Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment

James W. Hall III, PhD

Professor
Salus University

Professor
University of Hawaii

Extraordinary Professor
University of Pretoria South Africa

jwhall3phd@gmail.com **www.audiologyworld.net**

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment

LEARNING OBJECTIVES

After this course, participants will be able to:

- **Identify key test parameters for optimizing ABR outcome**
- **Describe the unique role of ASSR in infant auditory assessment**
- **List 4 specific strategies for minimizing ABR test time without sacrificing diagnostic accuracy**
- **Describe a clinically applicable test protocol for efficient assessment of infant hearing**

Presented in Partnership with

CONTINUED

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment: Time Ordered Agenda

- 0-10 mins: Rationale for Infant ABR Assessment
- 11-30 mins: Evidence-Based ABR Protocol
- 31-35 mins: Pediatric ABR Measurement and Analysis
- 36-45 mins: Strategies for Minimizing Test Time
- 46-50 mins: Role of ASSR in Infant Assessment
- 51-55 mins: ABR within an Objective Test Battery
- 56-60 mins: Summary and Conclusion

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment
Rationale for Infant Hearing Assessment … Origins

Marion Downs
(2004 … age 90 years)

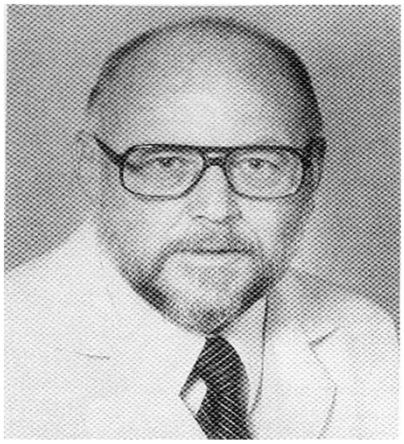
- Froding et al (1960). Acoustic investigation of newborn infants. Acta Otolaryngology 52: 31-41 *(aural-palpebral response, APR)*
- Downs & Sterrit (1964) Identification audiometry for neonates: A preliminary report. J Auditory Res 4: 69-80 *(APR, startle and behavioral responses to 3000 Hz narrow band stimulus)*
- Downs & Sterrit (1967) A guide to newborn and infant hearing screening programs. Arch Otolaryngol 85: 37-44
- Downs & Hemenway (1969). Report on the hearing screening of 17,000 neonates. Int'l Audiology 8: 72-76 *(study led to formation of first Joint Committee on Infant Hearing in 1969)*

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment
Rationale for Infant Hearing Assessment … Screening with ABR

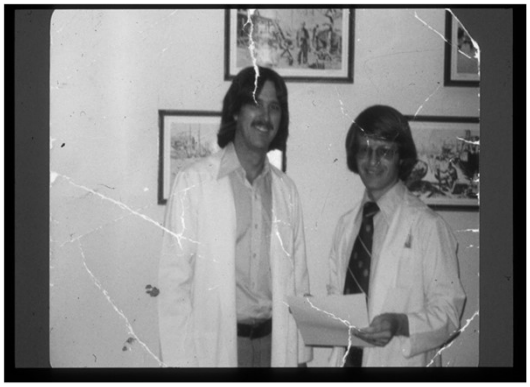
Robert Galambos
(1914-2010)

- **1971: Jewett & Williston. Auditory evoked far fields averaged from the scalp of humans. *Brain, 4* (Don Jewett was a post-doctoral student of Robert Galambos)**
- **1974: Hecox & Galambos. Brain stem auditory responses in human infants and adults. *Arch Otolaryngol, 99***
- **1975: Schulman-Galambos & Galambos. Brain stem evoked responses in premature infants. *JSHR, 18***
- **1979: Schulman-Galambos & Galambos. Brain stem evoked responses in newborn hearing screning. *Arch Otolaryngol, 105***

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment
Rationale for Infant Hearing Assessment … My Introduction to ABR



James Jerger in the 1970s
The Methodist Hospital and
Baylor College of Medicine, Houston Texas



Jerger JF and Hall JW III. Impedance and behavioral audiometry in the era of brainstem evoked response audiometry. In Controversy in Otolaryngology, Snow JB Jr (ed). Philadelphia: WB Saunders Co, 1980, pp. 138-144

