ELECTRODIAGNOSTIC TESTS AND INTRAOPERATIVE MONITORING

INTRODUCTION

- Evoked response studies are recordings of the nervous system's electrical response to the stimulation of specific sensory pathways (e.g., visual, auditory, general sensory).
- Evoked response studies provide information relative to the functional integrity of pathways within the nervous system.

Evoked potentials monitoring can be classified according to the type of stimulation used

- 1- Visual-evoked potentials (VEPs)
- 2- Brainstem auditory-evoked potentials (BAEPs)
- 3- Somatosensory-evoked potentials (SSEPs)
- 4- Motor evoked Potentials (MEPS)
- 5- Cognitive evoked potentials (ERPs)

VISUAL-EVOKED POTENTIALS (VEP)

Electrical activity induced in visual cortex by light stimuli

Anatomical basis of the VEP:

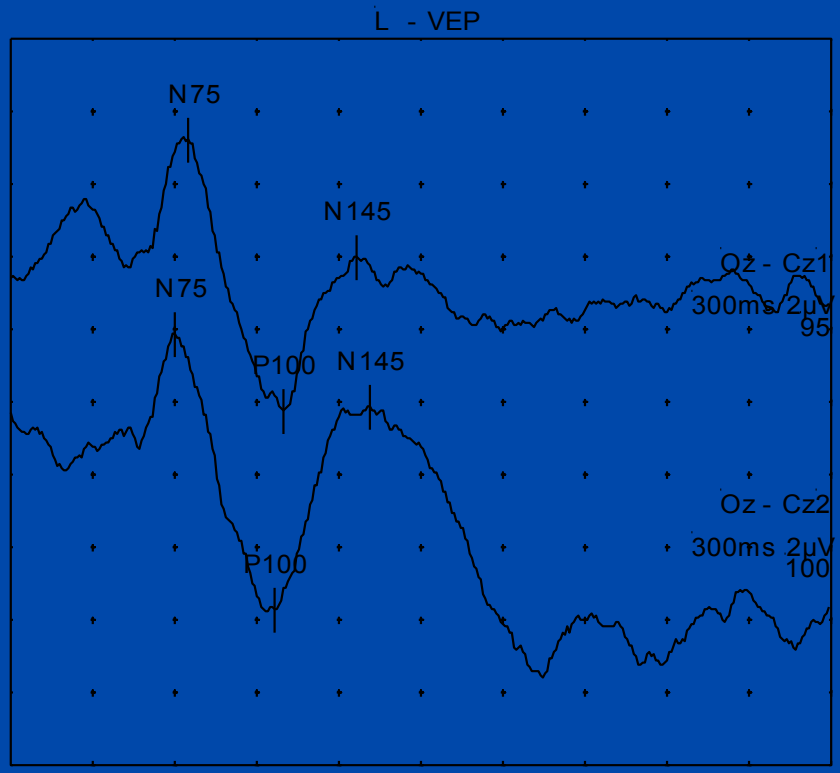
- Retina
  - Rods and Cones
  - Bipolar neurons
  - Ganglion cells
- Optic nerve
- Anterior visual pathways
  - Optic chiasm
  - Optic tract
  - Lateral geniculate body
- Retrochiasmal pathways
  - Optic radiation
  - Occipital lobe, visual cortex

TECHNICAL RECOMMENDATIONS OF VEP STUDY (IFCN)

- Channel 1: Oz- Fpz
- Channel2 : Oz-A1A2
- Ground : Cz
- Analysis time:250 ms
- No. of epochs at least 100
- Stimulation-B & W checkerboard 50-80 % contrast
- Size of pattern 14 x 16”
- Rate of stimuli-1 Hz (transient), 4-8 Hz (steady state)
- Mean luminance of the central field- 50 cd/m2
- Background luminance- 20_40 cd/m2

VEP ABNORMALITIES

- VEPs represent mass response of cortical and possibly the subcortical areas.
- The common waveforms- N75,P100,N145.
- <u>Assessment of abnormal VEP</u>
- 1-Latency prolongation
  2-Amplitude reduction
- 3-Combined latency and amplitude abn.



Normative VEPs

Parameters	Sharokhi et al 1978(mean+_SD)
P100: latency	102.3+- 5.1
Amplitude (microvolt)	10.1+_ 4.2
Duration	63.0+_8.7

ABNORMAL VEP

- **1-P100 latency prolongation** -when P100 Latency is outside the 95th to 99th percentile or when P100 is -not, then VEP considered abnormal
- Prolonged P 100 – latency with normal amplitude - demyelination of the anterior visual pathways

- **2-P100 amplitude attenuation with normal P100 latency** - isch. ON causing axonal loss, but P100 amplitude has wide interindividual variability, so less clinical utility .

- **3-P100 amplitude attenuation with prolonged P100 latency-** Optic nerve compression causing segmental demyelination and axonal loss.

- **4-Inter eye latencies differences-** it is useful to look intereye latency diff.,if >10 msec diff-indicate pathology in that eye.

1-Retinopathies and maculopathies-

- In maculopathies- patterned ERG are –nt or prolonged. But normal retino cortical time
- In optic nerve disease- VEPs may be absent or prolonged but patterned ERG are normal.
- In optic nerve disorder with large central scotoma or optic atrophy-both pattered ERG and VEPs –nt.

2-Disorder of optic nerve and chiasma-

- VEP are even more sensitive than MRI in detecting lesion and still Ix of choice in suspected demylinating disease of ON.
- Temporal dispersion of VEP (diff. in latency b/w N75 and N145) are charecteristic of ON compression, but it can be seen in both compression and demylination.

3-Retrochiasmatic Disorders

- ? Reliability
- Full field stimulation are usually normal in pt with u/l hemispheric lesion, but flash or hemi field stimulation pattern can help but not sufficiently sensitive.
- VEP – often preserved in b/l retrochiasmatic lesions producing cortical blindness.(ie, generator in extrastiate visualcortex or remnants of cortical area 17.

Newer……..Multifocal VEP

- Patient views a display containing 60 sectors ,each with checkerboard pattern . It can be used for diagnosing/following ON/MS,and excluding nonorganic visual loss.
- It can be combined with multifocal ERG.
- Still in infancy stage ? Sensitivity ? Reliability.

CLINICAL APPLICATION OF VEPs

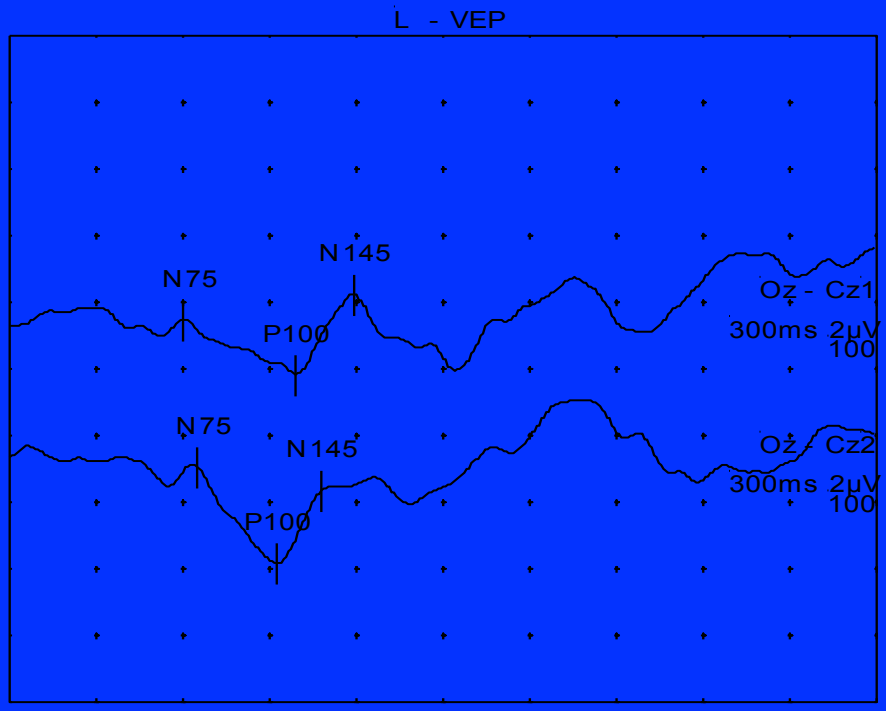
- 1- Demyelinating disease-(MS)- P100 mean latency is prolonged by 10-30msec..
- 2-Optic nerve/chiasmatic disease-(AION, nutritional/ toxic)
- 3-Extrinsic compression of anterior visual pathways results in loss of amplitude, distortion of waveform ,and prolongation of $P_{100\ latency.}$
- 4- VEP has been found to be more sensitive in detecting the compression of anterior visual pathways and found to be abnormal even in a patients with normal visual acuity.

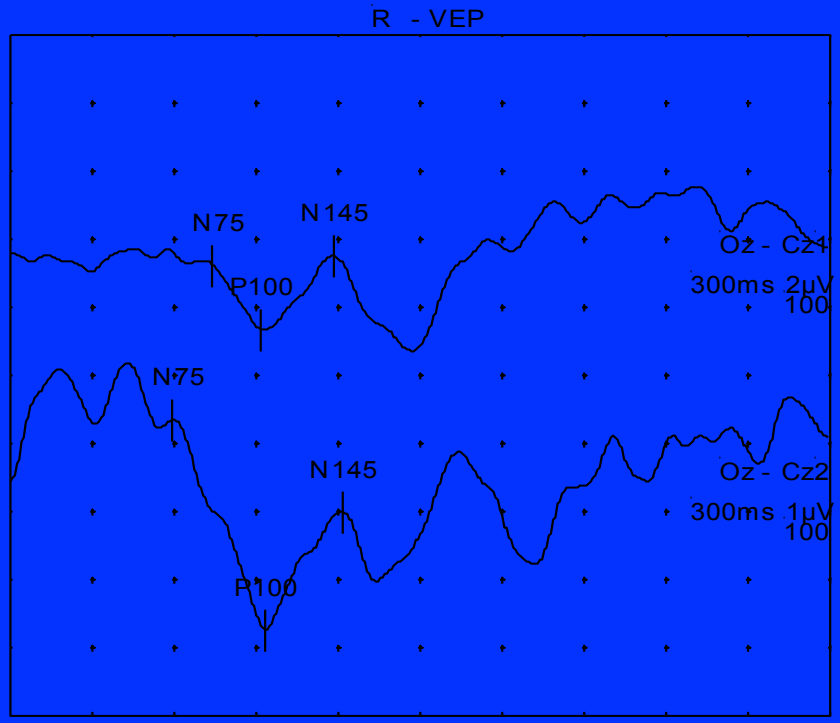
Contd….

