

16th Coalition of Global Hearing Health, October 2026 - Chennai

Fostering Inclusiveness, Changing Mindsets

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

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Associate Professor and Head

Department of Audiology

Sri Ramachandra Faculty of Audiology and Speech Pathology

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More *Time-Ordered Agenda*

9:00 am	Introduction and learning objectives
8:45 am	Crosscheck principle in pediatric hearing assessment
9:00 am	Objective techniques for auditory assessment of infants
9:30 am	Frequency-specific ABR measurement
10:30 am	Break
10:45 am	Live demo of frequency-specific ABR measurement
11:00 am	Attendee hands-on ABR measurement activities
12:45 pm	Questions & answers
1:00 noon	Adjourn

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More *Handouts (jh4325@drexel.edu)*

OBJECTIVE ASSESSMENT OF INFANT HEARING: ESSENTIAL FOR EARLY INTERVENTION

James W. Hall III^{1,2,3}

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Abstract

Substantial evidence supports the benefits of early intervention in infant hearing loss. Intervention can lead to the acquisition of effective communication skills and psychosocial development. Accurate diagnosis of infant hearing loss is not possible with conventional behavioral audiometry techniques. Objective auditory procedures are invaluable in the assessment of infant hearing because they do not rely on behavioral responses to sound and are unaffected by listener variables such as cognition, motivation, and language impairment.

Journal of Hearing Science, 2016

Clinical White Paper

Asking Some Clinical Questions About the Auditory Brainstem Response 50 Years After Its Discovery

Author:

James W. Hall III, PhD

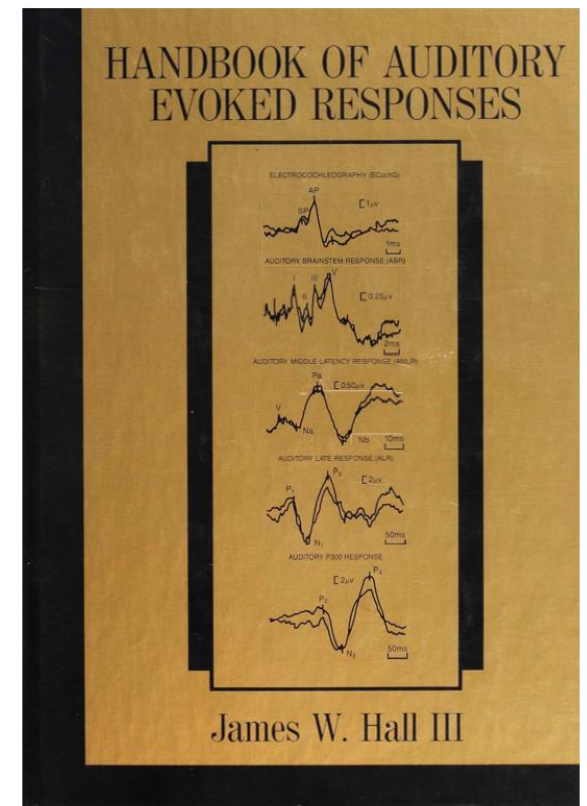
Professor

Salus University and University of Hawaii

jwhall3phd@gmail.com

1. The first paper on the auditory brainstem response (ABR) was published in 1970, 50 years before publication of this 20Q article (Jewett, Romano & Williston, 1970). Therefore, it seems totally appropriate to focus here on some clinically-relevant questions about this valuable audiologic procedure. I'll begin with an electrode question. What are the advantages and disadvantages to using a high forehead versus vertex placement for the non-inverting electrode when recording ABRs from infants?

2020



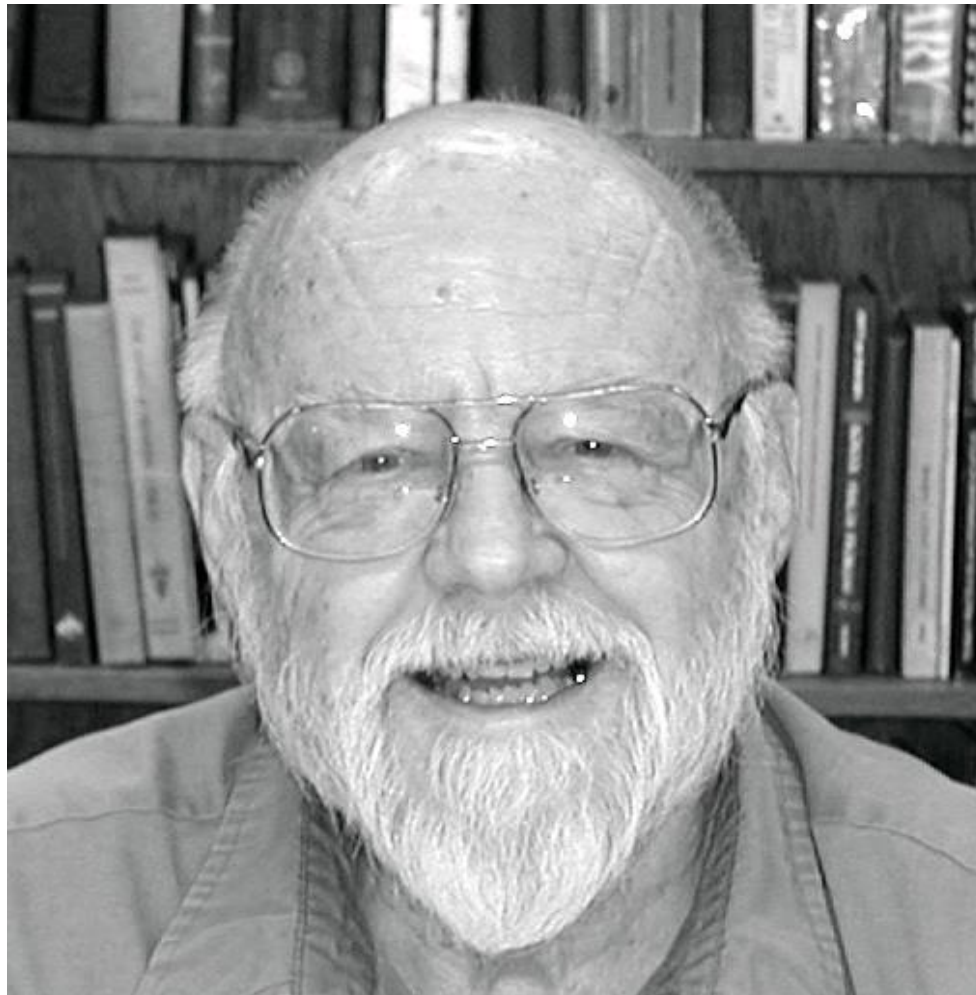
1992

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

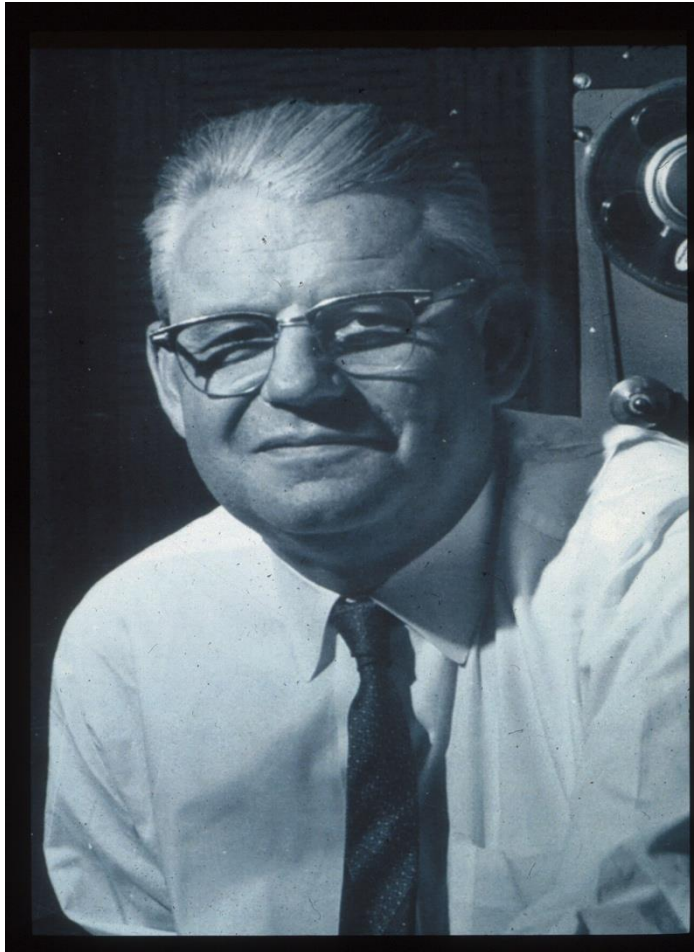
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The Cross-Check Principle

(Jerger J & Hayes D. Arch Otolaryngology, 102, 1976)



Tribute to James F. Jerger, PhD (1928 – 2024)



Raymond Carhart



The Cross-Check Principle in Pediatric Audiology

Test Battery in 1976

- **Behavioral audiometry**
 - **Pure tone audiometry**
 - **Simple speech audiometry**
- **Immittance (impedance) measurements**
 - **Tympanometry**
 - **Acoustic reflexes (contralateral only with SPAR)**
- **Auditory brainstem response (brainstem-evoked response audiometry or BSER)**
 - **Click stimulus (air conduction)**
 - **Click stimulus (bone conduction)**

The Cross-Check Principle in Pediatric Audiology

(Jerger J & Hayes D. Arch Otolaryngol 102: 1976)

“We have found than simply observing the auditory behavior of children does not always yield an accurate description of hearing loss”...

“The basic operation of this principle is that no result be accepted until it is confirmed by an independent measure.”

“As long as audiologists are willing to accept the results of a single test measure they will continue to misdiagnosis and mismanage some children.”

Celebrating the 50th Anniversary of The Cross-Check Principle

Current Pediatric Audiology Test Options

- **Behavioral Audiometry**
- **Otoacoustic Emissions (OAEs)**
- **Aural Immittance Measurements**
 - **Tympanometry**
 - **Acoustic Reflexes (ipsi- and contralateral conditions)**
- **Auditory Brainstem Response (ABR)**
 - **Air- and Bone Conduction Stimulation**
 - **Click, Tone Burst and Chirp Stimulation**
- **Auditory Steady State Response (ASSR)**
- **Electrocochleography (ECoChG)**
- **Cortical Auditory Evoked Responses**

The Cross-Check Principle in Audiology

A 40-Year Perspective

(Request via email)

REVIEW

J Audiol Otol 2016;20(2):59-67

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Crosscheck Principle in Pediatric Audiology Today: A 40-Year Perspective

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St. Augustine, FL, USA
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The crosscheck principle is just as important in pediatric audiology as it was when first described 40 years ago. That is, no auditory test result should be accepted and used in the diagnosis of hearing loss until it is confirmed or crosschecked by one or more independent measures. Exclusive reliance on only one or two tests, even objective auditory measures, may result in a auditory diagnosis that is not clear or perhaps incorrect. On the other hand, close and careful analysis of findings for a test battery consisting of objective procedures and behavioral tests whenever feasible usually leads to prompt and accurate diagnosis of auditory dysfunction. This paper provides a concise review of the crosscheck principle from its introduction to its clinical application today. The review concludes with a description of a modern test battery for pediatric hearing assessment that supplements traditional behavioral tests with a variety of independent objective procedures including aural immittance measures, otoacoustic emissions, and auditory evoked responses.

J Audiol Otol 2016;20(2):59-67

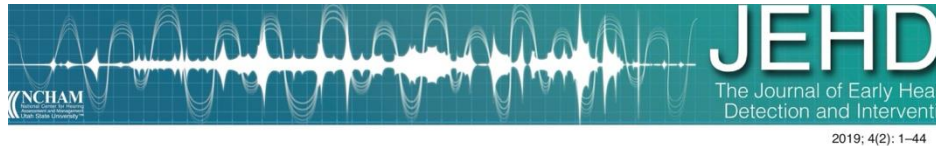
KEY WORDS: Auditory brainstem response · Auditory steady state response ·
Aural immittance measures · Crosscheck principle · Otoacoustic emissions.

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

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Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More *Objective Auditory Assessment is Standard of Care*



Year 2019 Position Statement: Principles and Guidelines for Early Hearing Detection and Intervention Programs

The Joint Committee on Infant Hearing

Table of Contents		Abbreviations
Executive Summary.....	2	AAA – American Academy of Audiology AABR – Automated Auditory Brainstem Response AAP – American Academy of Pediatrics ABA – American Board of Audiology ABR – Auditory Brainstem Response AHRQ – Agency for Healthcare Research and Quality ANSI – American National Standards Institute ASHA – American Speech-Language-Hearing Association ASL – American Sign Language ASSR – Automated Steady-State Response BOA – Behavioral Observation Audiometry CART – Communication Access Real-time Translation CAEP – Cortical Auditory Evoked Potentials CMV – Cytomegalovirus cCMV – Congenital Cytomegalovirus CDC – Centers for Disease Control and Prevention CE – Click Evoked CI – Cochlear Implant dB – Decibel DEC – Division of Early Childhood DPOAE – Distortion Product Otoacoustic Emissions DSL – Desired Sensation Level ECMO – Extracorporeal Membrane Oxygenation EHDI – Early Hearing Detection and Intervention EHDI PALS – Early Hearing Detection & Intervention: Pediatric Audiology Links to Services
Background.....	3	HIPAA – Health Insurance Portability and Accountability Act HL – Hearing Level HRCT – High Resolution Computed Tomography HRSA – Health Resources and Services Administration IDEA – Individual with Disabilities Education Act IEP – Individualized Education Program IFSP – Individual Family Service Plan IOM – Institute of Medicine ISO – International Organization for Standardization JCAHO – Joint Commission on Accreditation of Health Care Organizations JCIH – Joint Committee on Infant Hearing LTF/LTD – Loss-to-Follow-Up/Loss-to-Documentation MRI – Magnetic Resonance Imaging NCHAM – National Center for Hearing Assessment and Management NICHD – National Institute of Children's Health Quality NIDCD – National Institute of Deafness and Communication Disorders NICU – Neonatal Intensive Care Unit NIH – National Institutes of Health NLM – U.S. National Library of Medicine
Principles.....	4	
Guidelines for Early Hearing Detection and Intervention Programs.....	4	
Newborn Hearing Screening Programs.....	5	
Pediatric Diagnostic Audiology.....	12	
Medical Evaluation.....	17	
Early Intervention: Services for Infants/Toddlers from Birth to Age Three Years and Their Families.....	24	
Medical Home and Ongoing Surveillance....	28	
Protecting the Rights of Infants/Toddlers and Families.....	32	
EHDI Information Technology Infrastructure	33	
Benchmarks and Quality Indicators.....	34	
Future Directions.....	35	
Research Needs.....	36	
Acknowledgments.....	37	
References.....	37	

- **Aural immittance measures**
 - Tympanometry
 - Acoustic reflexes
- **Otoacoustic emissions**
- **Auditory brainstem response**
 - Air-conduction click stimuli
 - Bone-conduction click stimuli
 - Tone burst stimuli
 - Chirp stimuli
- **Auditory steady state response**

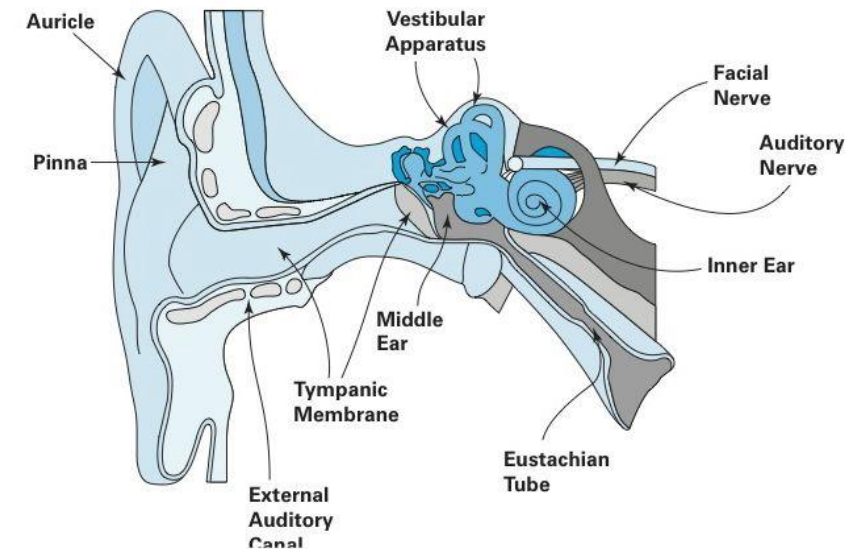
Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More *Aural Immittance Measurement*

The key aspects of audiologic assessment for infants and young children are:

- Auditory brainstem response is the gold standard test for threshold estimation for infants and children who cannot complete behavioral audiologic assessment. ABR provides ear- and frequency-specific threshold estimates that are necessary for the diagnosis of the type, degree, and configuration of hearing loss and provision of amplification (Gorga et al., 2006).
- Measures of middle ear function should be completed as part of the diagnostic audiologic process for infants and young children. Either tympanometry or wideband reflectance can be used to characterize middle ear function (Hunter et al., 2013).
- Acoustic reflexes are an important test of middle ear function and the integrity of auditory brainstem pathways (de Lyra-Silva et al., 2015).
- Otoacoustic emissions provide important information about the integrity of the outer hair cells of the cochlea and provide critical information about the differential diagnosis of auditory neuropathy spectrum disorder and sensorineural hearing loss (Gorga et al., 2000).
- Behavioral assessment of hearing is the gold standard for estimation of hearing thresholds. Visual reinforcement audiometry (VRA; for infants 6–24 months; Widen et al., 2005) and condition play audiometry (CPA; for toddlers 24+ months; Norrrix, 2015) are established methods based on conditioned responses to sound.

