

# PRINCIPLES of ELECTROPHYSIOLOGY

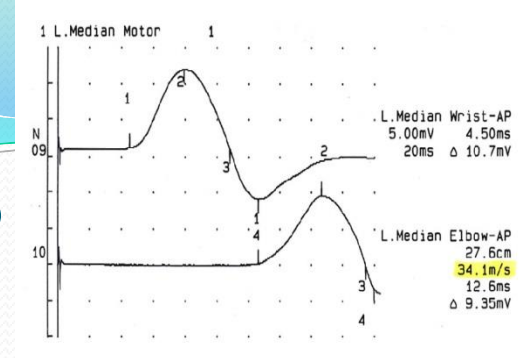
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# Nerve Conduction Studies

- Test to evaluate the function of motor / sensory nerves
- Evaluate
  - Paraesthesia (numbness, tingling, burning)
  - Weakness of arms and legs
- Common conditions
  - Peripheral neuropathy
  - Carpal tunnel and ulnar neuropathy
  - GBS
  - Radiculopathies

# Nerve Conduction Studies

- **Motor**
- Electrical stimulation of peripheral nerve and recording from muscle supplied by the nerve
  - Distal motor latency (ms)
  - Compound muscle action potential amplitude (mV)
  - Motor conduction velocity (m/s)
    - Latency from 2 sites gives motor conduction velocity
- **Sensory**
- Electrical stimulation of peripheral nerve and recording from a purely sensory portion of the nerve
  - Sensory nerve action potential amplitude (uV)
  - Sensory conduction velocity (m/s)



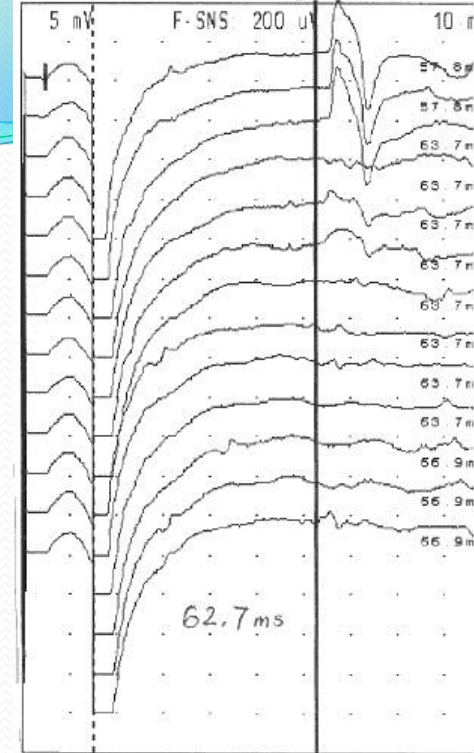
# F and H waves

- **F waves**

- Assess function of proximal portion of peripheral nervous system
  - Roots and plexus
- Supramaximal stimulation of motor nerve
- Recordable from most skeletal muscles
  - Due to discharge of a few anterior horn cells by anti-dromic (proximally) impulses reaching the cell bodies along their axons