Jerger J and Hall JW III. Effects of age and sex on auditory brainstem response (ABR). Archives of Otolaryngology 106: 387-391, 1980

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment
Rationale for Infant Hearing Assessment … ABR Screening of At Risk Infants

- **1982 Joint Committee on Infant Hearing Risk Indicators for Hearing Loss**
  - ✓ **Family history of childhood hearing loss**
  - ✓ **Congenital infection associated with hearing loss, e.g., cytomegalovirus (CMV), herpes, syphilis, rubella**
  - ✓ **Bacterial meningitis**
  - ✓ **Craniofacial anomalies (morphologic abnormalities of the ear)**
  - ✓ **Low birth weight (< 1500 grams)**
  - ✓ **Hyperbilirubinemia (requiring exchange transfusion)**
  - ✓ **Aphyxia (APGAR scores of 0 – 3 at five minutes)**

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment
Rationale for Infant Hearing Assessment … Concerns About ABR Screening of Only At Risk Infants

Category	Births Annually	Prevalence	Total Hearing Loss
Healthy	3,600,000	3/1000	10,800
At-risk	400,000	30/1000	12,000
Total	4,000,000	5.7/1000	22,800

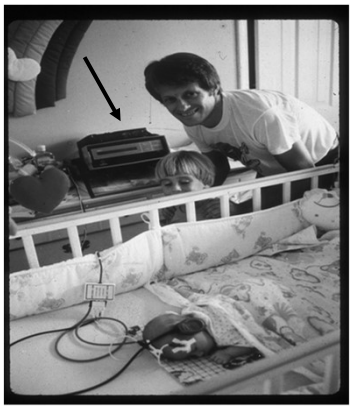
Northern & Hayes, 1994

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment
Rationale for Infant Hearing Assessment … Concerns About ABR Screening of Only At Risk Infants

Hearing Loss	Suspicion	Dx	HA fitting	Intervention
No Risk Factor				
Mild/moderate	**15**	**22**	**28**	**28**
Severe/profound	**8**	**13**	**16**	**16**
Known Risk Factor				
Mild/moderate	**8**	**12**	**22**	**28**
Severe/profound	**7**	**12**	**15**	**16**

Harrison & Roush, 1996

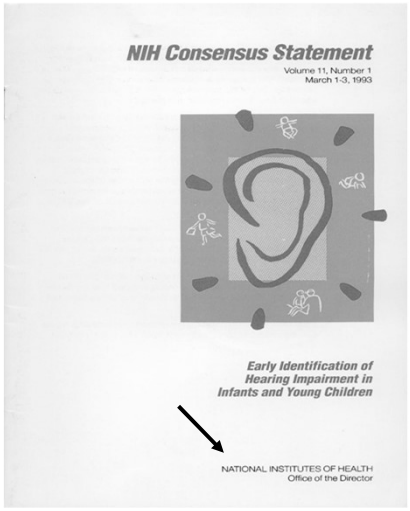
Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment
Rationale for Infant Hearing Assessment … Automated ABR Screening



Hall JW III, Kileny PR & Ruth RA (1987). Clinical trials for the ALGO-1 newborn hearing screening device. Presented at the 10th IERASG Conference, Charlottesville VA

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment

Rationale for Infant Hearing Assessment
… Beginning of Universal Newborn Hearing Screening in the USA



"There is general agreement that hearing impairment should be recognized as early in life as possible, so the remediation process can take full advantage of the developing sensory systems and so that the child can enjoy normal social development."

Recommendation (1993):

Universal Newborn Hearing Screening

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment

Rationale for Infant Hearing Assessment … Introduction of the 1-3-6 Principle for EHDI
1 = Screen before 3 mos; 3 = Diagnose before 3 mos; 6 = Intervention by 6 mos

Christie Yoshinaga-Itano

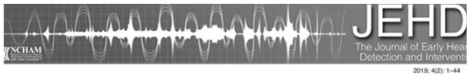
Yoshinago-Itano et al (Univ. of Colorado). Pediatrics 102 (5): 1161-1171, 1998.