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More *Aural Immittance Measures*

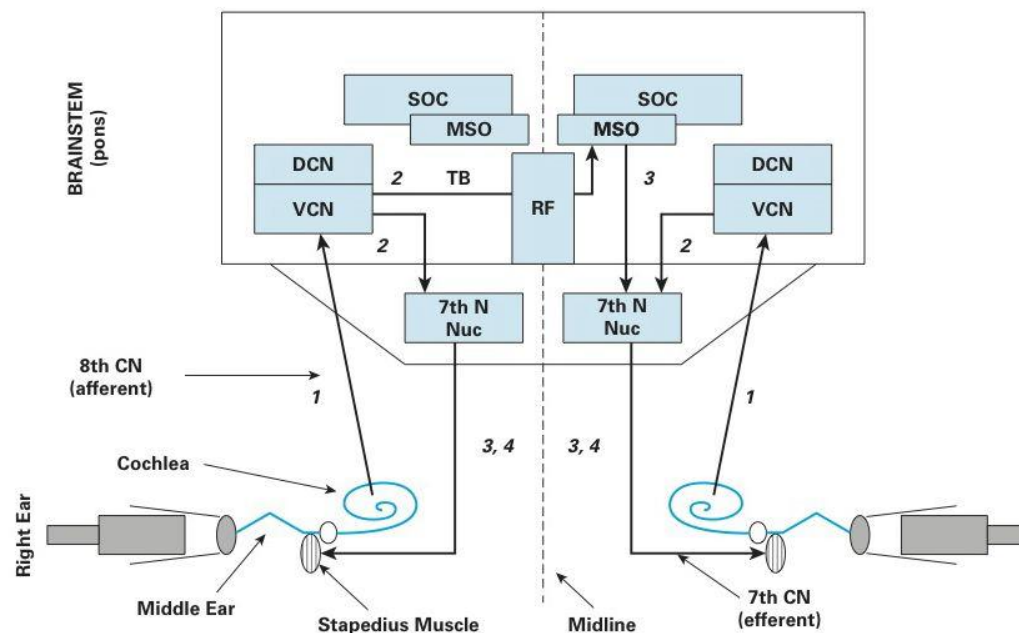
- **Ear canal volume**
- **Static compliance**
- **Tympanometry**
 - 220 vs. 1000 Hz probe tones for adults vs. neonates
 - Multiple admittance components
 - Middle ear resonance
 - Toynbee and Valsalva procedures
 - Gradient
 - Fistula test
- **Acoustic reflexes**
 - Ipsi - and contralateral
 - Multiple response parameters



Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

A Variety of Acoustic Reflex Measurements

- **Acoustic threshold (ART) or mini response level**
- **Acoustic reflex amplitude**
- **Acoustic reflex decay**
- **Acoustic reflex latency**



Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

Acoustic Reflex Latency



Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

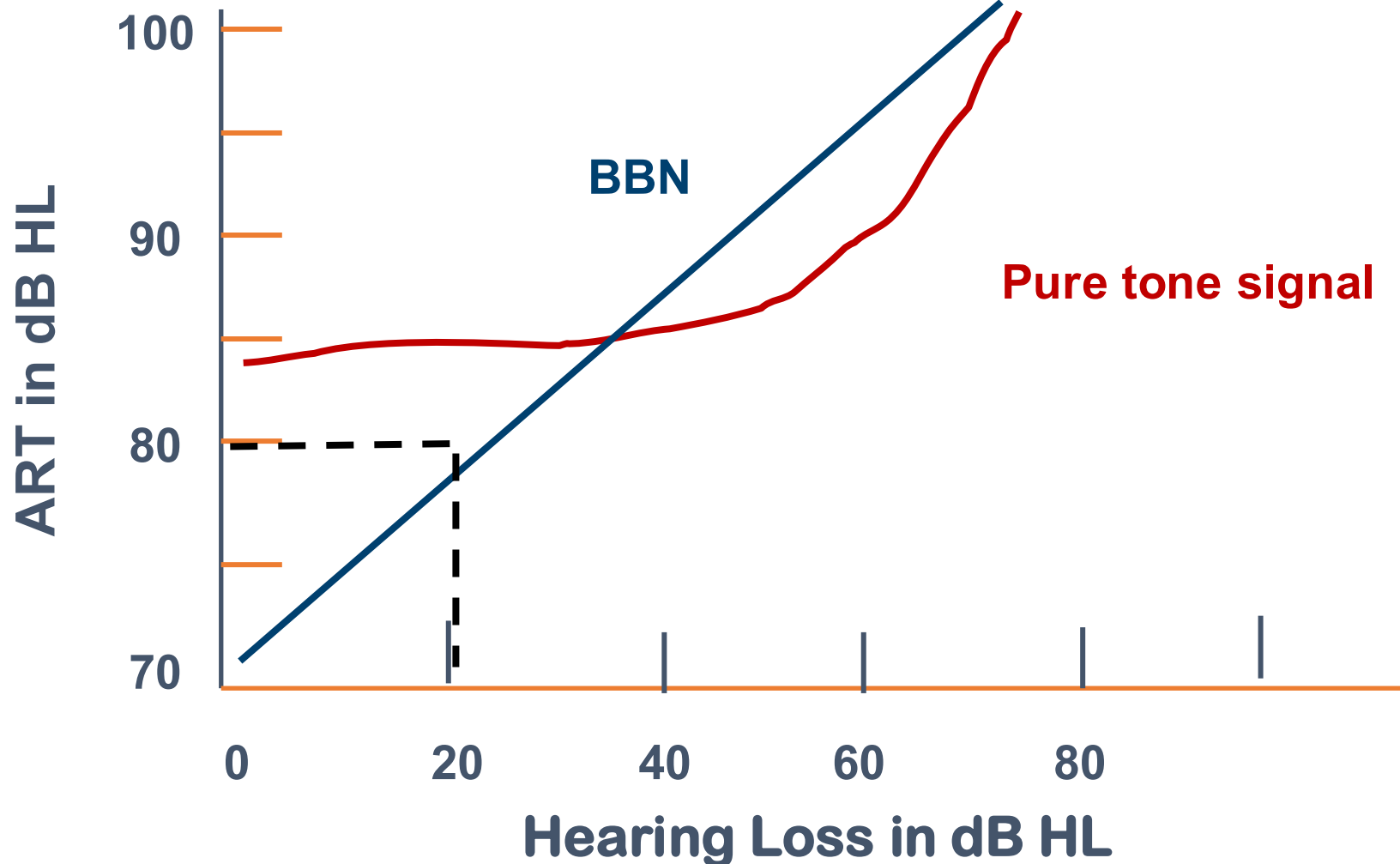
Valuable Acoustic Reflex Applications in Young Children

- **Detection of even subtle middle ear dysfunction**
- **Normal hearing sensitivity versus sensory hearing loss**
- **Detection of 8th nerve dysfunction**
- **Detection of 7th nerve dysfunction**
- **Detection of brainstem auditory dysfunction**
- **Diagnosis of auditory neuropathy spectrum disorder**
- **Identification of false or exaggerated hearing loss**

Simplified SPAR

(Sensitivity Prediction by the Acoustic Reflex)

Hall JW III, Berry GA and Olson K. Identification of serious hearing loss with acoustic reflex data:
Clinical experience with some new guidelines. Scandinavian Audiology 11: 251-255, 1982



Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

Valuable Acoustic Reflex Applications in Young Children

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Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

Valuable Acoustic Reflex Applications in Young Children

16th Coalition of Global Hearing Health, October 2026 - Chennai
Fostering Inclusiveness, Changing Mindsets

Sunday 11th October 2026

11:00 -
1:15 PM

Hall 1: Oral presentations

Session theme: Epidemiology (10 slots)

Hall 2: Oral presentations

Session theme: Economics & health systems (11 slots)

1:00 - 1:12
PM

35. 35. Making the most of middle ear and acoustic reflex measurements, **James Hall**

OP35

45. Tinnitus in school-going adolescents: prevalence, clinical profile, and severity determinants, **Archana Gundmi**

OP46



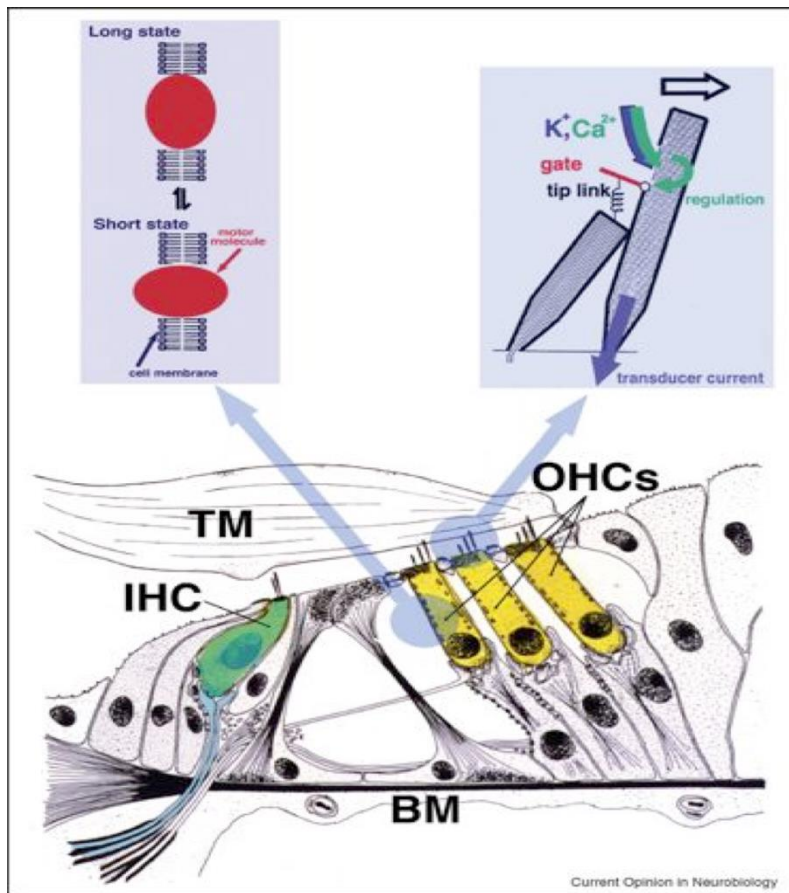
Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More *OAE Measurement is Standard of Care*

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Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

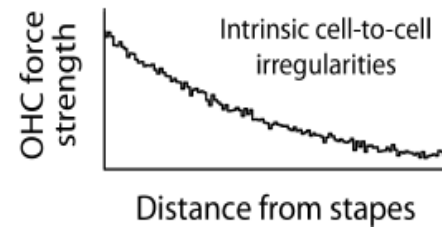
Anatomy and Physiology of OAEs



Hypothesis: Types of Otoacoustic Emissions

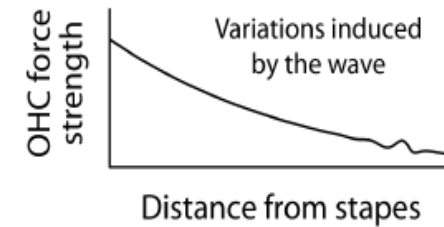
Otoacoustic Emissions

Reflection-Source



Generation requires cochlear *irregularity* (but not nonlinearity)

Distortion-Source



Generation requires cochlear *nonlinearity* (but not irregularity)

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

Anatomy and Physiology of OAEs

- **Outer hair cell motility with prestin motor protein**
- **Stereocilia**
- **Tectorial membrane**
- **Basilar membrane mechanics**
- **Stria vascularis**
- **Middle ear (inward delivery of stimulus and outward propagation of OAE energy)**
- **External ear canal**
 - **Stimulus presentation**
 - **OAE detection**

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

Four Important Steps Prior to OAE Measurement

- **Perform otoscopic inspection**
- **Determine risk for middle ear dysfunction**
 - **Patient history**
 - **Conduct tympanometry and acoustic reflexes as indicated to rule out or confirm middle ear dysfunction**
- **Verify stimulus calibration in the patient's external ear canal**
 - **Actual stimulus levels are in alignment with target stimulus levels (e.g., L2 = 55 dB; L1 = 65 dB)**
- **Confirm low noise levels in the external ear canal**
 - **Less than the 95%ile upper limit for normal subjects**

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

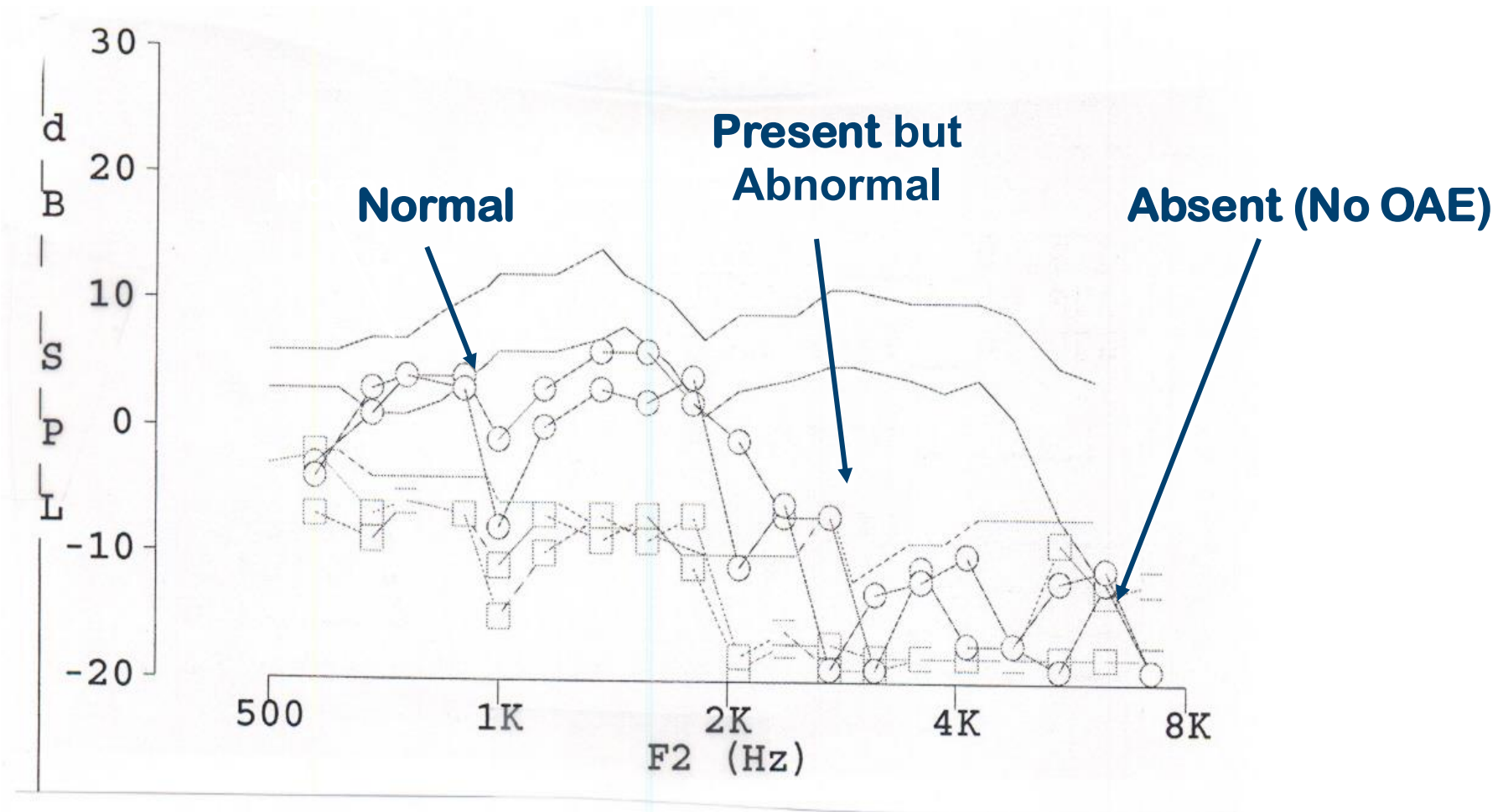
General Steps in Analysis of OAE Findings

- **Verify adequately low noise floor (< 90% normal limits)**
- **Perform analysis at all test frequencies**
- **Verify repeatability of TEOAE or DPOAE amplitude (+/- 2 dB) from at least two runs**
- **Is OAE - NF difference > 6 dB?**
 - **Yes? OAEs are present**
 - **No? There is no evidence of OAEs**
- **Is DP amplitude within normal limits?**
 - **Yes? OAEs are normal**
 - **No? OAEs are abnormal (but present)**