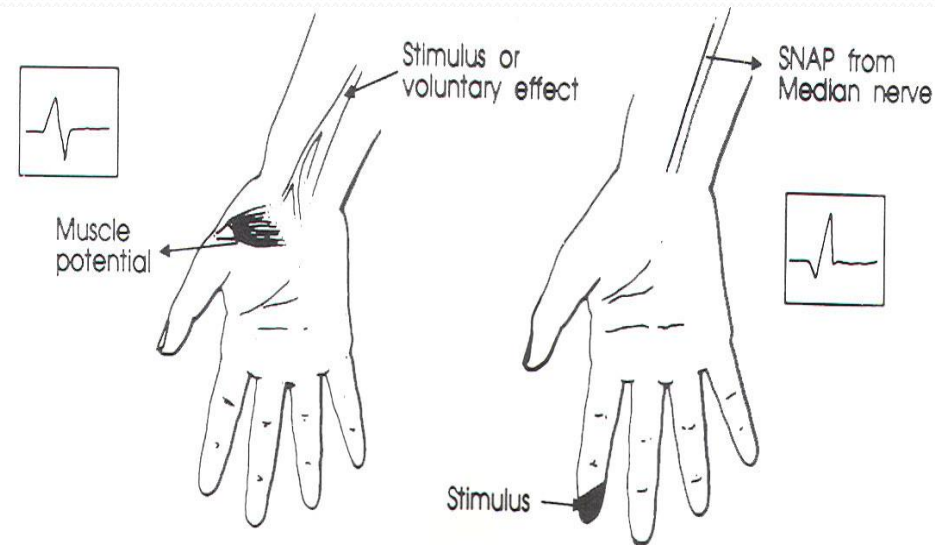
- **H waves**

- Electric counterpart of ankle reflex
  - Monosynaptic reflex recorded from soleus in response to low intensity stimulus of tibial nerve
- May be lost in PN even when conventional NCS are normal
- Also lost in S1 radiculopathies



# Studies Performed

- Sensory
  - Median (Palm and Digit II)
  - Ulnar (Digit V)
  - Sural
- Motor
  - Median- APB
  - Ulnar – ADM
  - Peroneal – EDB
  - Tibial-AHB
- F waves
  - Median / Ulnar
  - Tibial / Peroneal



(A) **Electromyography (EMG)**

(B) **Sensory Nerve Action Potential (SNAP)**

# Normal results

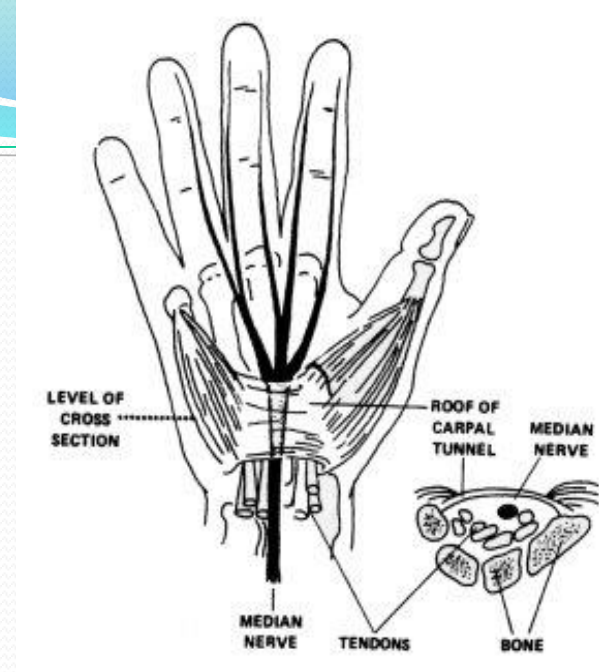
- **Upper limb**
  - Median DML <4.0ms
  - Ulnar DML <3.0ms
  - CMAP >5mV
  - SNAP >10uV
- Conduction velocities >50m/s
- F waves
  - Upper limb <30ms
  - Persistence >75%

# Normal results

- **Lower limb**
  - Peroneal DML <5.0ms
  - Tibial DML <6.0ms
  - Peroneal CMAP >2mV
  - Tibial CMAP >5mV
  - Sural SNAP >5uV
  - Conduction velocities >40m/s
  - F waves
    - Lower limb <50ms
    - Persistence >75%

# Mononeuropathies

- Sensory loss and weakness in the territory of an individual nerve
  - Entrapment neuropathy
    - Median nerve at the wrist
    - Ulnar nerve at the elbow
    - Common peroneal nerve at the fibular head
  - Diabetes
  - Trauma
  - Vasculitis
  - Leprosy and Sarcoid
- Hereditary sensitivity to pressure palsies
- Multifocal motor neuropathies





# Numbness of right hand

## Motor Nerve Conduction:

Nerve and Site	Lat. ms	Amp. mV	Segment	L.D.	Dist. mm	CV. m/s
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### **Median nerve.R**

Wrist	6.1	1.9	APB-Wrist			
Elbow	10.6	1.4	Wrist-Elbow	4.5	220	50

### **Median nerve.L**

Wrist	3.7	8.7	APB-Wrist			
Elbow	8.2	8.8	Wrist-Elbow	4.5	220	50

### **Ulnar nerve.R**

Wrist	2.5	9.8	ADM-Wrist			
Above Elbow	7.2	9.6	Wrist-Above Elbow	4.7	320	68

## Sensory Nerve Conduction:

Nerve and Site	Lat. ms	Amp. $\mu$ V	Segment	Dist mm	C.V. m/s
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### **Median nerve.R**