- **N = 72 children with HL identified by 6 months and N = 78 children identified later**
- **All children received intervention services with 2 months of identification**

Conclusion: "Significantly better language development was associated with early ID of hearing loss and early intervention . . . the language advantage was found across all . . . degrees of hearing loss."

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment

Rationale for Infant Hearing Assessment … 2019 JCIH Position Statement



2019; 4(2): 1–44

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

The Joint Committee on Infant Hearing

Table of Contents

Abbreviations

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 – Extracorpeal Membrane Oxygenation
EHDI – Early Hearing Detection and Intervention
EHDI PALS – Early Hearing Detection & Intervention: Pediatric Audiology Links to Services
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
NICHQ – National Institue for 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

EHDI 1-3-6 Goals

1. All infants should undergo hearing screening prior to discharge from the birth hospital and no later than one month of age, using physiologic measures with objective determination of outcome.
2. All infants whose initial birth-screen and any subsequent rescreening warrant additional testing should have appropriate audiologic evaluation to confirm the infant's hearing status no later than 3 months of age.
3. A concurrent or immediate comprehensive otologic evaluation should occur for infants who are confirmed to be deaf or hard of hearing.
4. All infants who are deaf or hard of hearing in one or both ears should be referred immediately to early intervention in order to receive targeted and appropriate services.
5. A simplified, coordinated point of entry into an intervention system appropriate for identified children is optimal.
6. Early intervention services should be offered through an approach that reflects the family's preferences and goals for their child, and should begin as soon as possible after diagnosis but no later than six months of age and require a signed Part C of IDEA (Individuals with Disabilities Education Act, 2004) Individualized Family Service Plan.
7. The child and family should have immediate access, through their audiologist, to high-quality, well-fitted, and optimized hearing aid technology. Access should also be assured, depending on the child's needs, to cochlear implants (CI), hearing assistive technologies, and visual alerting and informational devices.

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment

Rationale for Infant Hearing Assessment … 2019 JCIH Position Statement

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

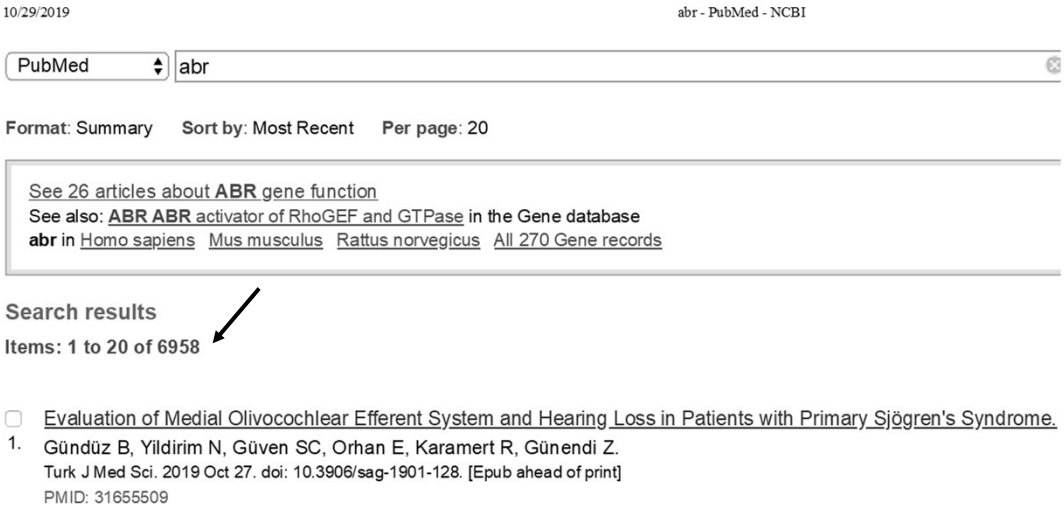
- Auditory brainstem response is the gold standard test for threshold estimation for infants and children who cannot complete behavioral audiologic assessment. ABR provides ear- and frequency-specific threshold estimates that are necessary for the diagnosis of the type, degree, and configuration of hearing 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 path ways (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 standar 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; Norrix, 2015) are established methods based on conditioned responses to sound.