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

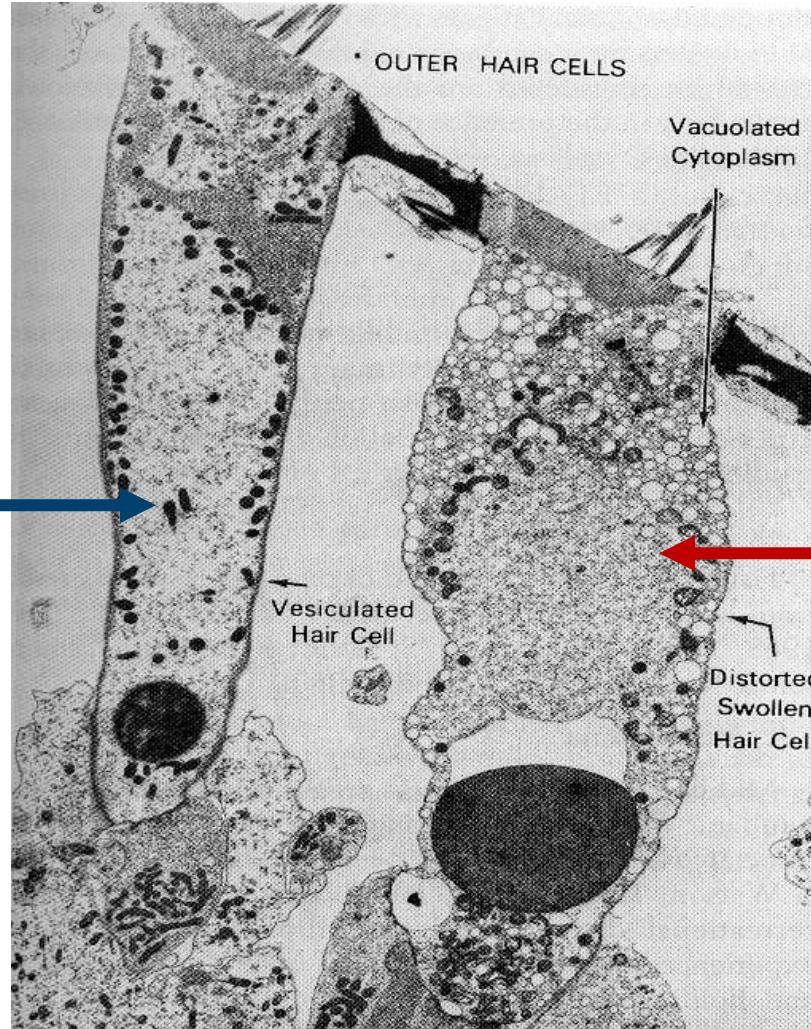
Analysis of DPOAEs

1. Normal 2. Present but Abnormal 3. Absent



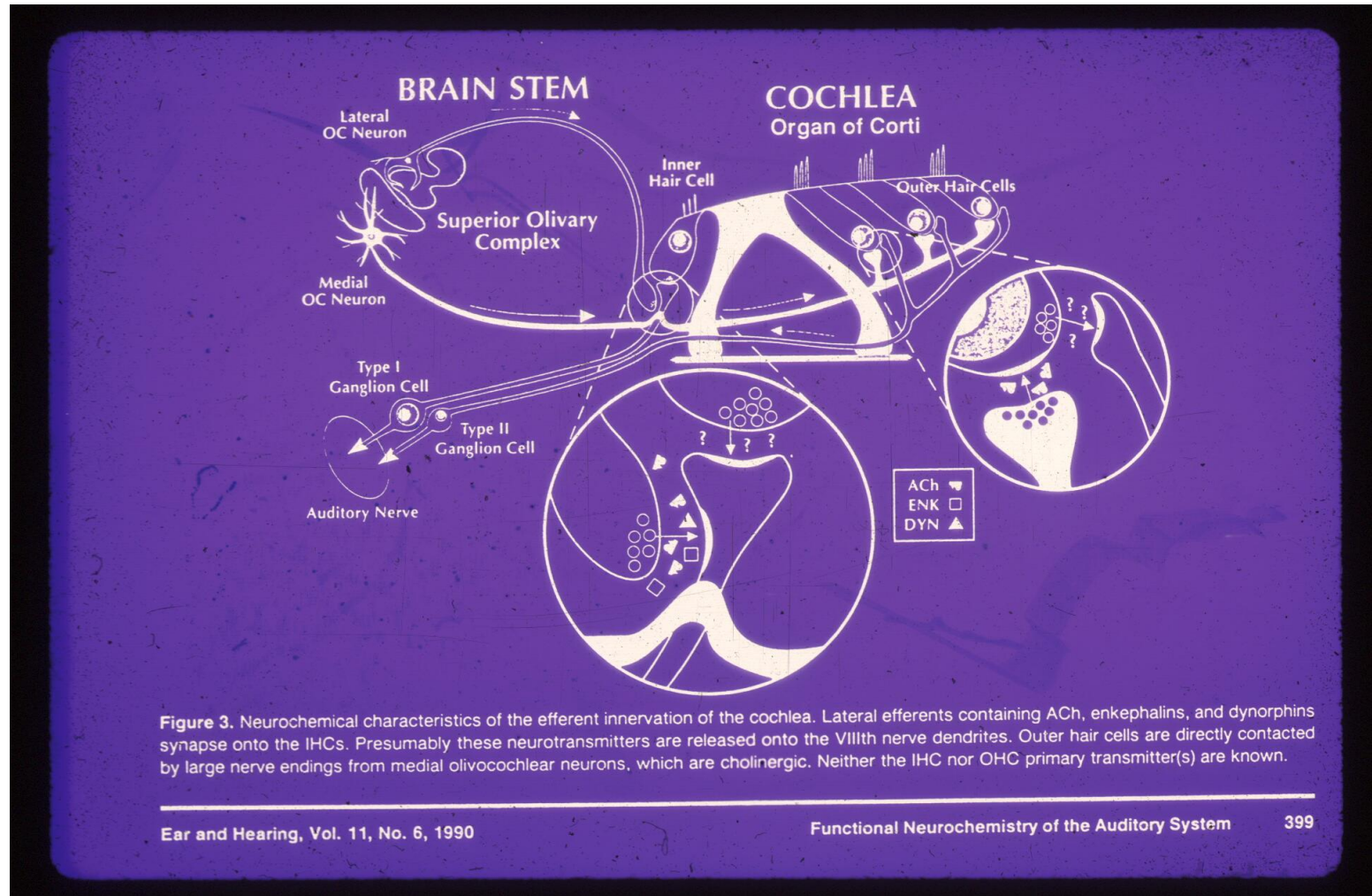
Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More *OAEs in Early Detection of Outer Hair Cell Dysfunction*

Normal
OHC
(OAEs)



Abnormal
OHC
(OAEs)

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More *Generation of OAEs is “Pre-Neural”*



Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

Relation of OAEs to Audiogram

OAEs	Audiogram	Possible Interpretation
Normal	Normal	Normal cochlear function
Abnormal	Normal	> Outer hair cell dysfunction > Rule out middle ear dysfunction
Normal	Abnormal	> Technical problems > Inner hair cell dysfunction > Neural auditory dysfunction > False hearing loss

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More *Selected Clinical Pediatric Applications of OAEs*

- Infant hearing screening
- Diagnosis of auditory dysfunction including ANSD
- Monitoring ototoxicity
- Pre-school hearing screening
- Identification of false or exaggerated hearing loss



Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

Minimal Test Battery According to 2010 ANSD Guidelines

- **Otoacoustic emissions (OAEs)**
- **Cochlear microphonic (CM may be present when OAEs are absent)**
- **Tests of auditory nerve function**
- **ABR for high intensity click stimulation (e.g., 80 to 90 dB nHL) with separate averages for rarefaction stimulus polarity vs. condensation stimulus polarity**

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eHandbook of Auditory Evoked Responses

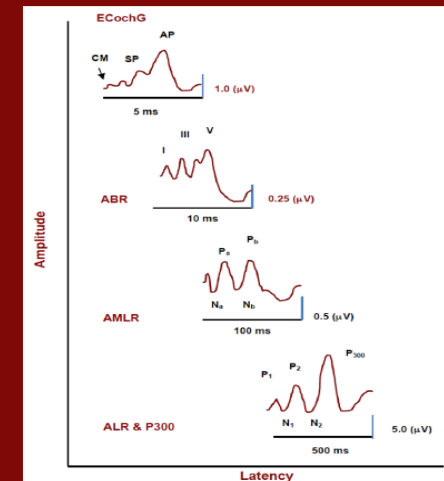
Available from Amazon.com

<http://www.amazon.com/dp/B0145G2FFM>

- **Chapter 1. Introduction to Auditory Evoked Responses**
- **Chapter 2. Introduction to Electrocochleography**
- **Chapter 3. ECoChG: Clinical Populations**
- **Chapter 4. Introduction to Auditory Brainstem Response (ABR)**
- **Chapter 5. ABR: Stimulus Parameters**
- **Chapter 6. ABR: Acquisition Parameters and Test Protocols**
- **Chapter 7. ABR: Analysis and Trouble Shooting**
- **Chapter 8. ABR: Clinical Applications and Patient Populations**
- **Chapter 9. Auditory Steady State Response**
- **Chapter 10. Auditory Middle Latency Response**
- **Chapter 11. Auditory Late Response**
- **Chapter 12. P300 Response and MMN**

eHandbook of Auditory Evoked Responses

Principles, Procedures & Protocols



James W. Hall III

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More *ABR Measurement is Standard of Care*

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Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More *ABR Protocol: Stimulus Parameters*

Parameter	Selection	Comment
Transducer	Insert earphones	A dozen good reasons
	Bone oscillator BC	ABR is often necessary
Type	Click or tone burst	Click for diagnosis
		Tone burst for threshold estimation
Duration	Click = 0.1 ms	Transient (synchronous firing) onset
	TB = 2-0-2 cycles	Tonal but transient
Polarity	Rarefaction	Larger amplitude; change as indicated
Rate	Click = 21.1/sec	Faster rate saves time; slow if necessary
	TB = 37.7/sec	Faster rate saves time; only need wave V
Intensity	Variable in dB nHL	High for neurodiagnosis; low for thresholds
Repetitions	Variable	Whatever is needed for good SNR
Masking	Rarely needed	Only if ABR is abnormal and no wave I

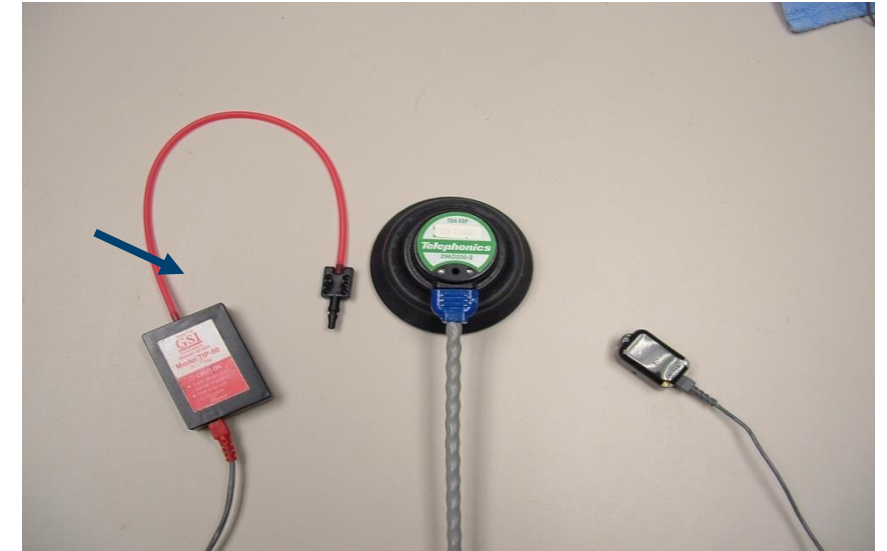
Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More *Advantages of Insert Earphones in ABR Measurement*

■ General

- Increased inter-aural attenuation
- Increased ambient noise attenuation
- Elimination of ear canal collapse
- Increased patient comfort
- **Improved infection control**
- More precise placement (reliability)

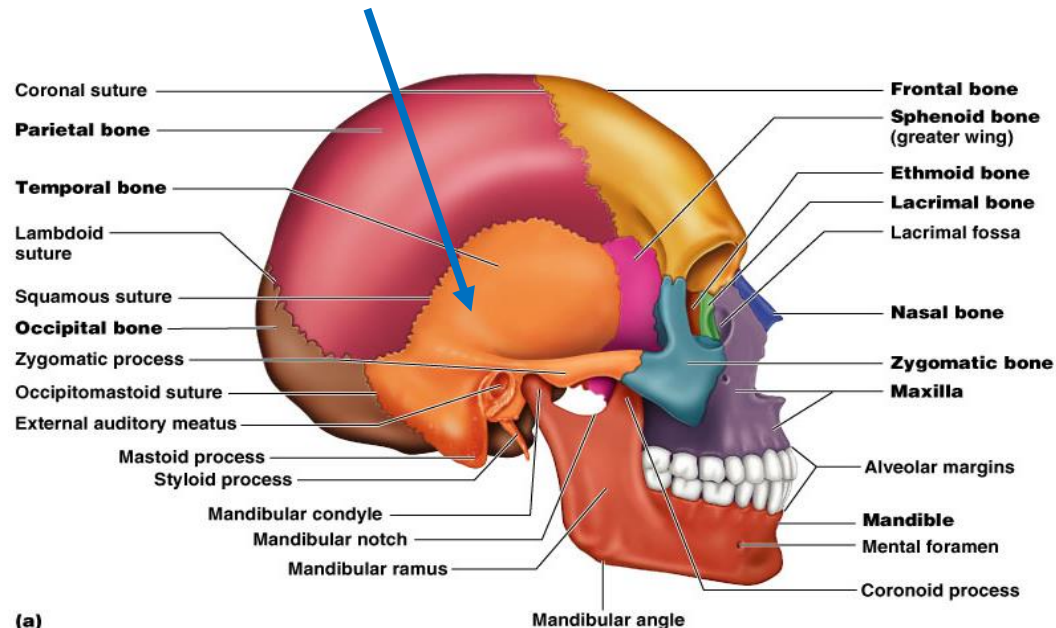
■ ABR specifically

- Reduced transducer ringing
- Reduced stimulus artifact with separation of transducer from inverting (earlobe) electrode



Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

A Modern Bone Oscillator Design for ABR Recording



(a)

B-81

High Output Bone Transducer

#8104108

Features

- Reliable performance
- Meets industry standards
- High maximum output, low distortion
- Mechanically robust
- Sensitivity: 119 dB re.1 μ N @ 1 VRMS & 1 kHz
- Total harmonic distortion: 1.1% @ 1 VRMS & 1 kHz
- Impedance: 12.5 ohm @ 1 kHz
- Secured plug concept
- RoHS compliant

Products:

- B-81 Bone Transducer, item #8104108
- Custom Safety Cable, item #8104110
- Standard Transducer Headband, item #8011098
- Pre-assembled packaged (incl. #8104108, #8104110, #8011098), item #8506491

**The Gold Standard**
of Audiometric Transducers



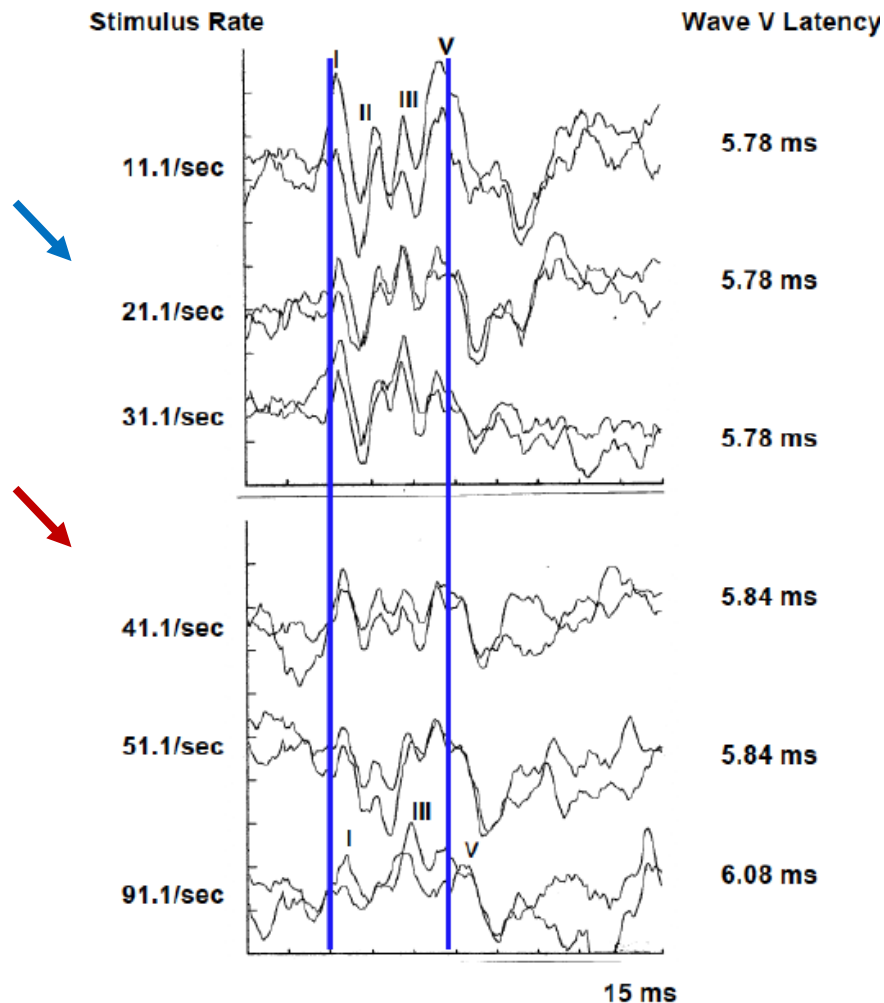
Audiometric Benefit

"The B-81 bone vibrator provides higher output and lower harmonic distortion compared to the B71. This may offer a significant clinical advantage. Conductive components of severe hearing losses that cannot be measured with the B71 vibrator may be measurable with the B-81. This is important for medical diagnosis and treatment, programming hearing aids, and determining cochlear implant candidacy."

Robert H. Margolis
Professor Emeritus, University of Minnesota

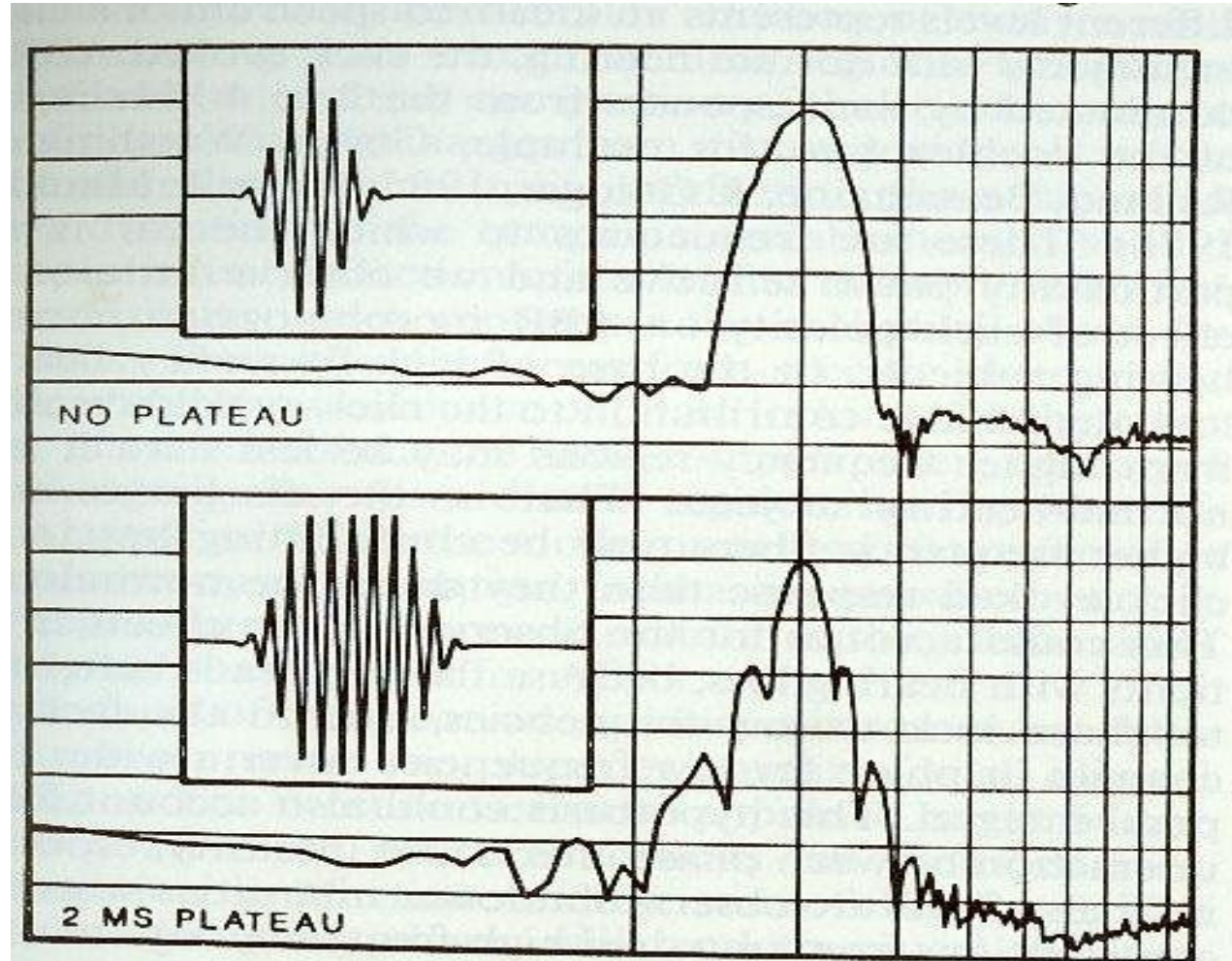
Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

What is the Optimal Stimulus Presentation Rate?