Palm	3.5	8	Palm-Wrist	75	22
Digit II	5.6	3	Digit II-Wrist	140	25

### **Median nerve.L**

Palm	1.5	40	Palm-Wrist	75	50
Digit II	2.8	10	Digit II-Wrist	140	50

### **Ulnar nerve**

Digit V.R	2.3	10	Digit V-Wrist	125	55
Digit V.L	2.3	10	Digit V-Wrist	125	55

# Paraesthesia of lateral fingers and palm

## Motor Nerve Conduction:

Nerve and Site	Lat. ms	Amp. mV	Segment	L.D.	Dist. mm	CV. m/s
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### **Median nerve**

Wrist.L	3.0	15.0	APB-Wrist			
Wrist.R	3.5	10.6	APB-Wrist			

### **Ulnar nerve.L**

Wrist	3.3	14.5	ADM-Wrist			
Below elbow	6.4	14.6	Wrist-Below elbow	3.1	210	67
Above elbow	9.0	14.6	Below-Above elbow	2.6	100	38

### **Ulnar Inching.L**

4cm below	6.8	12.1	2cm-4cm below	0.6		
2cm below	7.4	12.7	2cm below-Med epi.	0.3		
Medial epi.	7.7	12.1				
2cm above	9.4	11.2	2cm above-Med epi.	1.7	n<0.6ms	
4cm above	9.8	11.4	2cm-4cm above	0.4		

## Sensory Nerve Conduction:

Nerve and Site	Lat. ms	Amp. $\mu$ V	Segment	Dist mm	C.V. m/s
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### **Median nerve**

Digit II.L	2.8	12	Digit II-Wrist	145	52
Digit II.R	2.9	13	Digit II-Wrist	145	50

### **Ulnar nerve**

Digit V.L	2.4	12	Digit V-Wrist	120	52
Digit V.R	2.2	10	Digit V-Wrist	110	50

# Symmetrical polyneuropathies

- Glove and stocking sensory loss with distal weakness
- Loss of ankle jerks
  - Other reflexes lost with severe axonal loss (earlier in demyelination)
- Causes
  - Metabolic - Diabetes, uraemia
  - Toxic – Alcohol, drugs, metals, solvents, radiation
  - Nutritional - B12, thiamine (B6)
  - Connective tissue disorders, vasculitis, amyloid
  - Hereditary - HSMAN, HSAN
  - Infection - HIV, Lyme disease

# Axonal Neuropathy

- If mild, NCS normal, esp if only involving small fibres
- Absent or low amplitude SNAP's
- Low amplitude CMAP's
- Slight slowing of motor and sensory CV's
  - Slow but  $>45\text{ms}$  in UL
  - Slow but  $>35\text{ms}$  in LL
  - Fast conducting fibres survive even when 75% of axons have died

# Demyelination Neuropathy

- Prolongation of DML's
- Conduction block
  - Slowed motor CV across block
  - Normal CMAP's distal to block
  - Reduced CMAP's proximal to block
  - Temporal dispersion
- Absent or prolonged F waves
- Normal SNAP's

# Numbness of both feet

## Motor Nerve Conduction:

Nerve and Site	Lat. ms	Amp. mV	Segment	L.D.	Dist. mm	CV. m/s
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### **Peroneal nerve.L**

Ankle	4.9	1.0	EDB-Ankle			
Fibular head	14.9	1.0	Ankle-Fibular head	10.0	350	35

### **Peroneal nerve.R**

Ankle	5.3	1.0	EDB-Ankle			
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### **Tibial nerve.L**

Ankle	6.3	2.0	Abd hallucis-Ankle			
Pop. fossa	18.4	2.0	Ankle-Pop. fossa	12.1	400	36

### **Tibial nerve.R**

Ankle	5.7	2.0	Abd hallucis-Ankle			
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## Sensory Nerve Conduction:

Nerve and Site	Lat. ms	Amp. $\mu$ V	Segment	Dist mm	C.V. m/s
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### **Sural nerve**

