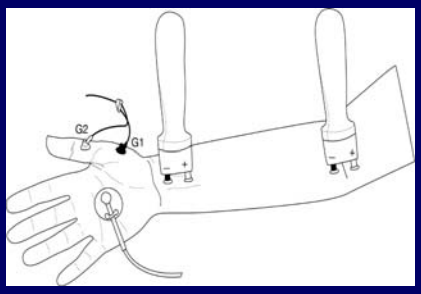
Spectrum of Electrodiagnostic studies

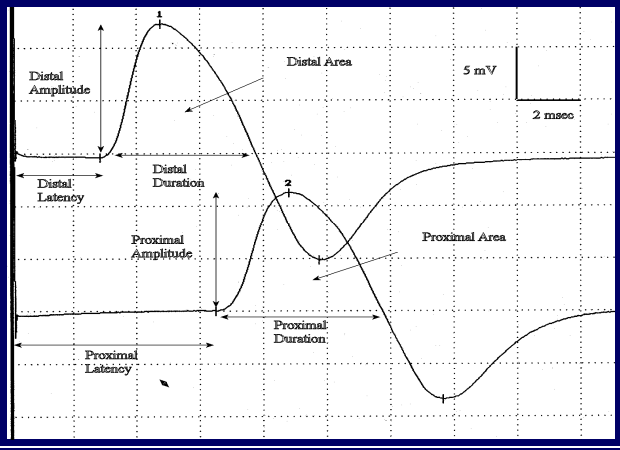
- Nerve conduction studies
  - Sensory, motor, mixed
- Needle EMG
  - Concentric
  - Monopolar
- Late responses
  - F waves
  - H reflexes
  - Blink reflexes
- Repetitive stimulation
  - Slow
  - Rapid
  - Postexercise
- Single fiber EMG
- Quantitative studies
  - MUP analysis
  - Turns and amplitudes
  - Macro EMG
  - Motor unit number estimate (MUNE)

Motor conduction studies

- Belly-tendon recording
  - An active lead (G1) placed on the belly of the muscle
  - An indifferent lead (G2) on the tendon
- Muscle recording has a magnifying effect.
  - Each motor axon innervates up to several hundreds muscle fibers

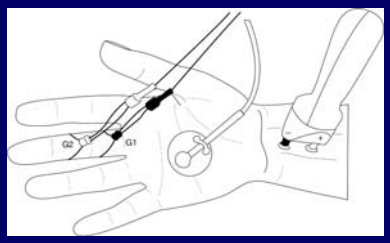


Motor conduction studies



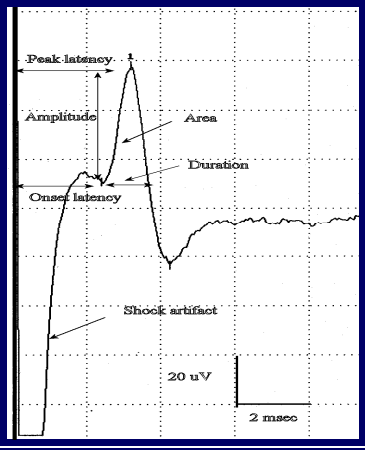
Sensory conduction studies

- Antidromic studies are performed by recording potentials directed toward the sensory receptors
- Orthodromic studies are obtained by recording potentials directed away from these receptors.
- Sensory latencies and conduction velocities are identical with either method, but amplitudes are higher in antidromic studies.



Sensory conduction studies

- *Onset latency* is often difficult to determine and subject to debate.
- *Peak latency* is very accurate and has replaced onset latency in most laboratories
- To measure conduction velocity, onset latency is required to reflect the largest conducting fibers



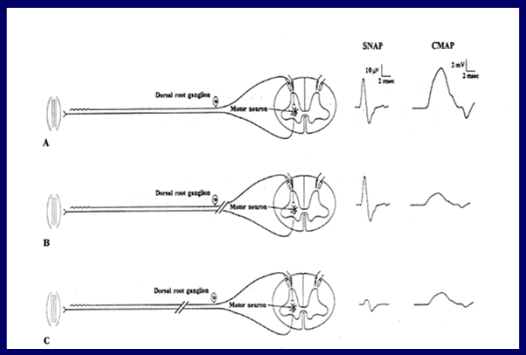
SNAP Differentiates Lesions Proximal vs. Distal to Dorsal Root Ganglion

SNAP is reduced or absent:

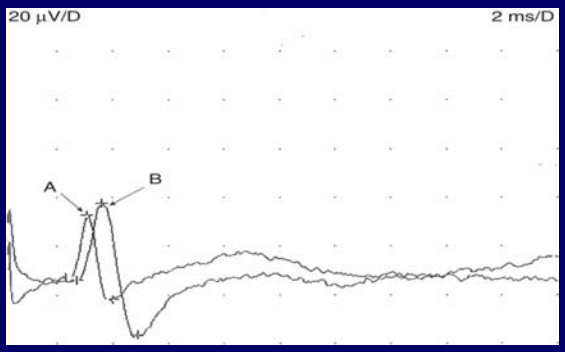
- Plexopathies
- Ganglionopathies

SNAP is normal:

- Radiculopathies
- Cauda/conus
- Spinal cord



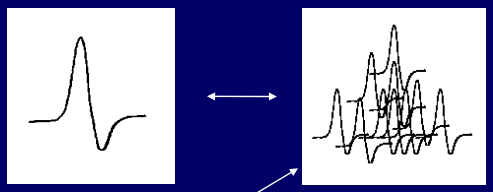
Temperature – median SNAP



A - 28^{0}C – Amp 14 usec, peak latency 2.6 msec
B - 33^{0}C – Amp 18 usec, peak latency 2.9 msec

CMAP and SNAP

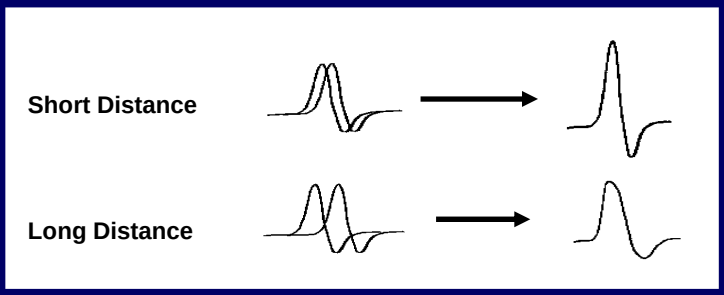
- The sensory nerve action potential (SNAP) and the compound muscle action potential (CMAP) are the summated response due to depolarization of thousands of axons



Large myelinated fibers

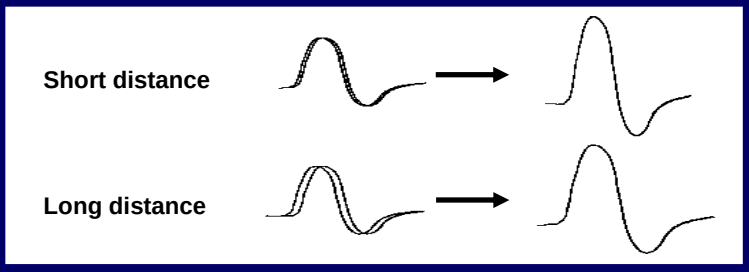
Small myelinated fibers

Temporal dispersion & phase cancellation – SNAP



- With short distance, action potentials summate well with little or temporal dispersion and phase cancellation
- With long distance, there is significant temporal dispersion and phase cancellation

Temporal dispersion & phase cancellation – CMAP

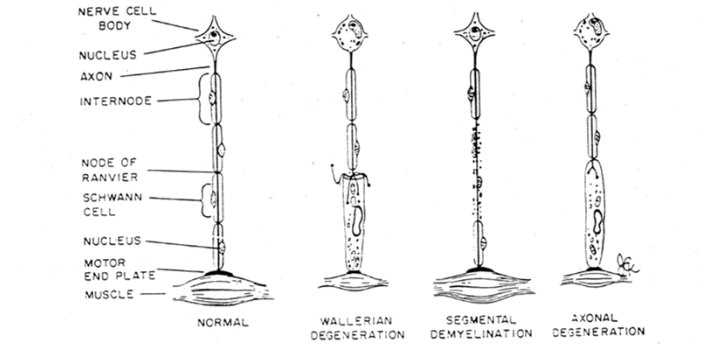


- Temporal dispersion & phase cancellation is much less prominent with CMAP than SNAP for 2 reasons:
  - The CMAP duration is much longer than the SNAP
  - The range of fiber conduction velocity is less spread (12 m/sec vs 25 m/sec).

