A Comprehensive Overview of Auditory Brainstem Responses (ABR)

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2024/27/11

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Audiology & Balance

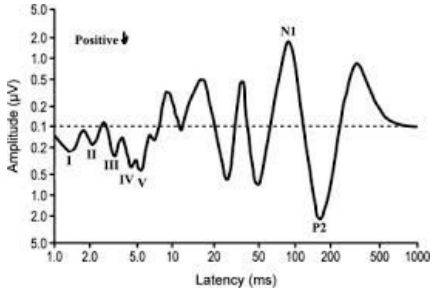
Risks/Limitations

- The applicability and accuracy of the course content may vary by the clinical, geographical, and cultural context; you should evaluate the course accordingly.
- As healthcare is rapidly evolving, new findings may change the validity of the information presented in this course. Providers should always consult the latest research and guidelines from professional associations.
- The interventions discussed in this course may be limited in generalizability, requiring practitioners to consider specific individual and population factors.
- The course may not cover all possible risk factors, diagnostic methods, or treatment options, and complex cases may require additional considerations.
- Healthcare providers should apply cultural competence and sensitivity to ensure effective and respectful care based on their patients' diverse needs.
- Providers should always evaluate the limitations of diagnostic and screening tools, considering their potential for false results as well as any ethical implications.
- It is the responsibility of course participants to critically evaluate the evidence from multiple sources to guide professional practice.

Learner Outcomes

- After this course, participants will be able to identify the key components and waveform patterns of Auditory Brainstem Responses (ABR) and their clinical significance.
- After this course, participants will be able to explain how to apply appropriate stimulus and acquisition parameters for conducting ABR tests across different patient populations.
- After this course, participants will be able to discuss how to interpret ABR results to differentiate between normal and abnormal patterns, including their implications for diagnosing hearing and neurological disorders.

Intro to the Webinar



- The webinar will present a general excursus into the area of Auditory Brainstem Responses (ABR), which as of today represent the most clinically used procedure to assess the functionality of the Auditory system from the Periphery to the Auditory Brainstem.
- The webinar contains elements from the graduate course in Audiology, University of Ferrara.

Sections of the webinar

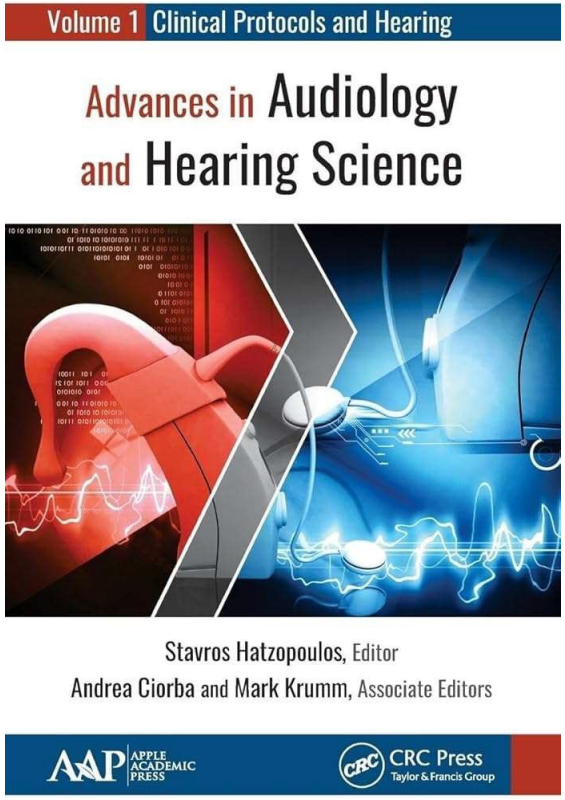
(1) A historical perspective of ABR, the relative anatomy and the waveform terminology.

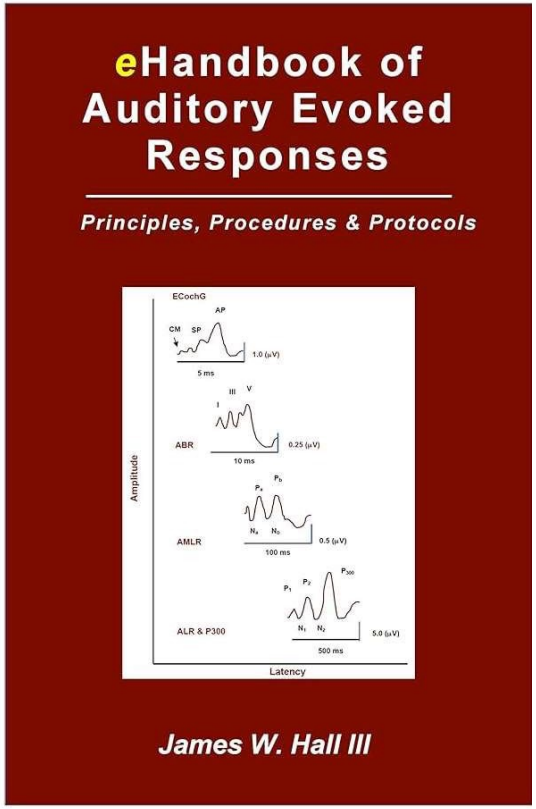
(2) Stimulus parameters, acquisition parameters and test ABR protocols.

(3) Analysis of the ABR response (conventional responses, abnormal ABR patterns, non -pathologic subject factors, the effect of drugs on the ABR morphology)

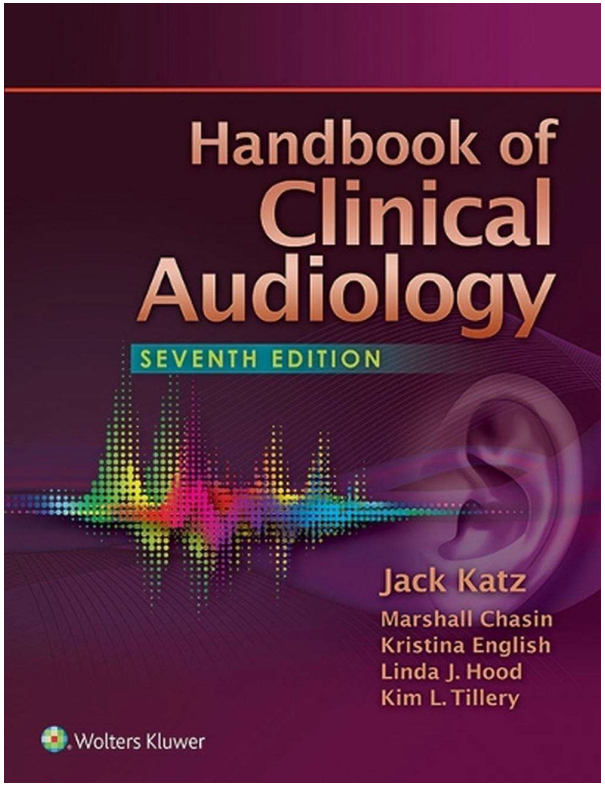
(4) A short exposure of the Clinical ABR applications (hearing screening, hearing disorders, intra-operative monitoring)

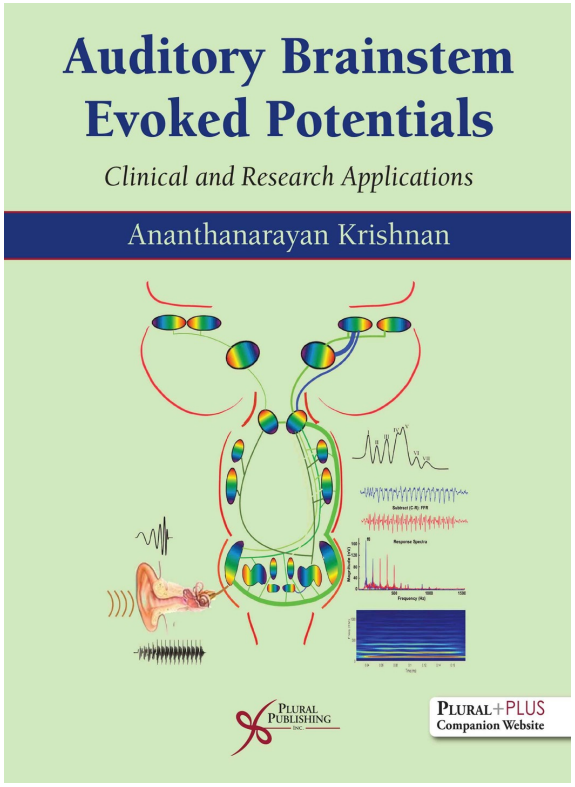
References


Volume 1 Clinical Protocols and Hearing
Advances in Audiology and Hearing Science
Stavros Hatzopoulos, Editor
Andrea Ciorba and Mark Krumm, Associate Editors
AAP APPLE ACADEMIC PRESS
CRC CRC Press Taylor & Francis Group

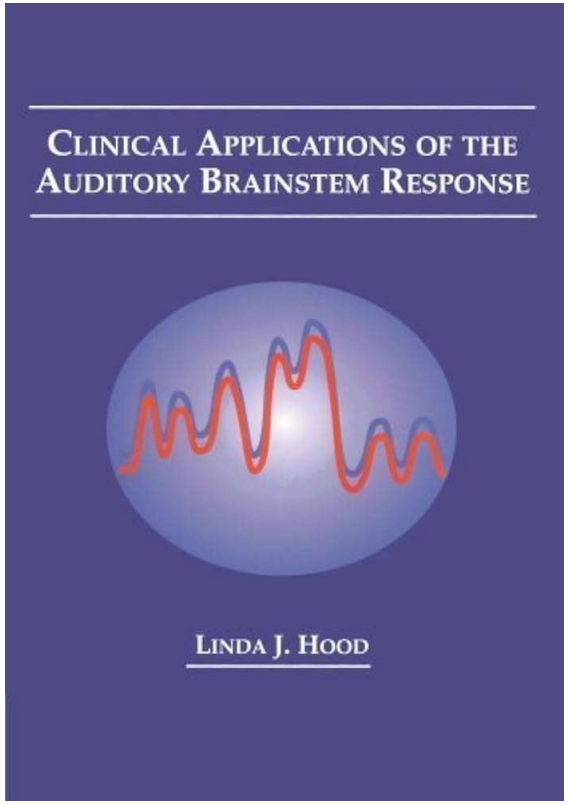

eHandbook of Auditory Evoked Responses
Principles, Procedures & Protocols
ECochG
AP
CM SP
1.0 (μV)
5 ms
ABR
0.25 (μV)
10 ms
AMLR
0.5 (μV)
100 ms
ALR & P300
5.0 (μV)
500 ms
Amplitude
Latency
James W. Hall III

References


Handbook of
Clinical
Audiology
SEVENTH EDITION
Jack Katz
Marshall Chasin
Kristina English
Linda J. Hood
Kim L. Tillery
Wolters Kluwer


Auditory Brainstem
Evoked Potentials
Clinical and Research Applications
Ananthanarayan Krishnan
Plural Publishing
Plural+Plus
Companion Website

References


CLINICAL APPLICATIONS OF THE
AUDITORY BRAINSTEM RESPONSE
LINDA J. HOOD

Section 1

A historical perspective of ABR, the relative anatomy and the waveform terminology.

Section 1 : Sound Transduction Pathway

SECTION 1: Evoked Potentials (EPs)

- The Evoked Potentials are electrical signals (potentials = differential signals), generated by groups of neurons, in response to a stimulation of a sense organ (ear, eye etc.).
- These small signals are usually acquired by surface electrodes, they are averaged and then amplified.

Nonmeclature

ABR: Auditory Brainstem Response (Audiology version)

BAER: Brainstem Auditory Evoked Response (Neuroscience version).

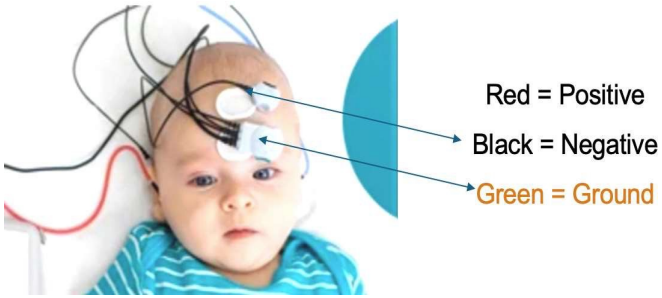
BAEPs: Brainstem Auditory Evoked Potentials (Neuroscience)

SECTION 1: The Historical Perspective

As early as 1967, Harvey (Haim) Sohmer and Moshe Feinmesser in a paper entitled "Cochlear Action Potentials Recorded from the External Ear in Man" showed waveforms resembling what we now would recognize as an upside down or inverted ABR.

SECTION 1: The Historical Perspective

Although these authors were investigating a non-invasive extra-tympanic technique for recording the ECochG, their electrode array was actually not that different from the electrode locations most audiologists use in ABR measurement with a non-inverting electrode on the earlobe and an inverting electrode on the bony bridge of the nose.