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment: Time Ordered Agenda

- **0-10 mins: Rationale for Infant ABR Assessment**
- **11-30 mins: Evidence-Based ABR Protocol**
- **31-35 mins: Pediatric ABR Measurement and Analysis**
- **36-45 mins: Strategies for Minimizing Test Time**
- **46-50 mins: Role of ASSR in Infant Assessment**
- **51-55 mins: ABR within an Objective Test Battery**
- **56-60 mins: Summary and Conclusion**

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment

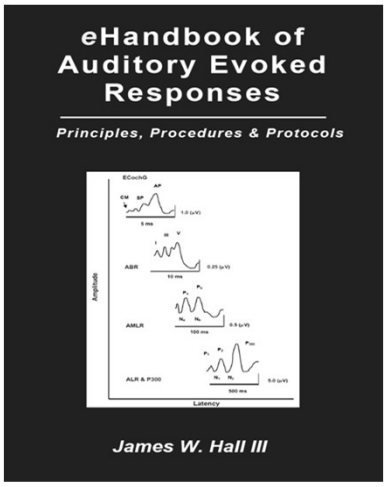
An Evidence-Based ABR Protocol ... 50 Years of Clinical Research and Experience



Presented in Partnership with

continued

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment
An Evidence-Based ABR Protocol … A Recent Resource



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

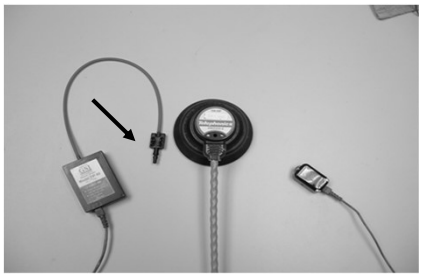
- Chapter 1. Introduction to Auditory Evoked Responses
- Chapter 4. Introduction to Auditory Brainstem Response (ABR)
- Chapter 5. ABR: Stimulus Parameters
- Chapter 6. ABR: Acquisition Parameters and Test Protocols
- Chapter 7. ABR: Analysis and Trouble Shooting
- Chapter 8. ABR: Clinical Applications and Patient Populations
- Chapter 9. Auditory Steady State Response

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment
An Evidence-Based ABR Protocol: Stimulus Parameters

Parameter	Selection	Comment
Transducer	Insert earphones*	A dozen good reasons *(more soon)*
	Bone oscillator *	Necessary; B-81 is now the best option
Type	Click or tone burst	Click for initial diagnosis of auditory dysfunction
		Tone burst for threshold estimation
Duration	Click = 0.1 ms	Transient (synchronous firing) of onset neurons
	TB = 2-0-2 cycles	Transient frequency-specific stimulus
Polarity	Rarefaction	Larger amplitude; vary 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 diagnosis; lower for thresholds
Repetitions	Variable	Whatever is needed for good (3:1) SNR
Masking	Rarely needed	Only if ABR is abnormal and there is no wave I

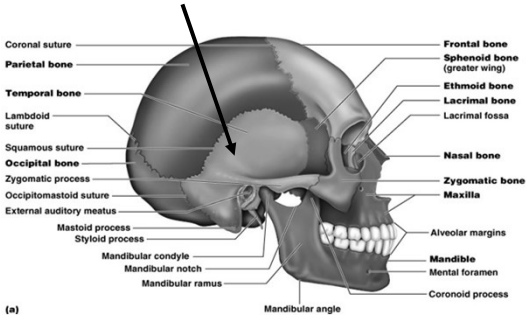
Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment
Many Advantages of Insert Earphones

- **General**
  - **Increased inter-aural attenuation**
  - **Increased ambient noise attenuation**
  - **Elimination of ear canal collapse**
  - **Increased patient comfort**
  - **Improved aural hygiene**
  - **More precise placement (reliability)**
- **ABR specifically**
  - **Reduced transducer ringing**
  - **Reduced stimulus artifact with separation of transducer from inverting (earlobe) electrode**

