Evoked Potentials – Part 1
Good Practice and Auditory Brainstem Response

Kathleen Hill, Au.D.
Education & Training Manager
Otometrics North America

otometrics
a division of natus

Learning Objectives

- After this course learners will be able to describe the electrode montages used for 1 and 2 channel ABR.
- After this course learners will be able to identify the difference between the infant and adult ABR response.
- After this course learners will be able to describe how increasing rate and intensity independently affects the ABR response.

otometrics
a division of natus

Evoked Potentials

- Electrical signals generated by the nervous system in response to a stimulus
- Event related (evoked by onset of stimulus)
- Useful in diagnosing a variety of neurological disorders

otometrics
a division of natus

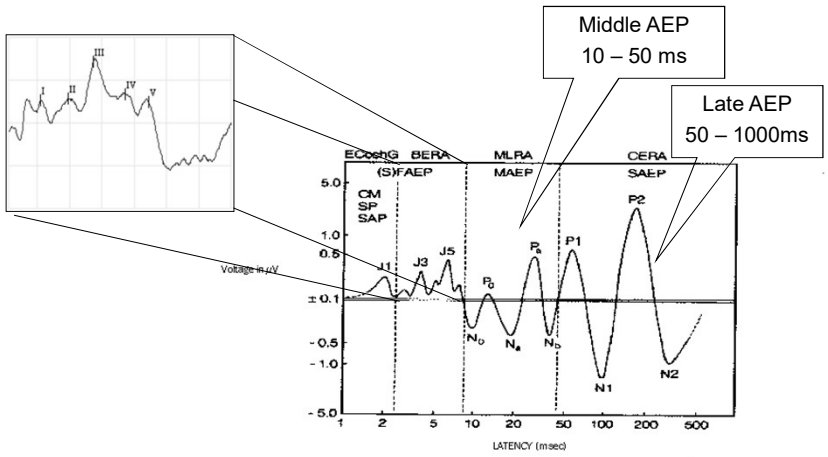
Auditory Evoked Potentials (AEP)

- Used to determine the integrity of the auditory system and to make inferences about hearing (not a hearing test!)
- An acoustic stimulus generates a response measured using electrodes on the surface of the skin
- Objectively tests the integrity of the hearing system to the level of the cochlea to the brainstem
- Common names: AEP, ABR, BAER etc.

otometrics
a division of natus

Auditory Evoked Potentials

OVERVIEW of AEP in the Time Domain



otometrics
a division of natus

Recording Evoked Potentials

- Far Field recording-electrodes placed on the scalp
- Electrodes assigned as Active (+), Reference (-), and Ground
- Record from a pair of electrodes (i.e. Cz to A1)
- Recording from an non-inverting (+) and inverting (-) electrode
- Amplify the difference between the signals
- Proper care of the electrodes & impedance are important because this is the medium for collecting the EP data

otometrics
a division of natus

Recording EP Data

- Common mode rejection
  - The voltage is different between the active and reference electrodes
  - The voltage related to noise is similar at both electrodes and the response voltage has the greatest difference
  - The response at the reference electrode (inverting) is added to the response at the active (non-inverting) electrode
  - The components which are “common” to both electrodes are cancelled (i.e. noise - mains, biological or environmental)
- Inter-electrode impedance is the most important (common mode rejection does not work well if inter-electrode impedance varies)

otometrics
a division of natus

Preparation

otometrics
a division of natus

Testing Environment

- Preamp should not be near the isolation transformer, monitor,etc.
- Turn off unnecessary computer monitors.
- Do not have preamp in front of monitor.
- If possible use a designated outlet.
- If patient is in chair that plugs in – unplug it.
- Assure wall outlet is grounded.
- Do not use cellular phones during testing.
- Turn off florescent light(s). Do not have dimmer switch set in the middle position.

otometrics
a division of natus

CHARTR EP 200 Preamp

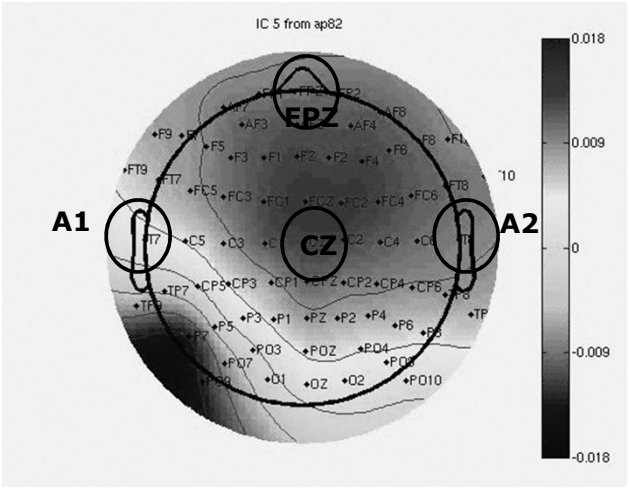
- Chartr EP 200 preamp connects to the Chartr EP 200 box via a 6 foot cable to allow ample distance between the patient and computer.
- The electrodes, transducers and VEMP Monitor plug directly into the preamp.

otometrics
a division of natus

Electrode Placement

True Cz = larger amplitude response

~15% reduction in amplitude using high forehead



otometrics
a division of natus

Application of Electrodes

Non-Disposable Electrodes & Disposable Electrodes

Skin Prep

otometrics
a division of natus

Application of Electrodes

Applies to All Electrode Types

- Tape electrodes together (making a sleeve with tape).
- Do not mix electrode types.
- Do not place ground electrode near the heart. Noise can be generated by large EKG.
- If doing bone conduction ABR, place electrode on FRONT of earlobe.
- Explain to the patient the process of placing the electrodes.
- Gently clean the electrode site (do not abrade skin). Do not mix alcohol with NuPrep or dry prep, this causes stinging sensation.
- If using Cz, alcohol pad will help dissolve hair product and will help reduce impedance.
- Electrodes on the earlobes or mastoids should be symmetrical.
- All electrode leads should run toward the top of the patient's head.
- Do not turn equipment on/off with patient connected.

otometrics
a division of natus

Application of Electrodes

Non-Disposable Electrodes

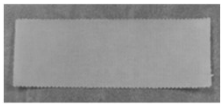
- Electrodes should be clean (use child toothbrush and warm water to remove paste).
- Electrodes will not last forever. Bad electrodes will result in high impedance, trending of the waveform and ultimately noisy recordings.
- Wet prep works the best.
- Prepare the electrodes by adding a small amount of paste.
- Apply the electrodes firmly.
- Use cotton to help electrodes adhere.
- Wait a minute for the electrodes to settle.
- Be aware of silver chloride – check to see if they need to be re-chlorided. To re-chloride the electrodes, place only the cup of the electrode into a small amount of chlorine bleach. Soak for 20 minutes. Do not let the wires touch the bleach.

Disposable Electrodes

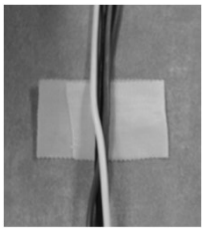
- Dry prep works the best.
- A small drop of water/saline will rehydrate the gel and help them restick.
- Some disposable electrodes can be cut down in size.

otometrics
a division of natus

Electrodes – keep them together



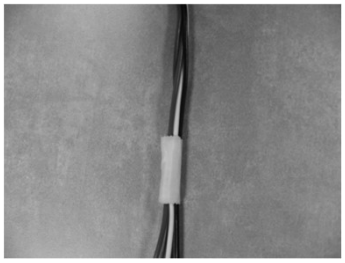
Step 1



Step 3

Well Maintained Electrode Leads

Step 2



Step 4

otometrics
a division of natus

Patient Comfort

- Have you tried out your chair or table?
- Send patient to the restroom before testing.
- Patient should feel secure and comfortable in the chair or on the table.
- Have blankets and pillows to assist with comfort.
- Pillow under the knees help support the lower back.
- Explain the test procedure before placing the earphones.