Section 1 : ABR Developments in the 70s & 80s

1970: Jewett described ABR in animal model
1970: Jewett, Romano & Williston first describe ABR in humans
1971: Jewett & Williston systematic study ABR in humans
1971: Moore completed unpublished PhD project revealing ABR
1973: Terkildsen, Osterhammel and colleagues conducted a series of studies on stimulus and acquisition parameters
1974: Hecox & Galambos described ABR in infants and children
1975: Schulman-Galambos & Galambos described ABR in premature infants
1975: Starr described ABR in patients with varied CNS pathologies
1976: Salamy investigated development of ABR in neonates
1976 Robinson & Rudge studied ABR in multiple sclerosis
1976: Davis described ABR slow negative wave (SN 10) in humans
1976: Greenberg applied ABR with other responses in acute head injury
1977: Selters & Brackmann applied ABR in acoustic tumor detection
1977: Clemis applied ABR in acoustic tumor detection
1977: Terkildsen et al applied ABR in acoustic tumor detection
1977: Stockard & Rossiter reported ABR in varied CNS pathologies
1977: Arlinger recorded ABR evoked with bone conduction stimulation
1977: Robinson & Rudge described ABR in multiple sclerosis
1978: Stockard, Stockard & Sharbrough published monograph on measurement
1978: Don & Eggermont investigated high pass masking for frequency specific ABR techniques
1979: Jerger & Mauldin described clinical bone conduction ABR data
1979: Yamada studied the effects of cochlear hearing impairment on ABR
1979: Chiappa described normal ABR variations
1979: Dobie & Berlin investigated binaurally elicited ABR
1979: Don studied frequency specific ABR with masking paradigms
1980: Jerger & Hall studied effect of age and gender on ABR

James Hall III : Handbook of Auditory Evoked Responses

Section 1 : What Happens upon stimulation

- *The cochlea, is stimulated by the broad sound spectrum of the transient stimulus (click) activating the hair cells within a wide region of the basilar membrane.*
- *The small electrode responses are averaged over time (500, 1000, 1500, or 2000 sweeps) and then amplified.*

Section 1 : What Happens upon stimulation

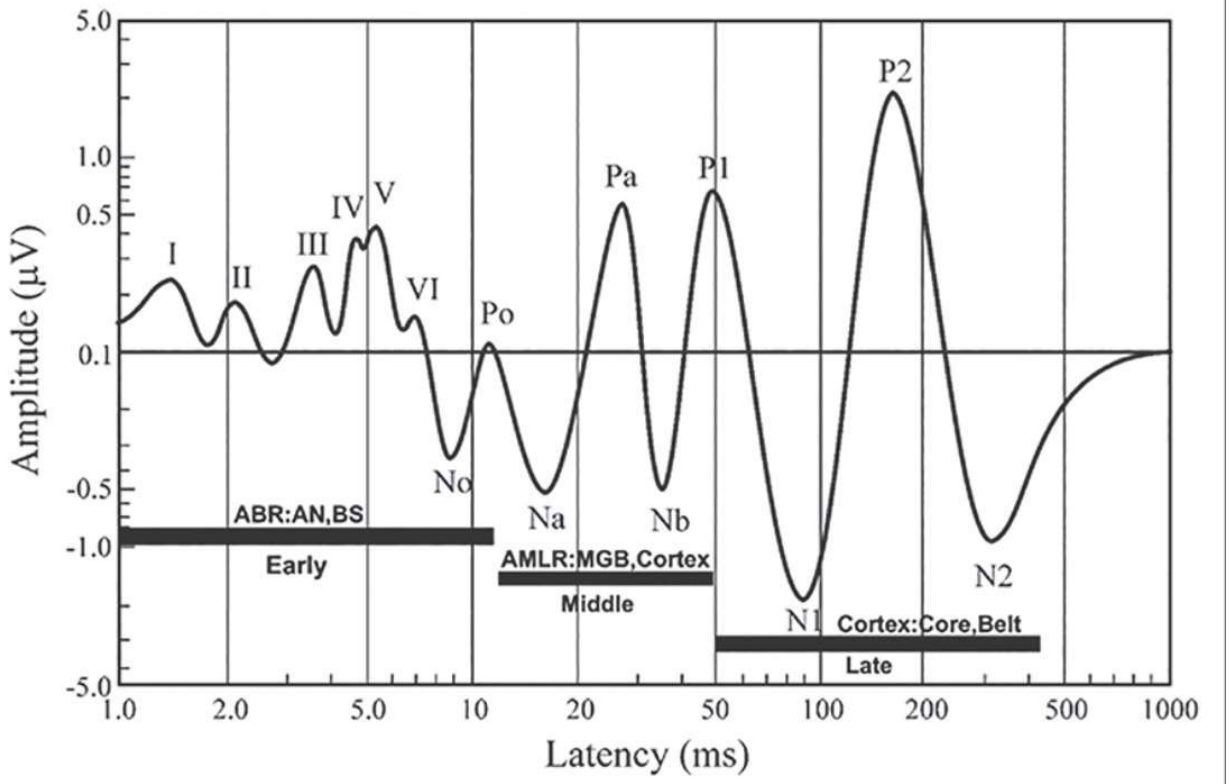
The frequency content of the auditory evoked response depends on a variety of other factors, such as:

- *(i)the stimulus intensity;*
- *(ii) the electro-acoustic properties of the transducer; (iii) the external and middle ear properties affecting sound transmission;*
- *and (iv) the functional status of the cochlear amplifier.*

Section 1 : What Happens upon stimulation

- *The ABR evoked with highly transient stimuli (clicks) cannot be used to define hearing sensitivity or cochlear status at audiometric frequencies or for specific frequency regions.*
- *Tone bursts and chirps are necessary in adult / pediatric applications of the ABR.*

Section 1 : What Happens upon stimulation. The Overall Response



Terence W. Picton: Human Auditory Evoked Potentials

Section 1 : What Happens upon stimulation

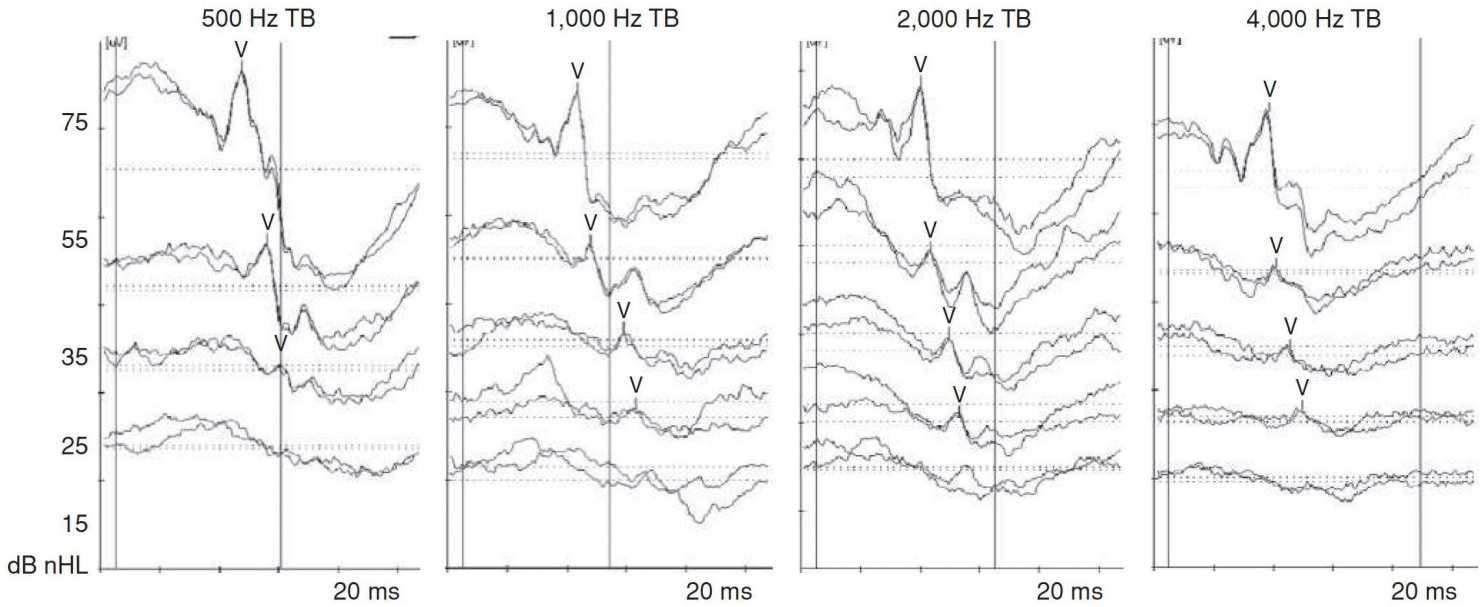


FIGURE 14.2 ABRs to tone bursts centered at 500, 1,000, 2,000, and 4,000 Hz recorded from an individual with normal hearing. The latencies of Wave V at 75 dB nHL are 8.53 ms for a 500-Hz tone burst, 7.70 ms for a 1,000-Hz tone burst, 7.03 ms for a 2,000-Hz tone burst, and 6.53 ms for a 4,000-Hz tone burst, demonstrating the latency decrease as center frequency of the tone burst increases.

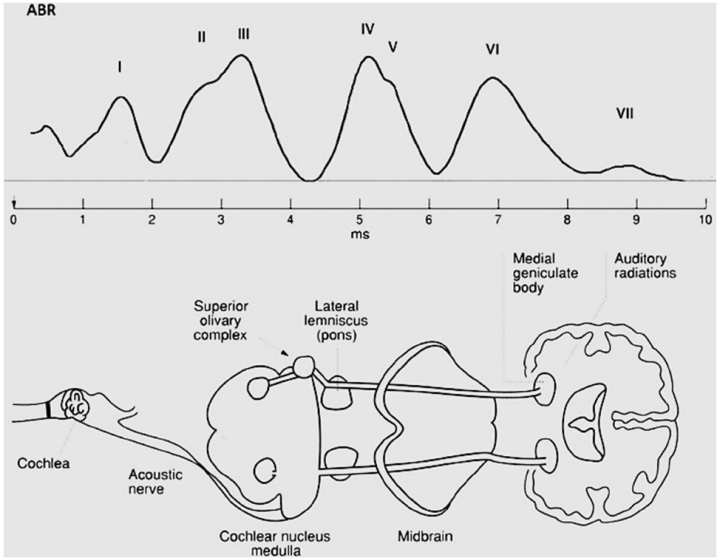
Linda Hood –Handbook of Clinical Audiology – Chapter 14

Section 1 : Waveform Terminology

Wave I: arises from eighth nerve potentials in man. The same is valid for various animal models. For the human data, multiple studies were conducted in the 80s.

Wave II: arises from the activity of the first order neurons (8th nerve) versus the auditory brainstem.

Wave III: Was traditionally believed that it was generated from neuronal activity in the Superior Olivary Complex (SOC). Data from intra-cranial recordings and EMF dipole models suggest that Wave III is generated beyond the 8th nerve closer to the Cochlear Nucleus (CN), where the negative pattern after wave III, it is believed that it is generated from the Trapezoidal Body (TB).



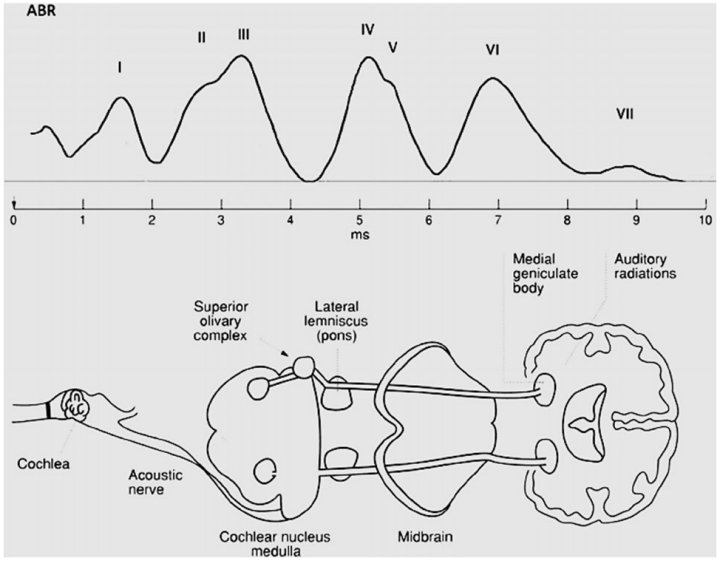
Section 1 : Waveform Terminology

Note: As we move towards the upper Cortex the spatial contribution of the various segments to ABR becomes quite complicated.

Wave IV: Often appears as the leading peak before Wave V. As in the case of Wave III, Intracranial research in the 80s and 90s, suggests that Wave IV arises from neurons in the pons primarily located in the Superior Olivary Complex (SOC).