- 5-In cortical blindness-damaged to area 17 with preservation of areas 18 and 19 associated with steady state VEP.
- 6-Malingering and hysteria-VEP normal in as low vision 20/120
- 7--Intra-operative monitoring-pituitary ,cavernous sinus tumour, aneurysm surgery.

QUESTION-1

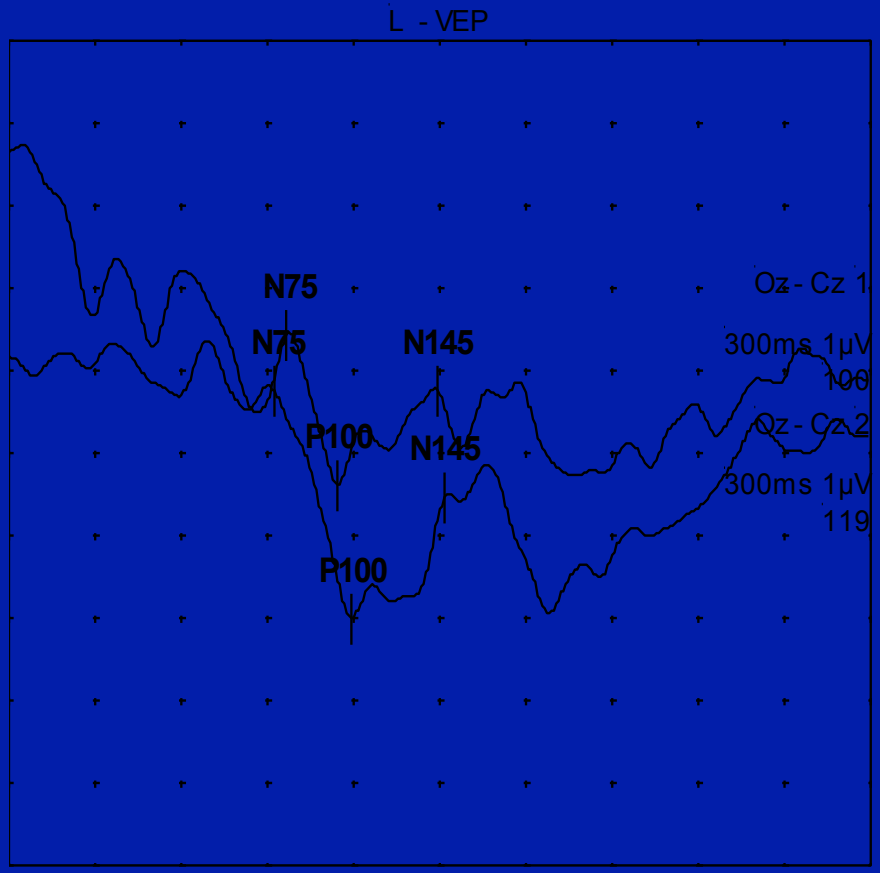
Protocol / Run	N75	P100	N145	P100	Size
	ms	ms	ms	µV	
L - VEP					
1 Oz - Cz	60.60	99.30	118.80	1.7	8
2 Oz - Cz	65.10	93.00	108.00	2.9	8
R - VEP					
1 Oz - Cz	73.80	92.10	118.20	1.9	8
2 Oz - Cz	59.40	93.60	122.10	3.1	8

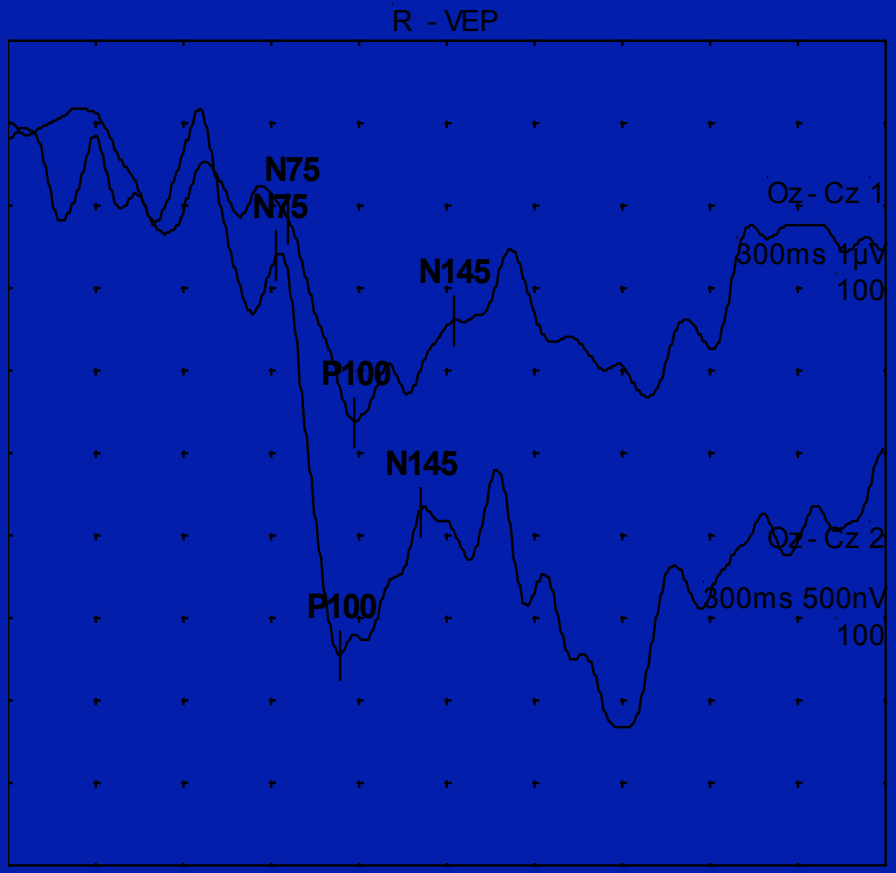




QUESTION-2

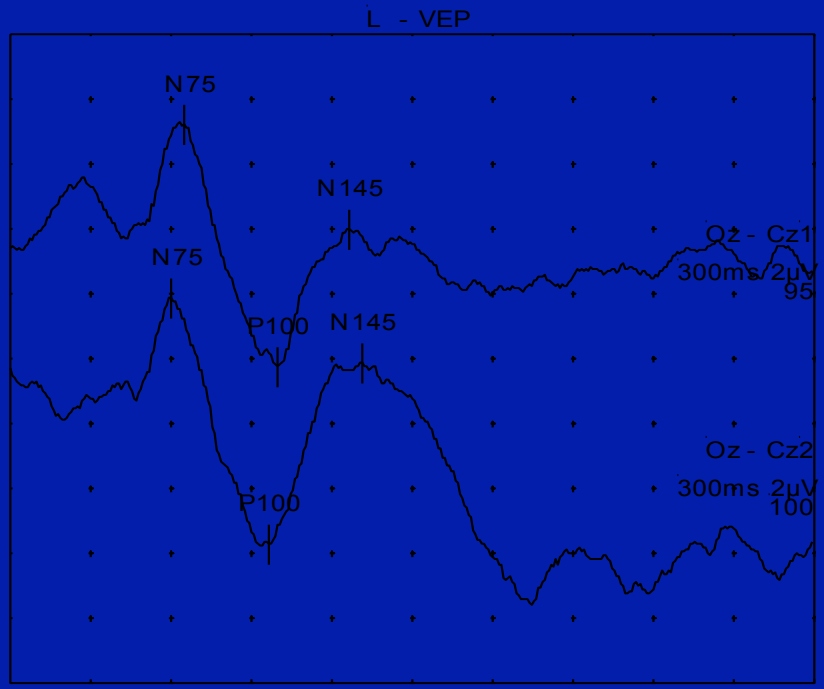
Protocol / Run	N75	P100	N145	P100	Size
	ms	ms	ms	µV	
L - VEP					
1 Oz - Cz	97.20	114.30	149.40	1.8	8
2 Oz - Cz	92.70	119.10	151.80	2.8	8
R - VEP					
1 Oz - Cz	95.40	119.10	152.40	2.5	8
2 Oz - Cz	92.10	113.40	141.60	2.4	8