- **General Guideline: Fastest rate that still produces an optimal response**
- **Click stimulus: 21.1/sec**
 - ✓ Extensive normative data for latency
 - ✓ Slow enough to identify wave I
 - ✓ Fast enough for rapid data collection
 - ✓ Odd number not in sync with 50 Hz or 60 Hz current
- **Tone burst stimulus: 37.7/sec**
 - ✓ Quicker test time
 - ✓ Not interested in wave I
 - ✓ No negative impact of rate increase on waveform morphology

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More *Effect of Tone Burst Plateau* (Gorga & Thornton, 1989)



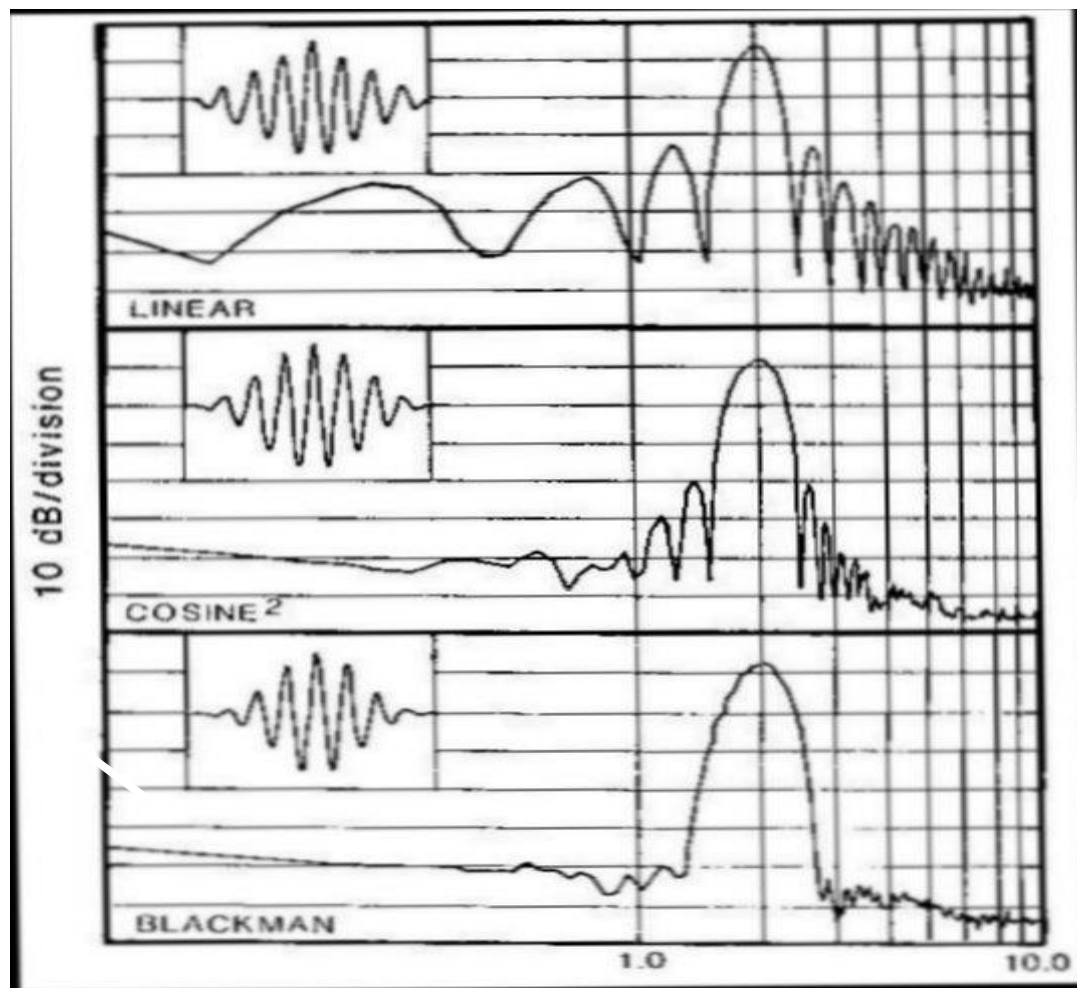
**Recommended Tone
Burst Duration:**

**2 cycles rise time
0 cycles plateau
2 cycles fall time**

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

Effect of Tone Burst Onset Ramp

(Gorga & Thornton, 1989)



Ralph B. Blackman
(1904-1990)

**MIT educated mathematician and
engineer**

**Pioneer in digital theory
(along with Claude Shannon,
John Tukey, et al)**

**Employed at Bell Telephone
Laboratories
(as was Harvey Fletcher)**

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More *Use Fastest Feasible Stimulus Presentation Rate*

- **Data Collection in a 1-Channel Pediatric ABR Assessment**
 - 4 stimuli (click + 3 tone burst frequencies)
 - 4 intensity levels per stimulus
 - 2 replications per intensity level
 - 2 ears
 - Total = $4 \times 4 \times 2 \times 2 = \sim 64$ separate ABR waveforms
- **Calculated Data Collection Time for a 1-Channel ABR Assessment**
 - Assume 1000 stimuli (sweeps) per waveform = 64,000 sweeps
 - Stimulus rate of 11.1/sec = 96 minutes
 - **Stimulus rate of 37.7/sec = 28 minutes**

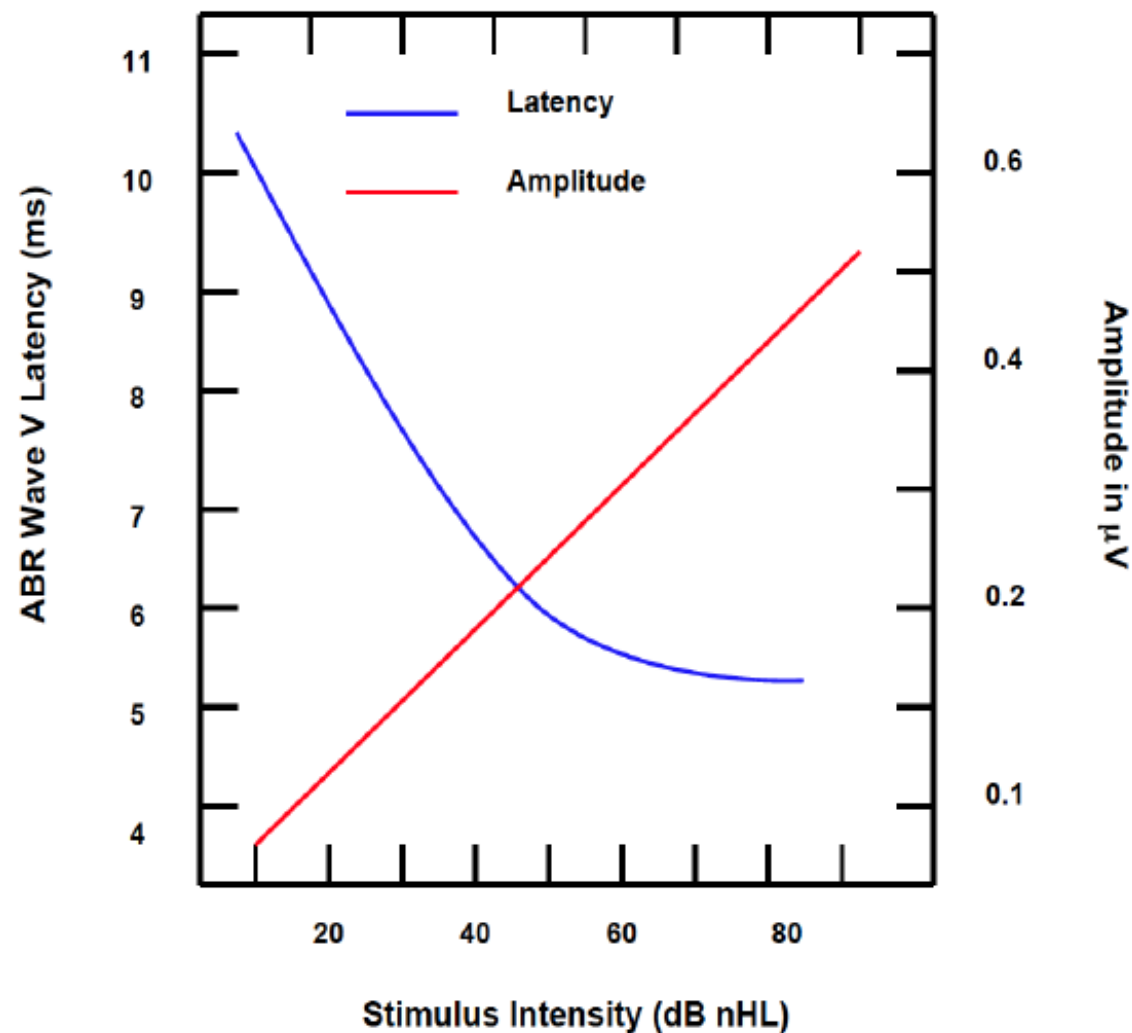
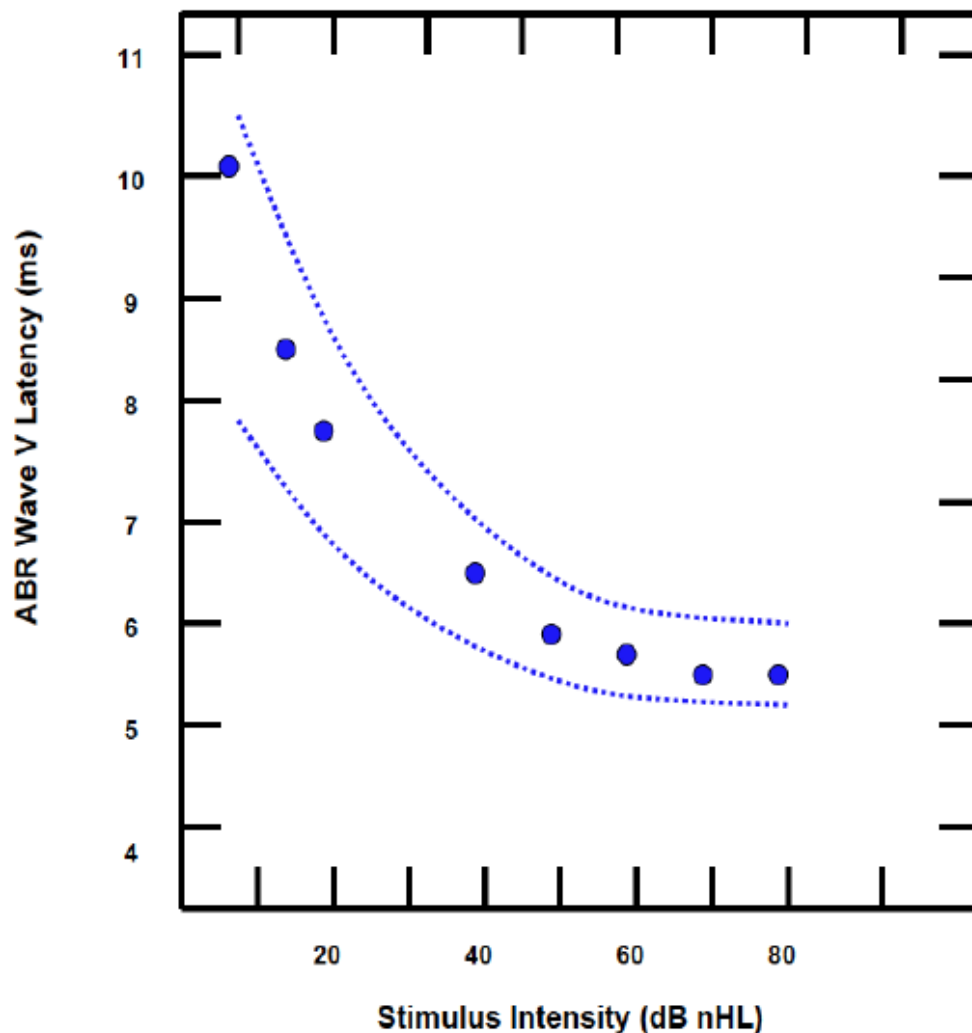
Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

Clinical ABR Concepts for Stimulus Intensity

- **Transient stimulus intensity is calibrated in dB pe SPL**
- **Intensity is described in dB nHL (normal hearing level)**
 - **0 dB nHL = average behavioral threshold for stimulus**
 - **0 dB nHL is approximately 30 dB peSPL**
- **ABR latency decreases as stimulus intensity increases**
 - **Greatest latency change is for intensity levels < 70 dB nHL**
 - **Flat “latency-intensity function or curve” > 70 dB nHL**
- **Wave V is normally detected within 10 dB of behavioral hearing threshold but not at behavioral threshold**
- **Wave I is usually observed to within about 35 dB of behavioral hearing threshold (smaller amplitude than wave V)**

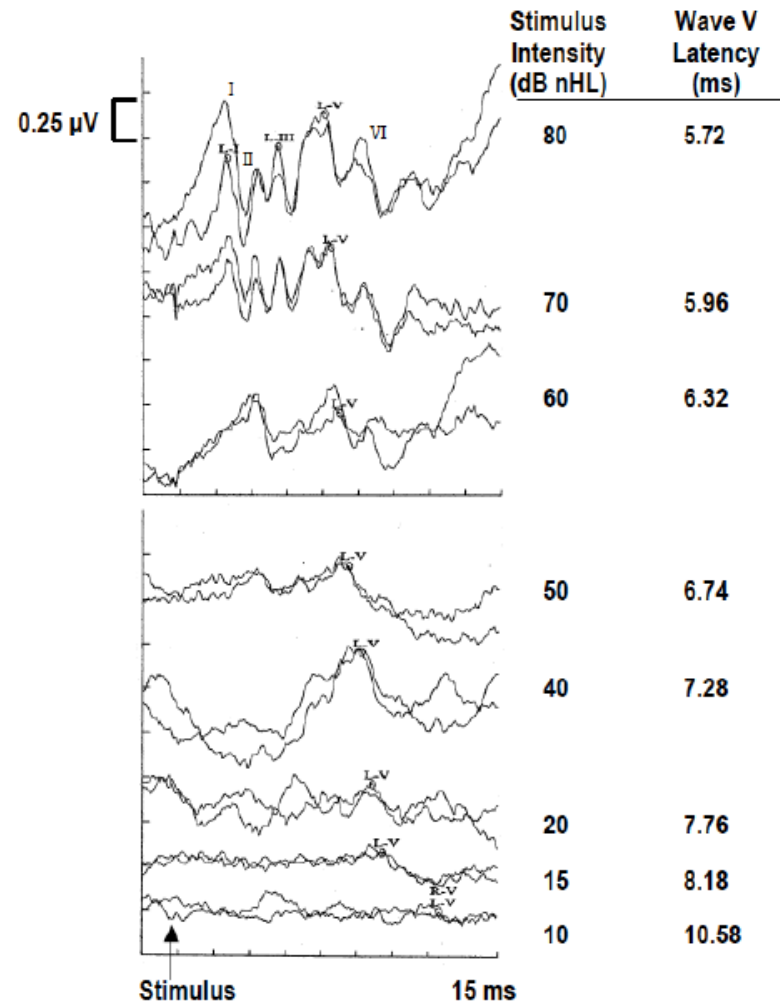
Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

Effect of Stimulus Intensity on ABR Wave V Latency



Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

ABR Wave V Latency versus Intensity



- Predictable increase in wave V latency for intensity levels < 70 dB nHL
- Decrease in amplitudes of all ABR waves with decreasing stimulus intensity levels
- Wave I normally disappears at about 35 dB nHL
- Wave V is normally observed
 - At lower intensity levels (larger amplitude)
 - At an intensity level within 10 dB of behavioral threshold

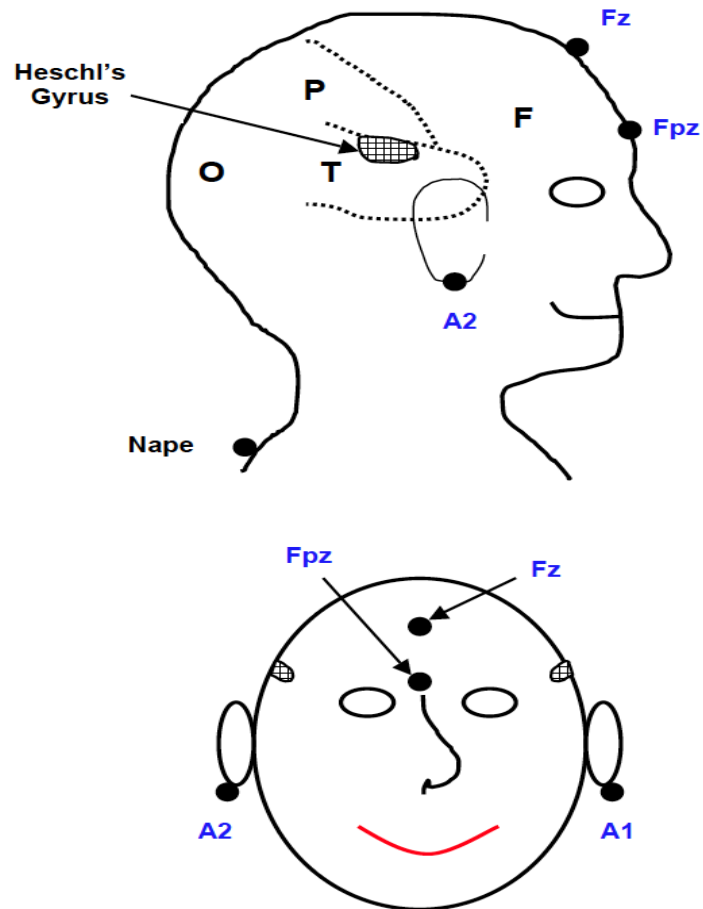
Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More *ABR Protocol: Acquisition Parameters*

Parameter	Selection	Comment
Channels	1 or 2	One channel is adequate for most applications
Electrodes*		
Noninverting	Fz	Advantages for high forehead vs. vertex
Inverting	Ai	Ipsilateral earlobe; Problems with mastoid
Ground Fpz		Any location is OK for common electrode
Filters		
High Pass	30 Hz	+ Low frequency energy in infant ABR
Low Pass	3000 Hz	2000 or 1500 Hz if there is high frequency artifact
Notch	Optional	May remove important low frequency energy
Amplification	X100,000	Or sensitivity of +/- 25 or 50 mV
Analysis time*	~ 15 ms	Encompasses ABR in most recording conditions
Pre-stim baseline	- 1 ms	Useful information on response quality
Sweeps (# stimuli)*	Variable	Whatever yields adequate SNR (ABR vs. Noise)