otometrics
a division of natus

Application of Earphones and Cable Position

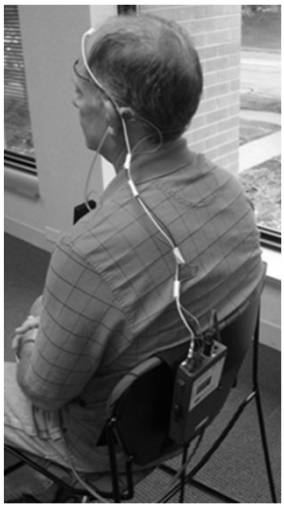
- Instruct patient before placing eartips.
- Always choose the largest size of ear tip to reduce the risk of stimulus leakage. Leakage can cause a reduction of dB SPL in the ear canal.
- Store set of eartips in orange plastic container.
- Compress foam tip, insert completely (no foam should be in the concha) and hold in place until expanded.
- Separate the electrode leads from the transducer cable using the patient's body.
- Do not clip the stimulus transducer box to the patient.
- Do not let tubing of the transducer touch the electrode wires.
- For infants, beige tips can be trimmed down. Also consider using clear tips.

otometrics
a division of natus

Patient Setup with Chair

otometrics
a division of natus

Patient Setup with Chair

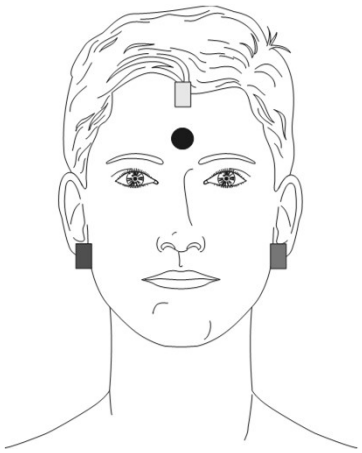


otometrics
a division of natus

Patient Setup with Table

otometrics
a division of natus

ICS Chartr EP 200 Preamp

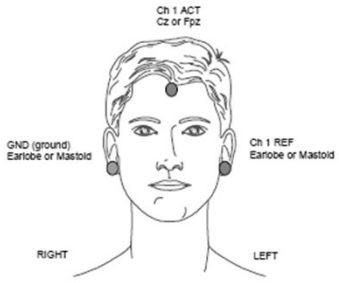


otometrics
a division of natus

One Channel Recording with Electrode Switching On

AUDITORY BRAINSTEM RESPONSE MONTAGES

1-Channel ABR
ELECTRODE SWITCHING ON

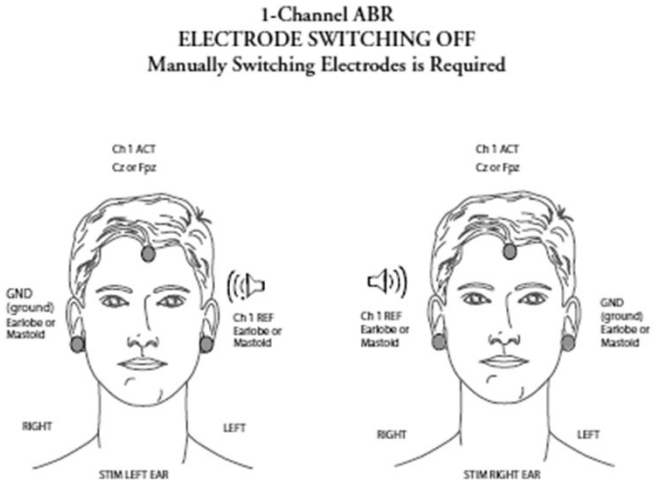


When performing bone conduction ABR, always place the refrence electrode and the ground on the front of the earlobe.

Caution - *If an alternate montage is used with Electrode Switching ON, the data collected will be inaccurate.*

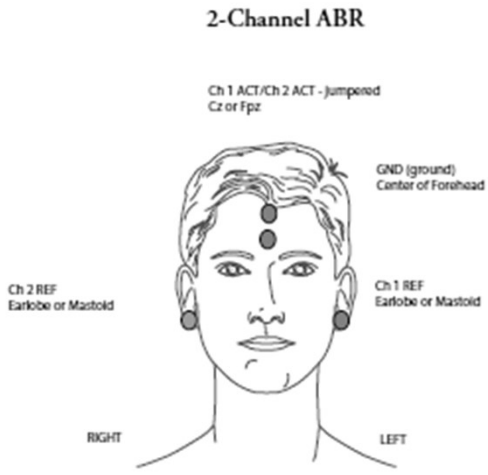
otometrics
a division of natus

One Channel Recording with Electrode Switching Off



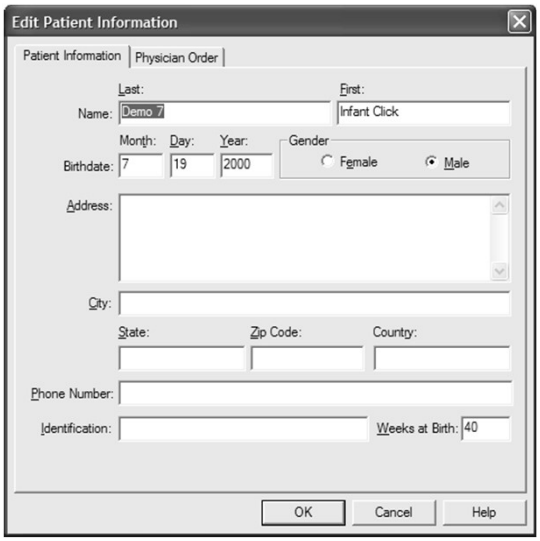
otometrics
a division of natus

Two Channel Recording



otometrics
a division of natus

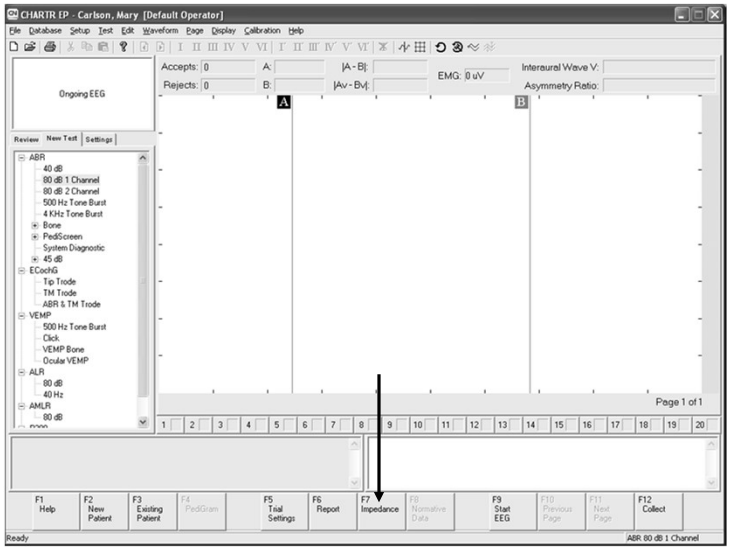
Setting up a New Patient Record



Must enter <u>Birthdate</u> & <u>Gender</u> to utilize the Normative Data

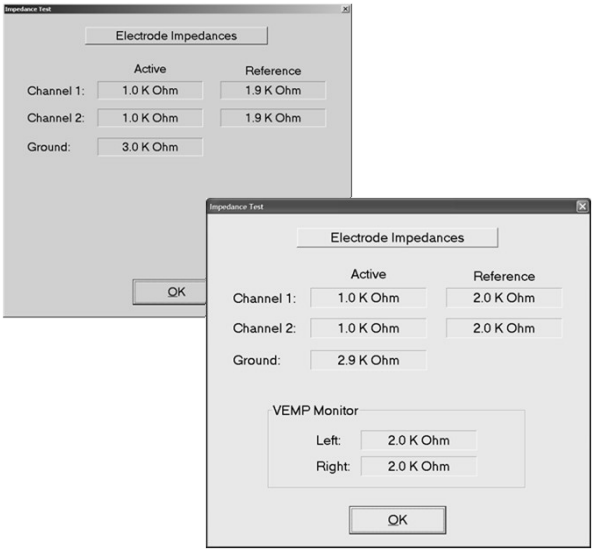
otometrics
a division of natus

Impedance



otometrics
a division of natus

Checking Electrode Impedance



Goal: Low electrode readings of **<5K** Ohms each balanced with no more than **<2K** Ohms difference between electrodes

Inter-electrode impedance is the most important (common mode rejection does not work well if inter-electrode impedance varies)