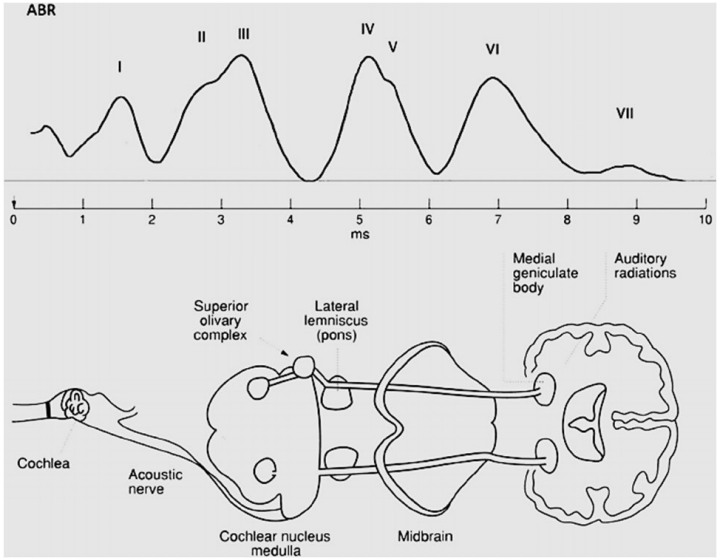
Wave V: Traditionally, Wave V was hypothesized to be generated by neurons in the Inferior Colliculus (IC). But more recent experiments with dipole models suggested that this wave is generated at the end of Lateral Lemniscus (LL) as its fibers enter the Inferior Colliculus.

NOTE: this is in a contralateral scheme to the stimulated ear.

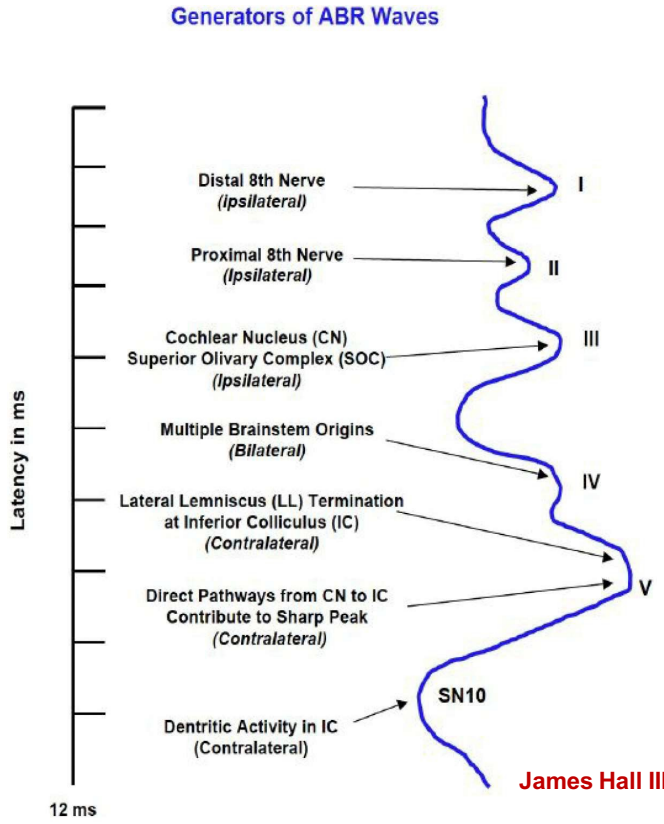


Section 1 : Waveform Terminology

Wave VI & VII: The exact spatial contributors of these two ABR components are still not well-defined. Some early observations in the 70s suggested that the generators might be located within the Thalamus in the Medial Geniculate Body (MGB). Other research (i.e Møller) suggests that these peaks originate from neurons in the Inferior Colliculus.



Section 1 : Summarizing the research data



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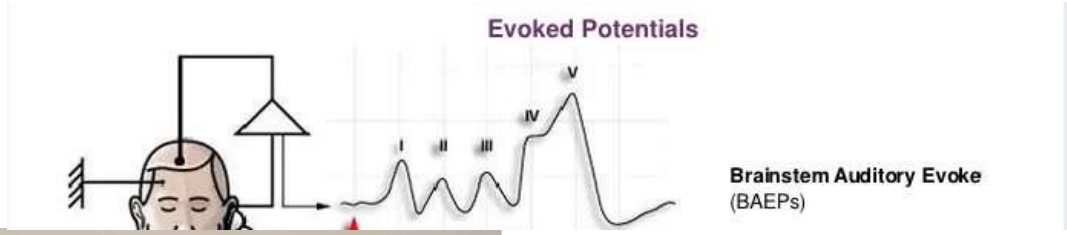
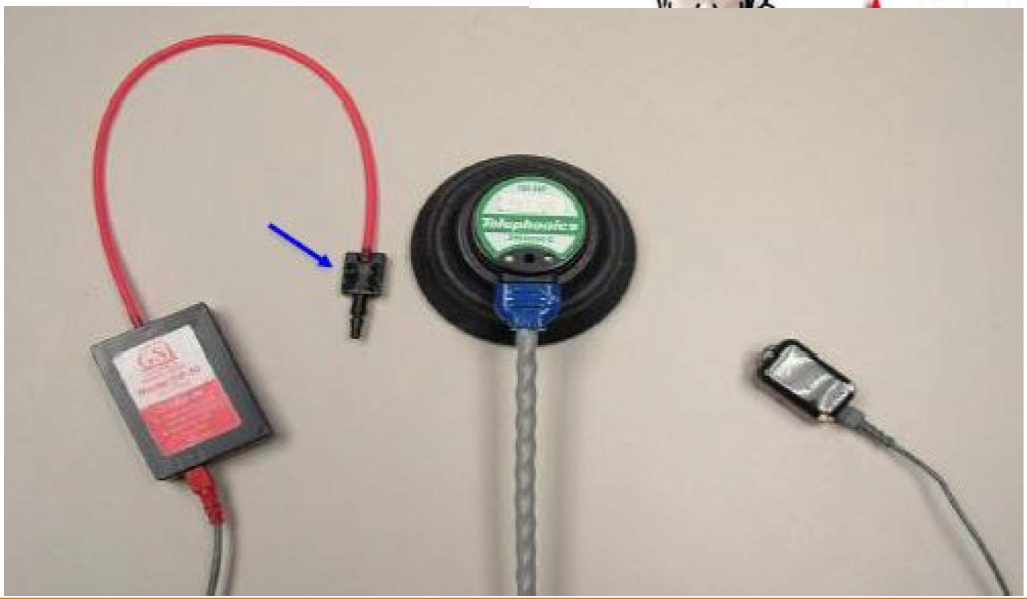
Section 2

Stimulus parameters, acquisition parameters and test ABR protocols.

Section 2 : Transducer types

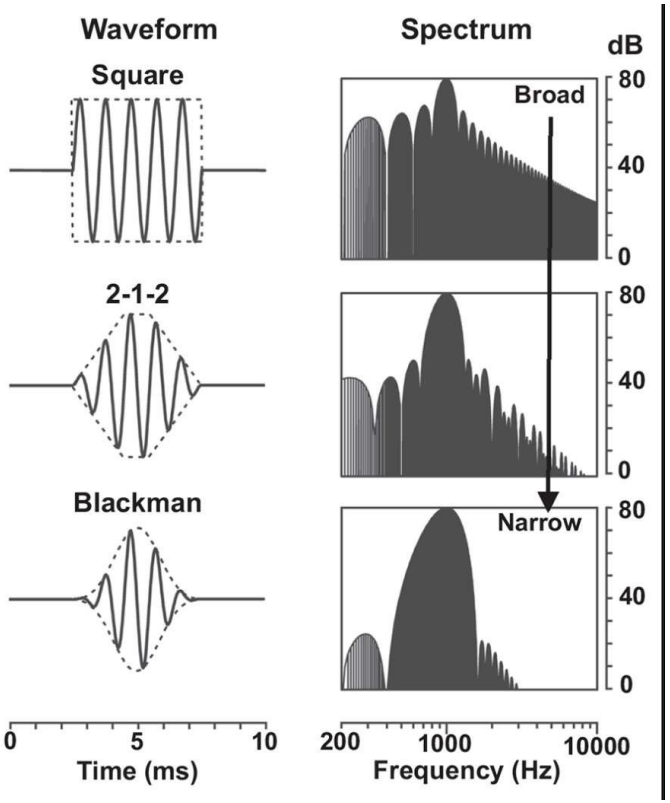




Left to Right:
Insert, disc electrode,
bone conduction oscillator.

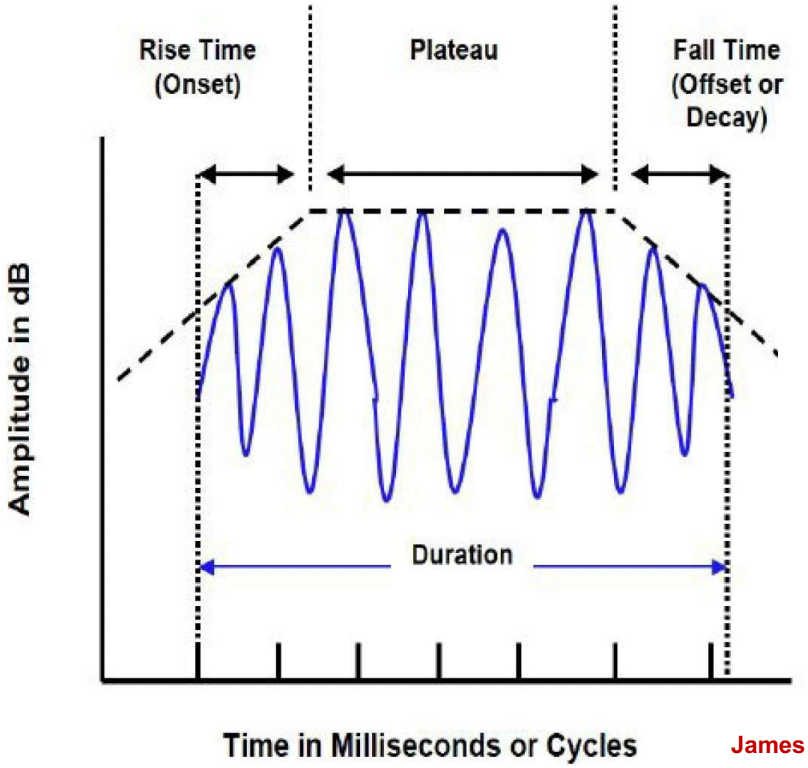
For the ABR acquisition we use an insert for the acoustic stimulation and disc electrodes for the signal recording.

Section 2 : Managing the form of the stimuli



In order to select which cochlear partitions (i.e. tested octaves) are to be stimulated , the ANALOG transient stimuli can be manipulated in such a way that their spectra show peaks in the areas of interest.

Section 2 : Stimulus parameters



Tone Burst Frequency	Duration in Milliseconds			
	Rise	Plateau	Fall	Total
500 Hz	4	0	4	8
1000 Hz	2	0	2	4
2000 Hz	1	0	1	2
4000 Hz	0.5	0.5	0.5	1.5

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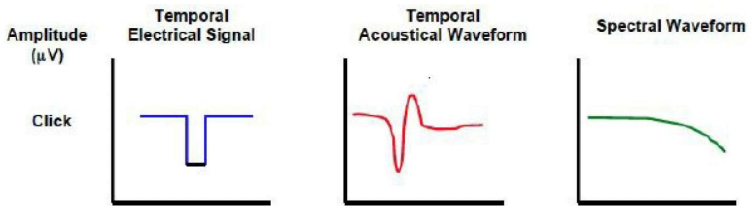
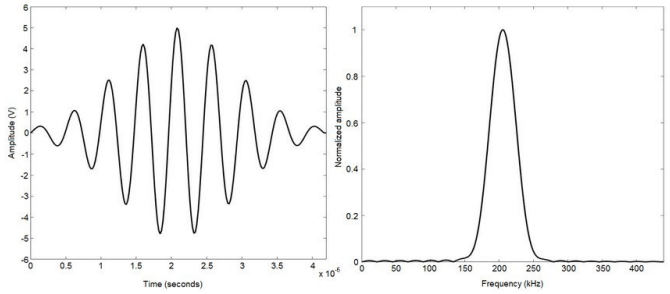
Section 2 : Common Stimuli (air conduction)

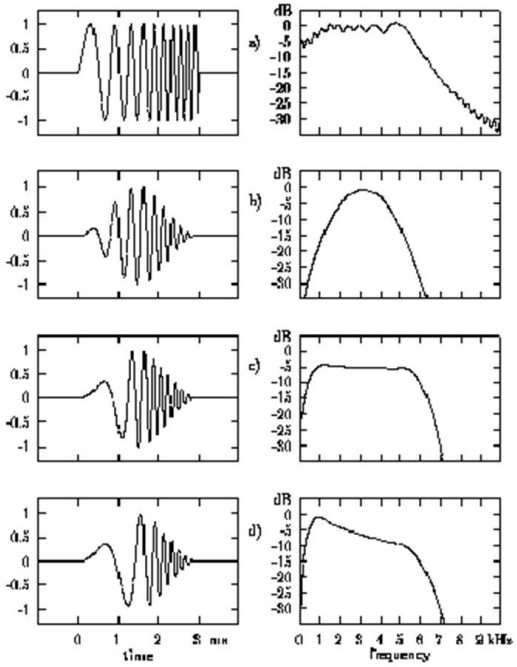
Clicks
(max 2 KHz)



