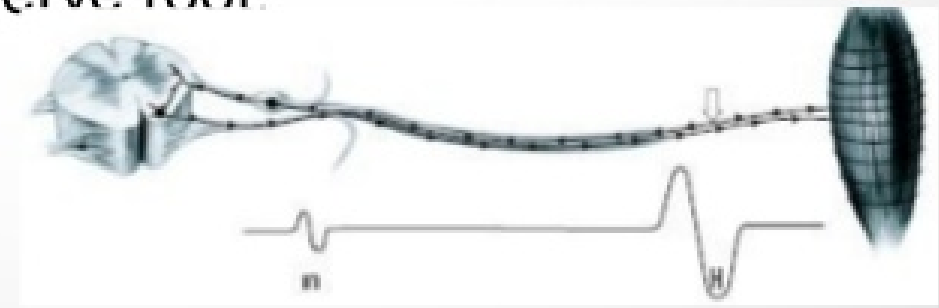
# H reflex




Submaximal stimulation of the afferent sensory fiber(1A) ->orthodromic conduction to the spinal cord->synaptic stimulation of the alpha motor neuron->evoked H response in the muscle.
A rudimentary M response is produced when a few motor axons are directly stimulated

# H - REFLEX

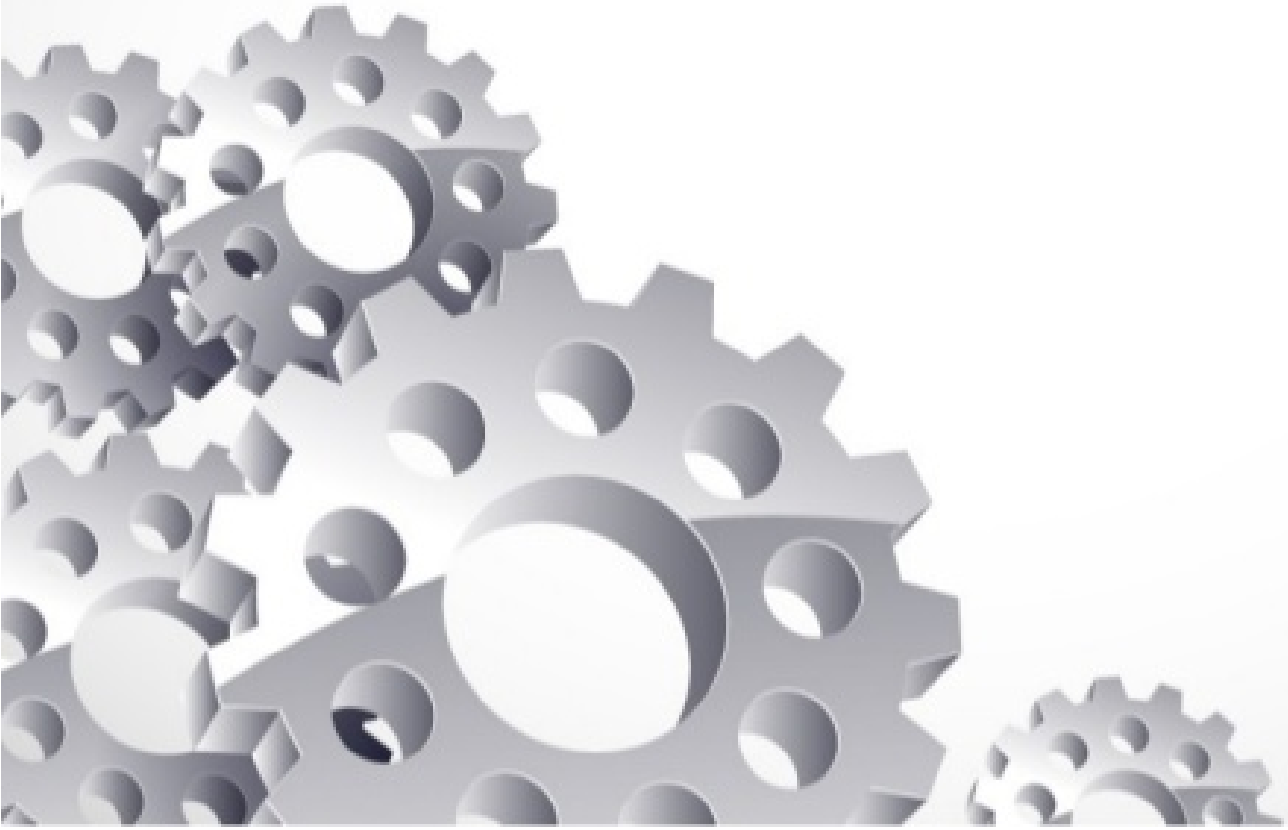
- H reflex with the shortest latency is measured and compared with a set of normal controls for height
- Unilateral lesion: Comparison with the contralateral side
  - significant if > 1.5 ms
- H reflex should always be present if ankle reflex present may still be present, If the ankle reflex is absent
- prolonged H reflex
  - in polyneuropathy,
  - proximal tibial and sciatic neuropathy,
  - lumbosacral plexopathy,
  - and lesions of the S1 nerve root