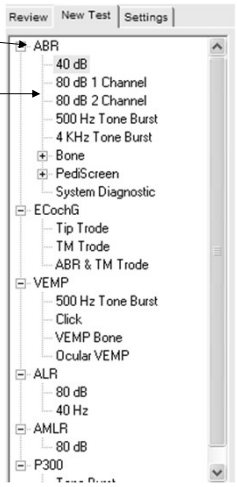
Chartr EP 200 reads up to 80 kOhms

otometrics
a division of natus

Selecting a Protocol

Procedure

Selected Protocol



The CHARTR EP default procedures are:

- **ABR (Auditory Brainstem Response)**
- **ASSR (Auditory Steady State Response) *(optional)***
- **ECochG (Electrocochleography)**
- **VEMP (Vestibular Evoked Myogenic Response)**
  - **EMG monitor *(optional)***
- **ALR (Auditory Late Response)**
- **AMLR (Auditory Middle Latency Response)**
- **P300 *(optional)***

otometrics
a division of natus

Listening Check

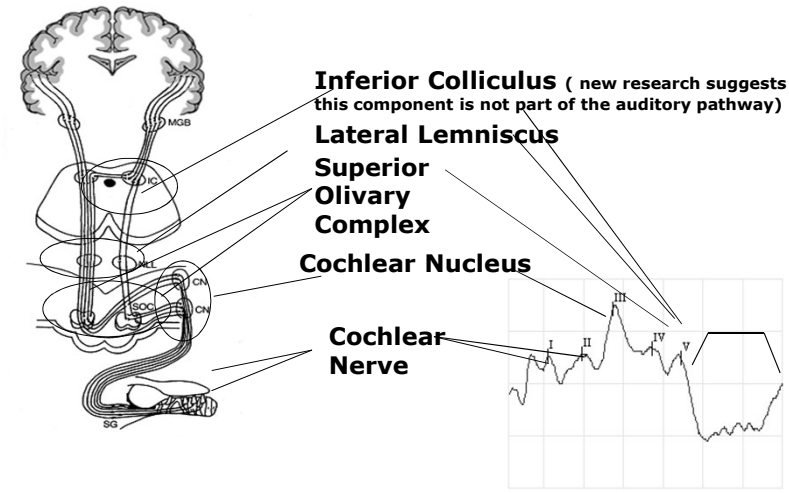
- Use subjects with hearing thresholds within normal limits
- Listen to the stimulus
- Should be able to barely hear it at 0-5 dB
- If the softest level anyone can hear the stimulus is 20 dB – there is a 20 dB correction factor
- Subtract the correction factor from the response obtained on the dial (i.e. patient's threshold is 60, 60-20=40; 40 is their true threshold)
- Call to have system calibrated – annual calibration

otometrics
a division of natus

Click
Air Conduction
ABR

otometrics
a division of natus

Anatomical and Physiological Principles



otometrics
a division of natus

Auditory Brainstem Response

- Markings used I, II, III, IV, V
- Each peak represents neural firing from a sum of activity arising from areas within the brainstem (auditory nerve)
- Wave I and Wave II generated predominantly from the action potential on the ipsilateral side
- Waves III-V are generated from the complex interaction of both contralateral and ipsilateral brainstem anatomy

otometrics
a division of natus

Determining if a Response is Present/Determining Threshold

Response must be:

- Repeatable
- Look like a typical response
- Follow the typical pattern when intensity is changed
  - Decrease intensity = Latency is longer
  - Decrease intensity = Amplitude is smaller
- Absolute latencies should be appropriate (compare to normative data)
- Amplitude should be larger than background noise (ex: 3 times)

Threshold is:

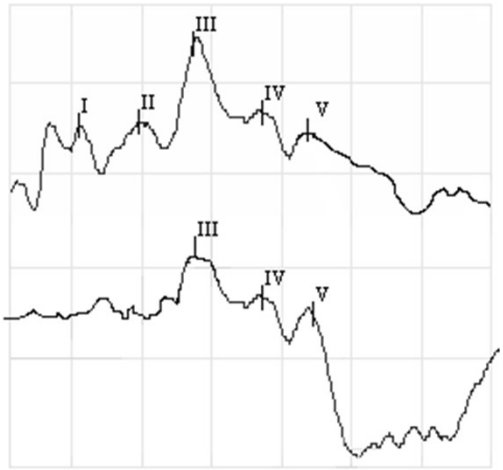
- Lowest intensity where response is present
- No response at intensity below where threshold is determined
- Absent response must be low in amplitude (~.05uV) – eliminating chance that response is buried in noise

otometrics
a division of natus

Ipsi versus Contralateral Waveforms

Ipsilateral

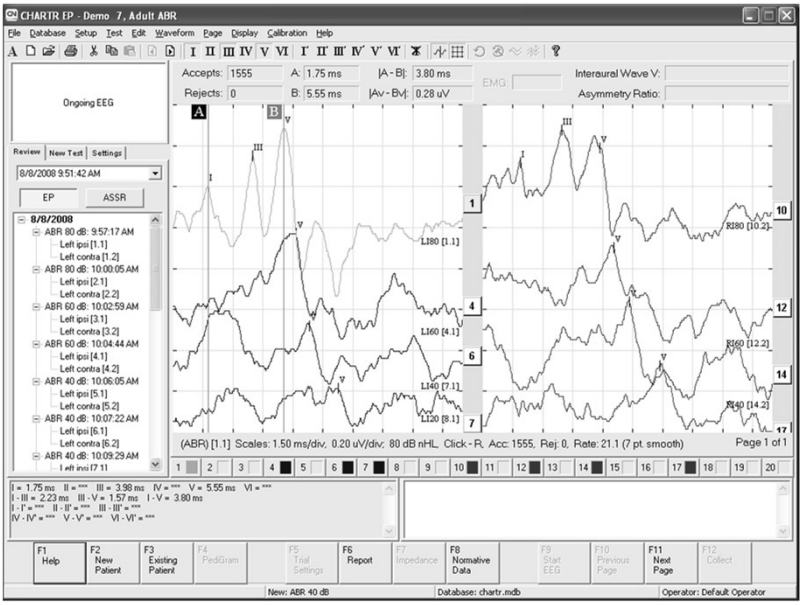
Contralateral



Note no Wave I, and Enhanced Wave V for contralateral Waveform

otometrics
a division of natus

Auditory Brainstem Response Test Screen



otometrics
a division of natus

Auditory Brainstem Response - Purpose

- Threshold Search (click, toneburst at various intensities)
- Neurological Assessment (comparing peak latencies and rate study)

otometrics
a division of natus

Threshold Search - What should you expect to know after the diagnostic assessment?

1) What is the type of hearing loss?
   - Sensorineural
   - Conductive
   - Mixed
   - Auditory Neuropathy
2) What is the degree of hearing loss?
   - Normal (UK) – 25 for inserts and 35 for headphones
   - Normal (US) – 20 or below
   - Mild – 20-40 dB
   - Moderate – 45-55 dB
   - Moderately Severe – 60-70 dB
   - Severe – 70-90 dB
   - Profound - >90dB

otometrics
a division of natus

Threshold Search - What should you expect to know after the diagnostic assessment?

3) What is the configuration of the hearing loss?
   - sloping
   - rising
   - flat
   - Cookie bite

otometrics
a division of natus

Click Air Conduction ABR

- The click air conduction ABR is the starting point.
- Using click air conduction ABR only, one cannot infer hearing loss configuration or have adequate information for a hearing aid fitting.
- The click air conduction ABR can miss both low and high frequency hearing loss.

otometrics
a division of natus

Click Air Conduction ABR

- Electrode Montage
  - 1) Non-Inverting Cz or high forehead - sometimes if the infant has a large soft spot it is difficult to get low impedance.
  - 2) Inverting A1 and A2 - use the earlobe instead of the mastoid, so that if bone conduction is needed you will have less placement difficulties with oscillator.
  - 3) Inverting C7 (nape) - using C7 instead of A1 and A2 can help increase amplitude of wave V, however you will decrease detection of wave I.
  - 4) Ground - usually center of forehead

otometrics
a division of natus

Click Air Conduction ABR

- Tips:
  - May need to open up epoch if patient is an infant or has neurological issues
  - Perform Biologic Calibration routinely to determine if correction factors are needed.
  - Insert Earphones are easier to use with infants
  - Software makes the .8ms latency correction for insert earphones.