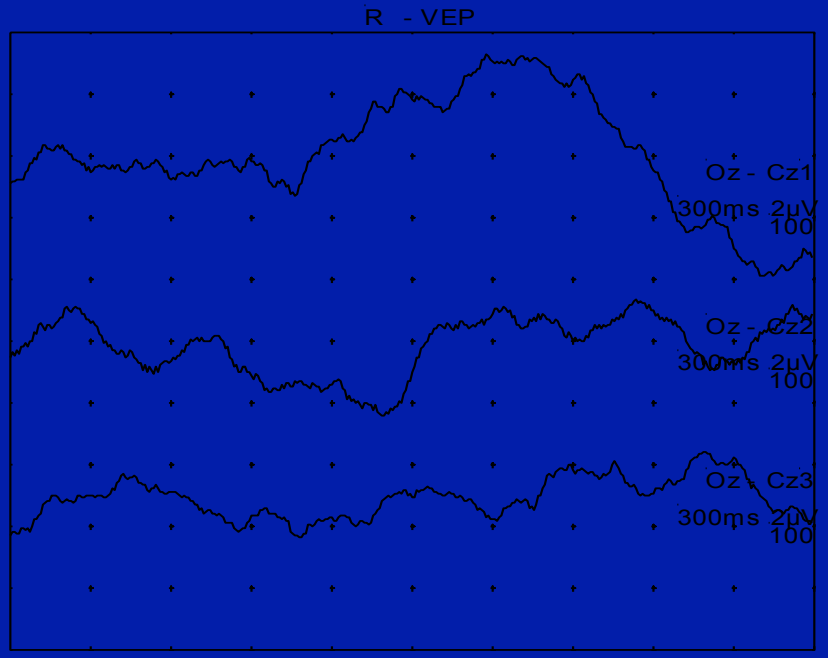




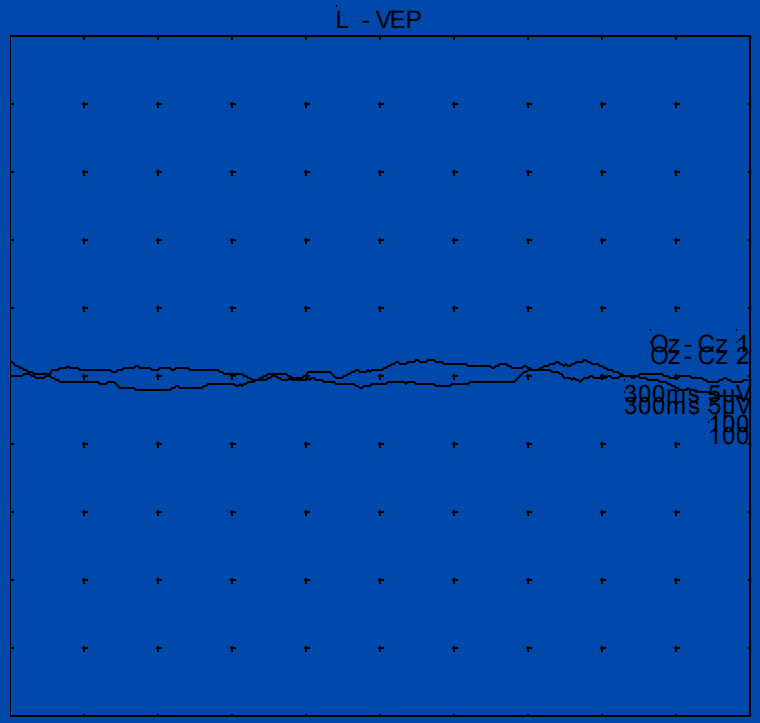
QUESTION-3

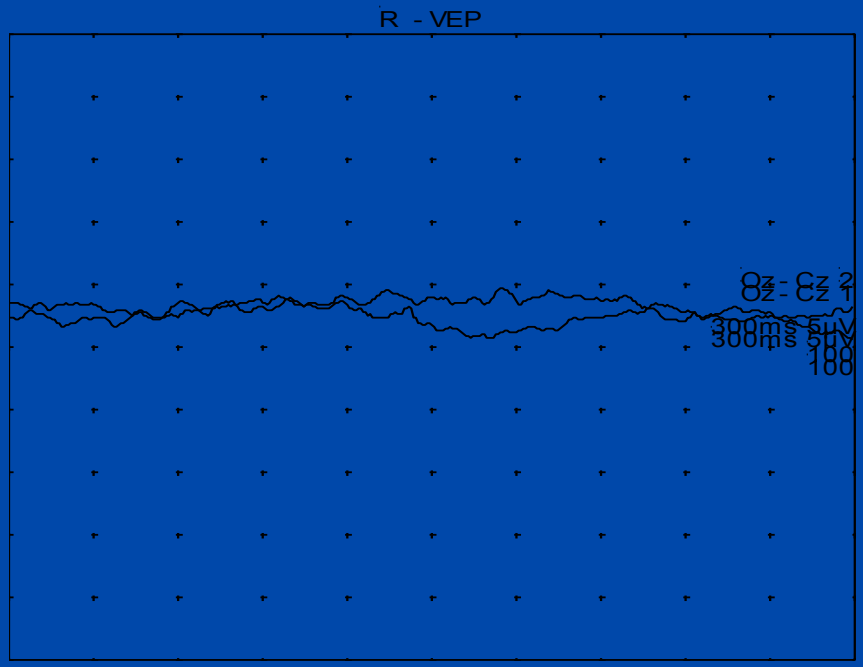
Protocol / Run	N75	P100	N145	P100	Size
	ms	ms	ms	µV	
L - VEP					
1 Oz - Cz	64.80	99.60	126.60	7.5	8
2 Oz - Cz	60.60	96.30	131.10	7.6	8





QUESTION-4


L - VEP
Oz - Cz 1
Oz - Cz 2
300ms 5uV
100

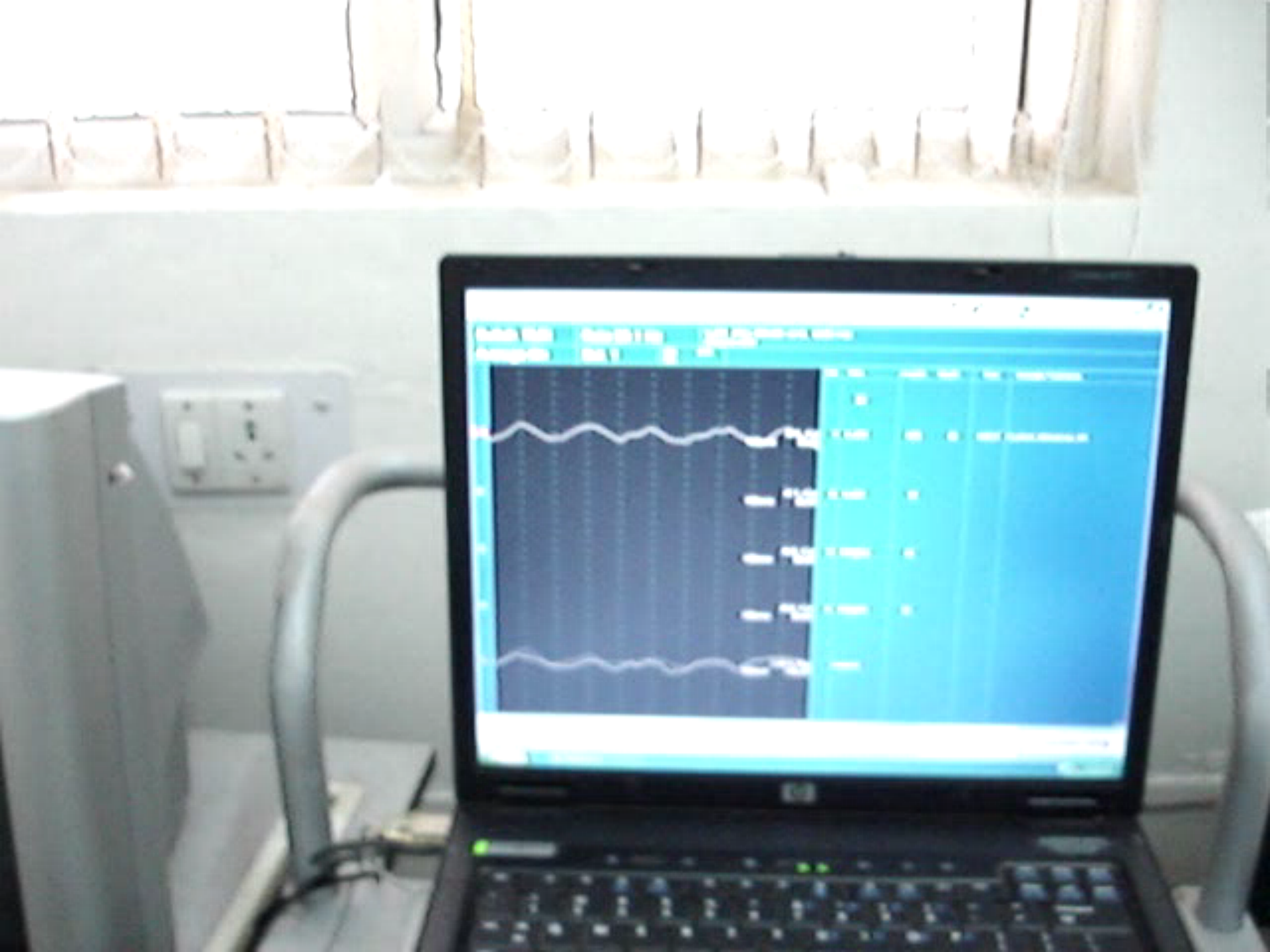

R - VEP
Oz - Cz 2
Oz - Cz 1
300ms 5uV
100

BRAINSTEM AUDITORY EVOKED POTENTIAL

- BAEPs are potentials recorded from the ear and vertex in response to a brief auditory stimulation to assess the conduction through the auditory pathway up to midbrain.

METHODS

- Elicited by brief acoustic click stimuli that are produced by delivering monophasic square pulses of 100 microsec duration to headphone / transducer at a rate of 10 Hz.
- Stimulus intensity should be loud enough to elicit a clear BAEP waveform -60-65 db
- Stimuli are delivered monoaurally.
- Electrodes- Fz- ground electrode, Cz-ref electrode, ear lobes- Ai,Ac.-recording electrodes.



GENERATOR OF BAEPS

Waveform	Generators
I	VIII Nerve
II	Cochlear nu.
III	Superior olivary nu.
IV	Lateral lemniscus
V	Inferior colliculi
VI	MGB, inf colliculus
VII	Auditory cortex

NORMAL VALUES OF BAEPS

Wave (latency ms)	Chiappa et al (1979)	AIIMS , EPS LAB
I	1.7+- 0.15	1.98
II	2.8 +- 0.17	
III	3.9 +- 0.19	4. 16
IV	5.1 +- 0.24	
V	5.7+- 0.25	6.03
VI	7.3 +_ 0.29	
I-III IPL	2.1 +- 0.15	2.47
III-V IPL	1.9 +_ 0.18	2.16
I-V IPL	4.0 +_ 0.23	4.24

ABNORMAL BAEPS

- 1-Absence of waveforms
- 2-Abnormal absolute or inter peak latencies
- 3-Amplitude ratio abnormalities
- 4- Right to left asymmetry

CLINICAL INTERPRETATION

- Assess-
- 1-Peak latencies of all wave
- 2- inter peak latencies of I-III,III-IV,I-V
- 3- IV/V:I amplitude ratio,
- 4-RT/LT Asymmetry
- Limit of normal range-2.5-3 SD from mean of normative data.
- Wave- I-if absent –reflect peripheral auditory dysfunction (conductive /cochlear)