Tone-bursts
(max = Fc)

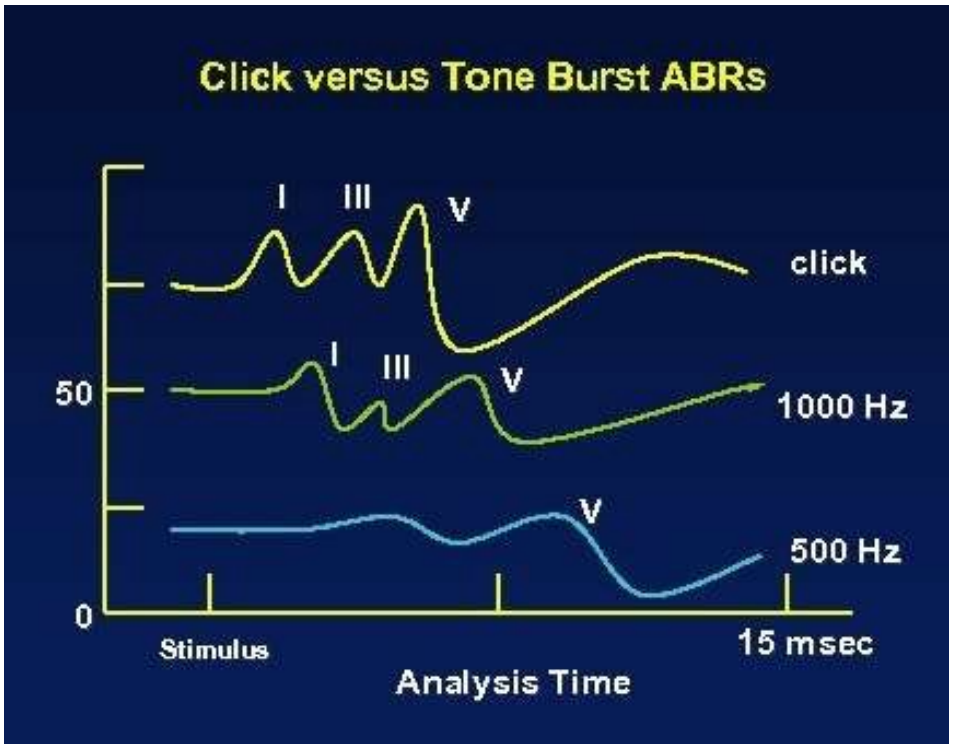


Chirp types



Obviously with different stimuli we <u>record relatively DIFFERENT</u> ABR morphologies !!!!

Section 2 : Common Stimuli (air conduction)



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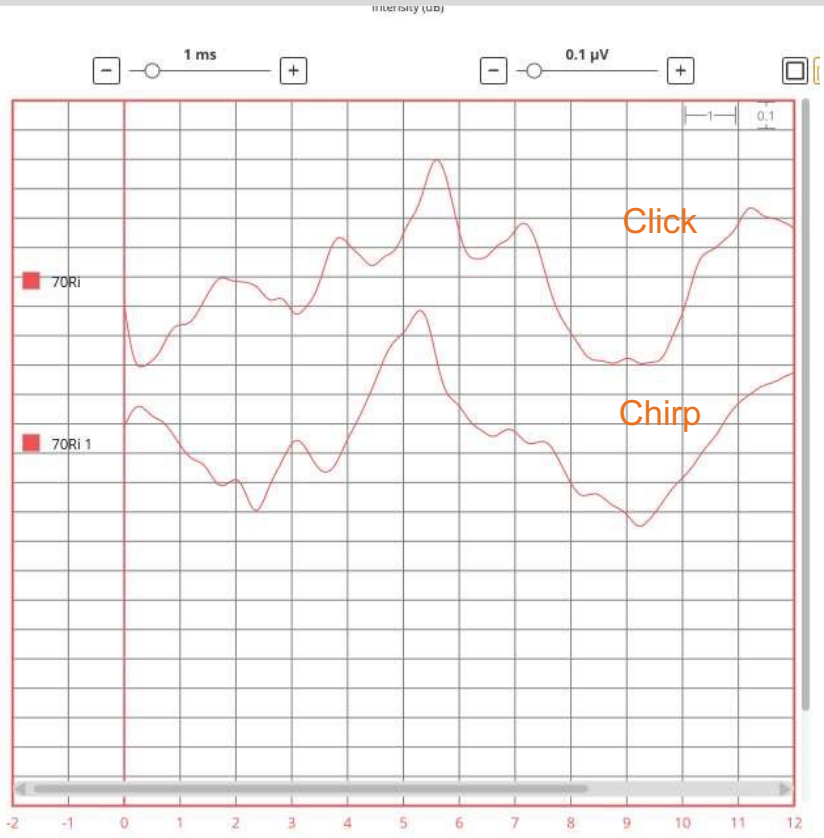
Obviously with different stimuli

we record relatively DIFFERENT ABR morphologies !!!!

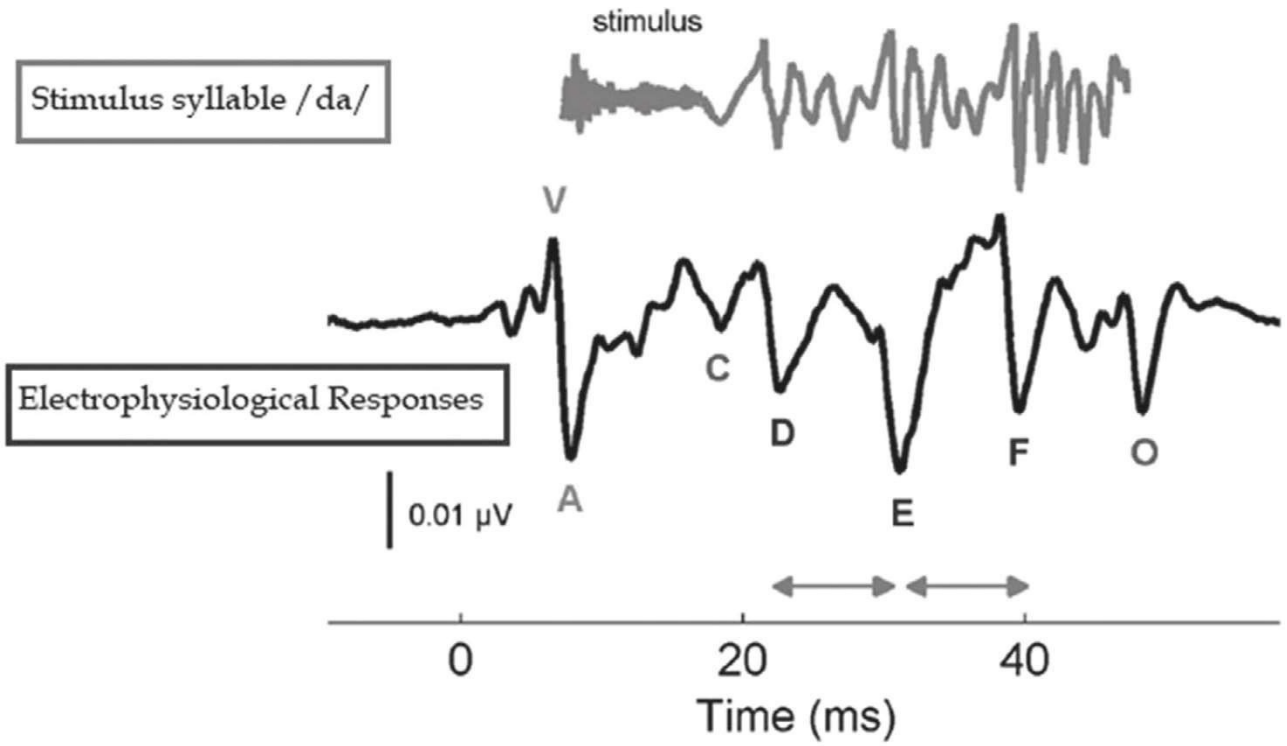
Section 2 : Chirp vs Click stimuli



With chirps wave V registers as a much larger response. often as a doubling in amplitude. This offers a number of clinical advantages including: 1)a more confident identification of wave V near the minimum response level or threshold; 2) the detection of an ABR at lower intensity levels for presumably more accurate estimations of thresholds; and 3) a decreased ABR acquisition time. The latter is crucial in the Pediatric ABR applications.

Section 2 : A new type of stimulation

Speech Evoked ABR (Frequency Following Response)



Sanfins & Hatzopoulos, IJPORL 90,(2016) 12-19

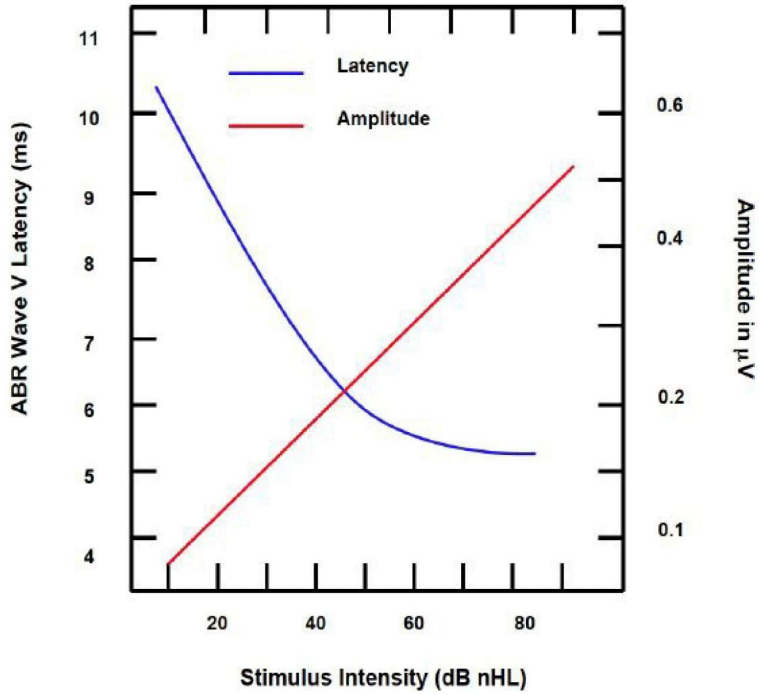
Section 2 : Technical Issues

Factors & Parameters affecting the ABR Recording

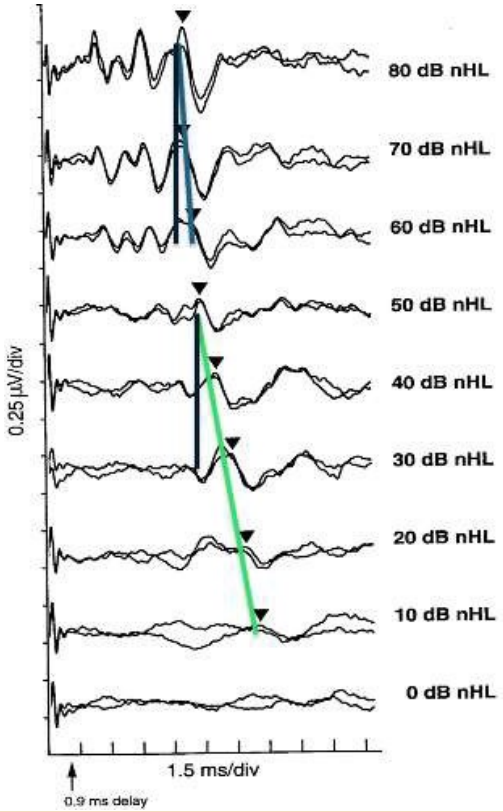
Stimulus Factors	Recording Factors	Patient Factors
Intensity	Electrode montage	Age
Rate	Filter settings	Gender
Polarity	Time window	Medications
Duration/rise time	Number of channels	Attention
Frequency	Number of sweeps	Body temperature
Monaural/binaural		Muscle artifact

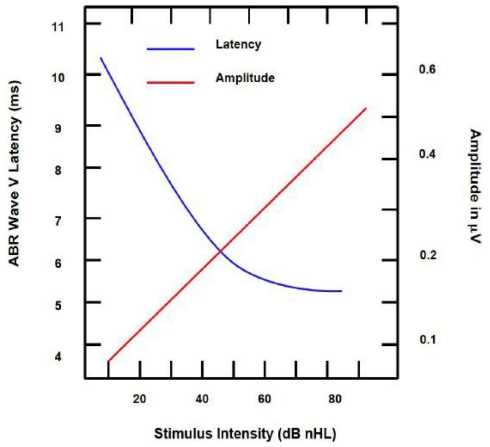
Section 2 : Stimulus Intensity

- As the stimulus intensity □
  - Latencies □
  - Amplitudes □
- The latency changes occur slowly for intensities from 90 to 60 dBnHL and then they increase more rapidly at lower intensity levels.