Temporal dispersion & phase cancellation. Summary

- Occur in *normal* nerves
- The longer the distance, the lower the amplitude and the longer the duration of the response
- Is a bigger issue in sensory studies than motor

Pathological responses to nerve injury



Schematic representation of nerve axon and myelin sheath. From left to right, normal structures, wallerian degeneration following transection of the fiber, segmental demyelination, and axonal degeneration secondary to disorders of the nerve cell. (From Asbury and Johnson,[3] with permission.)

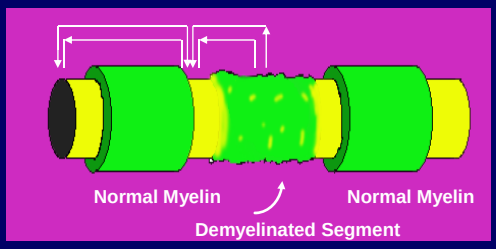
Classification of nerve injuries

Seddon	Neurapraxia	------ Axonotmesis --------			Neurotmesis
Sunderland	First degree	Second degree	Third degree	Fourth degree	Fifth degree
Physiology	Conduction block	---------- Axon loss ----------			
Pathology	Segmental demyelination	Axons only	Axons + endoneurium	Axons + endoneurium + perineurim	Transection

Electrophysiological findings in focal neuropathies

- Demyelination
  - Focal slowing
  - Conduction block
- Axon loss
  - Early (before wallerian degeneration)
  - Late (after wallerian degeneration)
- Mixed

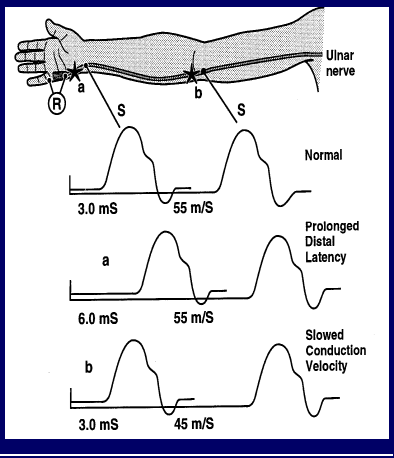
Demyelination of a single axon



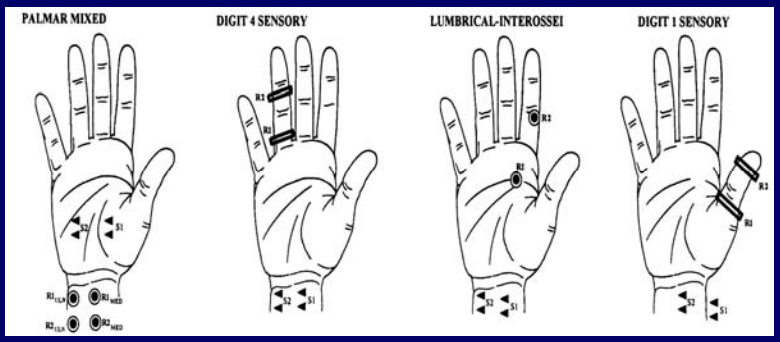
- Slowing of conduction due to slowing of nerve depolarization across the segment
- Conduction block occurs when action potentials cannot cross a severely demyelinated internode

Focal (synchronized) slowing

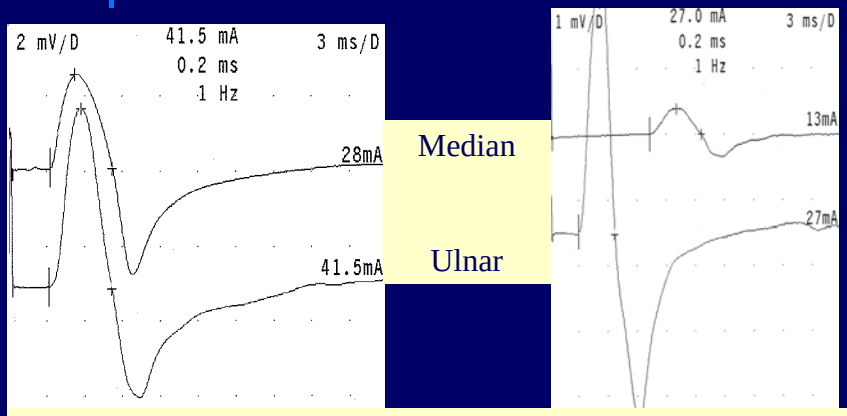
- Most commonly seen with chronic entrapments
  - Carpal tunnel syndrome
  - Ulnar neuropathy at elbow
- Is due to paranodal demyelination (widening of the nodes of Ranvier) that affect all the large myelinated fibers equally
- Does not cause symptoms unless associated with other pathologies