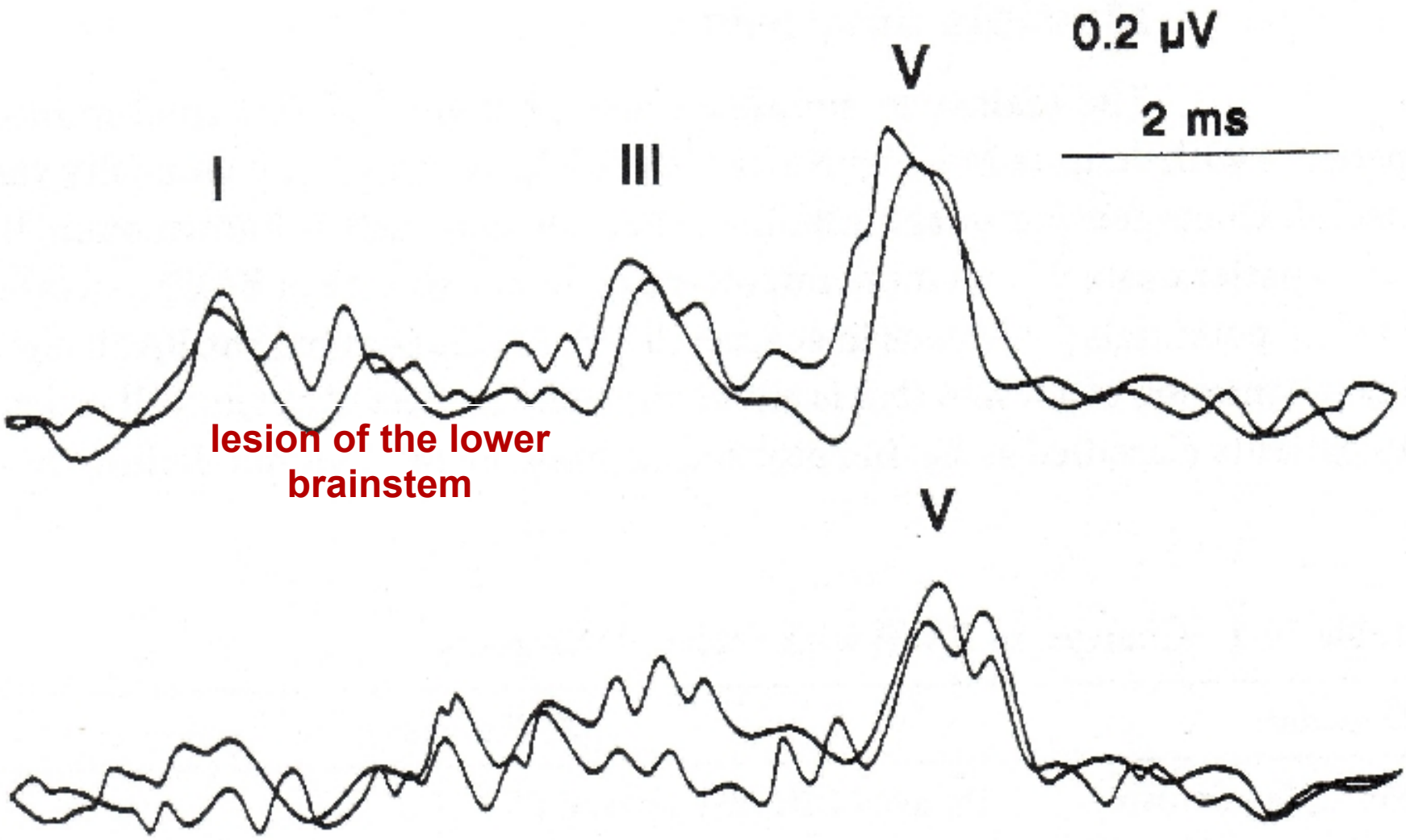
Inter peak latencies BAEPs

- I-III inter peak latency- reflect abn within neural auditory pathway b/t **distal 8th nerve** and **lower pons** , abn in acoustic neuroma /demyelinating/vascular lesion of brainstem.
- III –V inter peak latency- reflect abn within neural auditory pathway b/t **lower pons** and **midbrain** , but it should be interpretated with IV/V:I amplitude ratio abnormailty.
- I-V inter peak latency- reflect abn within neural auditory pathway b/t **distal 8th** nerve and **midbrain**.

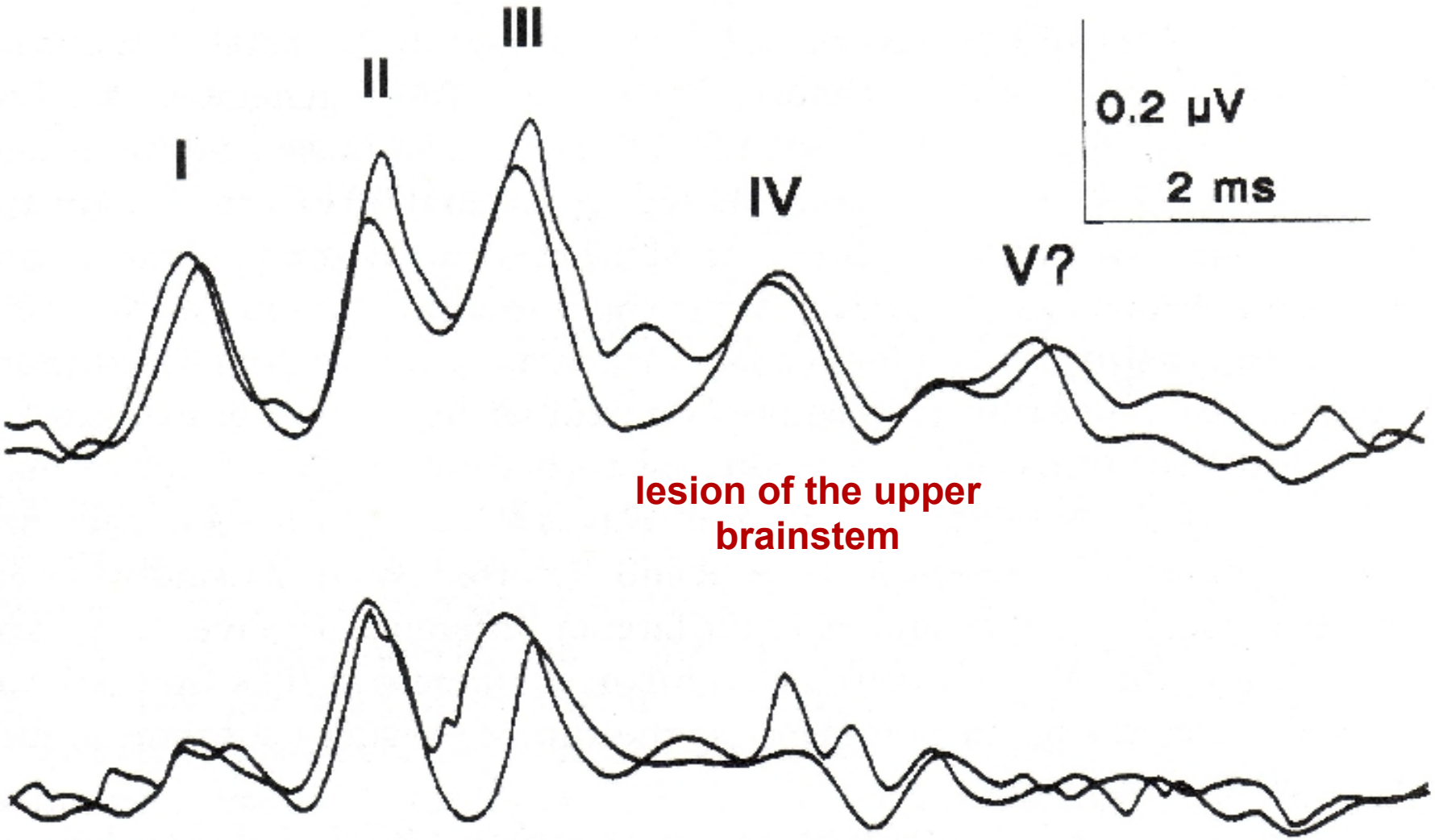
AMPLITUDE RATIO OF BAEPS

- Amplitude ratio IV/V:I amplitude ratio- reflect abn within neural auditory pathway b/t distal 8th nerve and midbrain.
- NORMAL VALUE-50-300%
- IN CENTRAL AUDITORY DYSFUNCTION- wave V amplitude is low, ratio < 50 %
- IN PERIPHERAL AUDITORY DYSFUNCTION- wave I amplitude low , ratio >300%

BAEPs



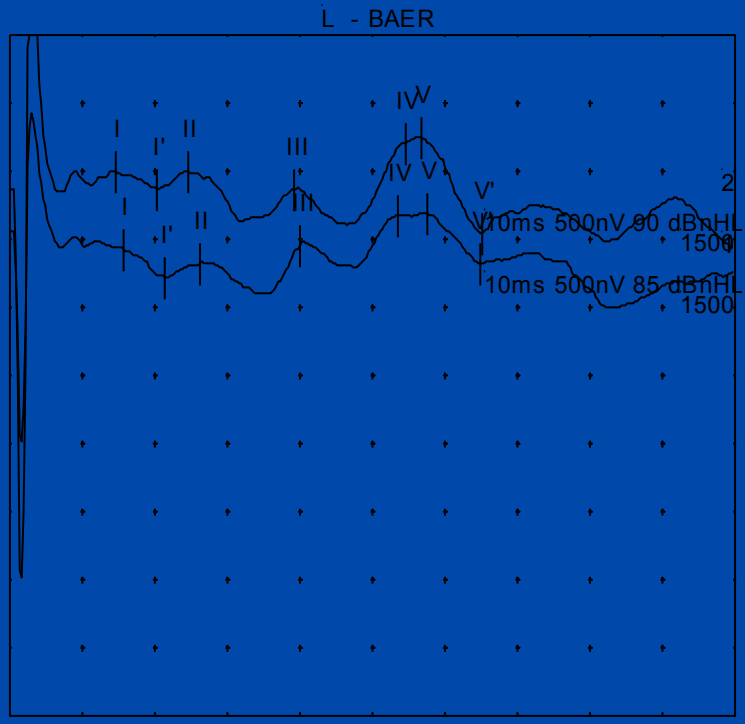
BAEPs

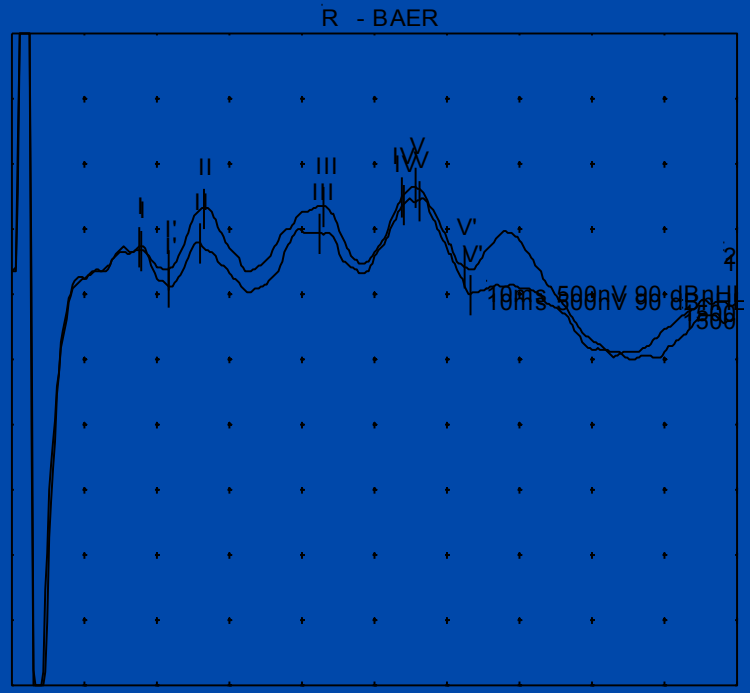


lesion of the upper brainstem

QUESTION-5

Protocol / Run	I	III	V	I-V	I-III	III-V	I-I'	V-V'
	ms	ms	ms	ms	ms	ms	µV	µV
L - BAER								
1	1.56	4.02	5.76	4.20	2.46	1.74	0.22	0.38
2	1.46	3.92	5.66	4.20	2.46	1.74	0.12	0.72
R - BAER								
1	1.76	4.22	5.62	3.86	2.46	1.40	0.32	0.74
2	1.78	4.30	5.56	3.78	2.52	1.26	0.15	0.61