Section 2 : Stimulus Intensity in Wave V

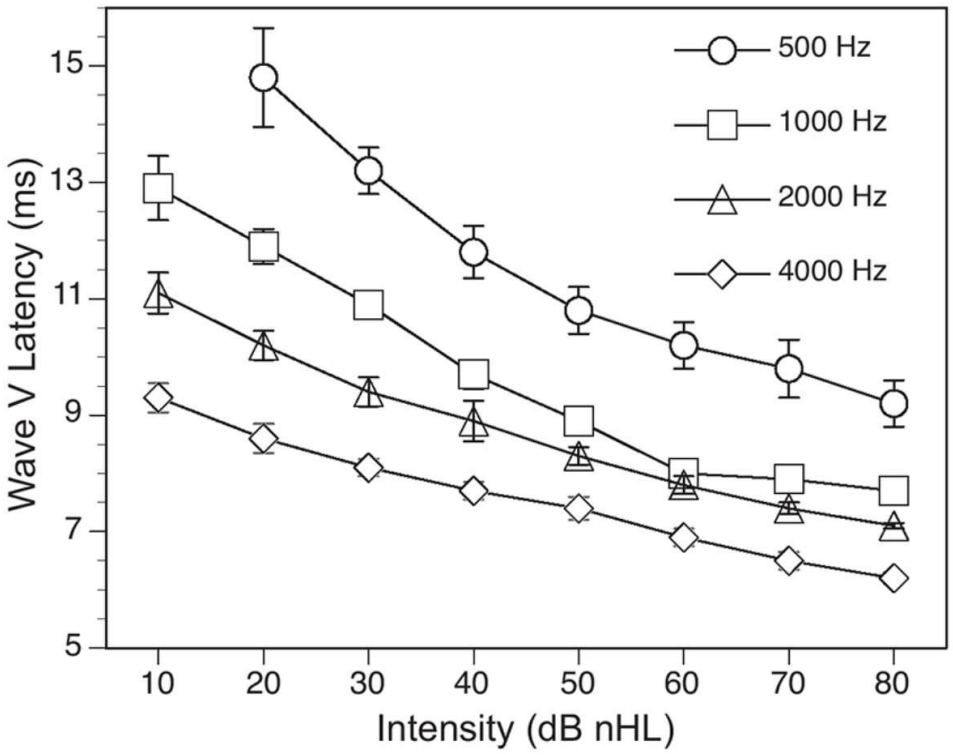




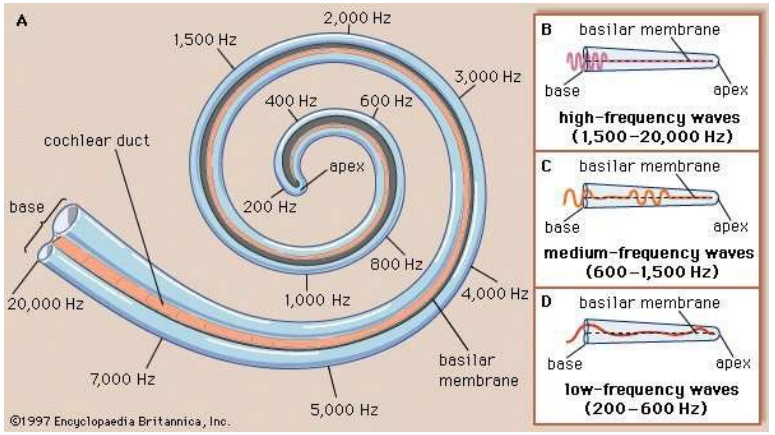
- At lower intensity levels, wave V is mostly visible.
- Earlier components tend to become indistinguishable at 30 dB.
- Near the threshold of the response, wave I occurs at approximately 4.0ms; wave V at 7-9ms.

  Wave I latency shifts more than wave V

Section 2 : Stimulus Intensity in Wave V



Ananthanarayan Krishnan Auditory Brainstem Evoked Potentials



Section 2 : Stimulus Intensity & mean Latency values

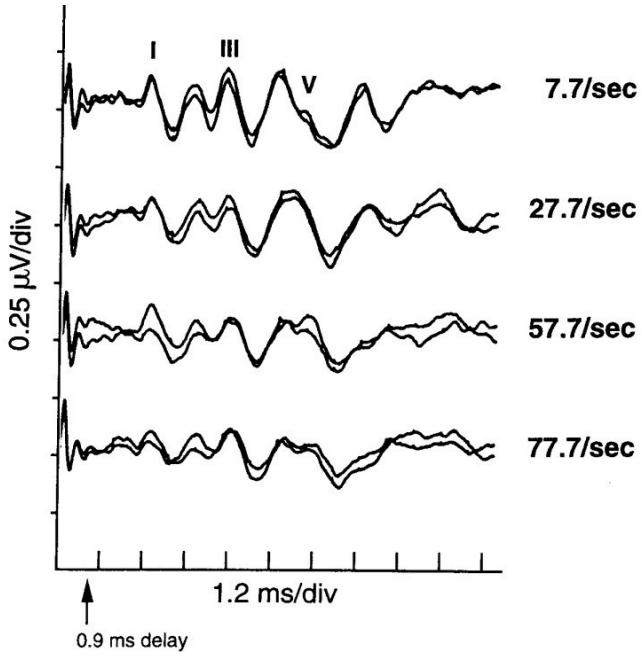
Stimulus Intensity		Absolute Latency (ms) I	II	III	IV	V	VI	Interwave Latency (dB) I–III	III–V	I–V
90 dB nHL 126 dB pSP	Mean	1.53	2.53	3.58	4.56	5.37	7.09	2.05	1.79	3.84
	SD	.11	.09	.09	.17	.12	.39	.14	.14	.16
	n	14	14	14	14	14	14	14	14	14
80 dB nHL 116 dB pSP	Mean	1.62	2.68	3.68	4.68	5.47	7.29	2.06	1.79	3.85
	SD	.12	.11	.08	.22	.12	.17	.11	.09	.14
	n	14	13	14	11	14	13	14	14	14
70 dB nHL 106 dB pSP	Mean	1.82	2.79	3.85	4.92	5.64	7.31	2.03	1.79	3.82
	SD	.17	.12	.13	.24	.16	.19	.11	.12	.11
	n	14	11	14	11	14	9	14	14	14
60 dB nHL 96 dB pSP	Mean	2.04	2.98	4.06	5.11	5.88	7.34	2.02	1.72	3.75
	SD	.20	.15	.21	.31	.25	.31	.12	.10	.11
	n	9	6	10	9	14	9	8	10	9
50 dB nHL 86 dB pSP	Mean	2.43	3.69	4.60	5.43	6.19	8.24	2.02	1.56	3.64
	SD	.17	.10	.23	.25	.32	.34	.19	.18	.19
	n	4	2	13	5	14	2	4	13	4
40 dB nHL 76 dB pSP	Mean	3.01	4.05	4.94	5.65	6.65	—	1.85	1.71	3.60
	SD	.25	.18	.25	.49	.32	—	.14	.14	.11
	n	4	2	7	5	14	—	4	7	4
30 dB nHL 66 dB pSP	Mean	—	—	5.45	—	7.24	—	—	1.74	—
	SD	—	—	.30	—	.42	—	—	.26	—
	n	—	—	7	—	14	—	—	7	—
20 dB nHL 56 dB pSP	Mean	—	—	5.56	—	7.52	—	—	1.88	—
	SD	—	—	.57	—	.63	—	—	.23	—
	n	—	—	2	—	7	—	—	2	—

Note: Intensity is expressed in nHL (level relative to a group of normal-hearing listeners) and pSP (peak sound pressure). Latency is in milliseconds and n is the number of subjects.

NOTE: For practical Reasons

pSP= SPL

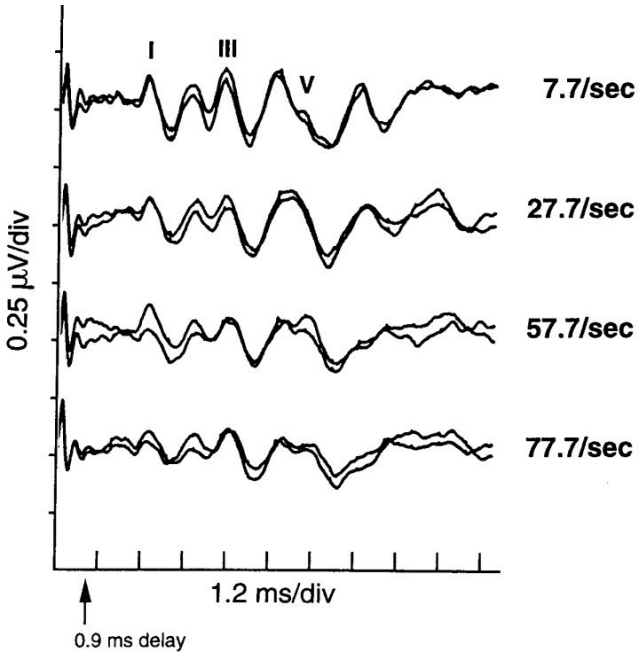
Section 2 : The stimulation rate



Rate	Wave I	III	V	I-III	III-V	I-V
7.7/s	1.52	3.66	5.89	2.14	2.23	4.37
27.7/s	1.62	3.80	5.89	2.18	2.09	4.27
57.7/s	1.62	3.90	6.11	2.28	2.21	4.49
77.7/s	1.69	3.95	6.30	2.26	2.35	4.61

Terence W. Picton: Human Auditory Evoked Potentials

Section 2 : The stimulation rate



High stimulus rates affect the wave latencies AND the Inter-wave latency differences.

Lets recall that the*Stimulus rate has a more pronounced influence on:*

- *ABR latency for premature than term neonates.*
- *For younger children under age 18 months than for older children*
- *For older children up to age 13 years than adults*

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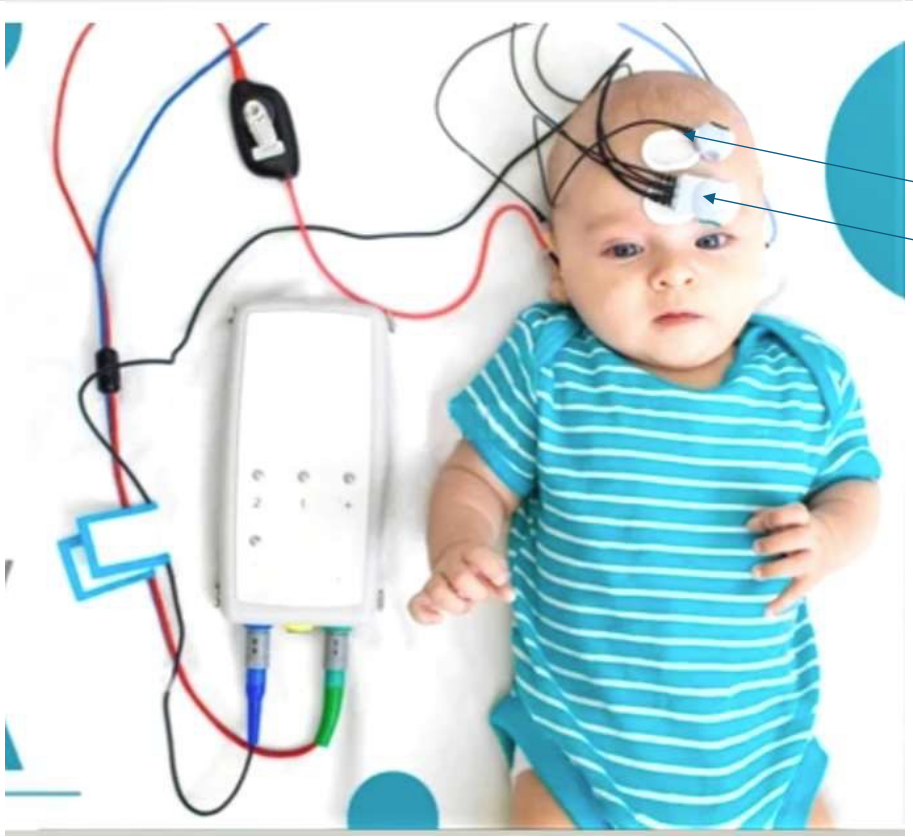
Section 2 : Electrode Montage-infants



Red = Positive

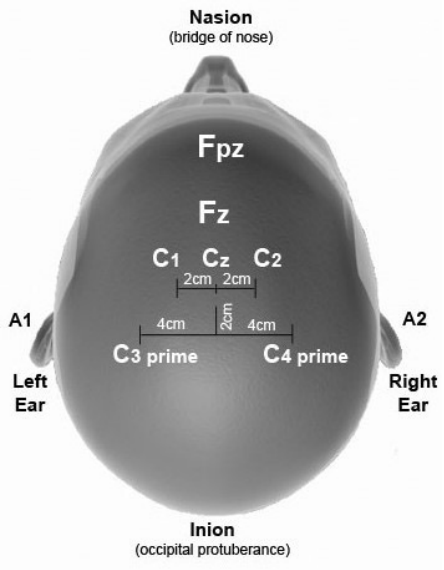
Black = Negative

Green = Ground

Section 2 : Electrode Montage

- Reccomended electrode placement for most conditions:
  - Cz (vertex);
  - A1 Lt ear, A2 Rt ear

Fpz (ground): can be put anywhere on the body, usually on the forehead.