# Significance of H reflex

1. Early polyneuropathy
2. S1 radiculopathy
3. Early GBS
4. Tibial and sciatic neuropathy, sacral plexopathy
5. Electrical correlate of ankle reflex

# Repetitive nerves conduction study



# Repetitive nerves conduction study

- Easy to learn, easy to perform, and requires no special equipment.

- However, it is poorly tolerated in some patients and is prone to technical problems

- Repeated stimulation given
- Response measure at different time frame
  - Baseline, Exercise, 30 secs, 1 min, 2 min, 3 minit, 5 min

# Repetitive nerves conduction study

- Repeated electrical stimulus applied to the **motor neuron** at a rate of **3-5 / second** , the amplitude of the muscle recorded

- Decrement of more than 10% is abnormal
- Supramaximal stimulus
- Used to find NMJ abnormalities
  - Eg: myaesthenia gravis
    Lambert Eaton syndrome

# Repetitive nerves conduction study

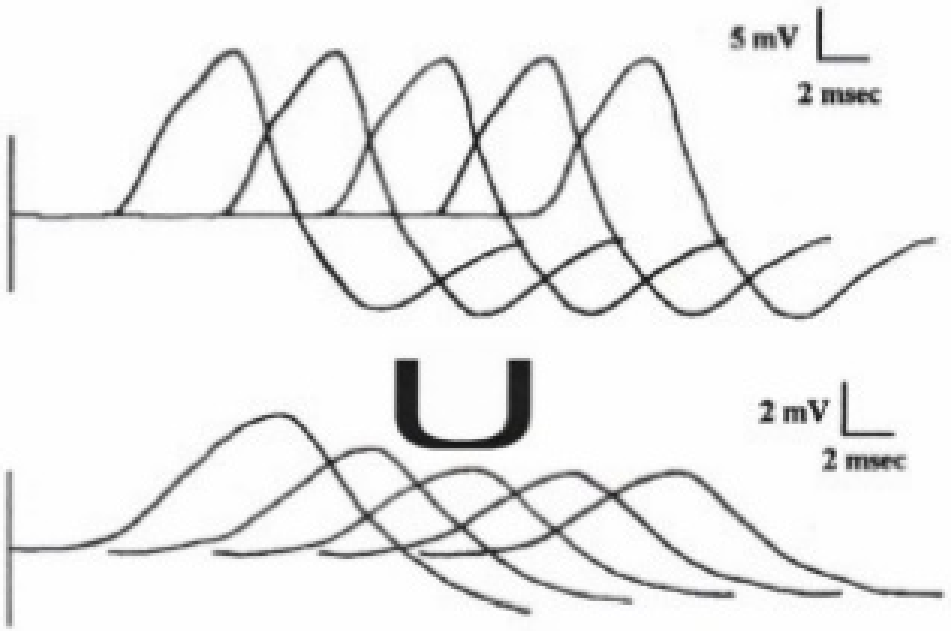
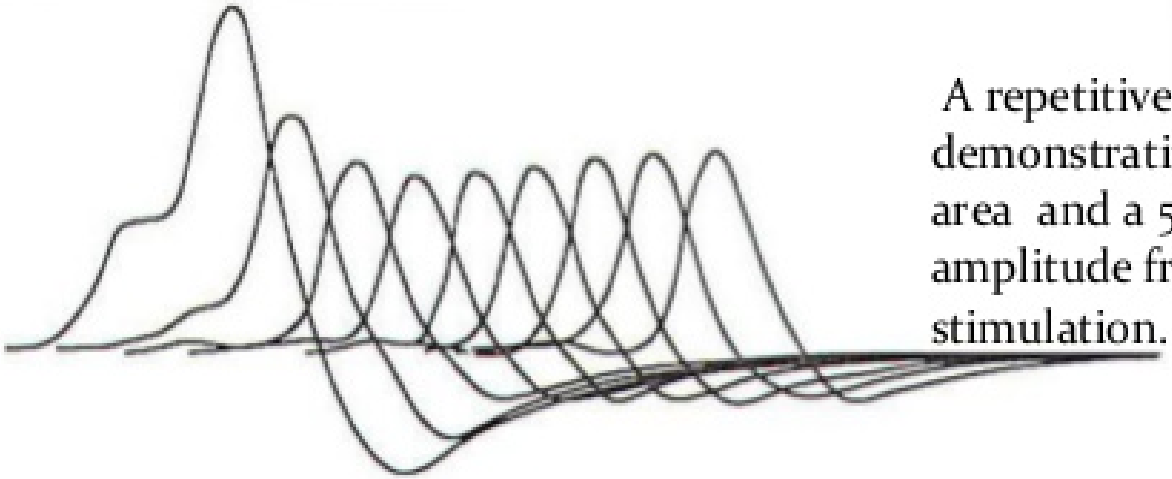
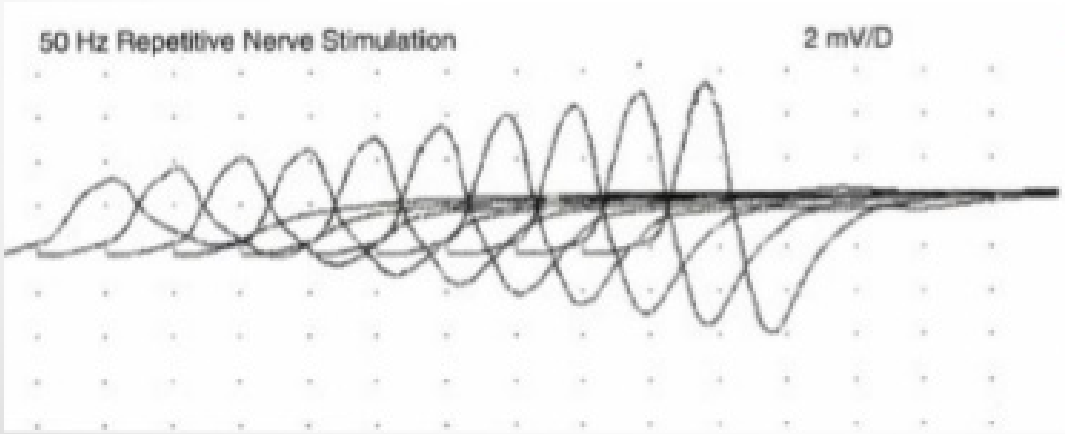