Mid calf.L	<b>Absent</b>		Mid calf-Ankle		
Mid calf.R	<b>Absent</b>		Mid calf-Ankle		

# Acute onset neuropathies

- GBS
- Diabetes esp. proximal
- Alcoholic
- Nutritional – B<sub>12</sub>
- Toxic - vincristine, organophosphate, arsenic, Pb
- Critical care polyneuropathy
- Vasculitis
- Porphyria, diphtheria

# Acute LL weakness and absent reflexes

## Motor Nerve Conduction:

Nerve and Site	Lat. ms	Amp. mV	Segment	L.D.	Dist. mm	CV. m/s
<b>Peroneal nerve</b>						
Ankle.R	9.3	1.5	EDB-Ankle			
Fibular head.R	17.5	1.0	Ankle-Fibular head	8.2	270	32
Ankle.L	13.3	0.3	EDB-Ankle			

## **Tibial nerve**

Ankle.R	6.3	1.4	Abd hallucis-Ankle			
Pop. fossa.R	22.4	1.0	Ankle-Pop. fossa	16.1	380	23
Ankle.L	8.9	2.1	Abd hallucis-Ankle			

## **Median nerve**

Wrist.R	13.5	0.3	APB-Wrist			
Elbow.R	22.5	0.2	Wrist-Elbow	9.0	200	20
Wrist.L	7.7	1.3	APB-Wrist			

## **Ulnar nerve.R**

Wrist	4.8	0.9	ADM-Wrist			
Above Elbow	12.8	0.9	Wrist-Above Elbow	8.0	300	37

## Sensory Nerve Conduction:

Nerve and Site	Lat. ms	Amp. $\mu$ V	Segment	Dist mm	C.V. m/s
<b>Sural nerve</b>					
Mid calf.R	2.6	10	Mid calf-Ankle	120	46
<b>Median nerve.R</b>					
Digit II	2.6	15	Digit II-Wrist	140	54

## F-Wave Studies:

Nerve	R. F-Latency	L. F-Latency	Persistence
<b>Median nerve</b>	<b>Absent</b>	<b>Absent</b>	
<b>Ulnar nerve</b>	<b>Absent</b>	<b>Absent</b>	
<b>Tibial nerve</b>	<b>Absent</b>	<b>Absent</b>	



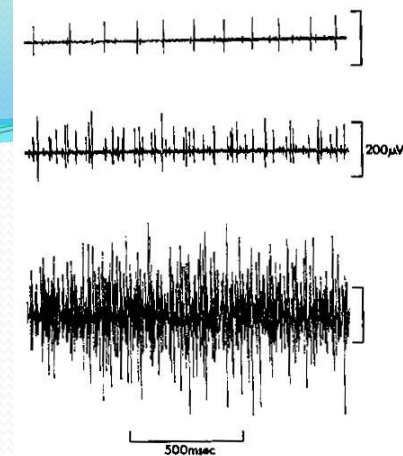
# EMG



- Extracellular electrical activity recorded from muscle
  - Spontaneous electrical activity and individual motor units cannot be seen with surface electrodes
- Needle electrodes placed within muscle
  - Concentric
  - Potentials valuated visually and aurally
- Used to:
  - Support diagnosis (neuropathy vs myopathy)
  - Confirm muscle weakness

# Needle EMG

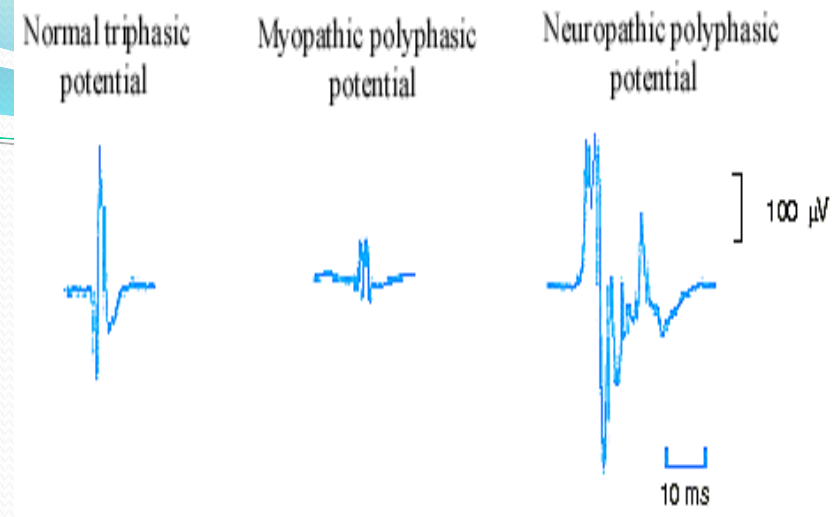
- Normal
  - Brief bursts of activity <2 secs with no spontaneous activity
  - Voluntary contraction activates motor units