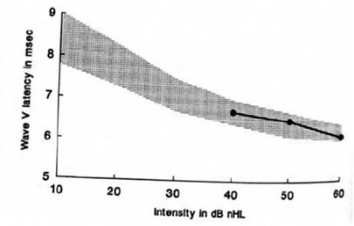
otometrics
a division of natus

Click Air Conduction ABR

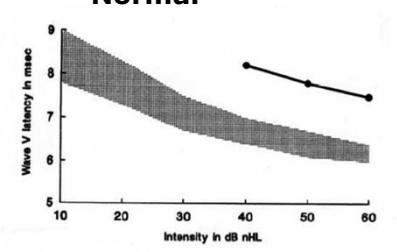
- Threshold Search ABR for unsedated patients
  - Start at a moderate level - 60 dB nHL
  - If wave V is present, decrease to 30 dB nHL
  - If present, decrease to 20 dB nHL. This is within normal limits.
  - If not present at 30 dB, bracket at 40 or 50 dB depending on latency of response.
  - If no response at 60 dB, increase to 80 dB.

otometrics
a division of natus

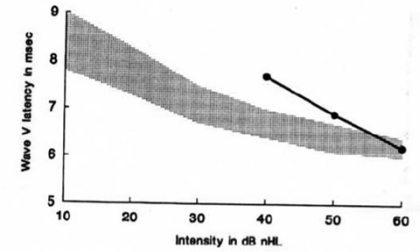
Latency Intensity Function



Normal



Conductive



Sensorineural

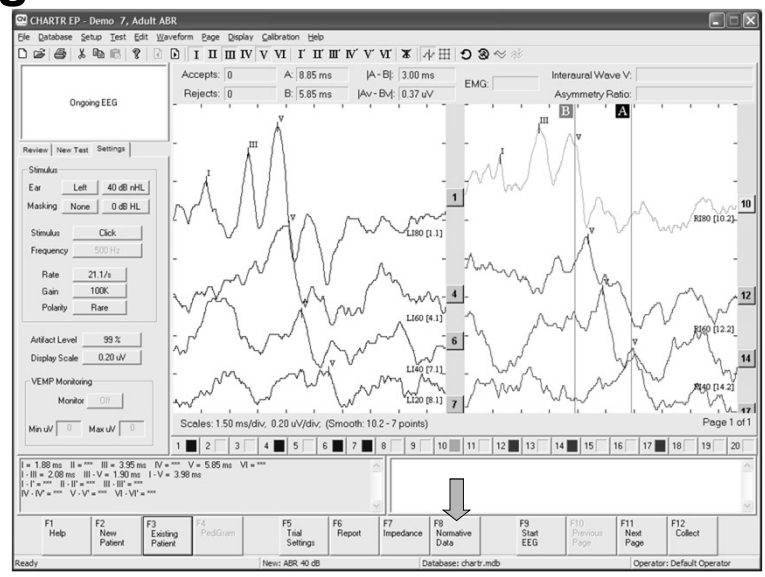
otometrics
a division of natus

Normative Data

- Includes a mean and standard deviation.
- Results are determined to within or outside of normal limits based on data collected by Dr. Michael Gorga (Boys Town).
- Age specific normative data is included within the software.
- Normative data is published in the literature.

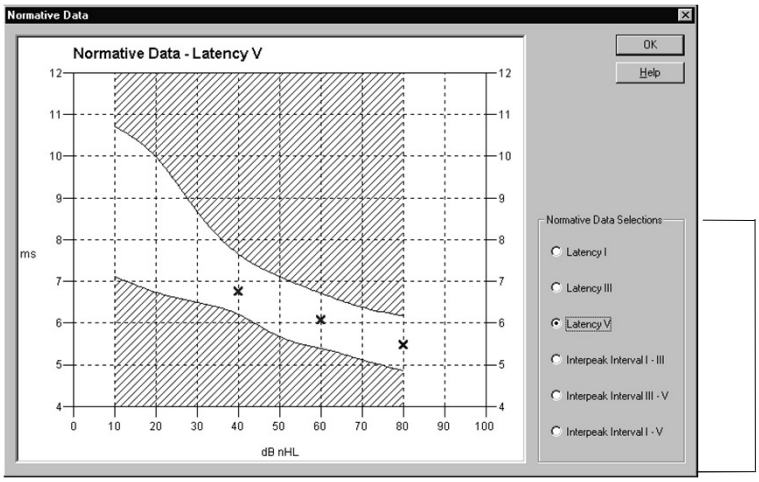
otometrics
a division of natus

Working with Normative Data



otometrics
a division of natus

Click Normative Data

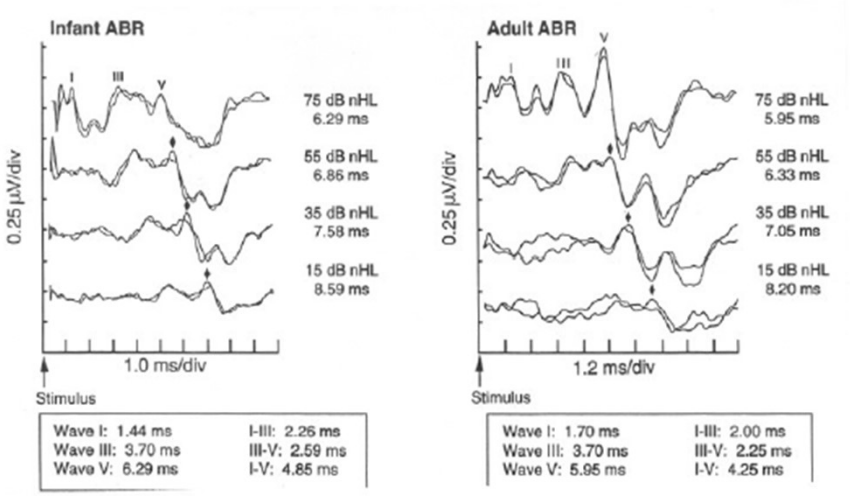


otometrics
a division of natus

What differences are there between infant and adult click ABR?

otometrics
a division of natus

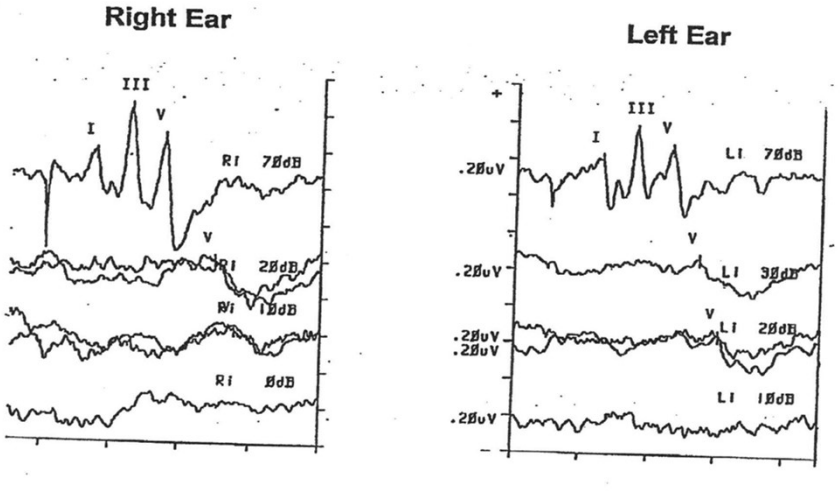
Comparison of Infant and Adult ABR's



Linda Hood: Clinical Applications of the Auditory Brainstem Response

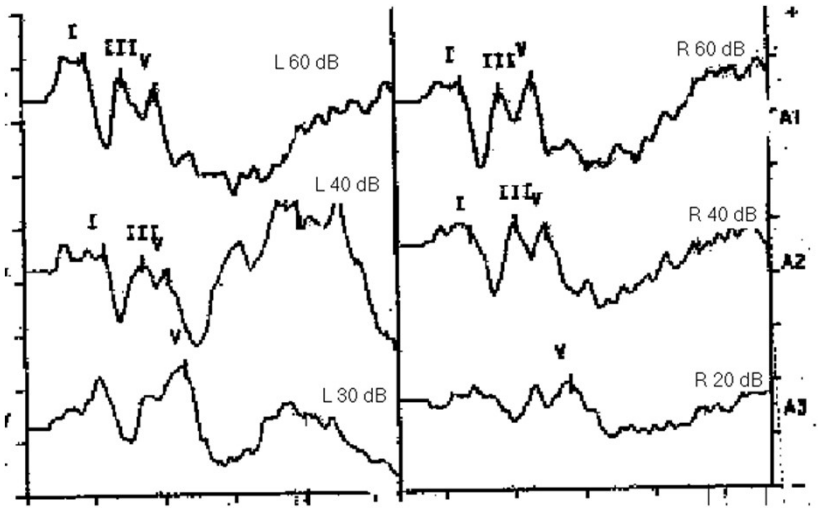
otometrics
a division of natus

Adult Click Air Conduction ABR



otometrics
a division of natus

Infant Click Air Conduction ABR



otometrics
a division of natus

Neurological Assessment - What should you expect to know after the diagnostic assessment?