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

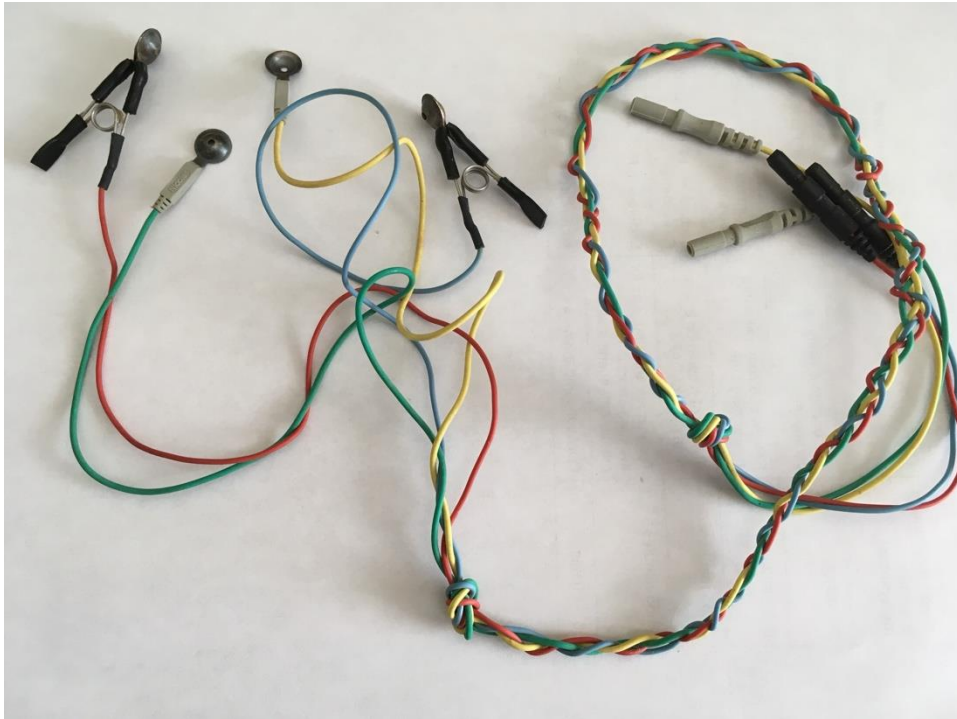
International 10-20 Electrode System

Auditory Brainstem Response (ABR)
Electrode Sites



Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

Electrode Application

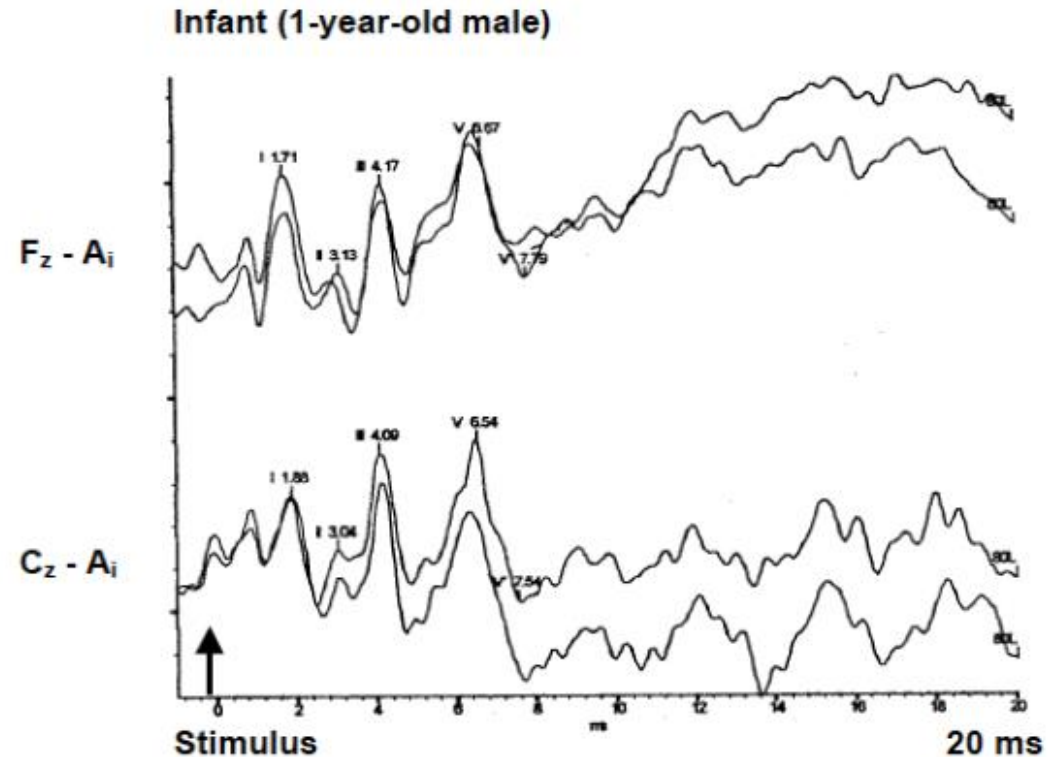
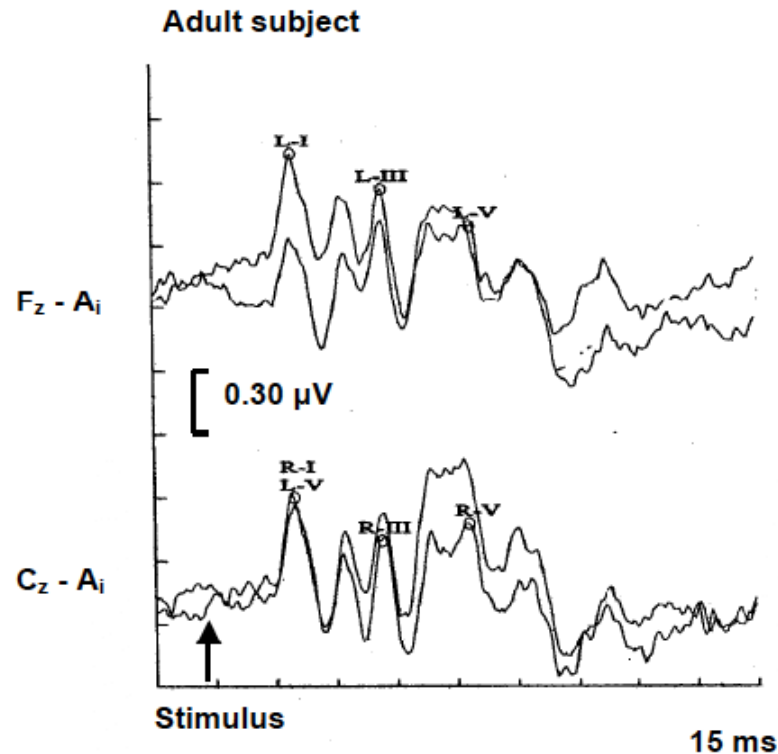


Why not use alcohol preps?

1. Possibility of alcohol intoxication
2. Less effective in removing old skin and debris
3. Dry and cracked skin on tester (→ infection risk)

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

ABR Measurement: Fz versus Cz Electrode Site

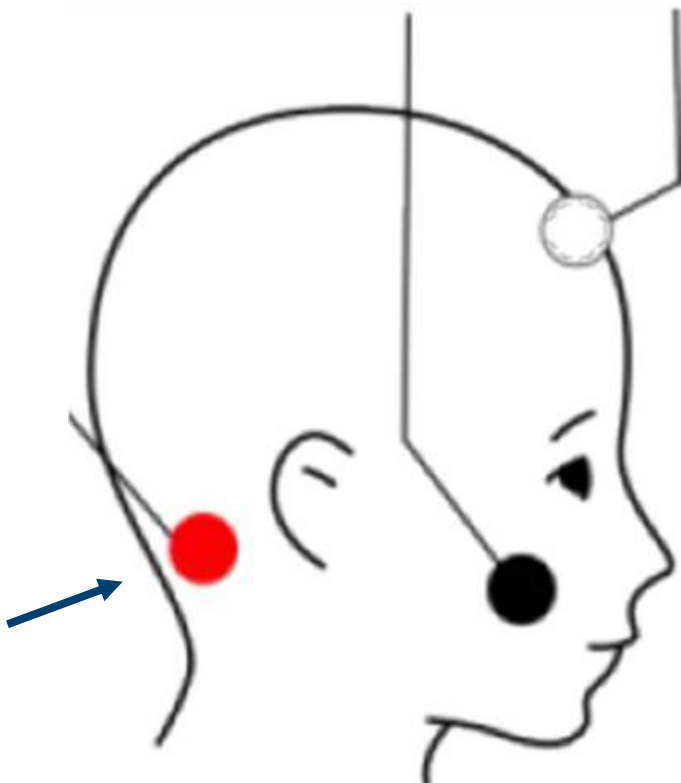


Advantage of Fz versus CZ Placement

1. More secure attachment (tape versus hair)
2. Avoid scrubbing fontanelle in newborn infants
3. Avoid bandages and cultural forms of head covering

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

Advantages for Earlobe vs. Mastoid Inverting Electrode

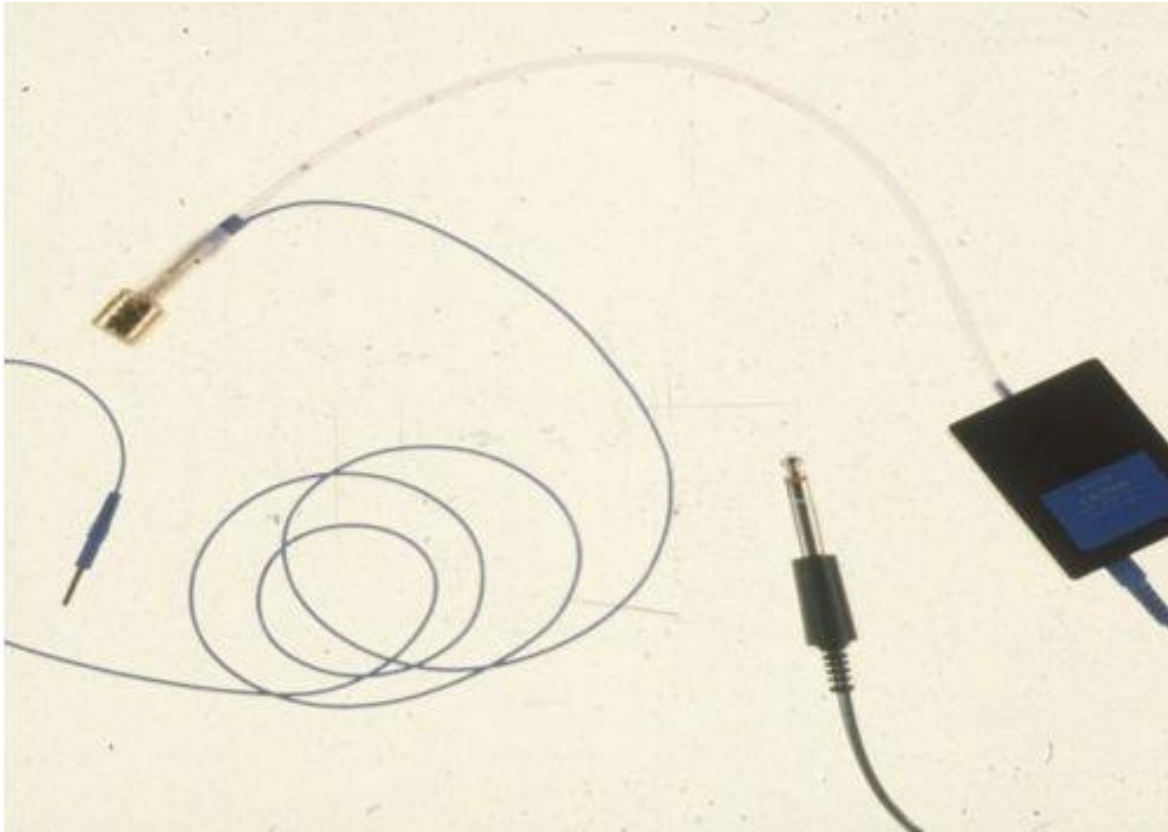


Advantages of Earlobe versus Mastoid Placement

1. On average 30% larger wave I amplitude with earlobe
2. Minimize post-auricular artifact
3. Extend electrode distance from bone oscillator to minimize stimulus artifact

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

TlPtrode Electrode Type: Transducer and Electrode



Advantage

- Larger wave I amplitude

Clinical Applications

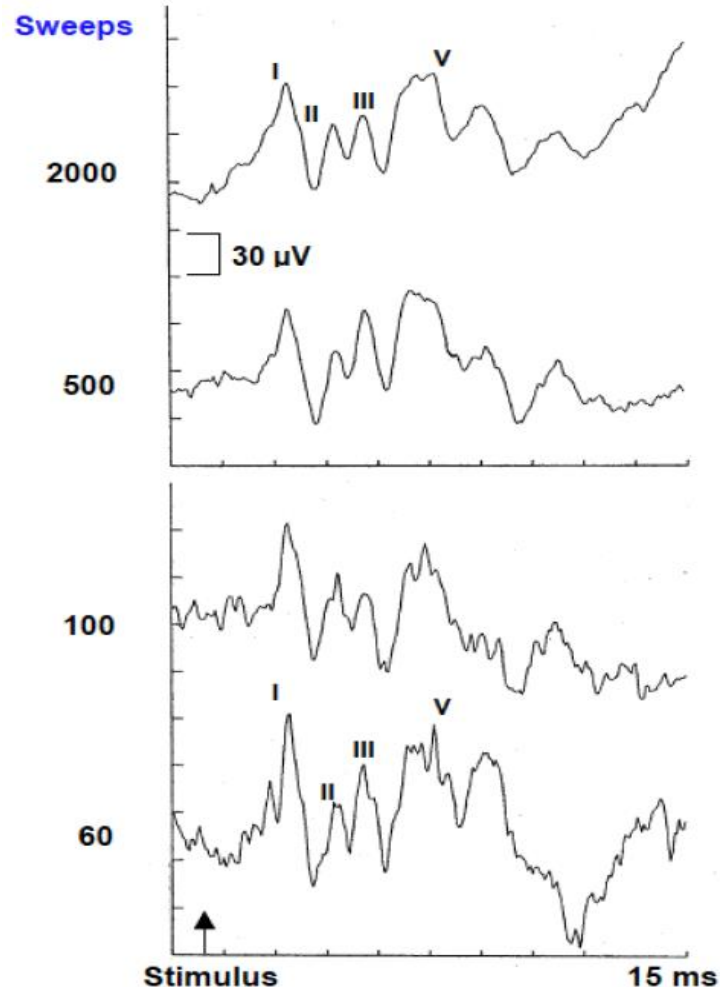
- Enhancement of ABR wave I (e.g., neuro-diagnostic ABR)
- Diagnosis of ANSD

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

Factors Affecting Decisions About ABR Analysis Time

ABR wave V latency for click stimulus at 85 dB nHL	~6.0-ms
Decrease in intensity to 20 dB nHL	+3-ms
Conductive hearing loss component of 50 dB	+2-ms
Age related latency increase for term infant	+1-ms
Latency increase with hypothermia (4 degrees)	+1-ms
Pre-stimulus baseline	+1-ms
	Total = 14-ms

Optimal Number of Stimuli (Signal Averages) Produces an ABR to Noise Ratio (SNR) of 3:1



**Signal-to-noise ratio (SNR) =
Signal Amplitude X Number of Averages**

Noise Amplitude

**where Signal = ABR and
Noise = any electrical activity that is NOT ABR**

Adequate $\text{SNR} \geq 3$
**(ABR wave V is 3 times larger than residual
background noise)**

Avoid Excessive Signal Averaging Despite Adequate SNR

(NHS Guidelines, 2013)

The number of sweeps per waveform accepted should be varied depending on both the size of the response and the level of background activity. The aim is to achieve a clear response or response absence rating (see later). The number of sweeps required to achieve this will normally vary between 1500 and 3000, although it may be higher when the responses are small or the background noise is high. Typically a figure of 2000 sweeps is recommended (minimum of 1500) for ckABR & narrowband chirp ABR and 3000 (minimum of 2000) for tpABR.

Exceptionally there may be such a large ABR response or low background activity that fewer sweeps can be used (subject to a minimum of 1500 for tpABR and 1000 for ckABR & narrowband chirp ABR). Any waveform must still be judged against the full clear response (**CR**) criteria, described later.