**FIGURE 6–9**
***Three-Hertz repetitive nerve stimulation of proximal and distal nerves in patient with myasthenia gravis. Top trace:*** *Normal decrement (4%) in the ulnar nerve.* ***Bottom trace:*** *Markedly abnormal decrement (42%) in the spinal accessory nerve. In myasthenia gravis, the yield of finding an abnormal decrement is greater with proximal nerves. Note the U-shaped decrement.*

# Repetitive nerves conduction study



A repetitive nerve stimulation study demonstrating a 61 percent **decrement** in area and a 54 percent decrement in amplitude from the first to the fourth stimulation.




**Increment during rapid repetitive nerve stimulation.** Recording the hypothenar muscles, stimulating the ulnar nerve at 50 Hz in a patient with Lambert-Eaton syndrome.

# Summary of

## Interpretation of nerve conductions

- The speed of nerve conduction is related to
  - the diameter of the nerve and,
  - the degree of myelination (a myelin sheath is a type of "insulation" around the nerve).
- A normally functioning nerve will transmit a stronger and faster signal than a damaged nerve.
- In general, the range of normal conduction velocity will be approximately 50 to 60 meters per second. However, the normal conduction velocity may vary from one individual to another and from one nerve to another.
- The Interpretation of nerve conductions is complex, but in general, different pathological processes result in:
  - changes in the latencies
  - changes in the amplitudes
  - slowing of the conduction velocity

# (continued..)

- Examples;
  - slowing of the NCS usually indicates there is damage to myelin.
  - slowing across the wrist for the motor and sensory latencies of the median nerve indicates focal compression of the median nerve at the wrist, called carpal tunnel syndrome.
  - slowing of all nerve conductions in more than one limb indicates generalized peripheral neuropathy (eg. in diabetes mellitus).

- Low amplitude CMAP and SNAP indicate axonal neuropathy

*Thank*

YOU