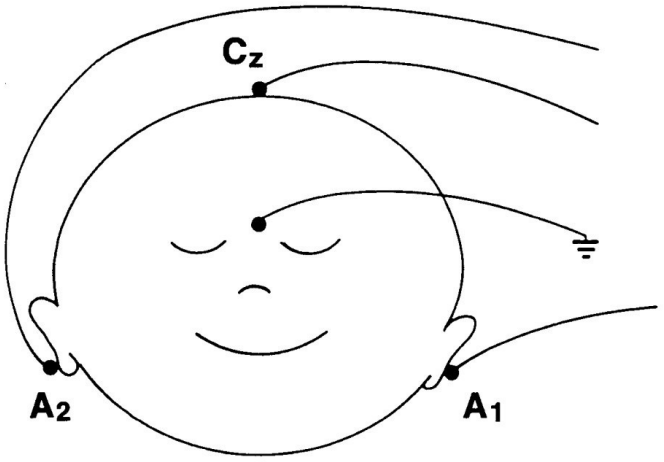


Figure 3-6. Electrode positions used for a two-channel ABR recording.

Section 2 : Electrode Montage

- Wave I-III: more prominent in ipsilateral recordings
- Wave IV, V: often better separated in contralateral recordings

- Earlobes sites: less muscle potential and greater wave I amplitude (than mastoid recording sites)
- Use of non-cephalic site (C7 vertebra): **enhance** wave V, VI

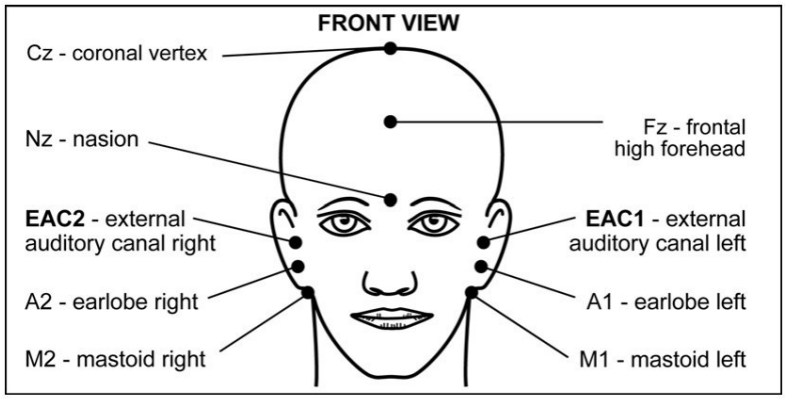
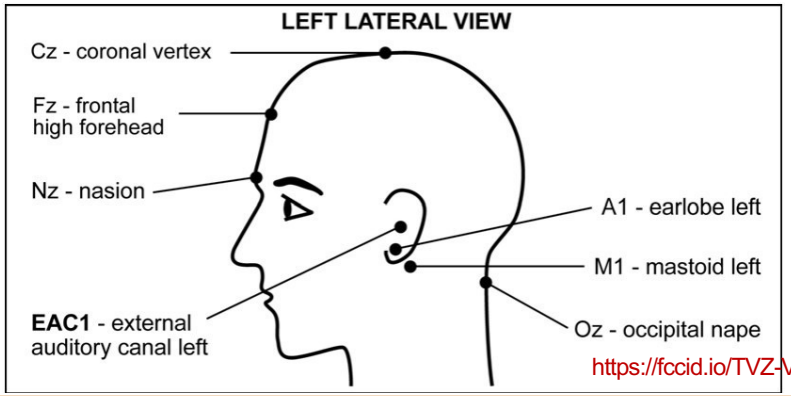


Figure 61 Typical electrode placement diagram - front view



Attention at the Hair !!!!!

They can cause

very large electrode impedance

https://fccid.io/TVZ-V50/User-Manual/USERS-MANUAL-2-624488

Section 2 : Electrode Montage

- Wave I-III: more prominent in ipsilateral recordings
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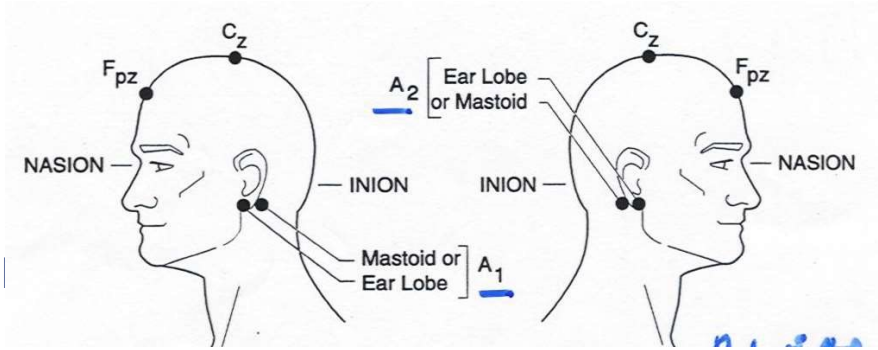


Attention at the Hair !!!!!

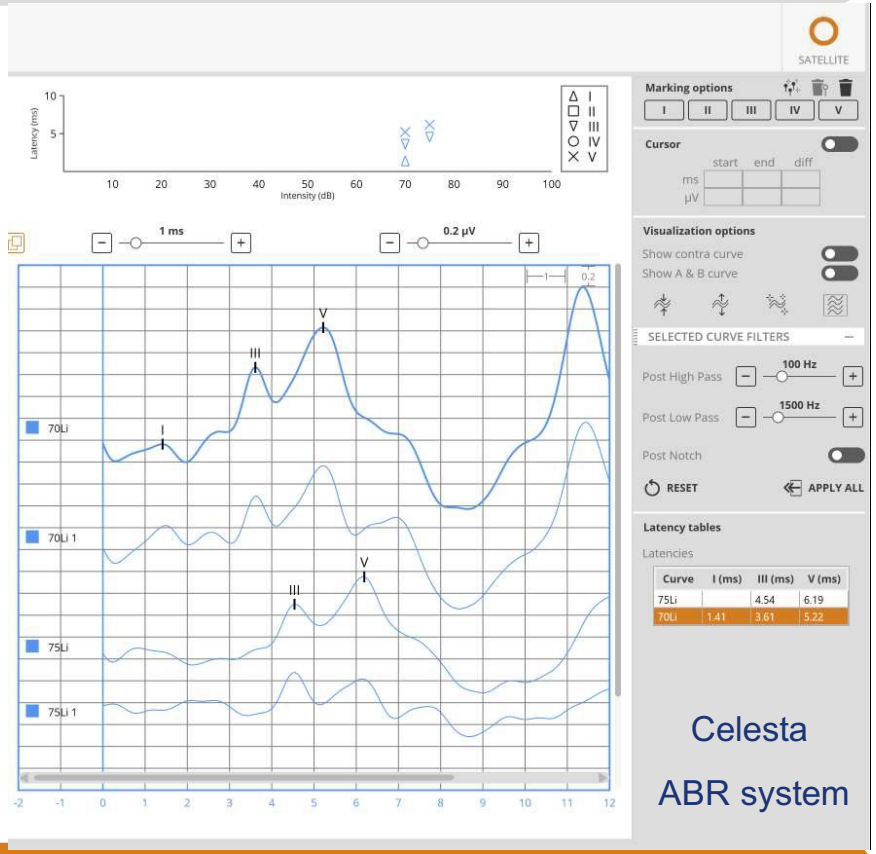
They can cause

very large electrode impedance

Section 2 : Filtering

- Filtering of the physiological response is used to eliminate as much as internal noise (e.g., unrelated muscle potentials), & external electrical noise (from environment 60Hz) as possible.

- Increasing the high-pass filter cutoff frequency (decreases low frequency energy) from 30Hz to 100Hz or 150Hz
  - DECREASES the amplitude and latency of the response

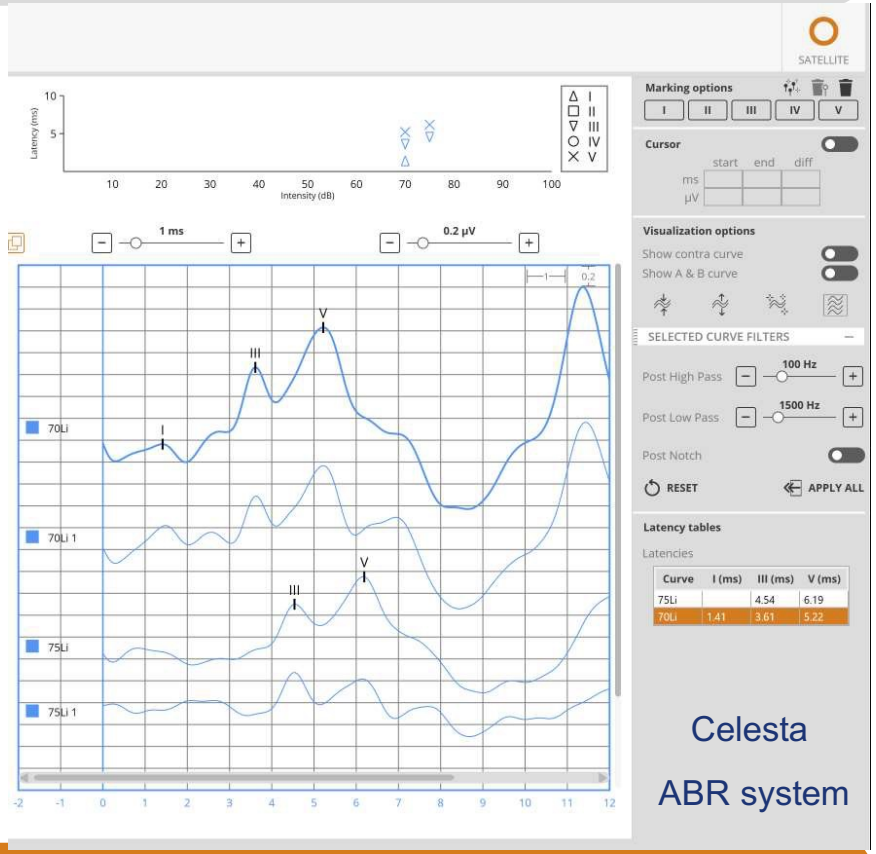


Celesta

ABR system

Section 2 : Filtering

- Allowing more low frequency information into the average:
  - Amplitude increases (particularly later components)
  - The Latency values slightly Increase
- Decreasing the low-pass filter cutting frequency (e.g., from 3000Hz to 1500Hz)
  - Some rounding of the peaks, but less effect on amplitude or latency



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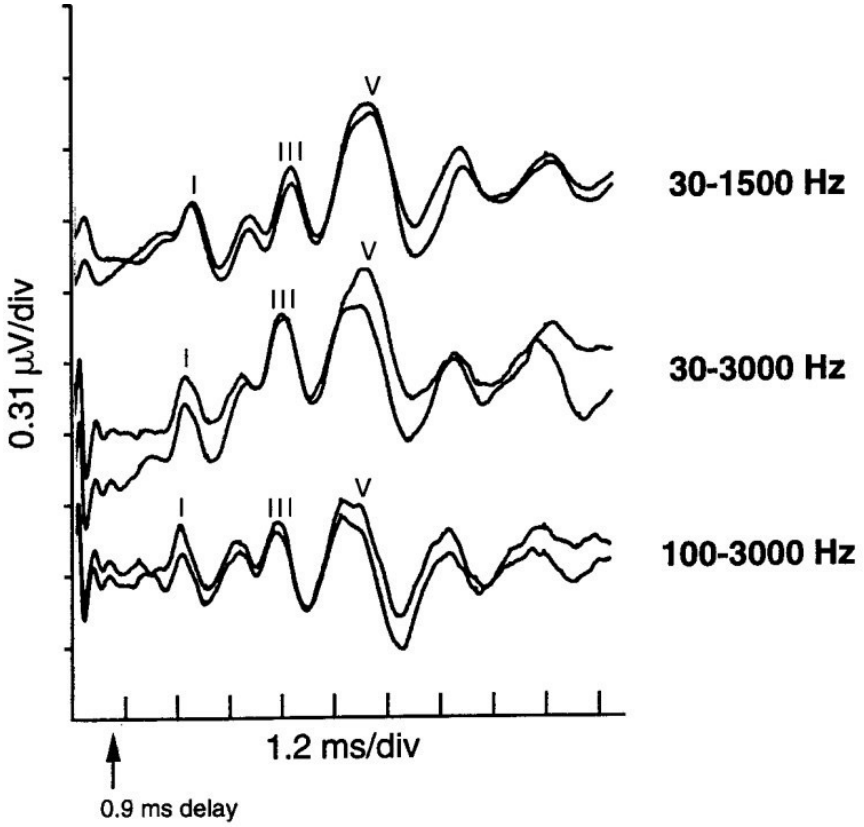