Internal comparison tests in CTS



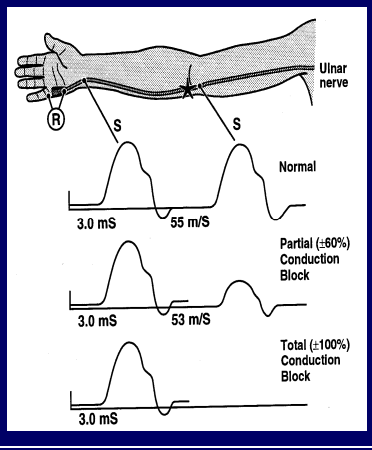
Focal slowing in CTS (Internal comparison studies)



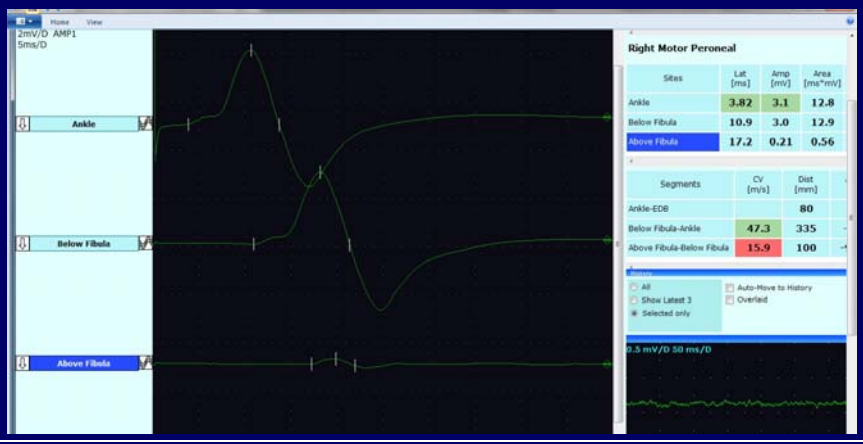
Median/ulnar comparison recording 2nd lumbrical/Interosseus

Conduction block

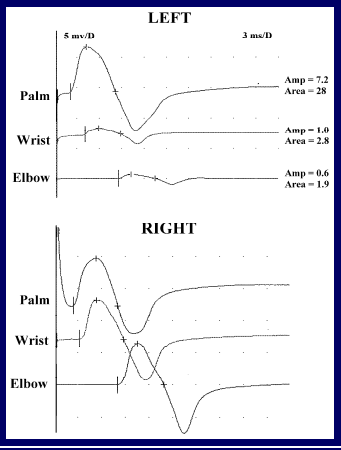
- Most common with acute nerve lesions
  - Peroneal at fibular neck
  - Radial at spiral groove
  - Ulnar at elbow
- Is due to segmental demyelination
- Is the electrophysiologic correlate of neurapraxia (first degree nerve inj.)



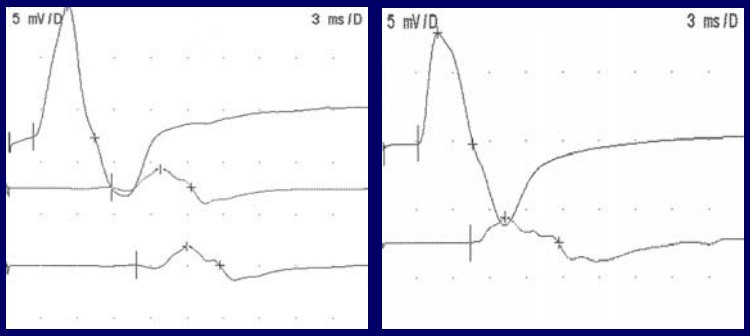
Peroneal nerve conduction block at the Fibular Neck (Slimmer palsy)



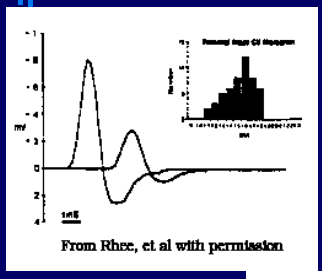
Acute compressive median nerve block at the wrist