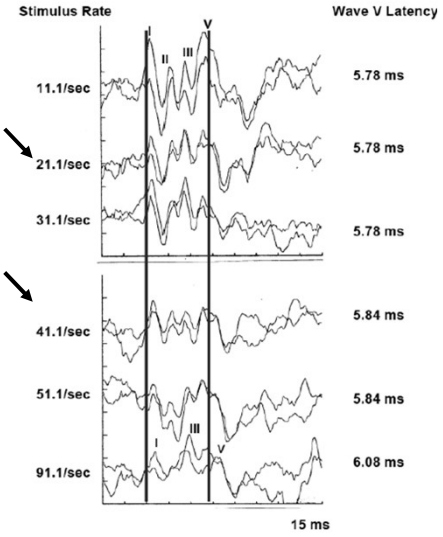


www.oaktreeproducts.com

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment
A Modern Bone Oscillator Design



Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment
What is the Optimal Stimulus Presentation Rate? Run Your ABR at the Stimulus Speed Limit



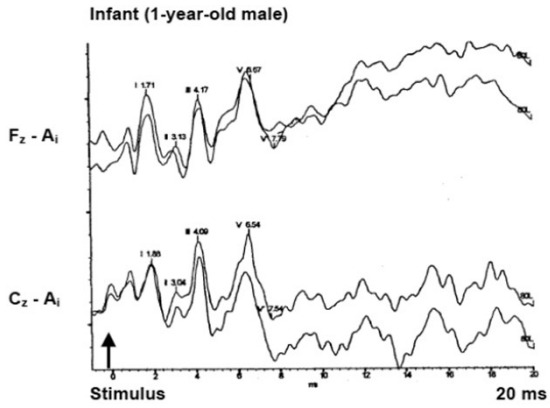
- General Guideline: Fastest rate that still produces an optimal response
- Click stimulus: 21.1/sec
  - ✓Extensive normative data for latency
  - ✓Slow enough to identify wave I
  - ✓Fast enough for rapid data collection
  - ✓Odd number not in sync with 50 Hz or 60 Hz current
- Tone burst stimulus: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

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment
An Evidence-Based ABR Protocol: Acquisition Parameters

Parameter	Selection	Comment
Channels	1	One channel is adequate for most ABR 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)

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment
Important and Unimportant Electrode Locations

Non-Inverting "Active" Electrode: 3 Advantages for Forehead vs. Vertex Placement

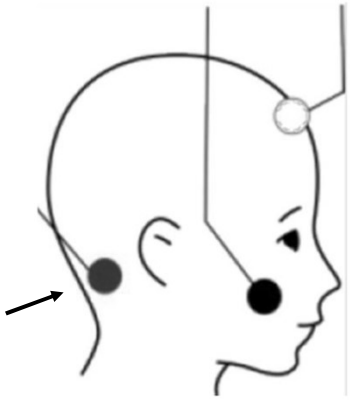


Advantages of Fz versus CZ Placement

1. More secure attachment (tape versus hair)
2. Avoid scrubbing fontanelle in infants
3. Avoid bandages and head coverings

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment
Important and Unimportant Electrode Locations

Inverting Electrode: 3 Advantages for Earlobe vs. Mastoid Placement

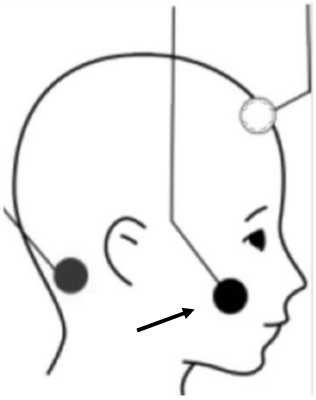


Advantages of Earlobe versus Mastoid Placement

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

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment
Important and Unimportant Electrode Locations

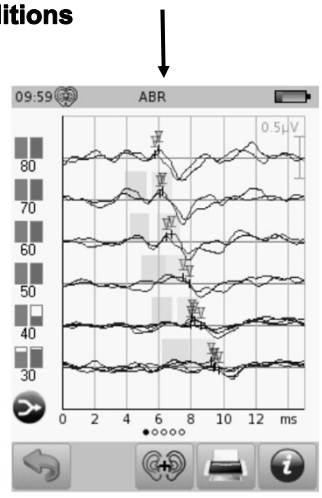
Ground (Common) Electrode: Any Location is OK



Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment
Selecting the Optimal Analysis Time

Analysis Time (Epoch) for ABR:
15 ms is Good for Most Stimulus and Patient Conditions
(10 ms is too short; > 20 ms is too long)

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



Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment
The Optimal Number of Stimuli (Signal Averages) … Just Enough

How many stimuli or averages are needed in infant ABR measurement?
Answer: The number that just produces a 3:1 SNR (ABR to Residual Noise)

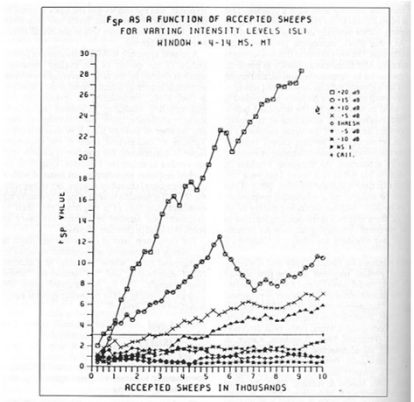
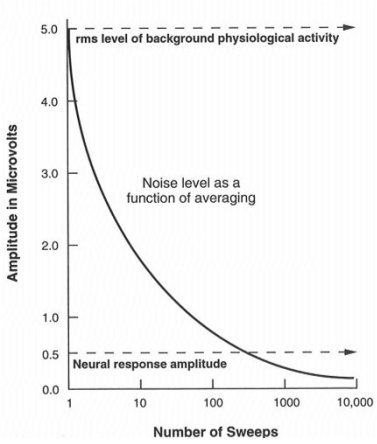
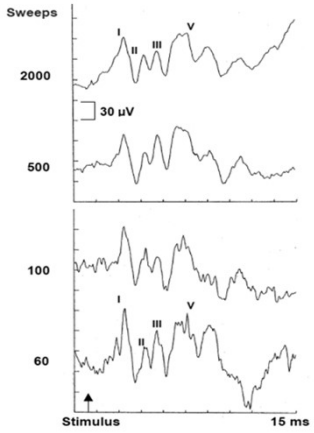


Figure 6–23. Change in F_{sp} measure as a function of the number of sweeps during ABR recording. See text for explanation. *Note.* From "Objective Detection of Averaged Auditory Brainstem Response" by M. Don, C. Elberling, M. Waring, 1984, *Scandinavian Audiology, 13,* pp. 219–228. Reprinted by permission.



Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment
The Optimal Number of Stimuli (Signal Averages) … Just Enough

How many stimuli or averages are needed in infant ABR measurement?
Answer: The number that just produces a 3:1 SNR (ABR to Residual Noise)



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 SNR = 3

(ABR wave V is 3 times larger than residual background noise)

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment
The Optimal Number of Stimuli (Signal Averages)
(British 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

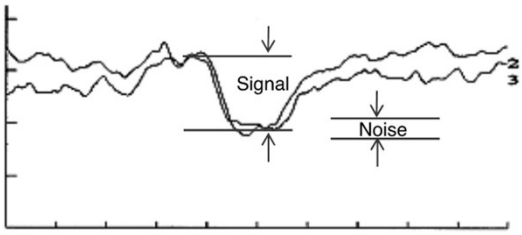


Figure 1

Scales:
150nV / div
2 ms / div

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment: Time Ordered Agenda

- **0-10 mins: Rationale for Infant ABR Assessment**
- **11-30 mins: Evidence-Based ABR Protocol**
- **31-35 mins: Pediatric ABR Measurement and Analysis**
- **36-45 mins: Strategies for Minimizing Test Time**
- **46-50 mins: Role of ASSR in Infant Assessment**
- **51-55 mins: ABR within an Objective Test Battery**
- **56-60 mins: Summary and Conclusion**