- Insertional activity
  - Increased in denervated muscles
  - Fibrillation potentials – biphasic discharges
  - Positive sharp waves
  - Spontaneous activity of single denervated muscle fibre
- Fasciculations
  - Involuntary contractions of whole group of fibres



# EMG changes



- **Neurogenic**

- Increased insertional activity
- Fibrillation potentials
- Large amplitude, long duration motor units
- High firing (reduced recruitment)

- **Myopathic**

- Increased insertional activity
- Fibrillation potentials
- Small amplitude, short duration motor units
- Polyphasic motor units
- Complete recruitment pattern

# Upper Limb Muscles

- **Upper Limb**
  - C5 – deltoid
  - C6 – Biceps
  - C7 – Triceps and EDC
  - C8 – APB
  - T1 – ADM

# Lower Limb Muscles

- **Lower limb**
  - L2 – Iliopsoas
  - L3 – Rectus Femoris
  - L4 – Tibialis Anterior
  - L5 – Peroneus Longus
  - S1 – Gastrocnemius

# Left foot drop

## Motor Nerve Conduction:

Nerve and Site	Lat. ms	Amp. mV	Segment	L.D.	Dist. mm	CV. m/s
<b>Peroneal nerve.L</b>						
Ankle	5.7	1.6	EDB-Ankle			
Fibular head	15.2	1.8	Ankle-Fibular head	6.5	330	50
Below Knee	4.0	1.0	TA-Below Knee			
Above Knee	5.9	1.0	Below-Above Knee	1.9	60	31

## **Peroneal nerve.R**

Ankle	5.2	5.3	EDB-Ankle			
Fibular head	12.3	5.2	Ankle-Fibular head	7.1	330	47
Below Knee	3.1	6.2	TA-Below Knee			
Above Knee	4.6	6.1	Below-Above Knee	1.5	60	40

## **Tibial nerve.L**

Ankle	6.1	10.1	Abd hallucis-Ankle			
Pop. fossa	15.0	10.5	Ankle-Pop. fossa	9.0	380	42

## Sensory Nerve Conduction:

Nerve and Site	Lat. ms	Amp. $\mu$ V	Segment	Dist mm	C.V. m/s
<b>Sural nerve</b>					
Mid calf.L	3.4	11	Mid calf-Ankle	150	44
Mid calf.R	2.6	16	Mid calf-Ankle	150	57