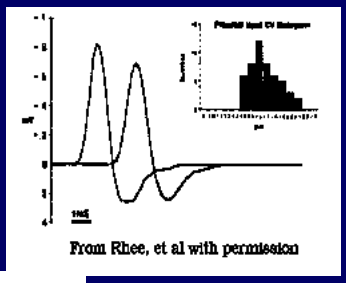


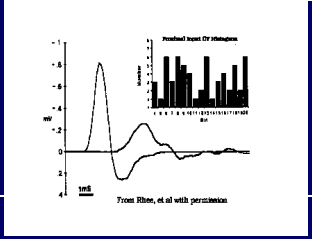
Ulnar and median conduction blocks in the forearm in multifocal motor neuropathy



Conduction block in subsets of neurons – Experimental data


From Rhee, et al with permission

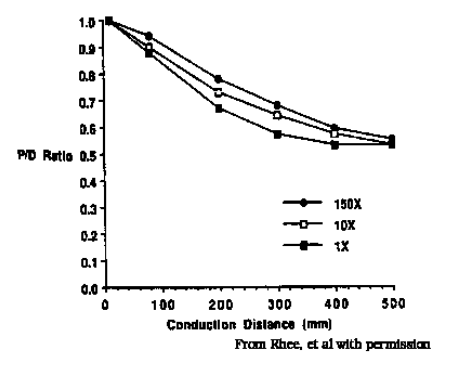

From Rhee, et al with permission



Rhee RK, England JD, Sumner AJ. *Ann Neurol* 1990;28:146-159.

Area drop in conduction block

- Area drop greater than 50% between stimulation sites, regardless of length of distance
- Over shorter distances (e.g. 10 cm) 20% is acceptable



Rhee RK, England JD, Sumner AJ. *Ann Neurol* 1990;28:146-159.

Conduction block

DEFINITE

- > 50% drop in CMAP amplitude with <15% prolongation of CMAP duration, or
- > 50% drop in CMAP area, or
- > 20% drop in area or amplitude over a short nerve segment (10 cm or less)

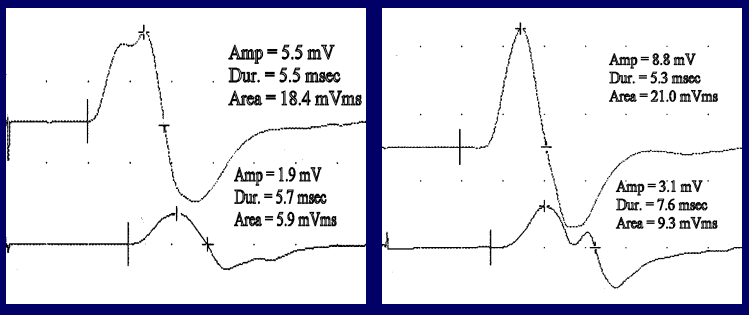
PROBABLE

- 20-50% drop in CMAP amplitude with < 15% prolongation of CMAP duration, or
- 20-50% drop in CMAP area

Conduction block

>50% loss of distal amplitude Abnormal amplitude reduction		
>15% of distal duration CMAP duration increased		
No	Yes	Yes
Area loss >50%	Area loss <50%	Area loss >50%
Pure conduction block (CB)	Temporal dispersion (TD)	CB/TD

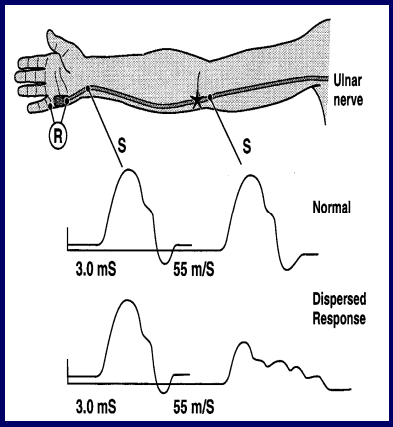
Conduction block Vs temporal dispersion



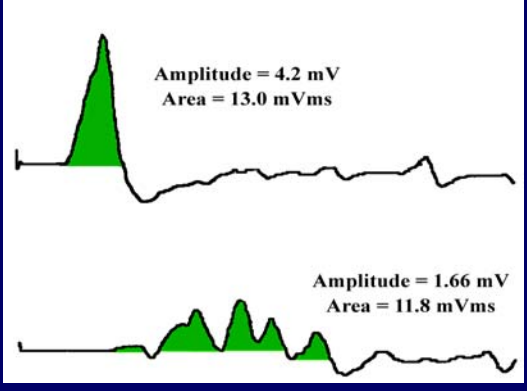
Ulnar neuropathies at the elbow

Differential (desynchronized) slowing

- Is due to conduction slowing along a variable number of the medium or small nerve fibers (average or slower conducting axons)
- Often it is associated with focal slowing