Section 3

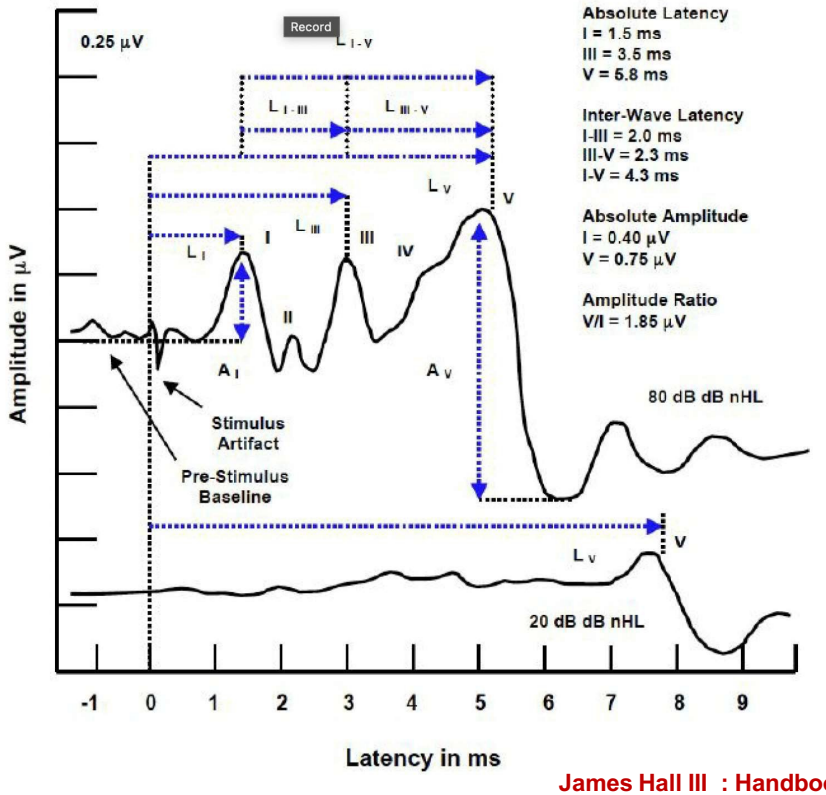
Analysis of the ABR response (conventional responses, abnormal ABR patterns, non -pathologic subject factors, the effect of drugs on the ABR morphology)

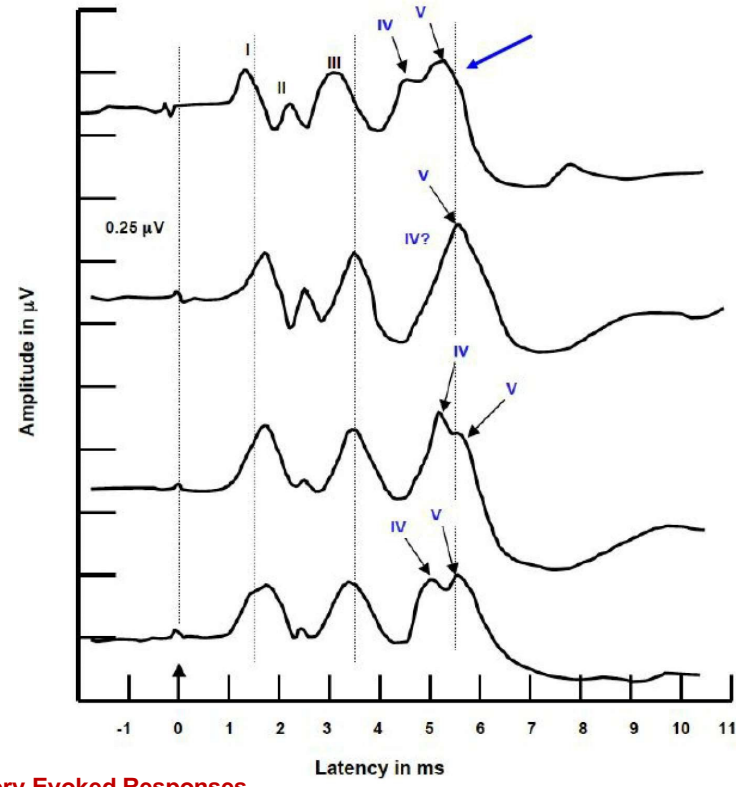
Section 3 : Response Variability

- *The conventional approach for determining whether an ABR is repeatable is to record two independent waveforms sequentially under the same conditions and to then compare the waveforms using some established criteria (Fsp).*
- *This option during ABR recording involves splitting the incoming sweeps into two independent sets of waveforms with ongoing evaluation of the repeatability of the two waveforms as the ABR measurement proceeds.*
- *Chirp stimuli generate ABRs with larger peaks and thus less noise and better reproducibility (high correlation).*

Section 3 : Response Analysis and Peak selection

ABRs from normal subjects





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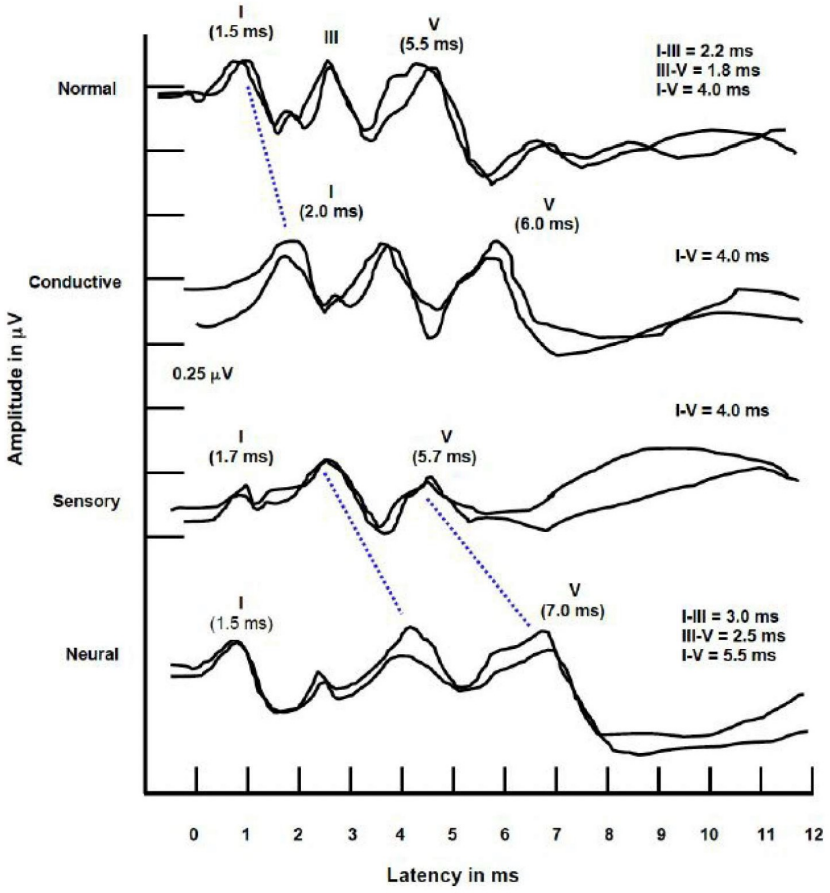
Section 3 : Normal- Abnormal ABR patterns



Criteria:

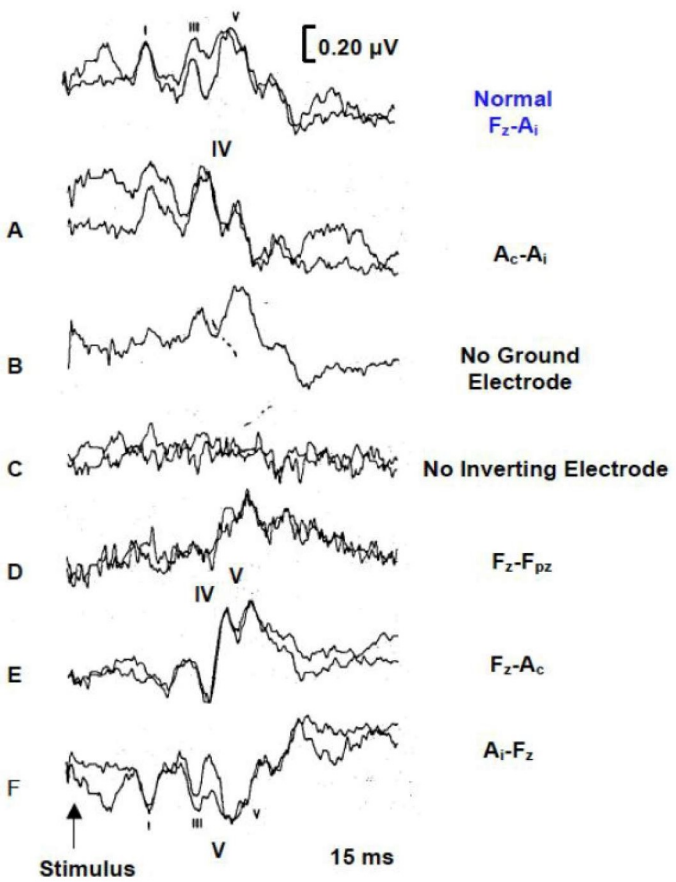
1. Wave Peak Detection
2. Inter-Wave latencies

Wave	Latency
I	< 2 ms.
II	< 3 ms
III	< 4 ms
IV	< 5 ms
V	< 6 ms
VI	< 7 ms

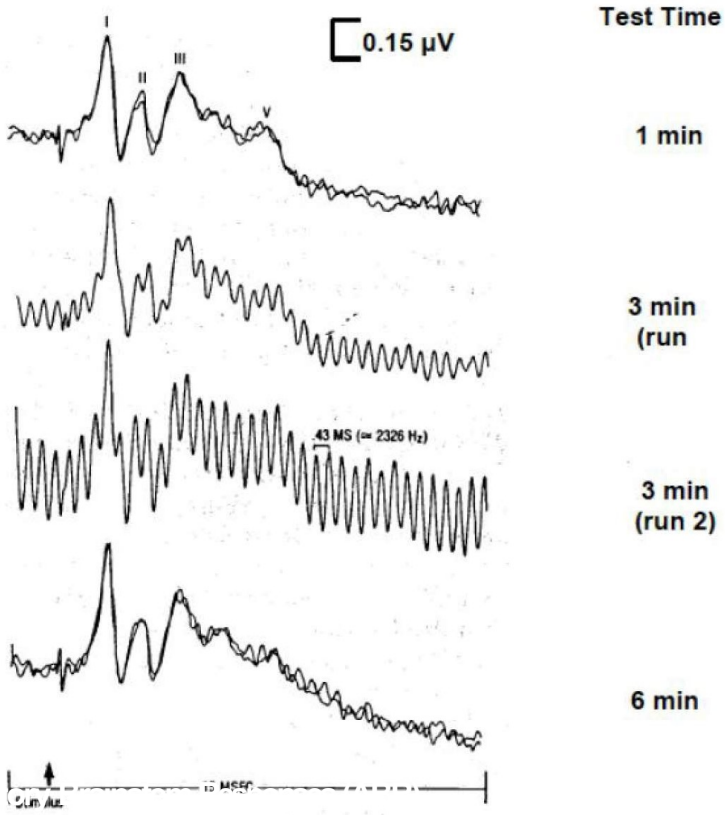
Section 3 : Abnormal ABR patterns

- Wave I : small amplitude, delayed or absent may indicate cochlear lesion
- Wave V : small amplitude, delayed or absent may indicate upper brainstem lesion
- I – III inter-peak latency: prolongation may indicate lower brainstem lesion.
- III – V inter-peak latency: prolongation may indicate upper brainstem lesion.
- I – V inter-peak latency: prolongation may indicate whole brainstem lesion. Shortening of the interval with normal latency of wave V indicate cochlear involvement.