1) Is neural transmission of auditory stimuli intact?
   - Yes
   - No

otometrics
a division of natus

Click Air Conduction ABR

- High Intensity ABR
  - Perform ABR at 75 dB nHL (infants) or 80 to 90 dB nHL (adults) to evaluate waveform morphology
    - Wave Morphology - Infants may have a larger Wave I than Wave V
    - Wave I to V Interpeak Latency

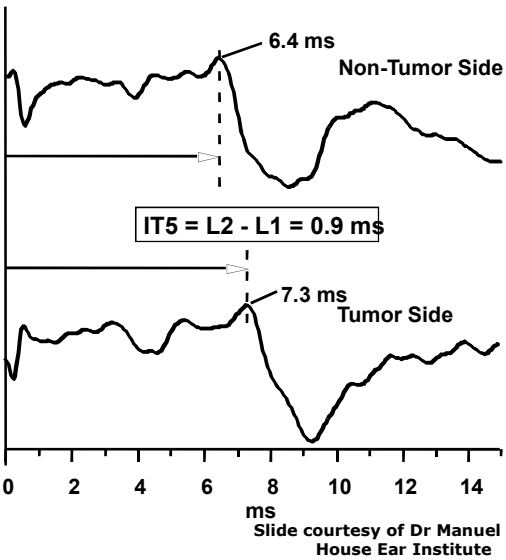
otometrics
a division of natus

Interaural differences

- Comparison of interaural Wave V absolute latencies can provide data sensitive to retrocochlear pathology
- Interaural Wave V latencies should differ by no more than 0.2-0.4 ms
- Be careful to account for asymmetries in behavioral thresholds

otometrics
a division of natus

IT5 = Interaural time delay for wave V. At the House Ear Clinic, the criterion is 0.2 ms with 0.1 ms correction for every 10 dB hearing loss greater than 50 dB at 4 kHz.

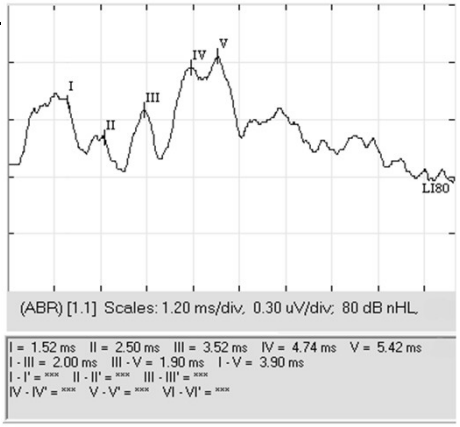


Slide courtesy of Dr Manuel Don, House Ear Institute

otometrics
a division of natus

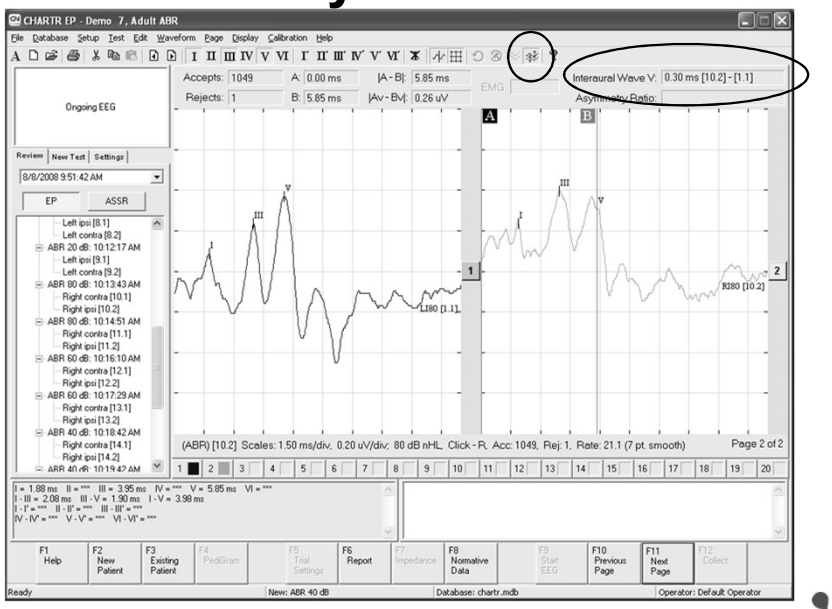
Interwave Latency Intervals

- Waves I-III and III-V: **2.0 msec** approx.
- Waves I – V: **4.0 msec** approx. At House Ear Institute 4.0ms is the criterion.



otometrics
a division of natus

Interaural Time Delay of Wave V



otometrics
a division of natus

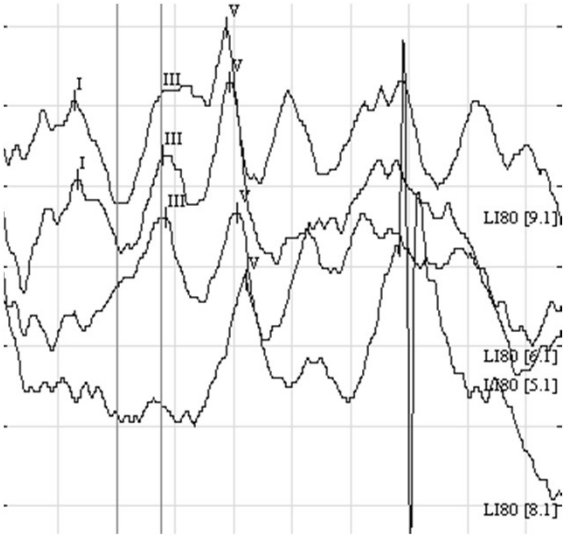
Rate Study

13.1 Clicks/sec.
Wave V = 5.80

21.1 Clicks/sec.
Wave V = 5.90

55.1 Clicks/sec.
Wave V = 6.10

90.1 Clicks/sec.
Wave V = 6.30



Increase in rate = taxes the neurological system

otometrics
a division of natus

What is Post Auricular Muscle Artifact?

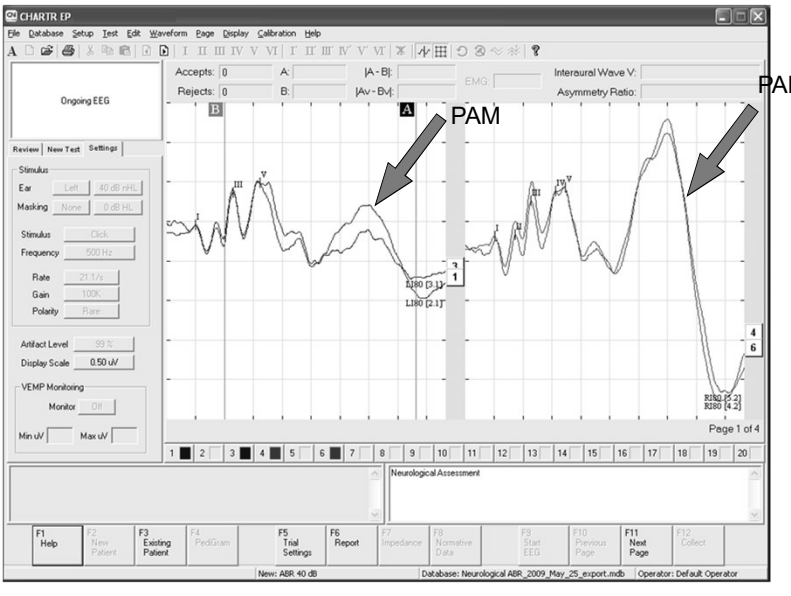
otometrics
a division of natus

What is Post Auricular Muscle Artifact and how to get rid of it?