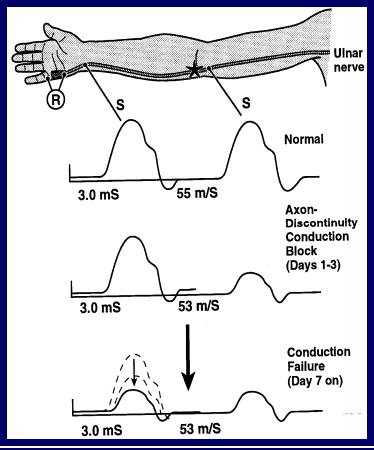


Differential slowing not conduction block

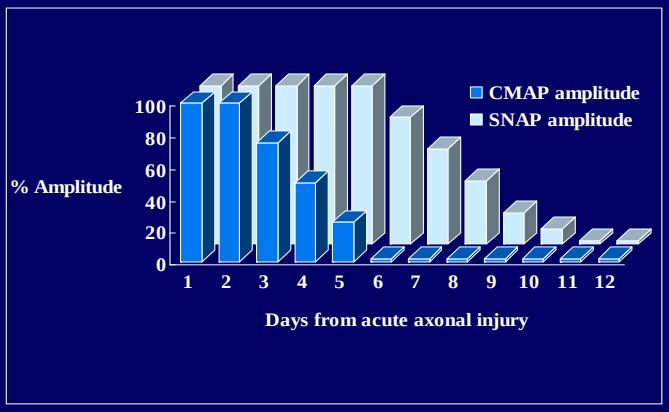


Axon loss

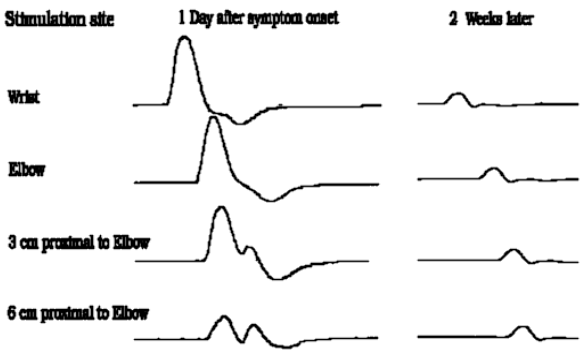
- The most common mononeuropathies seen in clinical practice
- Result in low CMAP from all stimulation sites
- May manifest with conduction block early (before wallerian degeneration)



Distal SNAP and CMAP amplitudes during wallerian degeneration

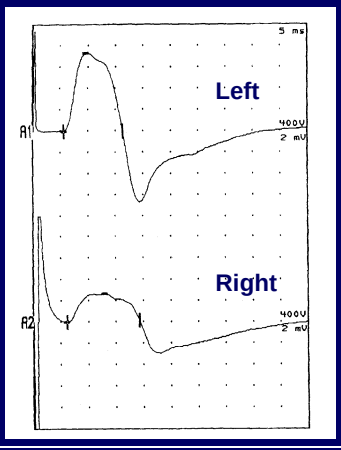


Early study in axon loss mononeuropathy is very useful in localization, while a second study is necessary to determine pathophysiology



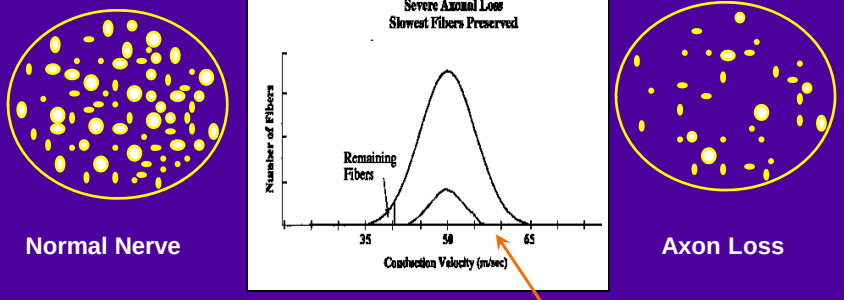
Ulnar nerve lesion in distal arm

CMAP amplitude and area are the best indicator of extent of motor axon loss



- 65 year old with right femoral neuropathy following an abdominal hysterectomy
- Femoral CMAPs recording rectus femoris is consistent with a partial axon loss lesion (50% of axons are lost)