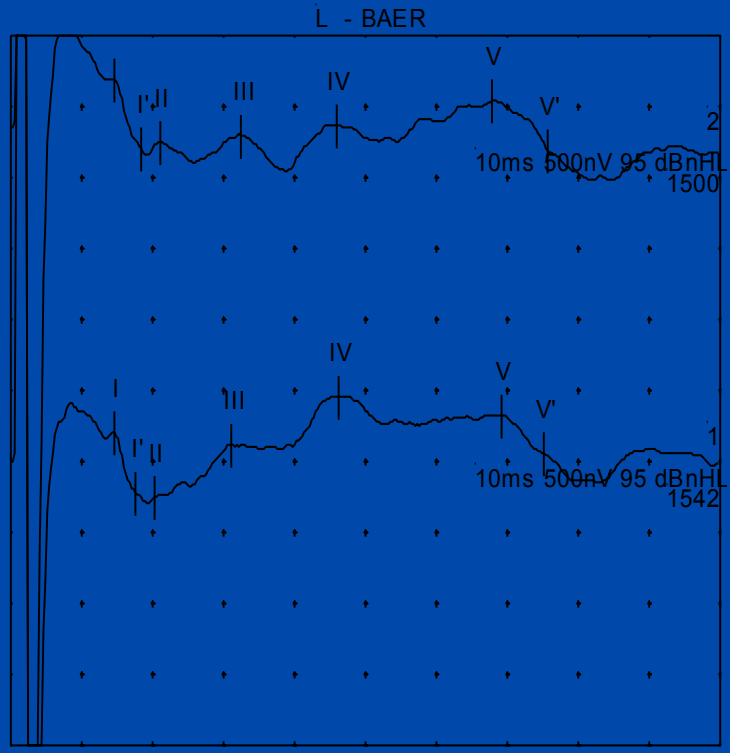


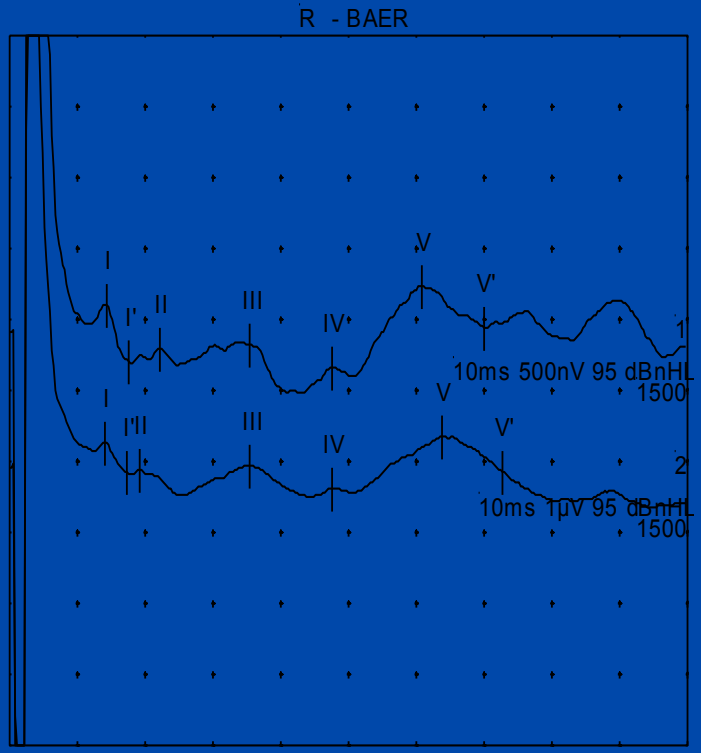


QUESTION-6

What will be the probable site of lesion in this BAER ?

Protocol / Run	I	III	V	I-V	I-III	III-V	I-I'	V-V'
	ms	ms	ms	ms	ms	ms	µV	µV
L - BAER								
1	1.46	3.10	6.90	5.44	1.64	3.80	0.43	0.30
2	1.44	3.24	6.80	5.36	1.80	3.56	0.50	0.37
R - BAER								
1	1.42	3.54	6.08	4.66	2.12	2.54	0.41	0.30
2	1.40	3.54	6.38	4.98	2.14	2.84	0.44	0.49





CLINICAL APPLICATIONS-OF BAEPS

- 1- Neoplastic -In acoustic neuroma/post fossa tumors-brainstem glioma
- 2- Cerebrovascular disease- abn in post circ. Stroke involving pontine tegmentum and cerebellar peduncle.
- 3-Demyelinating disease- 67% with definite MS, 41% in probable MS, 30% in possible MS.
- 4- Coma/death/locked in state.

BAEP FINDINGS IN CP ANGLE TUMOR

- Unrecordable BEAP
- Only wave 1 recordable
- Prolongation of wave 3 and 5 latency
- Prolonged 1-3 and 1-5 IPL
- Rt to Lt asymmetry in wave 5 latency>0.5 ms

BAEP IN COMA

- In coma following brainstroke ,abnormal BAEP correlated with unstable clinical course and poor prognosis .
- Regardless of etiology and depth of coma ,recovery in all patients with normal BAEP and death in all the patient in whom BAEP was unrecordable .

INTRAOP USE OF BAEP

- PRESERVATION OF VESTIBULOCOCHLEAR NERVE
- AVOID BRAIN STEM INJURY

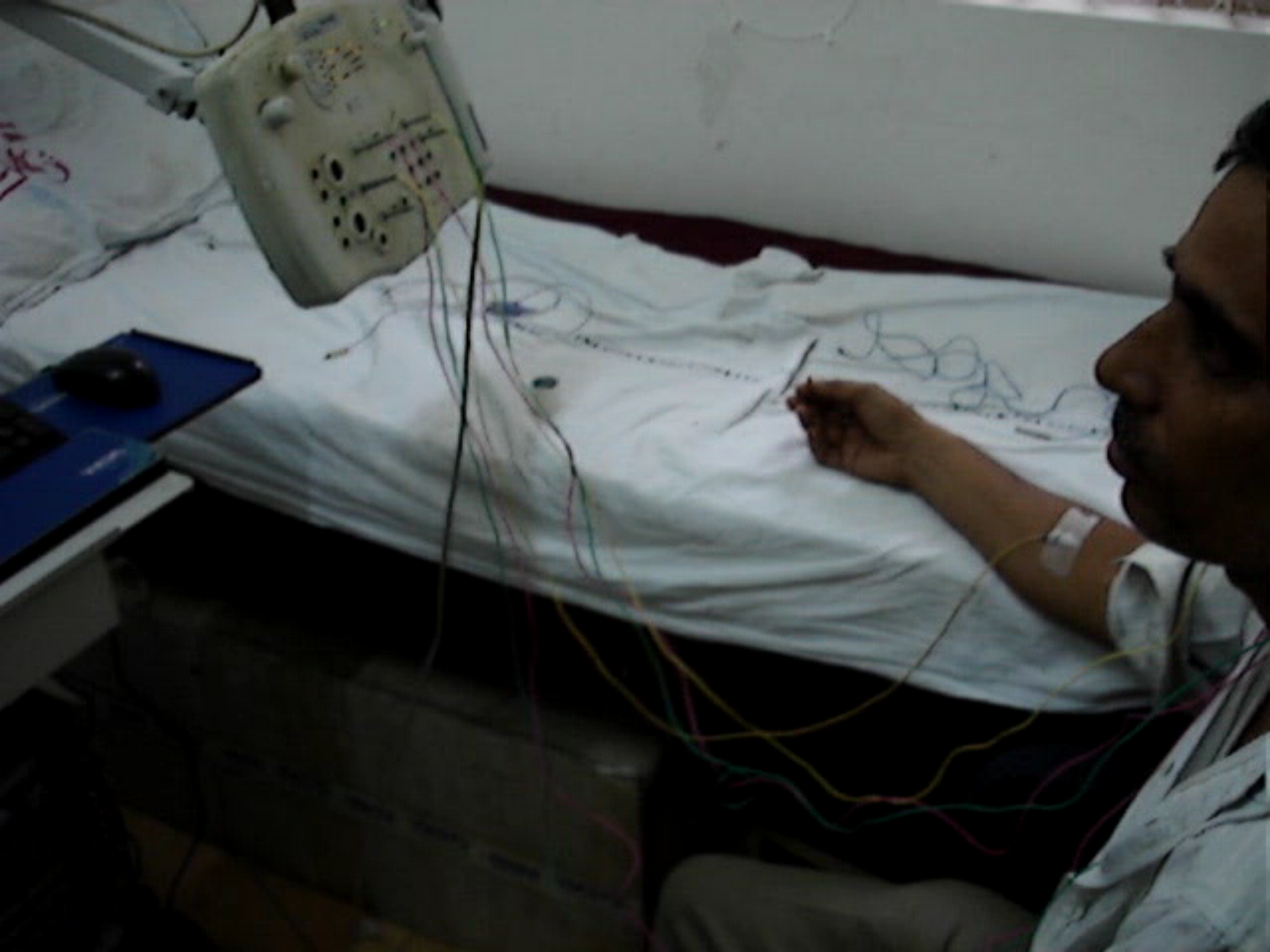
SOMATOSENSORY EVOKED POTENTIAL

SOMATOSENSORY EVOKED POTENTIAL

- SSEPs are the electrical potentials generated mainly by the large diameter sensory fibers in the peripheral and central nervous system in response to a stimulus.
- SSEP evaluate the proprioceptive pathways.
- Commonly used median and post tibial nerves .
- Parameters measured-
- 1-Latency 2- Amplitude
- 3-Inter peak latency