Example of a clear response (CR), satisfying the 3 to 1 signal to noise criterion

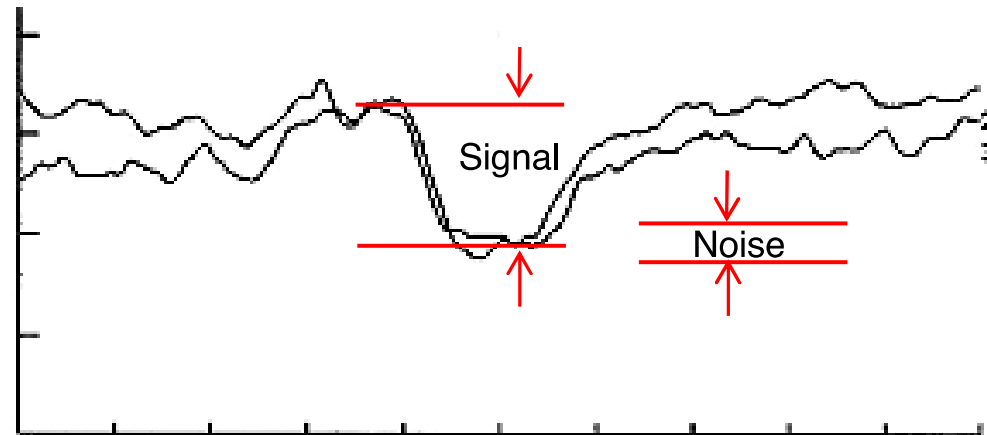


Figure 1

Scales:
150nV / div
2 ms / div

Saving Time in Pediatric ABR Measurement

Avoid Excessive Signal Averaging Despite Adequate SNR

Efficient Data Collection in a Typical Pediatric ABR Assessment:

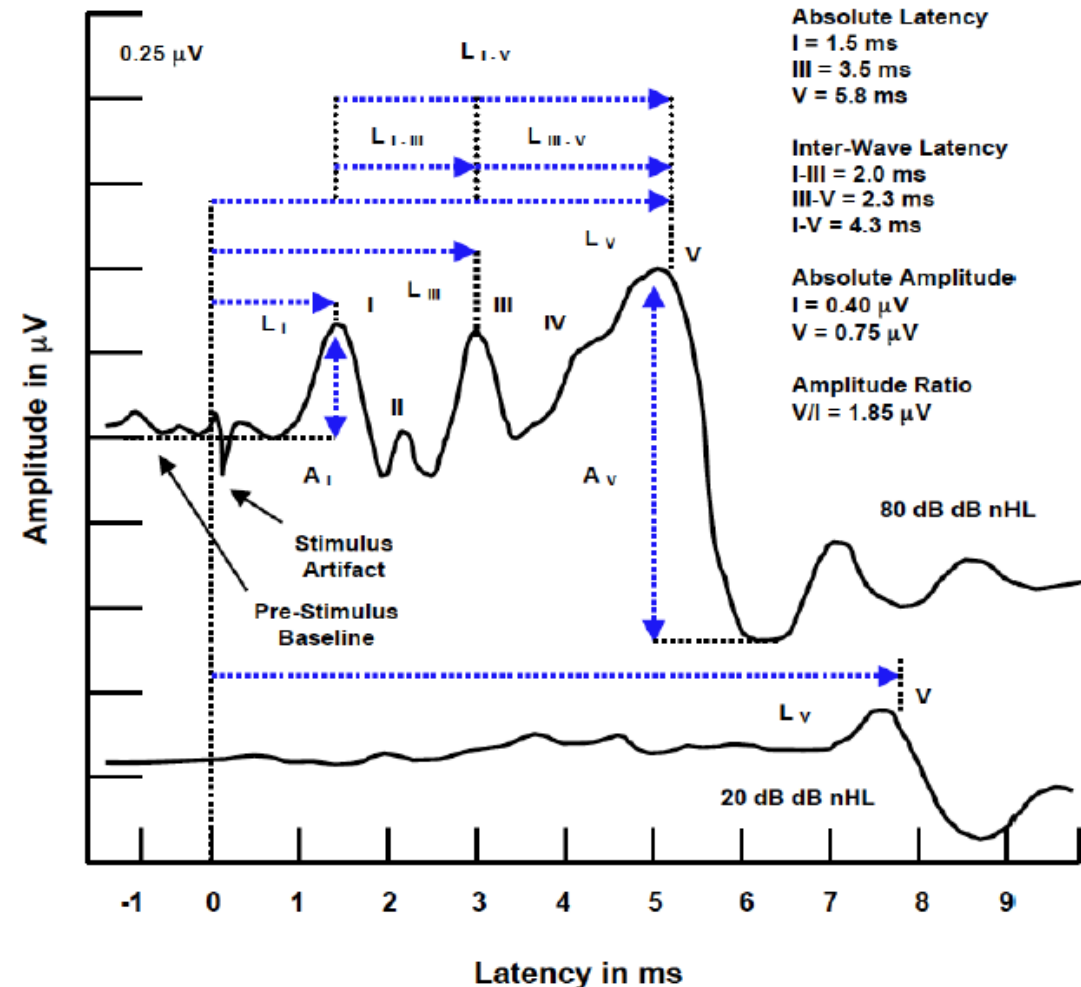
- 4 stimuli (click + 3 tone burst frequencies)
- 4 intensity levels per stimulus
- 2 ears
- 500 stimuli (sweeps) per waveform for 3 higher intensity levels
- 1000 sweeps for two replicated waveforms at threshold intensity level
- Total = $1500 + 2000 = 3500$ sweeps per stimulus X 4 stimuli X 2 ears = 28,000 sweeps

Calculated Data Collection Time

- Assume stimulus rate of 37.7/sec
- Averaging of 500 sweeps requires only 13 seconds
- Data collection time = $28,000/37.7 = 12.5$ minutes

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

Analysis of Latency and Amplitude

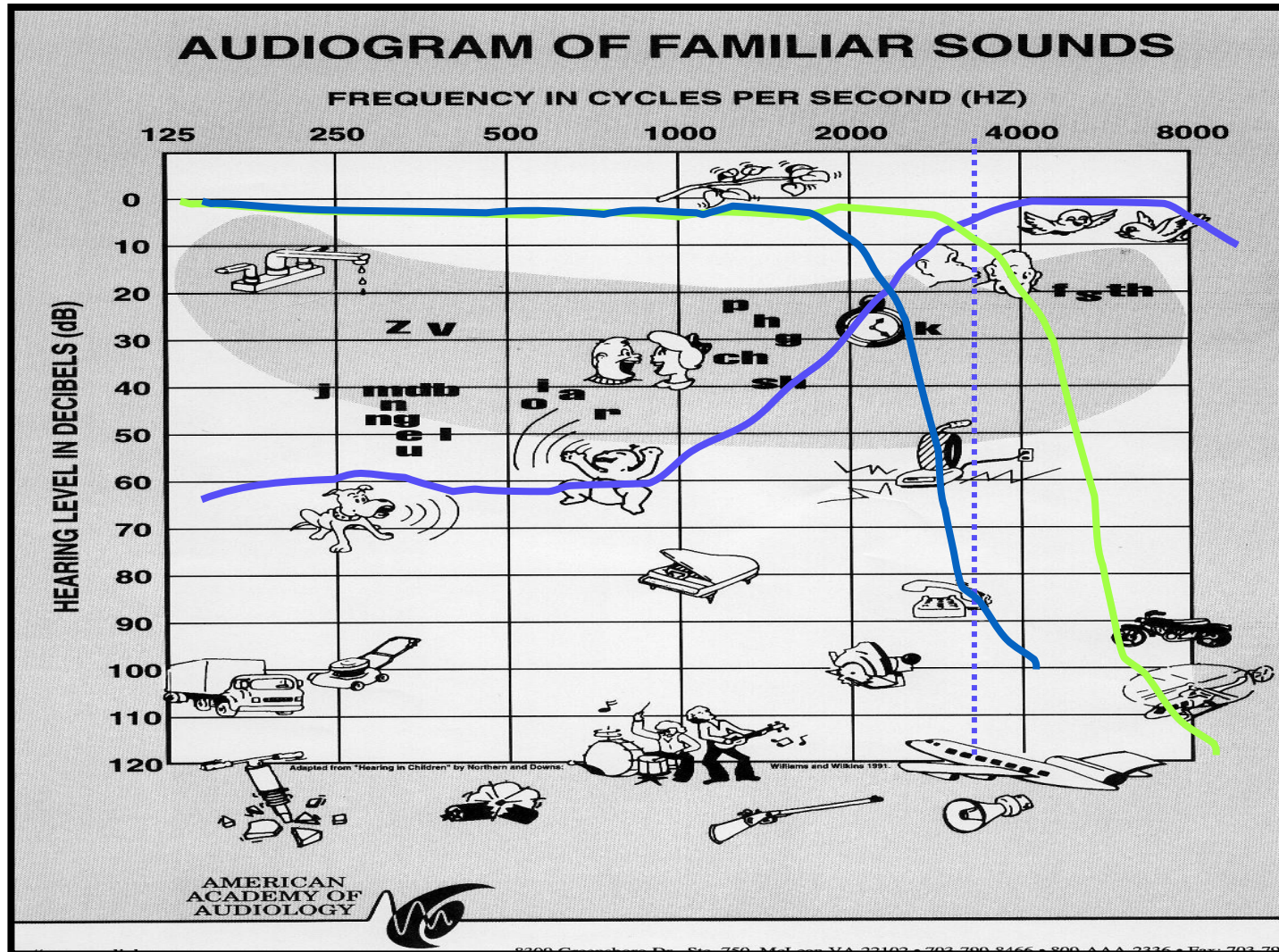


Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

Factors Influencing ABR Analysis

- **Age**
 - **Marked developmental changes**
 - **Modest changes with advanced age**
- **Gender**
 - **Significantly shorter latencies in females versus males**
 - **Use separate normative data for females versus males**
- **Body temperature**
 - **Prolonged latency in *hypothermia* (0.2 ms/1 degree)**
 - **Shorter latency in *hyperthermia***
- **Drugs (medications)**
 - **Sedatives = no effect**
 - **Selected anesthetic agents = slight effect**

Strengths and Weaknesses of Click-Evoked ABR: Diagnostically Useful but Limited Frequency-Specificity



- Normal click ABR
- Abnormal or no click ABR

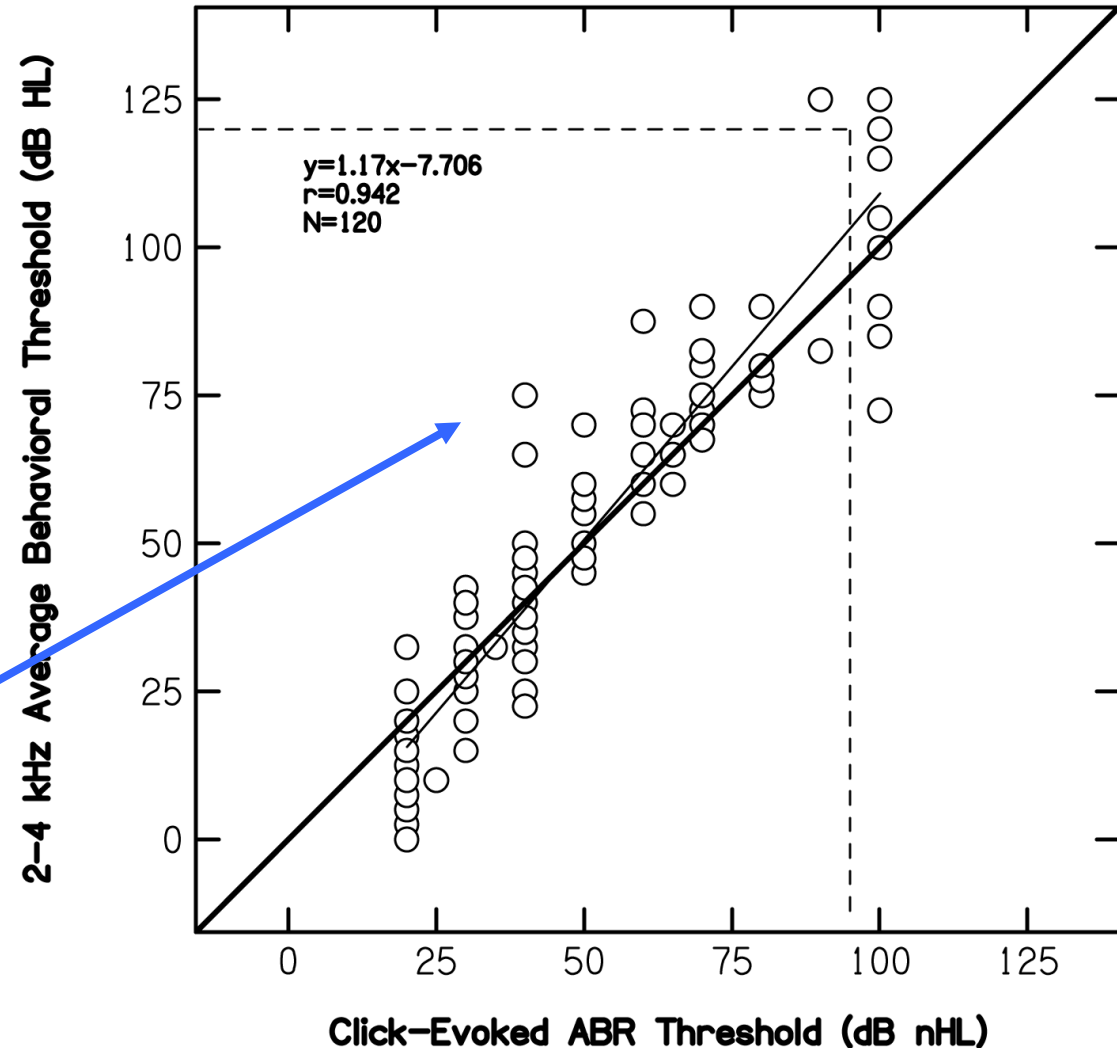
Click-Evoked ABR Correlation with Audiometric Thresholds in the 2000 to 4000 Hz Region

Gorga et al (2006)

*Click ABR Threshold versus
Pure Tone Hearing Threshold
(2 to 4 K Hz)*

*N = 77
71 = < 5 years*

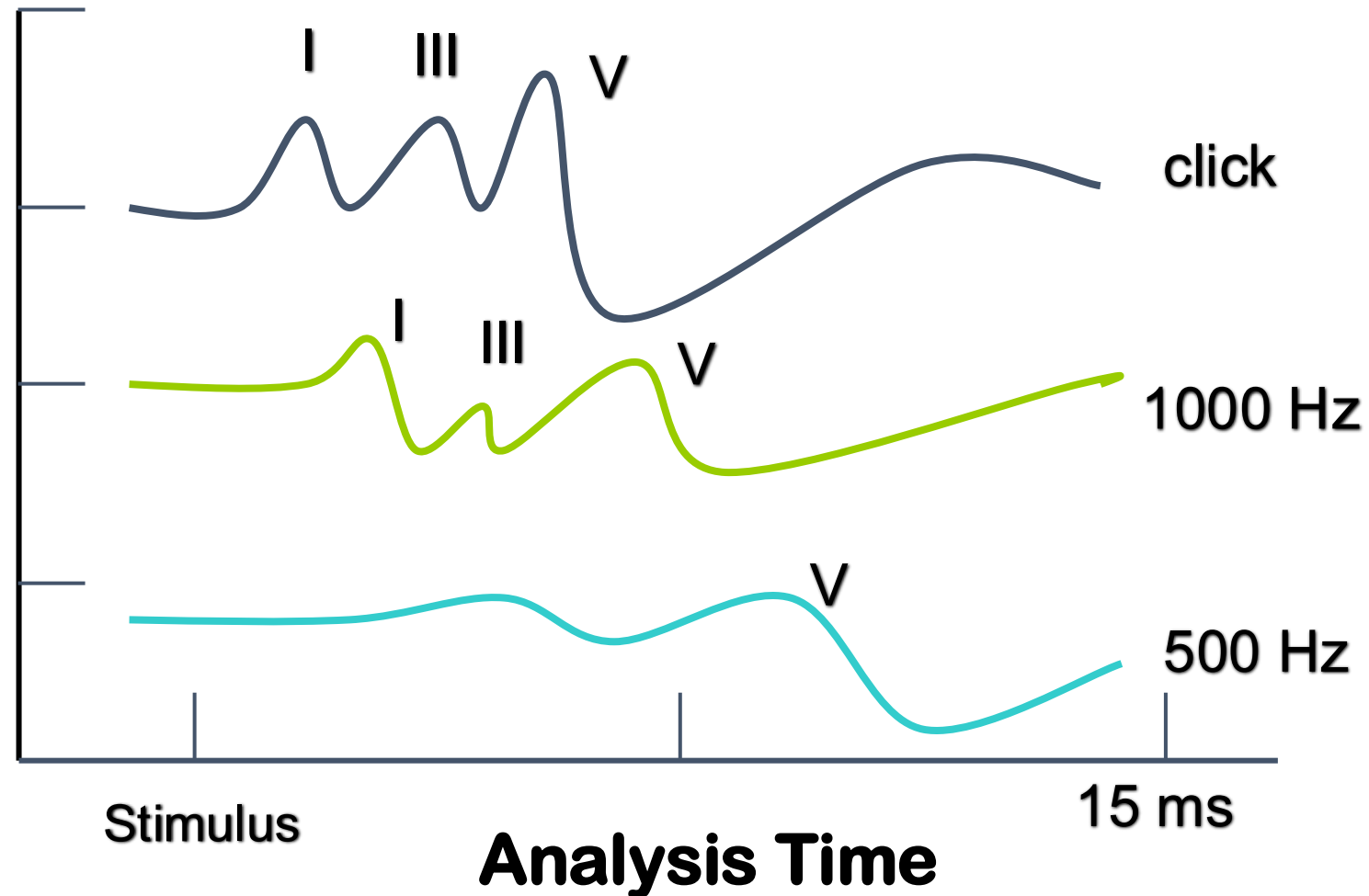
*Click ABR Threshold
Better Than
Pure Tone Threshold*



Click versus Tone Burst ABRs:

3 Differences in Morphology and Latency

1. Smoother waves; 2. Wave I disappears; 3. Latency increases



**Correction Factors for Converting ABR Thresholds in dB nHL
to Estimated Behavioral Thresholds in dB HL (or EHL)**
Normal Hearing Patients

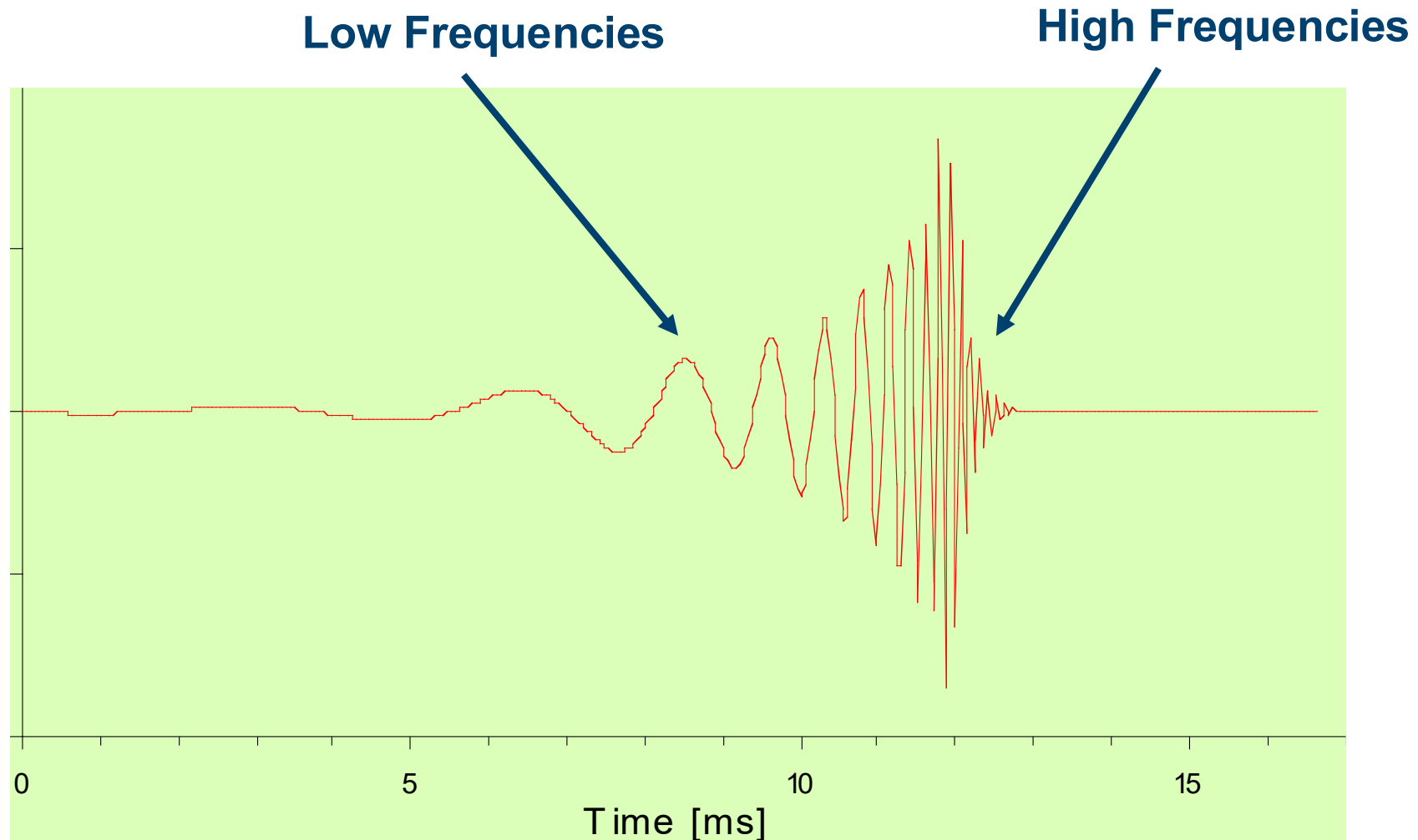
Source	500 Hz	1000 Hz	2000 Hz	4000 Hz
BCEHP	-15 dB	-10 dB	-5 dB	0 dB
Bagatto (2006)	-20 dB	-15 dB	-10 dB	-5 dB
Hall (2007)	-15 dB	-10 dB	-10 dB	-5 dB