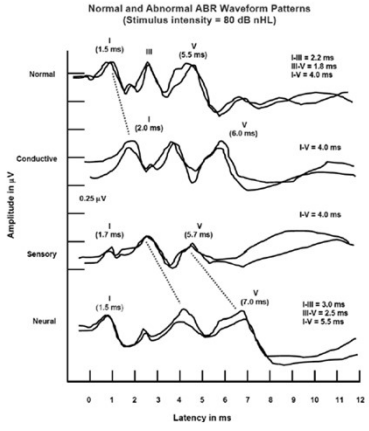
Presented in Partnership with

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment: Pediatric ABR Measurement and Analysis

- **Principles of Measurement: Preparation**
  - **Review patient history**
  - **Verify why the child is undergoing ABR assessment**
  - **Develop an initial strategy for measurement**
  - **Equipment is ready to go with demographic information entered and initial protocol uploaded**
  - **All necessary supplies are available in test area**
  - **Outpatients:**
    - ✓ **Parents implement natural sleep deprivation**
    - ✓ **Patient is scheduled for the early morning Inpatients: Plans are in place for sedation or anesthesia**
  - **Prepare skin for electrode placement ASAP**
  - **Secure and plug in all electrodes**
  - **Verify inter-electrode impedance**
  - **Insert earphone probe tips or cushion in each ear**

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment: Pediatric ABR Measurement and Analysis

- **Principles of Measurement: Strategies for Analysis**
  - **Determine first test ear based on history and previous findings (suspected abnormal ear first)**
  - **Begin with click evoked ABR (2 - 4 minutes) to**
    - ✓ **Differentiate quickly among types of auditory disorders**
    - ✓ **Rule out auditory neuropathy spectrum disorder (ANSD)**
    - ✓ **Quickly estimate click ABR threshold (2000 – 4000 Hz region)**
  - **Promptly trouble shoot unexpected findings**
  - **Select tone burst stimuli based on click ABR findings Record necessary findings as quickly as possible**
  - **Think ahead to determine while recording next step in ABR assessment**
  - **Supplement ABR with other objective procedures including ASSR, OAEs and aural immittance**



Presented in Partnership with

CONTINUED

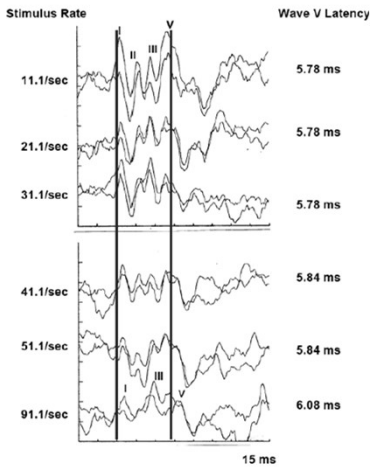
Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment: Pediatric ABR Measurement and Analysis

- **Principles of Measurement: Strategies for Analysis**
  - **Analyze ABR for rarefaction vs. condensation polarity to rule out ANSD**
  - **Calculate absolute and inter-wave latencies for waves I, III, V, and I - V**
  - **Calculate wave V amplitude**
  - **Analyze ABR waveforms while recording**
  - **Plot ABR thresholds on audiogram-type form during measurement**
  - **Take into account factors that influence ABR latencies**
    - ✓ **Young age (up to 18 mos. Developmental)**
    - ✓ **Body temperature (hypothermia delays wave V and I-V by ~ 0.2 ms/degree**
    - ✓ **Anesthetic agents (e.g., propofol) which delay wave V and I-V by ~ 0.2 ms/degree**

Adjust Normative Data

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment: Time Ordered Agenda

- **0-10 mins: Rationale for Infant ABR Assessment**
- **11-30 mins: Evidence-Based ABR Protocol**
- **31-35 mins: Pediatric ABR Measurement and Analysis**
- **36-45 mins: Strategies for Minimizing Test Time**
- **46-50 mins: Role of ASSR in Infant Assessment**
- **51-55 mins: ABR within an Objective Test Battery**
- **56-60 mins: Summary and Conclusion**



Presented in Partnership with

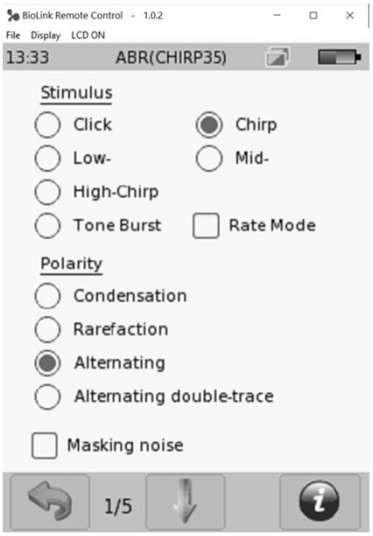
Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment: Strategies for Minimizing Test Time