Axon loss and conduction slowing

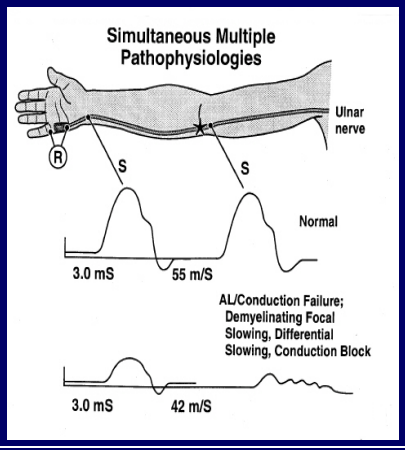


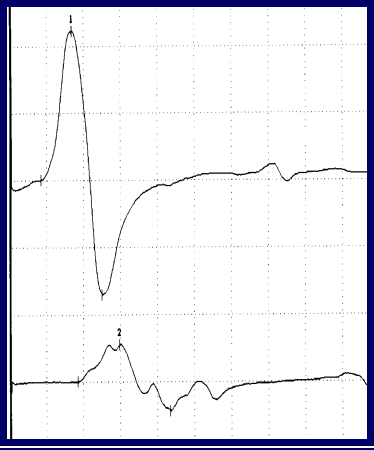
Normal Nerve

Axon Loss

Largest fibers

Multiple pathologies





A 45 year man with progressive ulnar neuropathy

Pitfalls and errors

- **Temperature**
  - Nerve impulses propagate slower by 2.4 m/sec or approximately 5% per degree centigrade from 38 to 29 C of body temperature.
  - CMAP and SNAP have higher amplitudes and longer duration with cooling
  - CMAP or SNAP with high amplitude and slow distal latency or conduction velocity should be highly suspicious of a cool limb.

Pitfalls and errors

- **Age**
  - Myelination is incomplete at birth. Nerve conduction velocities are roughly
    - one-half the adult value in full-term newborns
    - one-third that of term newborns in 23- to 24- week premature newborns.
  - They reach adult values at 3–5 years
  - Conduction velocities slow about 10% after 60 years
  - With aging, CMAP and SNAP amplitudes decline
    - upper limb SNAP amplitude drops up to 50% by age 70.
    - Lower limb SNAPs above the age of 60 years are low in amplitude or often unevokable.

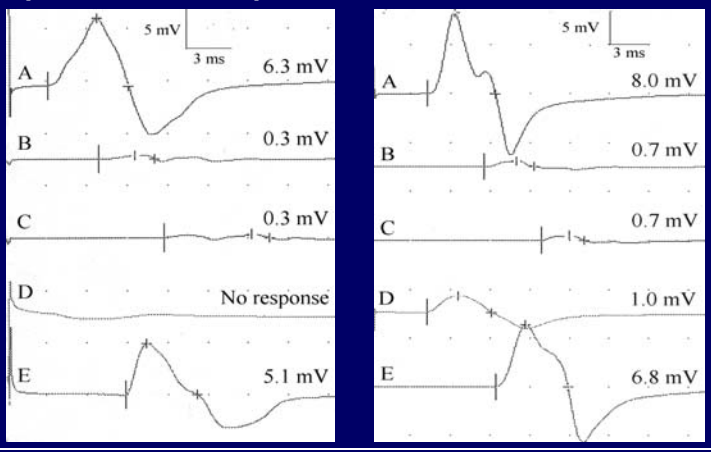
Pitfalls and errors

- Height and nerve segment
  - An inverse relationship between height and nerve conduction velocity
  - Longer nerves generally conduct slower than shorter nerves.
  - Hence, peroneal and tibial nerves are 7–10 m/sec slower than the median and ulnar nerves.
- Anomalies
  - Martin-Gruber anastomosis
  - Accessory deep peroneal nerve