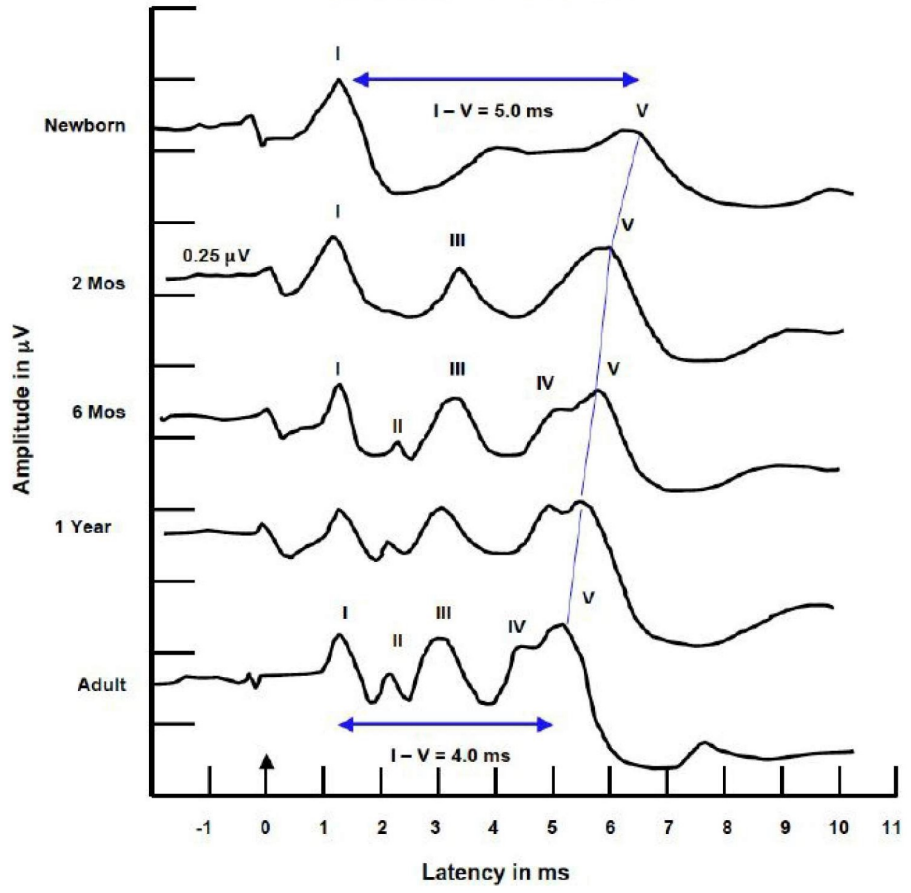
Section 3 : Abnormal ABR patterns. Electrode issues



Electrical Artifact over time



Section 3 : Abnormal ABR patterns. Maturation



Section 3 : Abnormal ABR patterns. Drugs

- Anesthetic agents, sedatives, potentially ototoxic drugs, and selected other medications must be considered in the analysis of ABR findings for all patients.
- The effect of drugs on ABR latency or amplitude can interact with and add to the effects of other factors.
- Anesthetic agents and sedatives almost always influence the ABR less than cortical auditory evoked responses. None of the medications entirely suppress the ABR.

Section 3 : Abnormal ABR patterns. Drugs

- Research confirms that some anesthetic agents and sedatives have statistically significant effects on ABR latency or amplitude that are not clinically significant.
- One must always be mindful of the distinction between statistical significance in ABR differences for group of research subjects and clinical significance that impacts the analysis of ABR findings for a single patient.

Section 3 : ABR vs ASSR

		ABR	ASSR
Stimulus			
	Type	Click or tone burst	Pure tone
	Duration	0.1-ms (click) 4 cycles (tone burst)	Steady state
	Modulation	None	Amplitude = 100%; frequency = 10%
	Frequency	Tone bursts at octave frequencies from 500 to 4000 Hz	Pure tones at octave frequencies from 250 to 8000 Hz
	Intensity	Maximum effective intensity of 90 dB nHL	Maximum effective intensity > 120 dB HL
Acquisition	Filtering	30–3000 Hz	Different filter settings are used among manufacturers
	Analysis time	~ 15 ms	Variable among manufacturers
Detection		Visual inspection of waveform peaks	Automated statistical confirmation
Analysis		Manual calculation of wave peak latencies, interwave latencies,	Mathematical calculation of stimulus versus response phase, stimulus versus response frequency, or stimulus repetition rate versus response repetition rate
Maximum estimated threshold (dB HL)		Approximately 80 dB HL	> 120 dB HL
Patient state		Quiet with minimal movement	Sleeping, sedated, or anesthetized
Gender		Shorter latencies for females than males after puberty	Lower ASSR thresholds for females versus males under selected stimulus conditions (Zakaria et al., 2016)

Hall & Momtaz: Current & Emerging clinical applications of ASSR, in Advances of Audiology & Hearing Science

Section 4

A short exposure of the clinical ABR applications (hearing screening, hearing disorders, intra-operative monitoring)

Section 4 : Clinical Applications. Differentiation

- Identifying the hearing loss
- Classification of type of deafness (conductive or sensorineural)

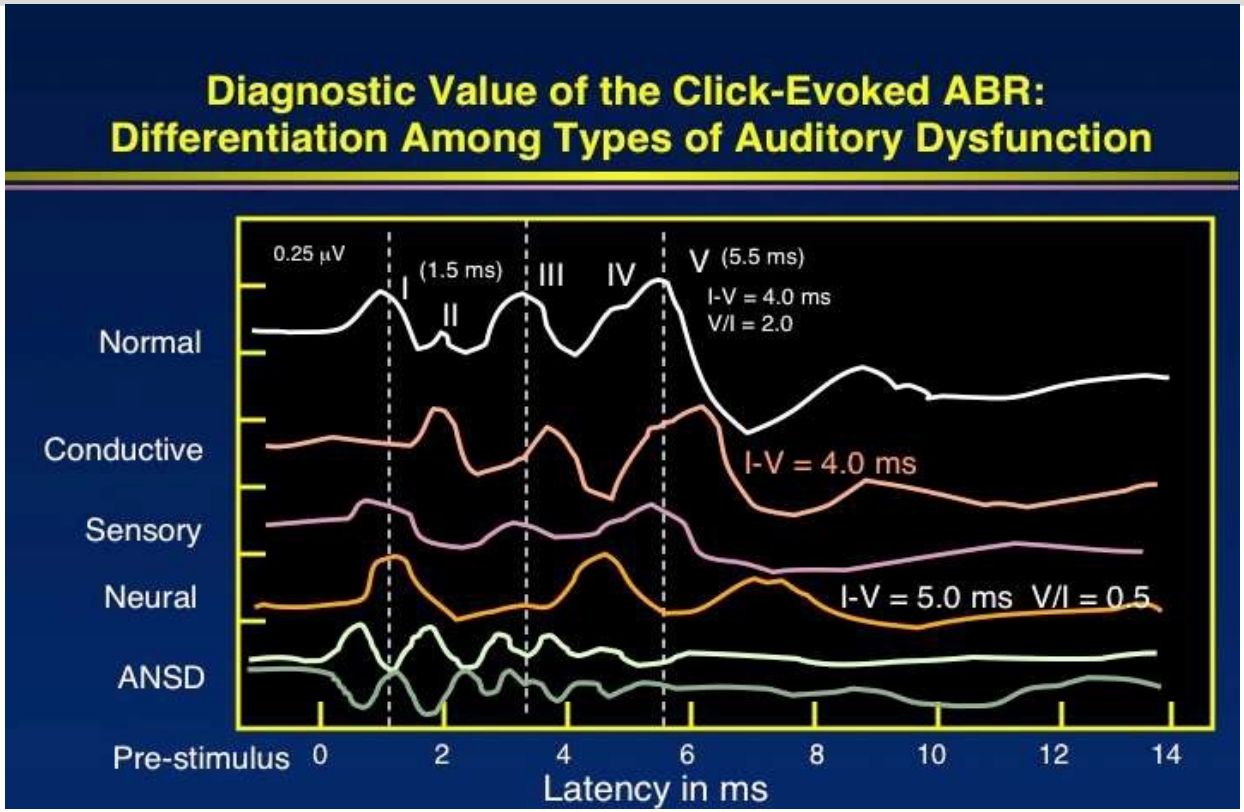
CONDUCTIVE DEAFNESS

1. The threshold of hearing is high.
2. Wave I to V are shifted to the right (latencies of all waves are delayed).
3. I-V interval is normal.
4. Latency-intensity curve for wave V runs above the normal curve and is parallel to it.

NERVE DEAFNESS

1. Threshold of hearing may be high.
2. Wave I is small and is delayed.
3. Wave V is within normal limits.
4. I-V interval is reduced.
5. The latency-intensity curve is of recruiting type (at high intensity, the curve is normal. But of lower intensity, the wave V latency is prolonged disproportionately).

Section 4 : Clinical Applications. Differentiation



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Section 4 : Clinical Applications

- **Identification of retrochoclear pathologies**

  The ABR is considered an effective tool in the clinical evaluation of suspected retrocochlear pathology, such as an acoustic neuroma or vestibular schwannoma.

NOTE: The max hearing level via ABR is ONLY

80 dB HL

Section 4 : Clinical Applications

NEWBORN SCREENING

- Several clinical trials have shown that the ABR (and the Automated-ABR) testing as an effective screening tool in the evaluation of hearing in newborns, with a sensitivity of 100% and specificity of 96-98%.
- The AABR algorithms usually seek the presence of wave V at a given latency range (at 70-80 dB NHL)

Section 4 : Clinical Applications

NEWBORN SCREENING

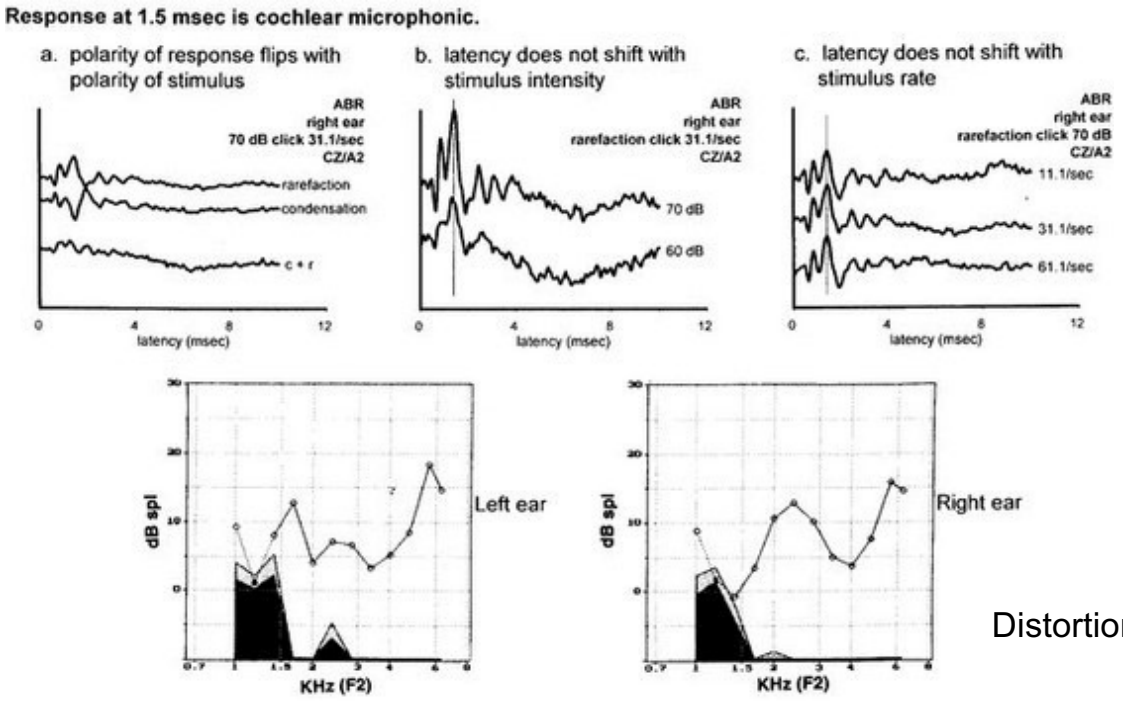
- Today ABR and OAE(Otoacoustic Emissions) protocols are widely used for the Identification of the hearing Impairment in the infant population.
- Well-babies are tested twice with OAEs prior to an AABR assessment.
- NICU residents are tested with OAEs upon discharge and then with AABR.

Section 4 : Clinical Applications

NEWBORN SCREENING

- The combined use of OAEs & AABR provides the possibility to identify cases with Auditory Neuropathy(AN) and Connexin 26 mutations.

Section 4 : Auditory Neuropathy



The three panels illustrate the absence of ABR waves. The waveforms show only the cochlear microphonic because the polarity of response flips with the polarity of the stimulus (a), latency does not shift with stimulus intensity (b), and latency does not shift with stimulus rate.

Distortion product OAEs

Kraus et al:Consequences of neural asynchrony: A case of auditory neuropathy ARO, 2000:33-45

Section 4 : Clinical Applications

Intraoperative monitoring

Auditory brainstem response (ABR), often used intraoperatively, provides early identification of changes in the neurophysiologic status of the peripheral and central nervous systems. This information is useful in the prevention of neurotologic dysfunction and the preservation of postoperative hearing loss.

For many patients with **tumors of CN VIII** or **the cerebellopontine angle**, hearing may be diminished or completely lost postoperatively, even when the auditory nerve has been preserved anatomically.

This is the End

That's all Folks !!