## F-Wave Studies:

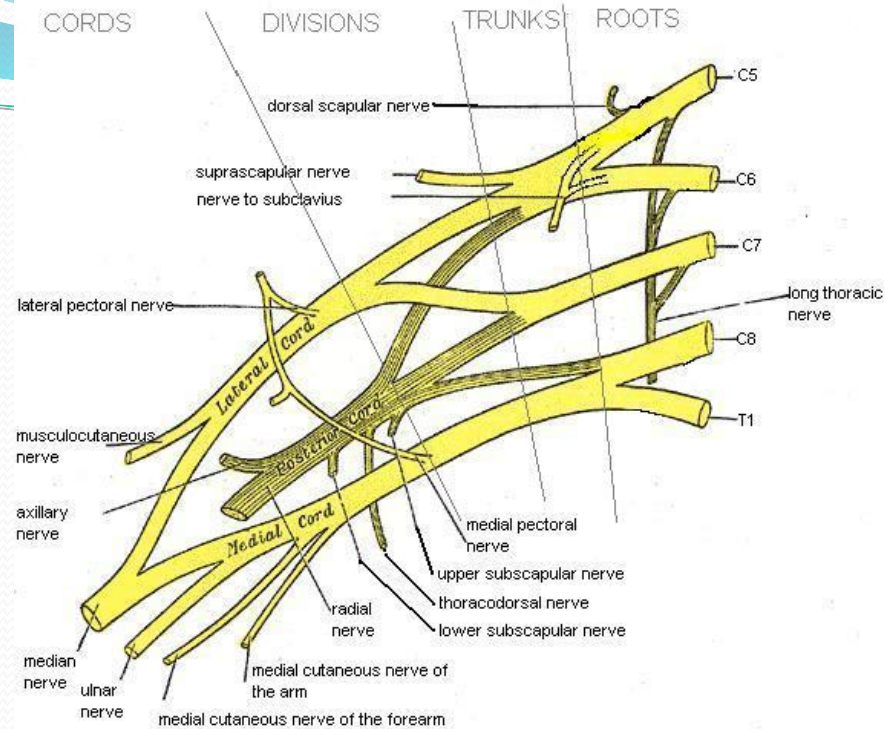
Nerve	L. F-latency	R. F-Latency	Persistence
<b>Tibial nerve</b>	48.8	48.3	100%

## Needle EMG Data:

		Insertional	Spontaneous Activity			Volitional Activity		Recruitment
		Insertional	Fibs	+ Wave	Fasics	Poly	MUP Amp	
Tibialis Anterior	L	Increased	3+	3+	None	None	Increased	Reduced
Peroneus Longus	L	Increased	3+	3+	None	None	Increased	Reduced
Gastroc Medial Head	L	Normal	None	None	None	None	Normal	Normal
Short Head of Biceps	L	Normal	None	None	None	None	Normal	Normal

# Brachial Plexus

- **Upper trunk – C5,C6**
  - Supraspinatus (trunk)
  - Deltoid (posterior cord)
  - Biceps (lateral cord)
- **Middle trunk – C7**
  - FCR (medial cord)
  - Triceps and EDC (posterior cord)
- **Lower trunk – C8,T1**
  - FCU, APB, ADM, 1<sup>st</sup> DI (medial cord)
  - ECU (posterior cord)



# Left upper limb radicular pain

## Motor Nerve Conduction:

Nerve and Site	Lat. ms	Amp. mV	Segment	L.D.	Dist. mm	CV. m/s
<b>Median nerve.L</b>						
Wrist	3.9	7.3	APB-Wrist			
Elbow	8.5	6.8	Wrist-Elbow	4.6	210	46

## Ulnar nerve.L

Wrist	2.7	14.0	ADM-Wrist			
Above Elbow	8.6	13.9	Wrist-Above Elbow	5.7	280	47

## F-Wave Studies:

Nerve	L. F-Latency	R. F-Latency	Persistence
Median nerve	29.0	28.4	100%
Ulnar nerve	31.3	27.9	100%

## Sensory Nerve Conduction:

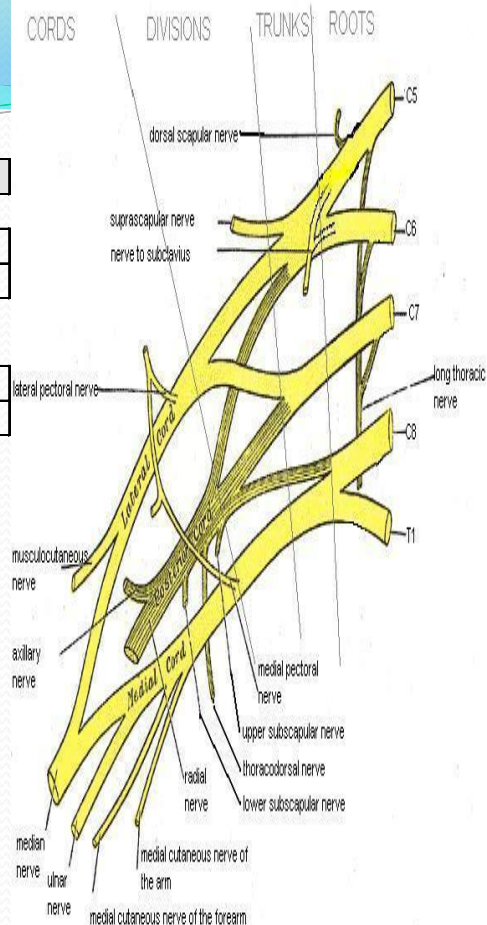
Nerve and Site	Lat. ms	Amp. $\mu$ V	Segment	Dist mm	C.V. m/s
<b>Median nerve.L</b>					
Palm	1.3	43	Palm-Wrist	70	54
Digit II	2.4	25	Digit II-Wrist	140	56