Correction Factors for Converting ABR Thresholds in dB nHL to Estimated Behavioral Thresholds in dB HL (or EHL) *Sensory Hearing Loss*

Study	500 Hz	1000 Hz	2000 Hz	4000 Hz
Stapells (2000)	+6 dB (+/-14)	+5 dB (+/-14)	+1 dB (+/-11)	-8 dB (+/-12)
Lee (2008)	+5 dB (+/-5)	0 dB (+/-5)	-5 dB (+/-8)	-5 dB (+/-8)
Vander Werff et al (2009)	+13 dB (+/-12)		0 dB (+/-9)	-3 dB (+/-14)

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

Temporal Compensation in Chirp Stimulus



Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

Chirp Evoked ABR Amplitude is Larger

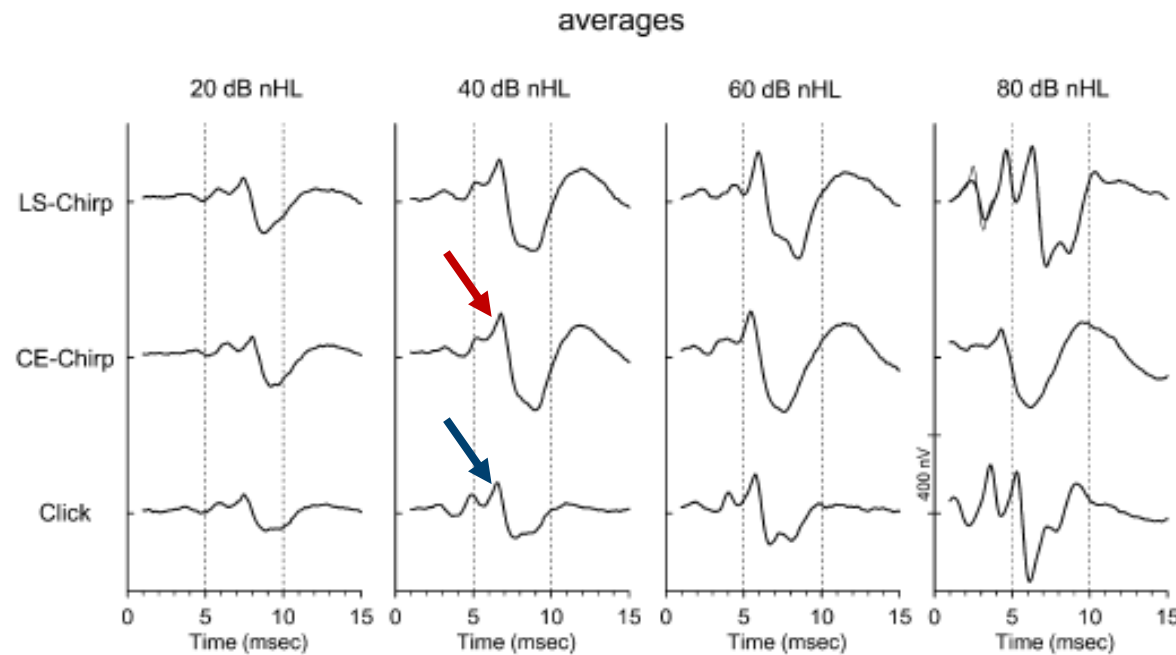


Figure 6. Grand Average ABR waveforms from $N = 20$ ears. The Grand Averages are obtained by time-shifting the underlying individual waveforms according the wave V latency. The thin line in the LS-Chirp/80 dB nHL condition shows a small part (corresponding to wave I) of the Grand Average obtained by using the latency of wave I instead of wave V for the temporal adjustment.

- Larger amplitudes for wave I and V (up to twice as large)
- More confident identification of ABR
- Detection of clear ABR in less than ideal noise conditions
- Possibility of more accurate ABR threshold
- Quicker ABR test time (higher signal increases SNR)

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

Growing Research Literature for Chirp Stimulus

Chronologic Summary of Publications on Chirp ABR and/or ASSR during the time frame from 2019 through 2024. (Number of peer reviewed articles)

Procedure (s)	2019	2020	2021	2022	2023	2024	Total
Chirp ABR	7	8	7	8	11	15	56
Chirp ASSR	2	6	7	6	4	7	32
Chirp ABR + chirp ASSR	1	2	2	3	3	4	15

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More *Ear Specific Bone Conduction ABR*

B-81 High Output Bone Transducer

#8104108

Features

- Reliable performance
- Meets industry standards
- High maximum output, low distortion
- Mechanically robust
- Sensitivity: 119 dB re.1 μ N @ 1 VRMS & 1 kHz
- Total harmonic distortion: 1.1% @ 1 VRMS & 1 kHz
- Impedance: 12.5 ohm @ 1 kHz
- Secured plug concept
- RoHS compliant

Products:

- B-81 Bone Transducer, item #8104108
- Custom Safety Cable, item #8104110
- Standard Transducer Headband, item #8011098
- Pre-assembled packaged (incl. #8104108, #8104110, #8011098), item #8506491

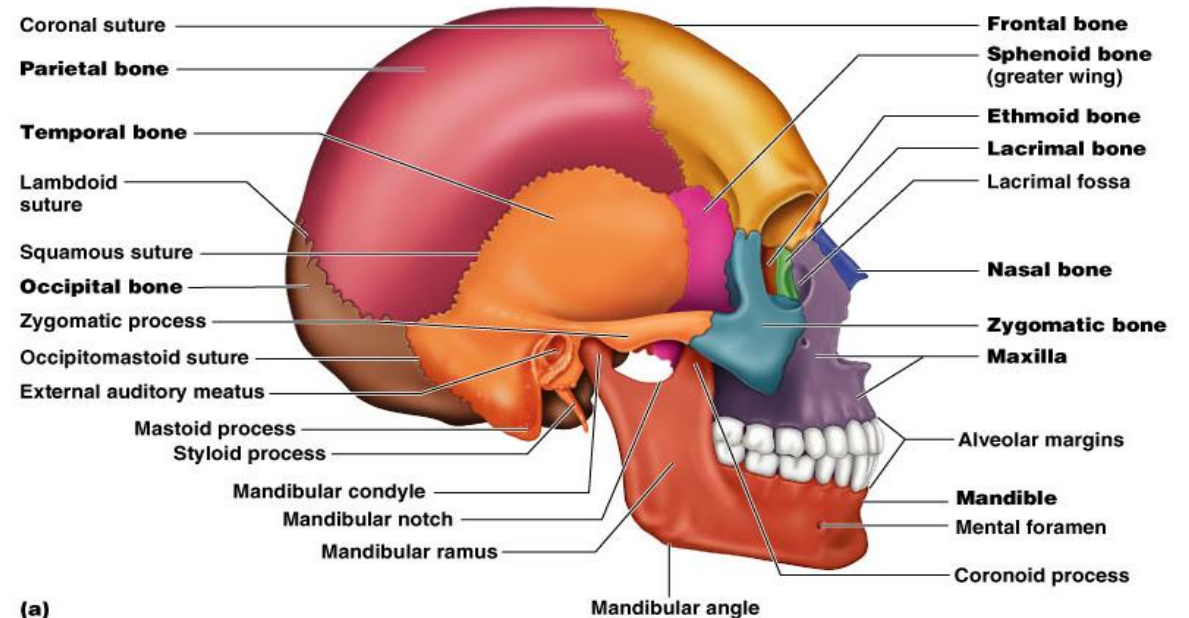


The Gold
Standard
of Audiometric Transducers

Audiometric Benefit

"The B-81 bone vibrator provides higher output and lower harmonic distortion compared to the B71. This may offer a significant clinical advantage. Conductive components of severe hearing losses that cannot be measured with the B71 vibrator may be measurable with the B-81. This is important for medical diagnosis and treatment, programming hearing aids, and determining cochlear implant candidacy."

Robert H. Margolis
Professor Emeritus, University of Minnesota

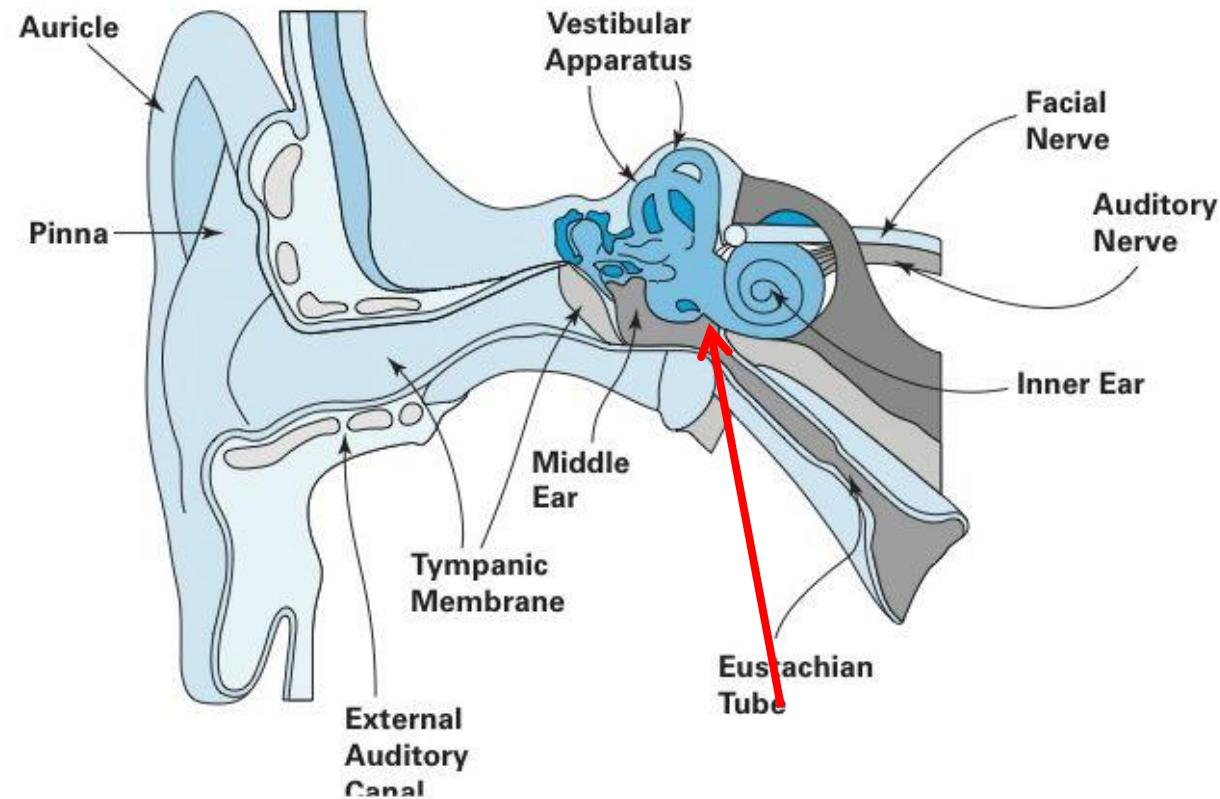


(a)

Experience with Bone Conduction ABR in Diagnosing Conductive Hearing Loss in Children



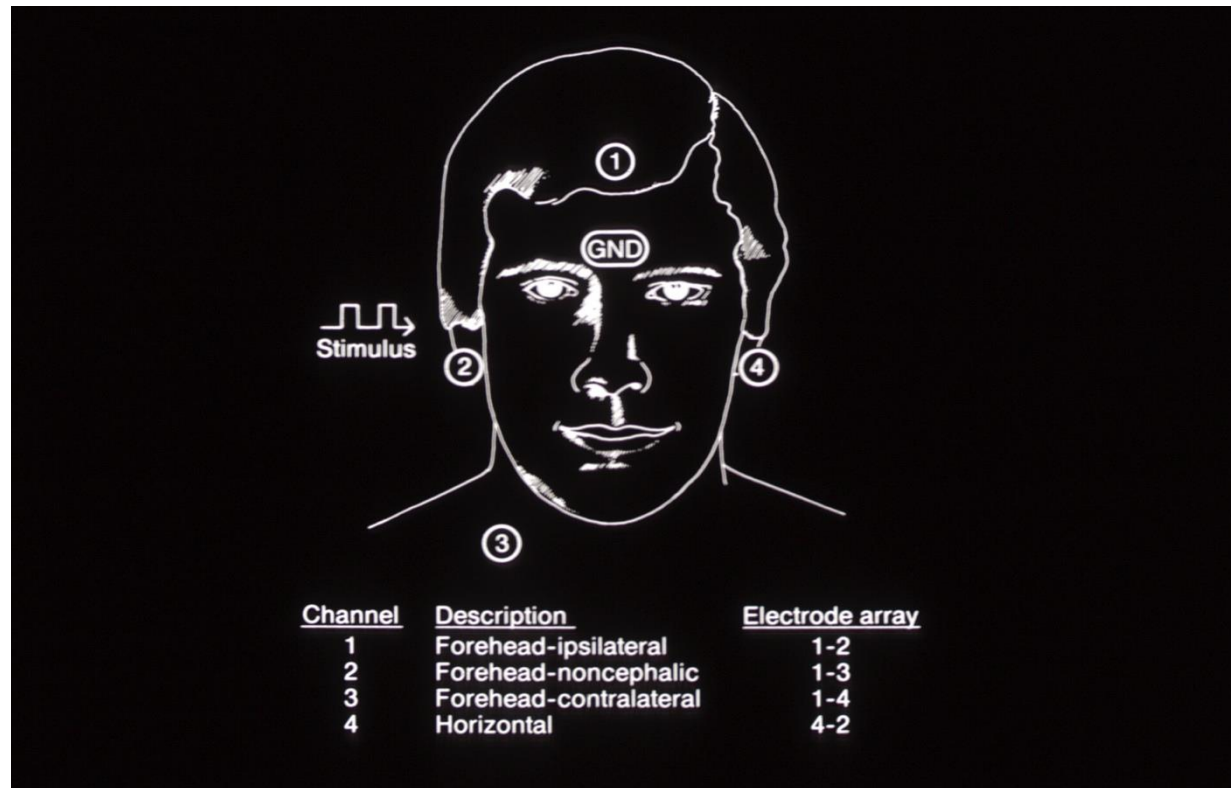
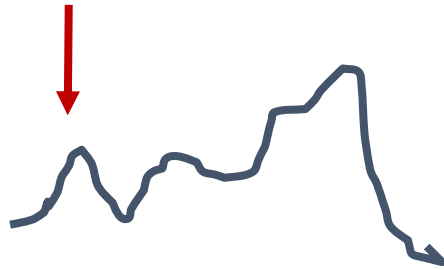
Air- versus Bone Conduction Click Evoked ABR: Differentiation of Conductive vs. Sensory Hearing Loss



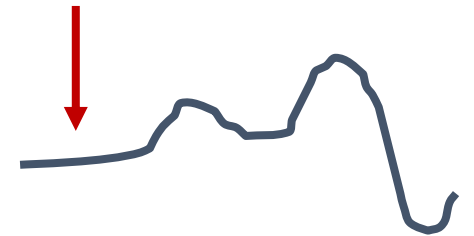
From Hall JW III. *Introduction to Audiology Today*. Boston: Pearson, 2014

Two-Channel Bone Conduction ABR Recording: Applying ECochG Principles to Verify the Test Ear

Ipsi Channel
Wave I



Contra Channel
No Wave I



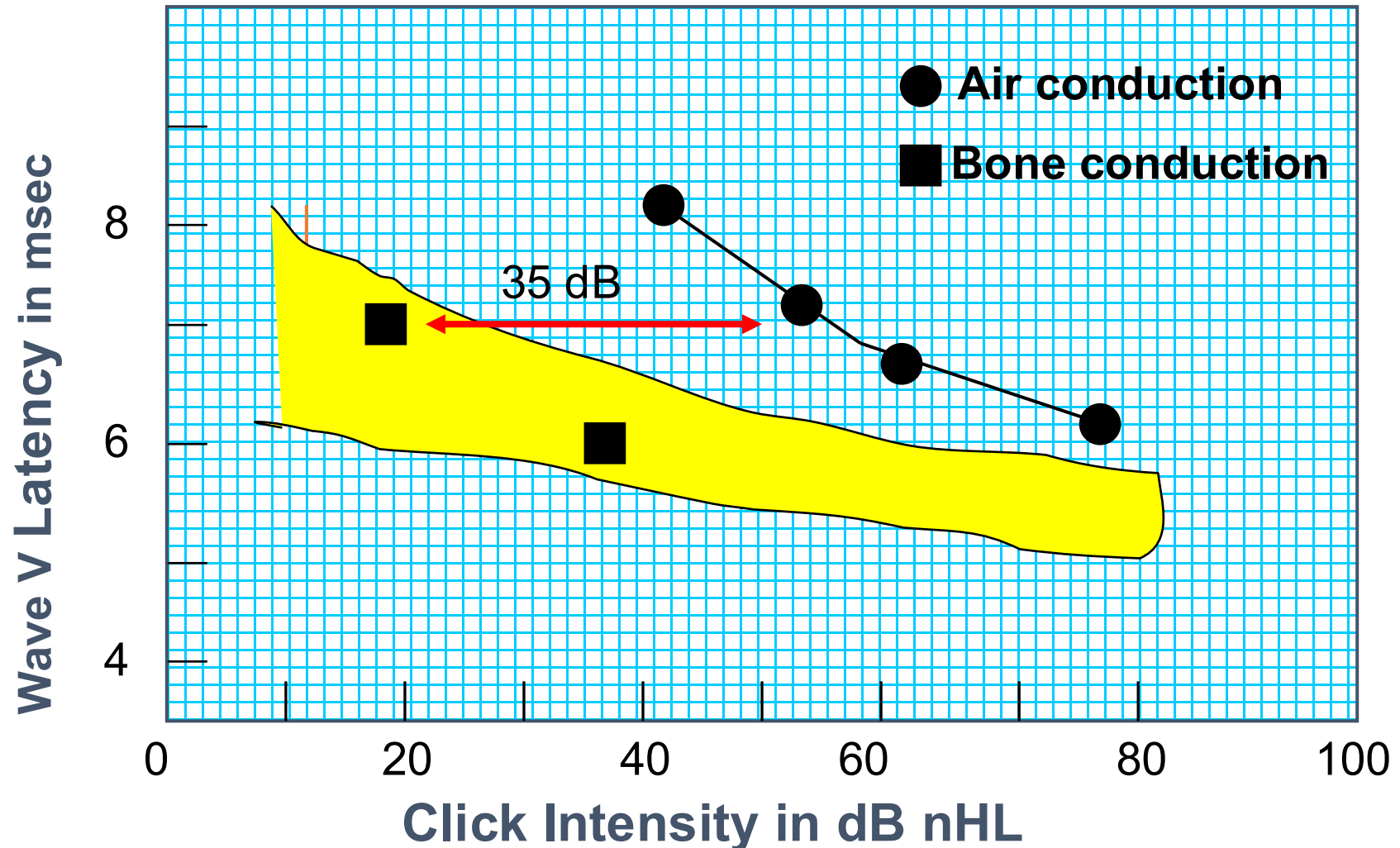
Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

Bone Conduction ABR is Standard of Care

quite feasible. Frequency-specific (toneburst) stimuli are used to elicit neural responses that enable determination of thresholds, and form the foundation for determining hearing aid amplification characteristics. Thresholds for both air-conducted and bone-conducted stimuli are measured to determine type (i.e., conductive, sensorineural, mixed) of hearing loss. Bone conduction thresholds are necessary to estimate additional hearing aid gain and output if there is a conductive component.