METHODS- MEDIAN SSEP

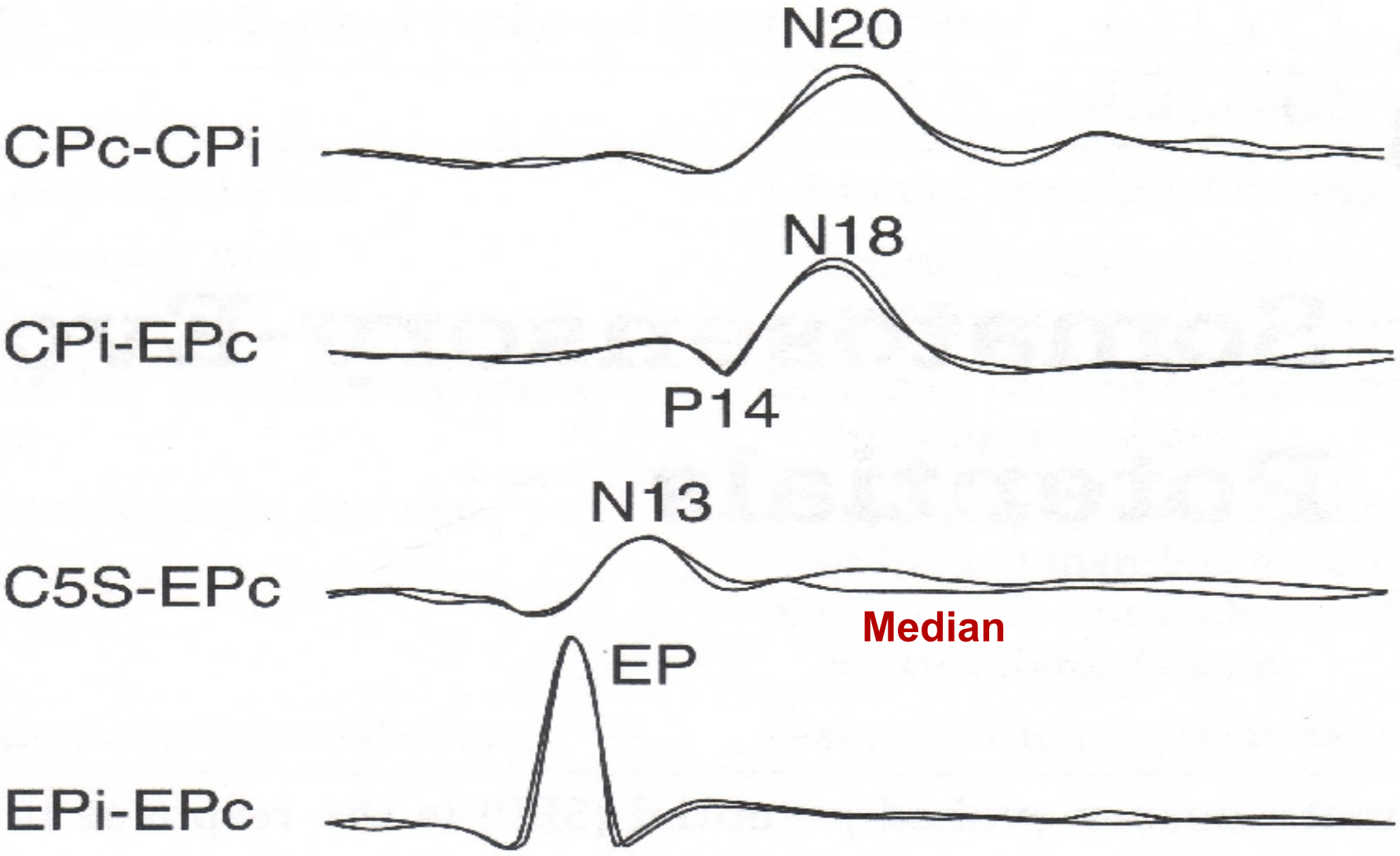
- Recording electrodes- placed at erb's points spinous process of C5,2 cm post. To C3,C4.
- Fz – reference electrode
- 200 uv square wave pulse (5-15 mA with 200 us duration) .Rate of stim-3-8 Hz., 1000 or more epochs to be averaged.
- Twice averaged to check for reproducibility.



Generators of waveform in Median SSEP

Waveforms	Generators
N9	Brachial plexus
N11	Dorsal cervical roots, ascend. Volley in Post column on C5 spinal segment
N13	Rostral cervical cord
P14	Medial lemniscus and brainstem collaterals
N18	Rostral brainstem nuclei, thalamus
N20	Primary sensory cortex, VPL, nu. Of thalamus

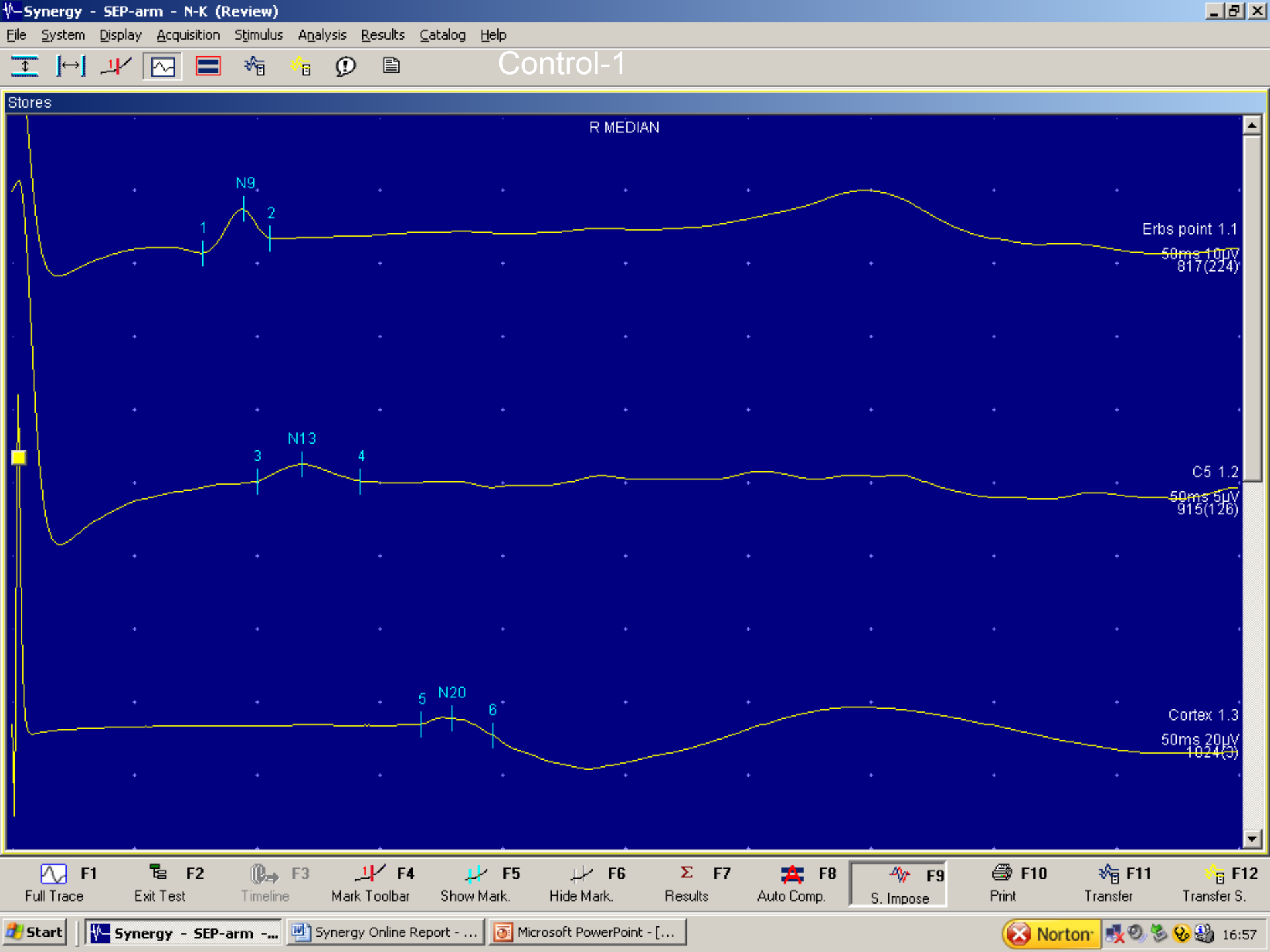
SOMATOSENSORY EPS



- Parameters measured-
- 1-Latency 2- Amplitude
- 3-Inter peak latency
- 4- **Two Important Interpeak Latencies-**
- A) Brachial plexus to spinal cord (N9-N13)
- B) Central sensory conduction time (N13-N20)

Normal values of median SSEP

Latency (ms)	IFCN Male –mean UL	IFCN Female –mean UL
N9	9.8 (11.0)	9.2 (10.5)
N20-N9	9.3(10.5)	9.0(10.1)
N20-N13	5.7(7.2)	5.6(7.0)
N13-N9	3.5(4.4)	3.2(4.0)
Amplitudes (uv)		
N9	4.8(1.0)	4.8(1.0)
N13	2.9(1.0)	2.9(1.0)
N20	3.2 (0.8)	3.2 (0.8)