- PAM occurs at 10-14 ms and can be present in one run and not the next.
- PAM can effect latency and will effect amplitude.
- PAM is caused by tension of the neck and/or jaw, head not being centered or lack of support of head or neck.
- Make sure patient keeps their eyes closed and relax the jaw. No teeth clenching!! If they wear a mouth guard during sleep, they should wear it during testing.
- Place a folded towel or pillow behind the neck/head and under their knees.
- Make sure the chair/table is comfortable.
- Try moving the electrodes off the mastoids onto the earlobes.

otometrics
a division of natus

Post-Auricular Muscle Artifact (PAM)

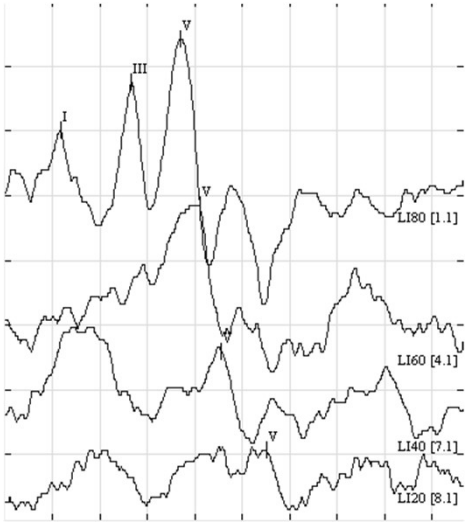


otometrics
a division of natus

How do changes in intensity, rate and filters effect the ABR recording?

otometrics
a division of natus

Latency & Morphology changes with Intensity



80 dBnHL

60 dBnHL

40 dBnHL

20 dBnHL

Decrease in intensity = increase in latency & decrease in amplitude

otometrics
a division of natus

Increased Rate Effect on Latency/Morphology

13.1 Clicks/sec.

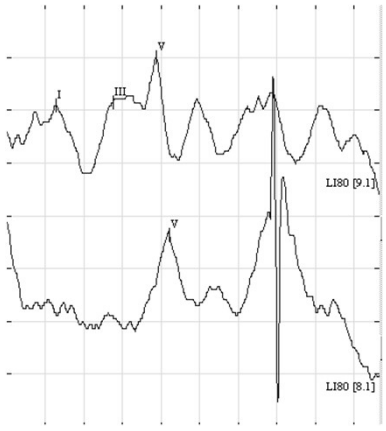
Wave V - 5.80

0.39 uV

90.1 Clicks/sec.

Wave V – 6.30

0.27 uV



Increase in rate = increase in latency & decrease in amplitude
Why use an odd number? so that the rate is not a multiple of the main power supply (50 or 60 Hz)

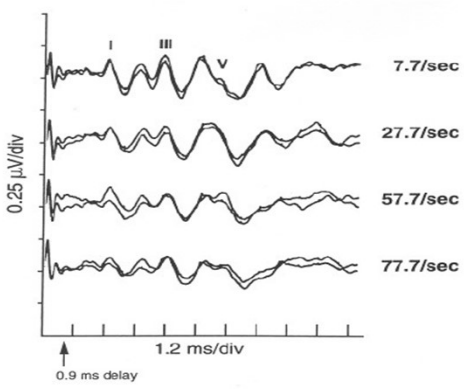
otometrics
a division of natus

Increased Rate Effect on Latency/Morphology

Taken from Linda Hood:

Clinical applications of the

Auditory Brainstem Response



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

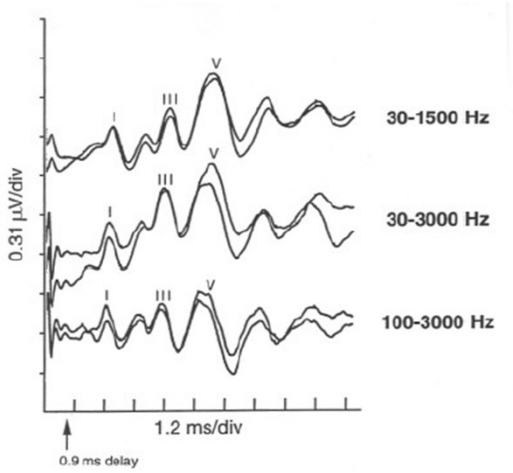
otometrics
a division of natus

Effect of Filters on Waveform Morphology

Taken from Linda Hood:

Clinical applications of the

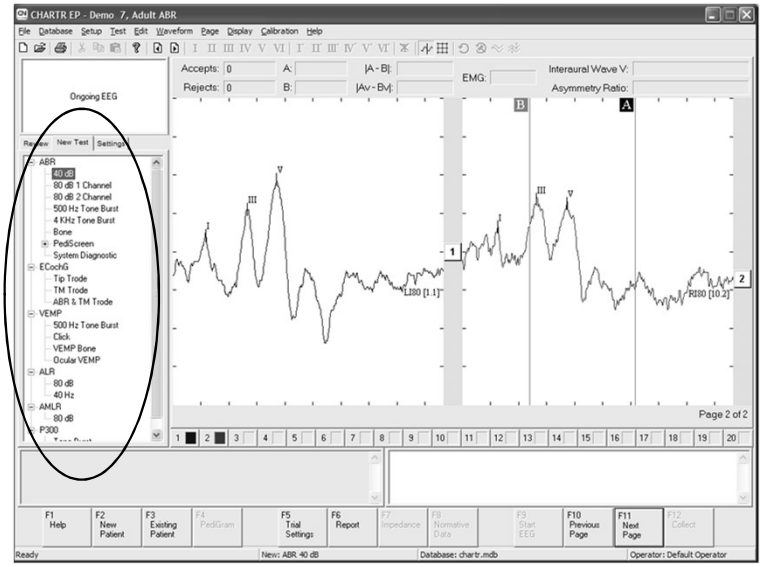
Auditory Brainstem Response



Trade off - Wider filters result in more fidelity; Narrower filter makes identification (presence/absence) of response more obvious