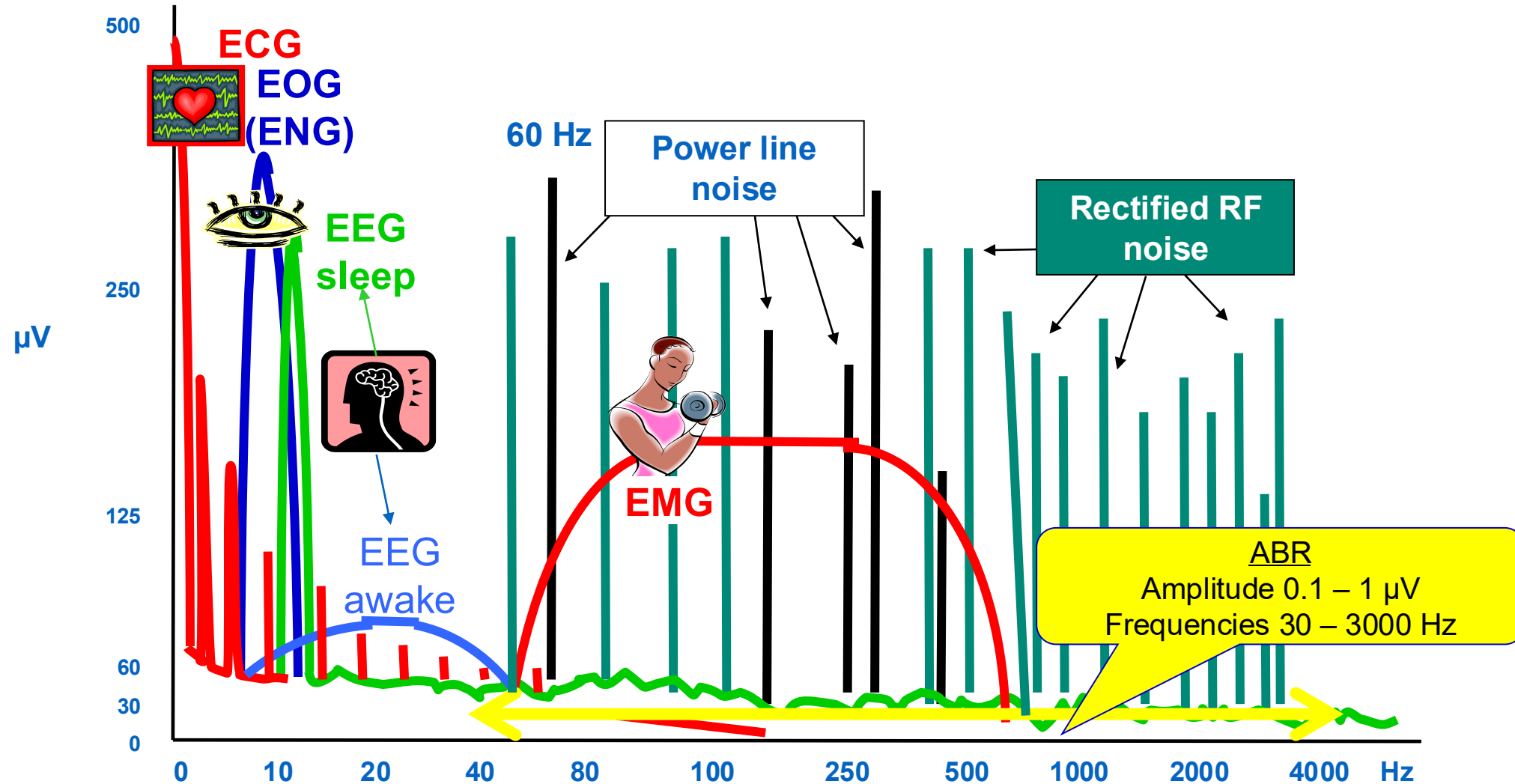
Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

Estimation of Air-Bone Gap with ABR



Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

Sources of “Noise” in ABR Measurement



Strategies for Enhancing a Quiet Patient State

Three Options for Pediatric ABR Assessment



Natural Sleep



Sedation



General Anesthesia

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More *ABR with Natural Sleep, Melatonin and Sedation*



audiology research



Review

Sedation Methods in Paediatric Auditory Electrophysiologic Testing: A Narrative Review

Violeta Necula ^{1,2}, Maria Eugenia Domuta ^{3,*}, Raluca Olariu ^{4,5,*}, Madalina Gabriela Georgescu ⁶, Ioan Florin Marchis ², Mirela Cristina Stamate ^{1,2}, Cristina Maria Blebea ¹, Maximilian George Dindelegan ^{1,7}, Alma Aurelia Maniu ^{1,2} and Sever Septimiu Pop ^{1,2}

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- 2025 Audiology Research
- Excellent review
- Natural sleep: average duration of 49 minutes
- Conscious sedation
 - Chloral hydrate
 - Triclofos (banned in US)
 - Midazolam
 - Dexmedetomidine (DEX)
 - Clonidine

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

Sleep Deprivation in ABR Measurement

- **Detailed instructions for parents/caregivers**
- **Atypically late bedtime**
- **Extra adult during transportation to clinic**
- **Schedule ABR for first appointment in morning**
- **Prepare for ABR immediately upon patient arrival at clinic**
- **Record ABR after feeding**



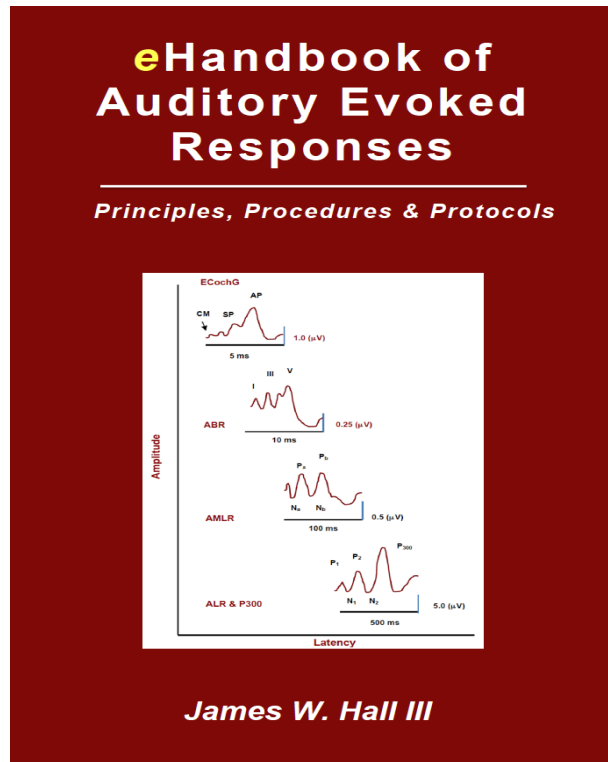
Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

Anesthesia as an Option in ABR Assessment of Children

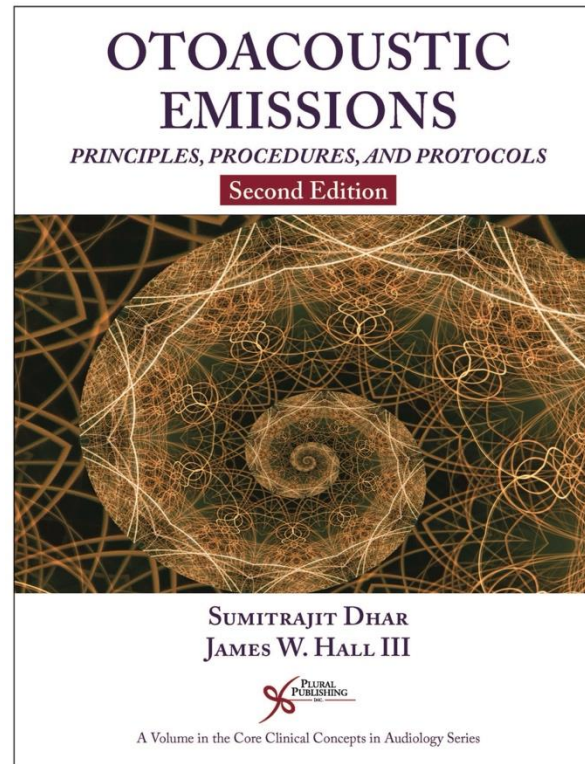


Propofol

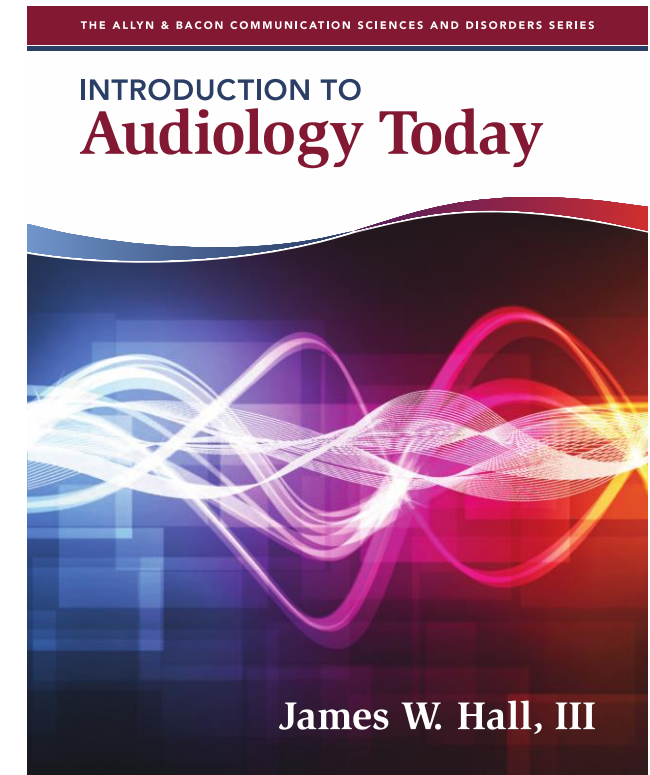
Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More *References for More Information*



**eBook 2015
(Amazon.com)**



**2018
(Plural Publishing)**



**Hardcopy or Kindle Version
(www.amazon.com)**

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More

Time-Ordered Agenda

9:00 am	Introduction and learning objectives
8:45 am	Crosscheck principle in pediatric hearing assessment
9:00 am	Objective techniques for auditory assessment of infants
9:30 am	Frequency-specific ABR measurement
10:30 am	Break
10:45 am	Live demo of frequency-specific ABR measurement
11:00 am	Attendee hands-on ABR measurement activities
12:45 pm	Questions & answers
1:00 noon	Adjourn

Hands-on Activities: ***Click-Evoked ABR (Air Conduction)***

- **Assembly test supplies (e.g., electrodes, ear tips, etc.)**
- **Create an air conduction click ABR protocol**
- **Instruct subject about test procedure**
- **Select an appropriate size probe tip**
- **Prepare subject for electrode placement**
- **Affix and plug in electrodes**
- **Check inter-electrode impedance**
- **Insert ear tips**
- **For each ear, record replicated ABR waveforms at ≥ 80 dB nHL with rarefaction and condensation polarity stimuli**
- **Terminate signal averaging when ABR wave V amplitude to noise ratio = > 3**
- **Quickly estimate click ABR threshold**
- **Analyze ABR findings**

Hands-on Activities:

Click-Evoked ABR (Air – and Bone Conduction)

Air Conduction Click-Evoked ABR Measurement

Please confirm that you performed the following tasks satisfactorily by marking YES or NO for the following.

	YES	NO
1. Explain the purpose and process of the test to the patient.....	☐	☐
2. Prepare scalp, attach electrodes, insert earphones.....	☐	☐
3. Check electrode impedance and reapply as needed.....	☐	☐
4. Create appropriate click ABR protocol.....	☐	☐
5. Estimate behavioral threshold for click stimulus	☐	☐
6. Describe "0 dB nHL" for click stimulus	☐	☐
7. Perform high intensity click evoked ABR with replication.....	☐	☐
8. Repeat click evoked ABR with condensation polarity	☐	☐
9. Verify ABR reliability with each stimulus polarity	☐	☐
10. Analyze ABR latency and amplitude	☐	☐
11. Assess ABR symmetry	☐	☐
12. Compare ABR latency and amplitude RE: normative data.....	☐	☐
13. Describe click-evoked ABR outcome	☐	☐

Bone Conduction Click-Evoked ABR Measurement

Please confirm that you performed the following tasks satisfactorily by marking YES or NO for the following.

	YES	NO
1. Create appropriate bone conduction click ABR protocol.....	☐	☐
2. Explain the purpose and process of the test to the patient.....	☐	☐
3. Prepare scalp, attach electrodes, place bone oscillator	☐	☐
4. Check electrode impedance and reapply as needed.....	☐	☐
5. Estimate behavioral threshold for bone conduction stimulus.....	☐	☐
6. Describe "0 dB nHL" for bone conduction click stimulus	☐	☐
7. Perform high intensity bone conduction ABR with replication ...	☐	☐
8. Identify ABR wave V with bone conduction click (1 ear)	☐	☐
9. Identify ABR wave I with bone conduction click (1 ear).....	☐	☐
10. Estimate behavioral threshold for bone conduction click (1 ear)	☐	☐
11. Analyze bone conduction ABR latency	☐	☐
12. Compare air versus bone conduction ABR findings	☐	☐
13. Describe air versus bone conduction ABR outcome.....	☐	☐

Hands-on Activities:

Click Evoked ABR (Bone Conduction)

- **Activity assumes the same subject has already undergone air conduction click evoked ABR measurement**
- **Create a bone conduction click ABR protocol**
- **Instruct subject about test procedure**
- **Select an appropriate size probe tip**
- **Prepare subject for electrode placement**
- **Place bone oscillator**
- **For each ear, record replicated bone conduction ABR waveforms at at varying stimulus intensity levels**
- **Terminate signal averaging when ABR wave V amplitude to noise ratio ≥ 3**
- **Verify presence of reliable wave I component**
- **Analyze bone conduction ABR findings**

Hands-on Activities: ***Tone Burst ABR (Air Conduction)***

- **Activity assumes the same subject has already undergone air and bone conduction click evoked ABR measurement**
- **Create a tone burst ABR protocol for 1000 Hz or another frequency**
- **For each ear, record replicated tone burst ABR waveforms at at varying stimulus intensity levels**
- **Terminate signal averaging when ABR wave V amplitude to noise ratio = > 3**
- **Determine tone burst ABR thresholds**
- **Estimate behavioral hearing thresholds**

Hands-on Activities:

Traditional Tone Burst and Chirp Evoked ABR

Frequency Specific (Conventional Tone Burst) ABR Measurement

Assumption: All electrodes are in place from click ABR recording

Please confirm that you performed the following tasks satisfactorily by marking YES or NO for the following

	YES	NO
1. Create tone burst ABR protocol for 4000 Hz	☐	☐
2. Create tone burst ABR protocol for 500 Hz.....	☐	☐
3. Estimate behavioral threshold for 4000 Hz tone burst	☐	☐
4. Estimate behavioral threshold for 500 Hz tone burst.....	☐	☐
5. Describe "0 dB nHL" for 4000 Hz and 500 Hz chirps.....	☐	☐
6. Find ABR threshold for 4000 Hz tone burst	☐	☐
7. Find ABR threshold for 500 Hz tone burst	☐	☐
8. Describe frequency specific ABR findings	☐	☐

Narrowband Chirp ABR Measurement

Assumption: All electrodes are in place from click ABR recording

Please confirm that you performed the following tasks satisfactorily by marking YES or NO for the following

	YES	NO
1. Create narrowband chirp ABR protocol for 1000 Hz	☐	☐
2. Create narrowband chirp ABR protocol for 500 Hz.....	☐	☐
3. Describe "0 dB nHL" for 1000 Hz and 500 Hz chirps.....	☐	☐
4. Find ABR threshold for 1000 Hz chirp.....	☐	☐
5. Find ABR threshold for 500 Hz chirp.....	☐	☐
6. Estimate behavioral threshold for 1000 Hz chirp	☐	☐
7. Estimate behavioral threshold for 500 Hz chirp	☐	☐
8. Describe frequency specific ABR findings	☐	☐

Evidence-Based Objective Assessment of Infant Hearing: Frequency-Specific ABR and More *Time-Ordered Agenda*

9:00 am	Introduction and learning objectives
8:45 am	Crosscheck principle in pediatric hearing assessment
9:00 am	Objective techniques for auditory assessment of infants
9:30 am	Frequency-specific ABR measurement
10:30 am	Break
10:45 am	Live demo of frequency-specific ABR measurement
11:00 am	Attendee hands-on ABR measurement activities
12:45 pm	Questions & answers
1:00 noon	Adjourn