Synergy - SEP-arm - N-K (Review)
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Control-1
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C5 1.2
50ms 5µV
915(126)
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Cortex 1.3
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1024(3)
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F2 Exit Test
F3 Timeline
F4 Mark Toolbar
F5 Show Mark.
F6 Hide Mark.
F7 Results
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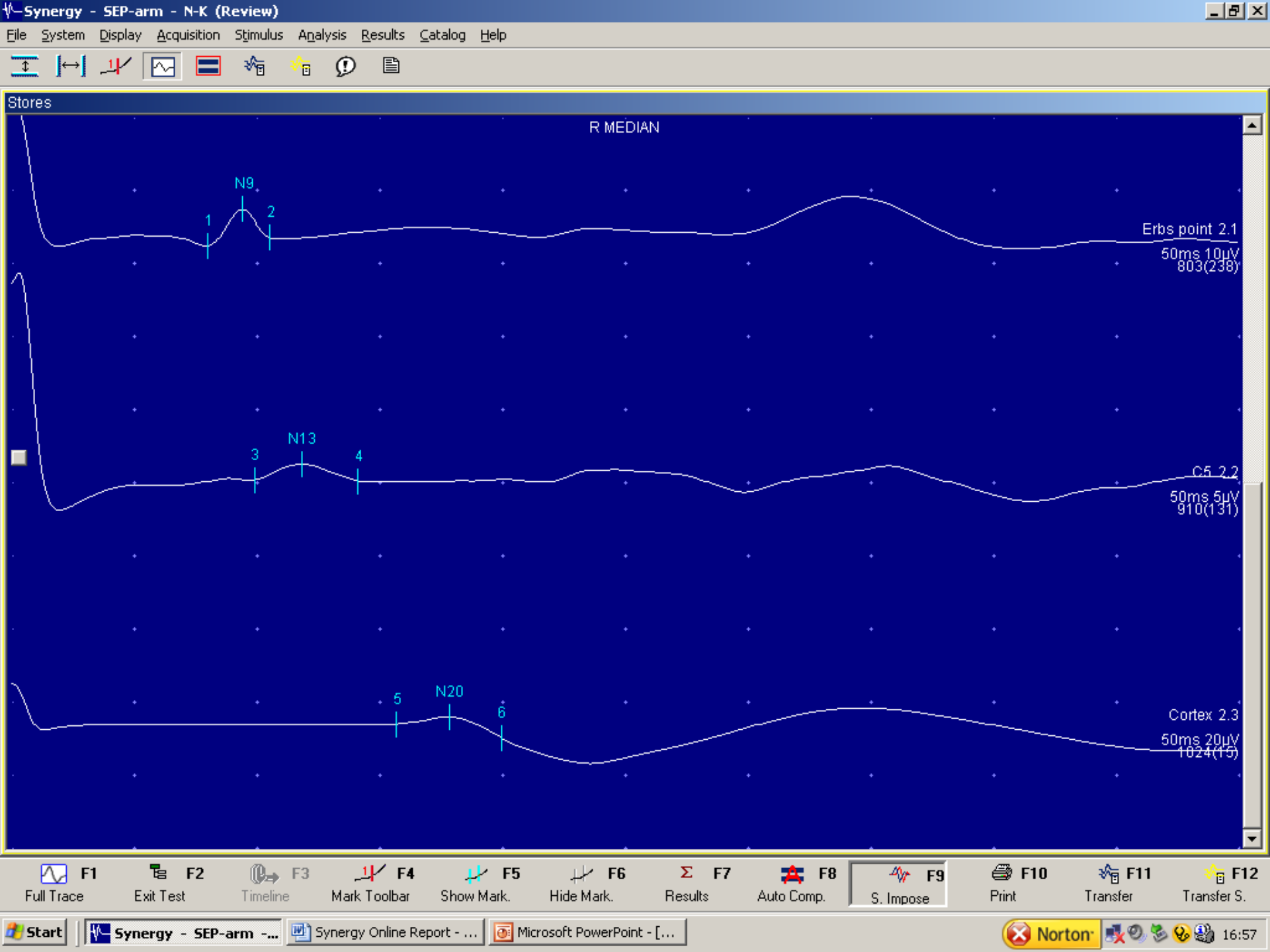
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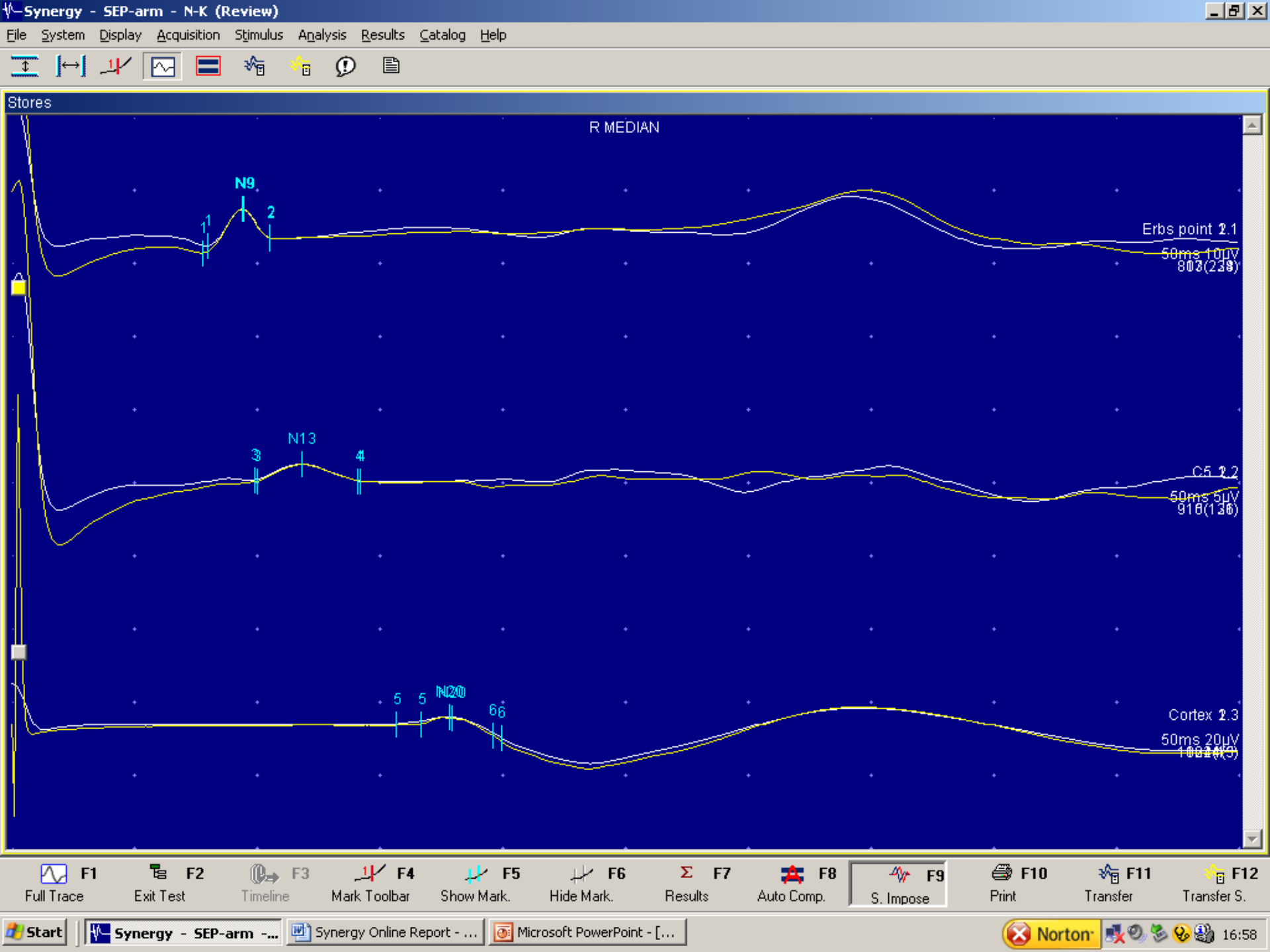
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F2 Exit Test
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F4 Mark Toolbar
F5 Show Mark.
F6 Hide Mark.
F7 Results
F8 Auto Comp.
F9 S. Impose
F10 Print
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F12 Transfer S.
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Synergy Online Report - ...
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Synergy - SEP-arm - N-K (Review)

File Results Help

Results Table

R MEDIAN

Run	N9 ms	N13 ms	N20 ms	A9 µV	A13 µV	A20 µV	L1 ms	L3 ms	L5 ms	Area9 µVms	Area13 µVms	Area20 µVms	Temp. °C	Dist. cm
1.1 Erbs point	9.40			-4.1			7.75			5.7			29	66
1.2 C5		11.80			-1.2			10.00			2.9			
1.3 Cortex			17.90			-1.8			16.65			4.3		
2.1 Erbs point	9.35			-4.1			7.95			5.1			28.7	66
2.2 C5		11.80			-1.2			9.85			3.1			
2.3 Cortex			17.80			-2.2			15.65			6.5		
3.1 Erbs point														
3.2 C5														
3.3 Cortex														

F1 Full Trace | F2 Exit Test | F3 Timeline | F4 Mark Toolbar | F5 Show Mark. | F6 Hide Mark. | F7 Results | F8 Auto Comp. | F9 S. Impose | F10 Print | F11 Transfer | F12 Transfer S.

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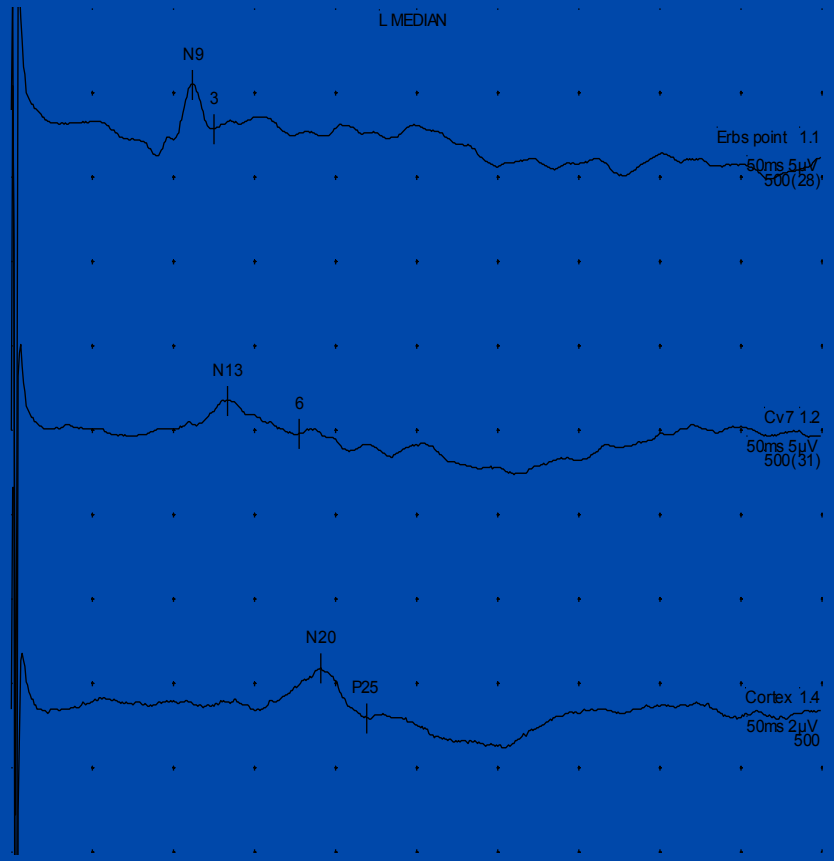
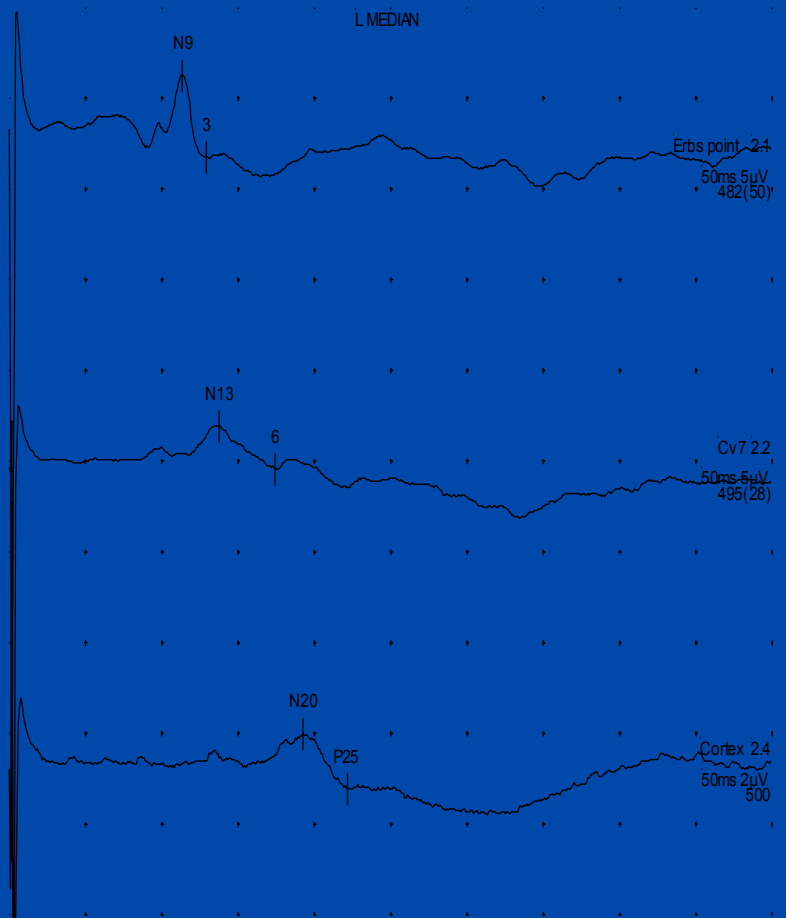
QUESTION-7