## Ulnar nerve.L

Digit V	2.3	17	Digit V-Wrist	125	54
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## Needle EMG Data:

		Insertional	Spontaneous Activity			Volitional Activity		Recruitment
		Insertional	Fibs	+ Wave	Fasics	Poly	MUP Amp	
Deltoid	L	Normal	None	None	None	None	Normal	Normal
Biceps	L	Normal	None	None	None	None	Normal	Normal
Extensor Digitorum Com	L	Increased	None	None	Few	None	Increased	Reduced
Triceps	L	Increased	None	None	Few	None	Increased	Reduced
1 <sup>st</sup> Dorsal Interosseous	L	Normal	None	None	None	None	Normal	Normal





# Right thigh weakness

## Motor Nerve Conduction:

Nerve and Site	Segment	Latency	Amplitude	Distance	Conduction Velocity
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### Peroneal.L

Ankle		3.7 ms	5.0 mV	mm	m/s
Fibula (head)	Ankle-Fibula (head)	10.4 ms	4.3 mV	330 mm	49 m/s
Above knee	Fibula (head)-Above knee	12.6 ms	4.0 mV	110 mm	50 m/s

### Tibial.L

Ankle		6.2 ms	13.0 mV	mm	m/s
Popliteal fossa	Ankle-Popliteal fossa	14.7 ms	12.5 mV	380 mm	45 m/s

### Peroneal.R

Ankle		5.0 ms	5.1 mV	mm	m/s
Fibula (head)	Ankle-Fibula (head)	11.9 ms	5.4 mV	320 mm	46 m/s
Above knee	Fibula (head)-Above knee	14.6 ms	5.3 mV	130 mm	48 m/s

### Tibial.R

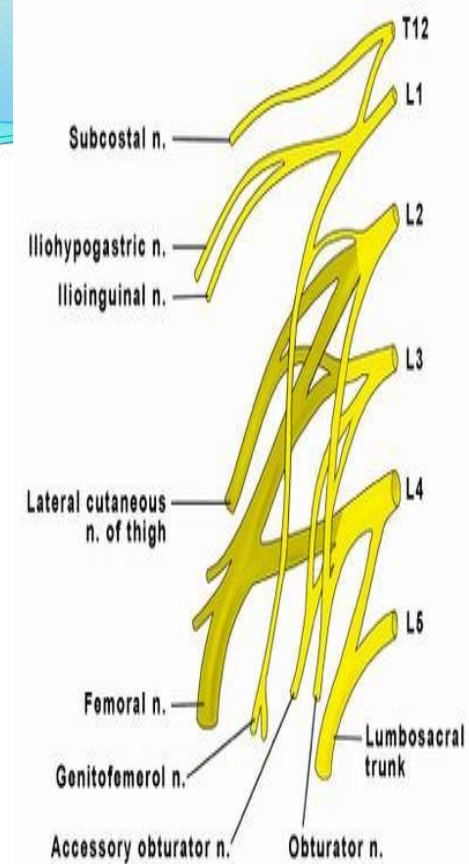
Ankle		4.7 ms	8.9 mV	mm	m/s
Popliteal fossa	Ankle-Popliteal fossa	13.2 ms	8.2 mV	380 mm	45 m/s

## F-Wave Studies

Nerve	M-Latency	F-Latency
Tibial.L	6.5	50.8
Tibial.R	4.3	53.3

## Needle EMG Examination:

Muscle	Insertional	Spontaneous Activity			Volitional MUAPs					Max Volitional Activity		
	Insertional	Fibs	+ Wave	Fasc	Duration	Amplitude	Poly	Config	Recruitment	Amplitude	Pattern	Effort
Vastus medialis.R	Normal	None	2+	None	Absent	Absent	Absent	Absent	Absent	Absent	None	Max.
Vastus lateralis.R	Normal	None	1+	None	Absent	Absent	Absent	Absent	Absent	Absent	None	Max.
Iliopsoas.R	Normal	1+	None	None	Absent	Absent	Absent	Absent	Absent	Normal	Distant	Max.
Tibialis anterior.R	Normal	None	None	None	Normal	Normal	None	Normal	Normal	Normal	Full	Max.