Martin-Gruber anastomosis

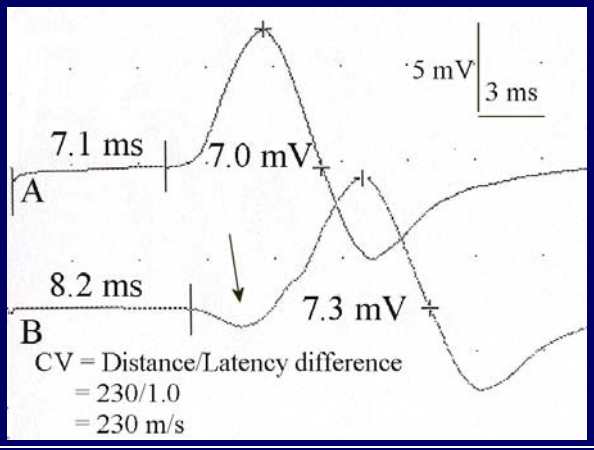
- Occurs in approximately 15-20% of population
- Fibers cross from the median to the ulnar nerve in the forearm.
- The communicating branch(es) usually consists of motor axons that supply the ulnar-innervated intrinsic hand muscles,
  - the first dorsal interosseous muscle
  - the hypothenar muscles
  - the ulnar thenar muscles
  - A combination of these muscles

Martin-Gruber anastomosis to ADM and FDI (Ulnar NCS)



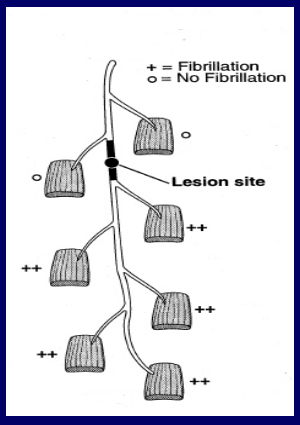
Recording ADM **Recording FDI**

Martin-Gruber anastomosis to ulnar thenar with CTS (median NCS)



Localization by needle EMG in axon loss lesions

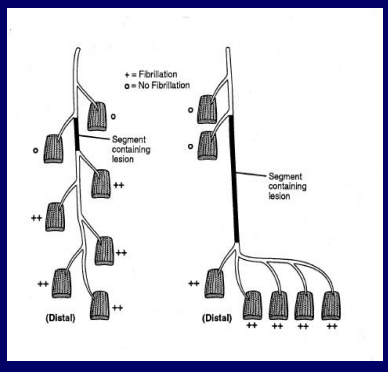
- The concept of localization by needle EMG is similar to clinical localization using manual muscle strength testing that is part of the neurological examination.
- Most often, muscles innervated by branches arising from the nerve distal to the lesion are weak, while those innervated by branches proximal to the lesion are normal.



Pitfalls of Localization by needle EMG

1. ***Nerve lesions along segments with no motor branches.***

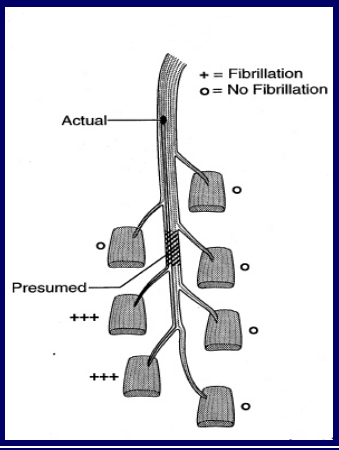
- The anatomy of the injured nerve plays an important role in the precise localization of nerve lesions.
- Many nerves travel substantial distances without giving out any motor branches.



Pitfalls of Localization by needle EMG

2. Fascicular nerve lesions.

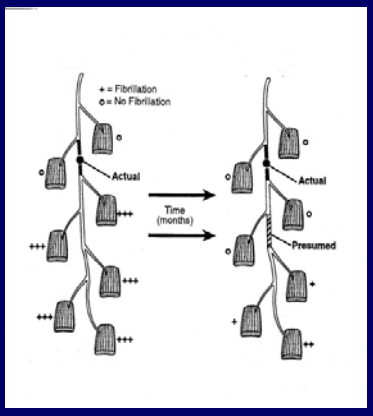
- Occasionally, peripheral nerve lesions spare one or two nerve fascicles resulting in muscles that escape denervation despite being located distal to the lesion site.
- This usually results in an erroneous localization that is more distal to the actual site of the lesion.



Pitfalls of Localization by needle EMG

3. Chronic nerve lesions.

- With mild or modest partial axon loss lesions, regeneration and reinnervation can be efficient in proximally located muscles resulting in remodeling of the motor units.
- Hence, a needle EMG done several years after such lesions may only detect the neurogenic changes in the more distal muscles



Axon loss mononeuropathy

- Localize lesion by needle EMG
- Location is always **AT OR ABOVE** the most proximally denervated muscle