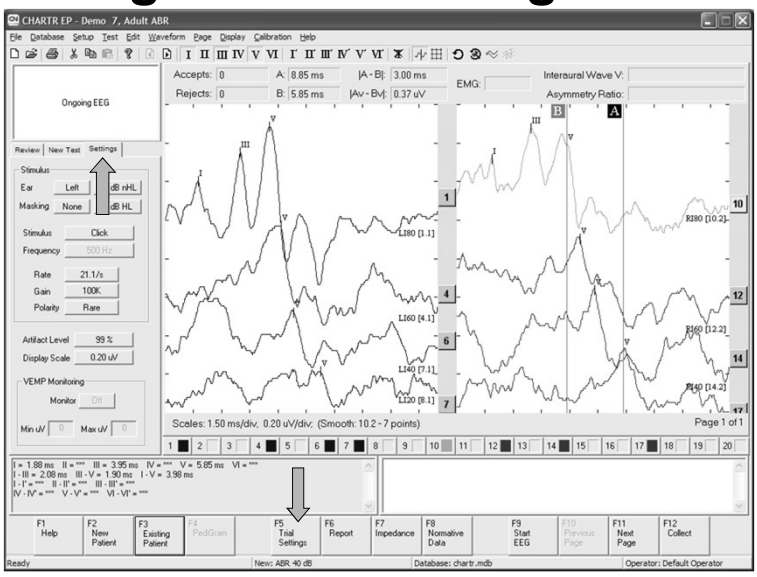
otometrics
a division of natus

Test protocol screen



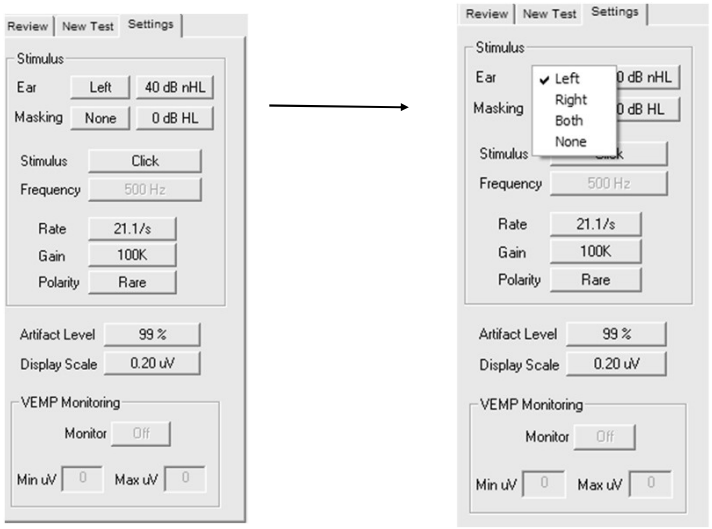
otometrics
a division of natus

Quick settings & Trial settings



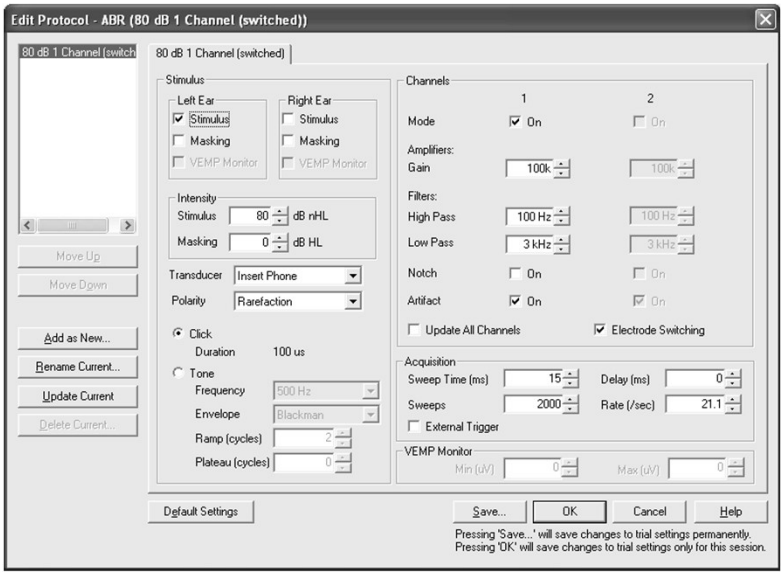
otometrics
a division of natus

Quick Setting Changes



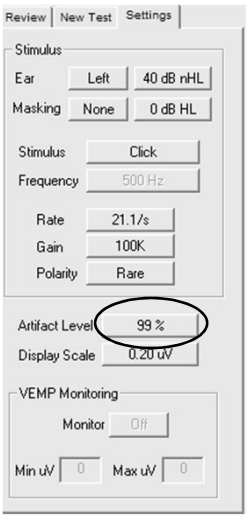
otometrics
a division of natus

Trial Setting Parameters



otometrics
a division of natus

Artifact Rejection and Averaging



The lower the number the more rejected sweeps will occur.

99% is the default setting

With the data set at 99%

- With gain set at 100k = 45.4uV peak to peak
- With gain set at 200k = 24.7uV peak to peak
- Data larger than this value will be rejected. Data smaller than this value will be accepted.

Averaging reduces the amount of noise and extracts the signal by 1 divided by the square root of N (number of sweeps) or 4 times as many sweeps averaged will reduce the noise by half.

otometrics
a division of natus

Obtaining a Clearer Response

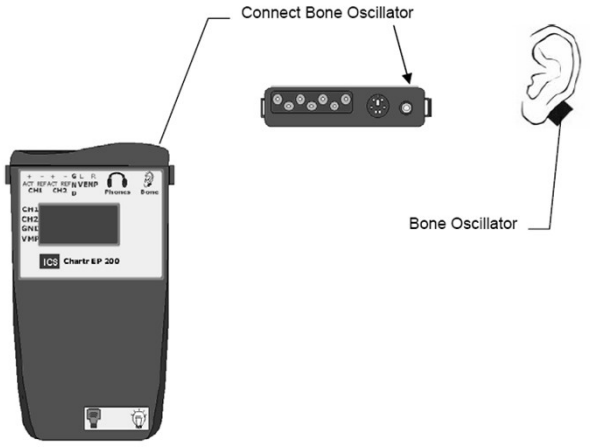
- Increase sweeps.
- Increase the stimulus level.
- If wave I is obscured-use a TMtrode or a gold foil Tiptrode.
- If Wave V is obscured-record from the nape of the neck.
- Slow down the stim rate.

otometrics
a division of natus

Click
Bone Conduction
ABR

otometrics
a division of natus

Connecting the Bone Transducer for EP 200



Connect Bone Oscillator to Preamp

otometrics
a division of natus

Click Bone Conduction ABR

- The click bone conduction ABR provides a differential diagnosis of the type of hearing loss (sensorineural vs. conductive vs. mixed)
- Provides the information you need to better counsel the infant's family and make your next step toward intervention
- One way to diagnose hearing loss in infants with craniofacial anomalies (aural atresia)
- Clearest indicator of middle ear dysfunction in infants.
- Conventional tympanometry is not valid and reliable until 6 to 7 months of age. Use 1000 Hz probe tone for tympanometry on patient's below 6 months of age
- Bone Oscillator should be placed on the mastoid (using forehead can reduce output as much as 15dB ANSI S3.6 1996)

otometrics
a division of natus

Click Bone Conduction ABR

- Electrode Montage and Transducer Placement
  - Perform a listening check routinely.
  - Always use Alternating polarity
  - Always use earlobe instead of mastoid placement.
  - Most bone oscillator headbands are too small for infants. Hand-held placement can be used. Firmly hold the oscillator to the infant's mastoid with 1 index finger. Push the oscillator on the mastoid until you could almost push the child's head away from you.
  - Transducer placement should be consistent to reduce variability. Never use 2 fingers to hold it as this can dampen the output.

otometrics
a division of natus

Click Bone Conduction ABR

- Threshold Search ABR
  - Start at a moderate level - 30 dB nHL. If you start too high the infant may wake up
  - Do not exceed 50 dB nHL. You will overdrive the oscillator.
  - Decrease in 10 dB steps
  - 20 dB nHL and below is within normal limits

otometrics
a division of natus

Toneburst ABR

otometrics
a division of natus

Toneburst Air Conduction ABR

- Provides Frequency Specific Information
- Can diagnose low and high frequency hearing loss.
- May take several attempts to replicate a wave
- Toneburst Stimuli
  - Toneburst presented in notched noise (not widely available)
  - Toneburst using Blackman envelope (ramp) - (commonly used)
- 500 Hz Toneburst
  - Need a 20 msec window minimum
  - More difficult to obtain repeatable waveforms because there is less synchronous activity at that region of the cochlea

otometrics
a division of natus

Toneburst Air Conduction ABR

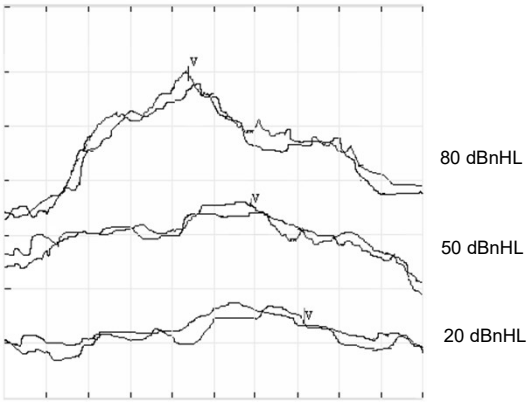
- 500 Hz
  - Using alternating polarity response is a broad rounded peak
  - Using rarefaction polarity response is peakier
  - Response is about 4 to 8 ms longer than the click
  - Cyclical stimulus ringing sometimes occurs - this is not a response.