Protocol / Run	N9	N11	N13	N20	P25	N20	Low	High
	ms	ms	ms	ms	ms	µV		
L MEDIAN								
1 Erbs point	11.15		13.30	19.05	21.95	1.2	3Hz	Off
2 Erbs point	11.35		13.70	19.20	22.15	1.3	3Hz	Off





Tibial SSEP

- Ch-1:C'z-Fz
- Ch 2:T12-T10
- Ch3 :L1-L3
- Ch 4:PF-K

Waveforms	Generators
N8	Tibial or sciatic nerve
N22	Dorsal gray matter of lumbar spinal cord
N28	Cervical spinal cord
P37	Primary sensory cortex

Normal values of tibial SSEP

Latency (ms)	IFCN mean UL
N8	8.5 (10.5)
N22	22.0(24.5)
N37	37.5(42.0)
N8- P37	28.5(32.0)
N22-P37	15.5(18.5)

CLINICAL APPLICATIONS OF SSEP

- **1-DEMELINATING DISEASE-** Diagnostic yield in MS – Abn SEP-60 %, VEP-56%, BAEP-32% (chiappa. 1983)
- Yield of SEP- more with Tibial (64 % ,than median SEP- 54 %.
- **2-TRAUMA-** Preganglionic lesion- if Erb P. N9 –normal , and spinal N13 -NR or reduced. Abnormalities of both N9,N13 –suggest post ganglionic lesion/ combined .

- **3-VASCULAR LESIONS**– Dejerine roussy thalamic syndrome- SEP increased latency with reduced amplitude of cortical potentials.
- SEP changes in intracerebral hemorrhage , -nt SEP in large Hm. Unrecordable SEP associated with poorer motor functions.

- **4- MYOCLONUS-** In cortical myoclonus SEP reveal giant potentials..
- **5- Spinal cord tumors- extra and intramedullary –SEP abn**

- **6-SURGICAL MONITORING-** Scoliosis surgery, CTVS – coarctation of aorta and carotid endarterectomy.
- indicator of decrease cerebral blood flow

MOTOR EVOKED POTENTIALS

MEPs

- MEP refers to the electrical potentials recorded from muscle, ph nerve , or spinal cord in response to stimulation of the motor cortex or motor pathway within CNS.
- MEP are of higher amplitude ,do not require prolonged averaging and easier to carry out.
- 2 way of stimulation- Electrical/Magnetic
- ADV- magnetic stim painless but jerk noise produced., while electrical stim lower cost, more focal stim, relative lack of latency shift on activation, and lack of interhemispheric inhibition.

ELECTRODE PLACEMENT FOR ELECTRICAL STIMULATION

- Anode placed 5-7 cm lateral and 2 cm anterior to interaural line. For facial muscle , 9-11 cm lateral and 2-3 cm anterior , For LL & pelvic muscle– 2 cm ant to Cz.
- Cathode is placed 7 cm lateral away from anode over vertex for UL and facial muscle, 7 cm post to Cz for LL, and pelvic muscle stimulation.
- For spinal stim cathode placed on C7 spine and anode prox. for UL. whereas cathode placed on 1st lumbar spine and anode proximal for LL.

ELECTRODE PLACEMENT FOR MAGNETIC STIMULATION

- In magnetic stimulation-coil positioned knowing the direction of current flow and it should be centered on anodal positions.
- For focal stim 2 type coil- angulated round coil, butterfly or figure of 8th coil.
- Magnetic coil also stim the roots and ph nerve.
- MEP are commonly recorded from the contra lateral UL or LL. common recording site biceps,ADM ,APB in UL and TA, EDB in LL.

Magnetic stimulator -MAGSTIM

MEASUREMENT OF CMCT

- CMCT –measured by subtracting the latency of MEP on spinal stimulation from that cortical stimulation.
- CMCT =MEP latency -1/2 (M+F+1)
- Where M= latency of direct motor response and F= min latency of F wave.
- 2 Major Abn of MEP ……..
- 1-Prolongation of CMCT 2- In excitability of motor pathways.

ANALYSIS

- CMCT- difference in the latencies b/t cortical and spinal stim is known as CMCT.

Muscle	Latency (msec)	CMCT (msec)
Biceps	11.6+_1.2	4.9+_ 0.5
Deltoid	10.6 +_ 1.0	4.9+_ 0.5
Thenar	20.1+_ 1.8	6.4+_ 0.3
Tib anterior	26.7+_ 2.3	13.2+_ 0.7
Anal sphincter	22.8+- 3.6	13.3 +_2.3

Clinical application Of MEPs

IN HEAD AND SPINAL INJURY

Documenting motor deficit

Prognostic significant

- Intra op monitoring
- Demylinating disease
- Degenerative disease-MNDS
- Inflammatory disease

COGNITIVE EVOKED POTENTIALS
OR
ENDOGENOUS EVENT RELATED POTENTIALS

COGNITIVE EVOKED POTENTIALS

- These are long latency evoked potentials related to cognitive processing .
- Endogenous evoked potentials have a longer latency, higher amplitude, and lower frequency.
- It requires patient's attention and cooperation.
- P3 elicited by unexpected or infreq (target)stimulus in random pattern.
- Recent study- P3a generate from frontal area & insula , P3b- from parietal and inf. temporal area form- N1,N2,P2,P3

P3 or P300

- Electrodes – Recording- Fz, Cz, Pz, Ground -Fpz , Referred to link mastoid, ear, nose.
- Wave form- N1, N2, P2, P3
- P3 -Symmetric wave max over midline, central, parietal regions with a latency varying between 250 ms and 600 ms depending on the stimulus and subject parameters
- P3 morphology broad- P3a, P3b
- Meseaurement- point of max P3 amp.or Intersectional extrapolation
- Normal P3- 346.9+_ 38.1

Clinical applications of P3

- 1- Dementia- Abn in 30-80 %. ,But early stage-N
- 2- Parkinson –prolonged in demented PD
- 3- HIV infection- In ADC N2P3 abn
- 4- Psychiatric -Acute schizophrenia… Frontal P3 amp. decreased
- 5-Mental retardation-Down, Turner, P -W syndrome- attenuated P3
- 6- Nutrition/Toxic/Metabolic Disorder –Prolonged in hepatic and uremic coma (Cohen et al)

- Significance of NCV is that the distal latency and conduction velocity measurements are helpful in evaluating the speed of conduction along distal and mid portions of a peripheral nerve.
- F wave latency is used for the evaluation of proximal segments of motor nerve.
- H reflexes are most useful when peripheral conduction studies are normal; abnormal responses suggests a proximal lesion.

Preservation Of Facial Nerve Function During Operations In CP Angles

- Monitoring of contractions of the facial muscles is performed during CP angle operations.
- Hand held stimulating electrode ,of short pulses is used.
- Recently ,EMG is determined from facial musculatures & recording of movements of the face using electronic sensors ;as these recordings are audible.
- Trigeminal nerve stimulation differs from facial nerve.
- EMG potentials are able to measure the latencies of the responses accurately.
- Bipolar and monopolar electrode can be used.
- Electric stimulation should consist of negative impulses of short durations.

ELECTROENCEPHALOGRAPHY

- It provides a non invasive method for studying the ongoing or spontaneous electrical activity of the brain.

TYPES OF WAVE FORMS :

- Alpha rhythm – it is forms when patient is awake ,but at rest with the eyes closed .it has periodicity of 8-12 hz.
- Beta rhythm- is characterized by low amplitude waves with a rhythm faster than 12 hz,most prominent in the frontal region.
- Theta rhythm – are seen over temporal lobes bilaterally mostly in older individual, but can occur as a result of focal or generalized ,cerebral dysfunction.
- Spikes waves- hace characteristic features and can occur as apart of seizure discharge or interictally in patients with epilepsy.

BISPECTRAL INDEX

- The Bispectral Index, that monitors the effects of anesthetics and other pharmaco-logical agents on the hypnotic state of the brain ,by recording EEG.
- Several clinical studies, and a growing body of evi-dence from routine users have shown that use of the BIS to manage anesthesia leads to:

  less drug usage

  faster wake-up in the OR

  earlier discharge eligibility from the PACU

  higher quality recovery

  significant cost savings.

- The Bispectral Index is computed real-time using a combination of three analysis steps.
- The first step is an EEG pre-processor, which breaks the EEG signal down second by second and marks those segments containing artifact that might arise from movement, EMG or electrocautery equipment. Segments of suppressed EEG are also identified.
- The second step is the calculation of the hypnosis/ sedation index by combining selected EEG features using the algorithm which was developed as previously described.
- In the third step, the hypno-sis/sedation index is modified to better reflect the level of suppression in the EEG.

- **Frequency Band Frequency Range (Hz)**
- Very Low Frequencies (Delta) 0-4 Hz
- Low Frequencies (Theta) 4-8 Hz
- Medium Frequencies (Alpha) 8-14 Hz
- High Frequencies (Beta) 14-30 Hz

THANKS