# Left lower limb radicular pain

## Motor Nerve Conduction:

Nerve and Site	Lat. ms	Amp. mV	Segment	L.D.	Dist. mm	CV. m/s
<b>Peroneal nerve</b>						
Ankle.L	5.3	8.1	EDB-Ankle			
Fibular head.L	13.3	8.2	Ankle-Fibular head	8.0	330	41
Ankle.R	4.6	7.0	EDB-Ankle			

## **Tibial nerve**

Ankle.L	4.9	11.2	Abd hallucis-Ankle			
Pop. fossa.L	13.1	11.2	Ankle-Pop. fossa	9.2	420	45
Ankle.R	4.7	8.7	Abd hallucis-Ankle			

## Sensory Nerve Conduction:

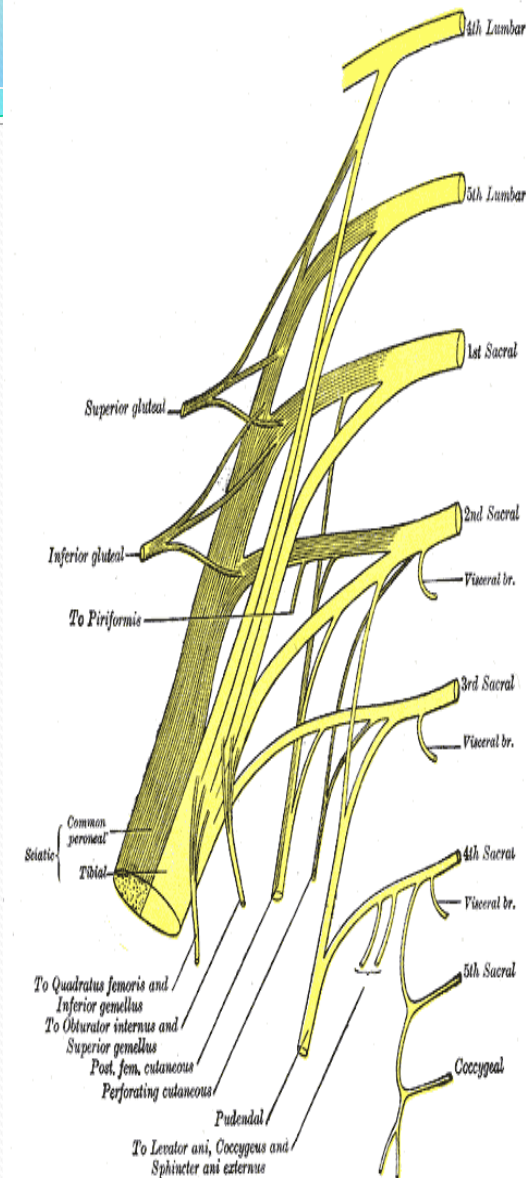
Nerve and Site	Lat. ms	Amp. $\mu$ V	Segment	Dist mm	C.V. m/s
<b>Sural nerve</b>					
Mid calf.L	2.6	10	Mid calf-Ankle	130	50
Mid calf.R	2.5	10	Mid calf-Ankle	130	51

## F-Wave Studies:

Nerve	L. F-latency	R. F-Latency	Persistence
Tibial nerve	59.1	60.3	100%

## Needle EMG Data:

		Insertional	Spontaneous Activity			Volitional Activity		Recruitment
		Insertional	Fibs	+ Wave	CRD's	Poly	MUP Amp	
Tibialis Anterior	L	Normal	None	None	None	None	Normal	Normal
Peroneus Longus	L	Increased	4+	4+	Many	Many	Increased	Reduced
Gastroc. Medial Head	L	Increased	2+	2+	Few	Few	Increased	Reduced





16/04/2010