otometrics
a division of natus

500Hz Toneburst Waveform

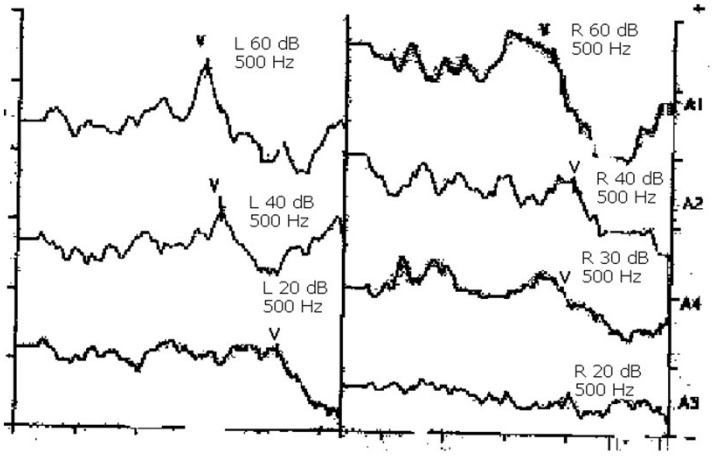
There may not be one single peak but rather a flatter area representing Wave V

Look for the trough



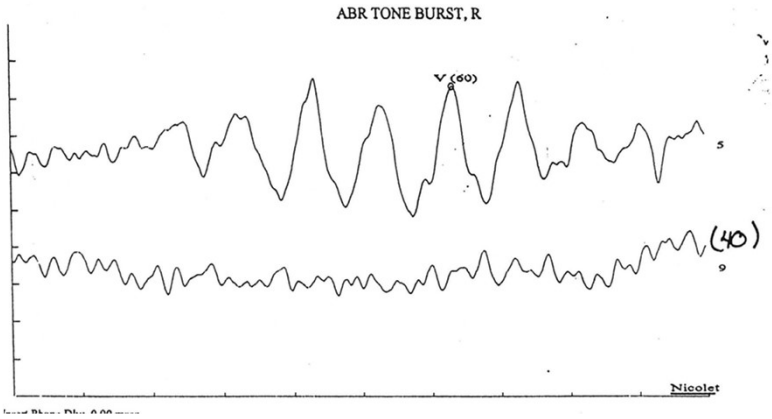
otometrics
a division of natus

500 Hz Toneburst Air Conduction ABR



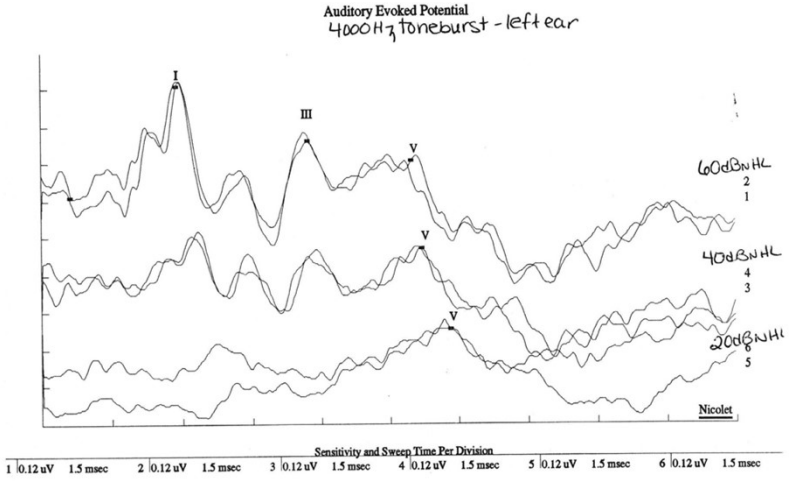
otometrics
a division of natus

This is <u>NOT</u> a Response to 500 Hz Toneburst Air Conduction ABR



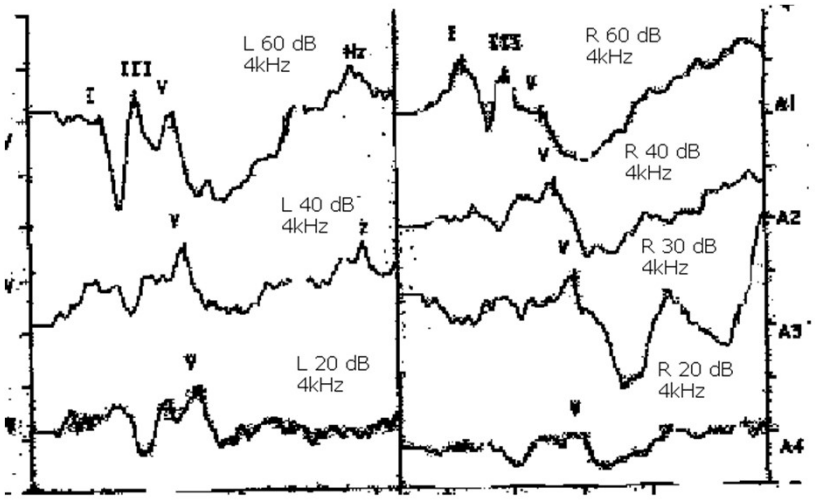
otometrics
a division of natus

4000 Hz Toneburst Air Conduction ABR



otometrics
a division of natus

4000 Hz Toneburst Air Conduction ABR



otometrics
a division of natus

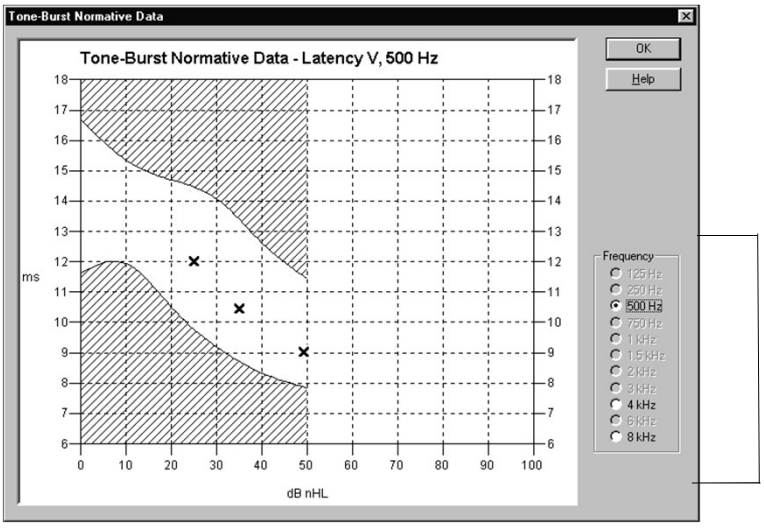
Toneburst Correction Factors

- There are varying opinions on whether correction factors are needed or not for toneburst responses.
- 500 Hz – 20 dB
- 1000 Hz – 15 dB
- 4000 Hz – 5 dB

- 8000 Hz – roll of for insert earphones is around 5000 Hz so 8000 Hz may not be frequency specific

otometrics
a division of natus

Tone Burst Normative Data



otometrics
a division of natus

Neural Disorders

- Infants in the NICU sometimes have delayed neuromaturation. Carefully monitor infants in the NICU for any improvement in hearing.
- Patients with auditory neuropathy have an abnormal ABR with present OAEs.

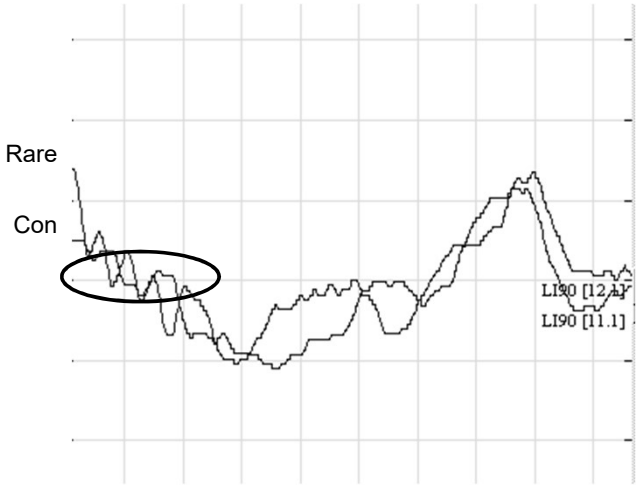
otometrics
a division of natus

Cochlear Microphonic

- Pre-neural response from cochlea that follows the stimulus waveform
- Suggests that outer hair cells are intact and there is some neural response in the auditory pathway
- Patients with auditory neuropathy have an abnormal ABR with present OAEs

otometrics
a division of natus

Cochlear Microphonic



Alternating click will result in the cochlear microphonic canceling

otometrics
a division of natus

Any Questions?

otometrics
a division of natus