Formula for Efficient and Successful ABR Measurement

Evidence-Based Test Protocol + Quiet Patient = Optimal ABR

Adequate SNR = 3

ABR wave V is 3 times > residual background noise



Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment: Strategies for Minimizing Test Time
Use Fastest Feasible Stimulus Presentation Rate

Data Collection in a Typical Pediatric ABR Assessment:

- **4 stimuli (click + 3 tone burst frequencies)**
- **4 intensity levels per stimulus**
- **2 replications per intensity level**
- **2 ears**
- **Total = 4 X 4 X 2 X 2 = ~ 64 separate ABR waveforms**

Calculated Data Collection Time

- **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**

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment: Strategies for Minimizing Test Time
Use Minimal Necessary Signal Averaging

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**

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment: Strategies for Minimizing Test Time
Record Chirp Evoked ABRs if Possible

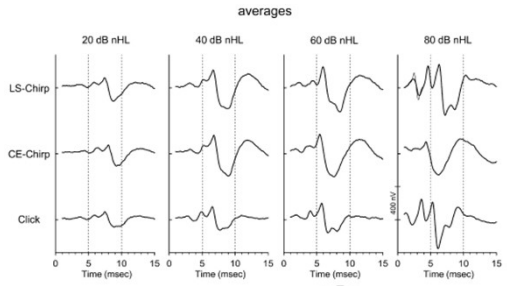
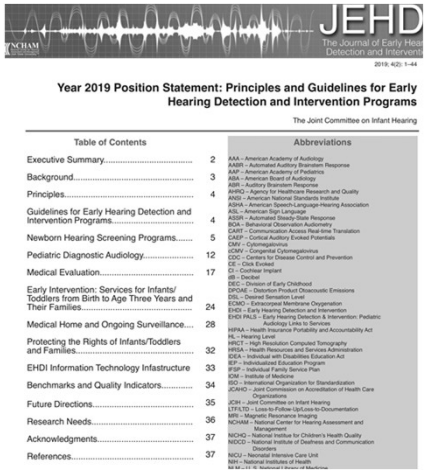


Figure 6. Grand Average ABR waveforms from N = 20 ears. The Grand Averages are obtained by time-shifting the underlying individual waveforms according the wave V latency. The thin line in the LS-Chirp/80 dB nHL condition shows a small part (corresponding to wave I) of the Grand Average obtained by using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

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment: Strategies for Minimizing Test Time
Record Chirp Evoked ABRs if Possible



JEHD
The Journal of Early Hearing Detection and Intervention
2019; 4(2): 1-44

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

The Joint Committee on Infant Hearing

Table of Contents

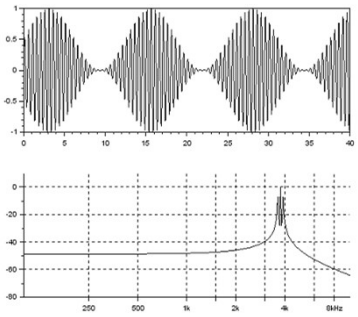
Abbreviations

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 – Auditory 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
HIPAA – Health Insurance Portability and Accountability Act
HL – Hearing Loss
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
NICHQ – National Institute for 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

- **Use of novel stimuli (brief-tone chirp or click evoked [CE]-chirp) has recently received attention as a potential alternative to click and toneburst stimuli, with reported improvements in frequency-specicity and shortened test duration. (p. 14)**
- **Limited data are currently available regarding the relationship between behavioral hearing thresholds and chirp-elicited responses in infants with a variety of types and degrees of hearing loss, warranting further study.**
- **Such advantages would need to include improved accuracy in auditory threshold estimation across all ages, types and degrees of hearing loss, and reduced duration of testing time.**

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment: Time Ordered Agenda

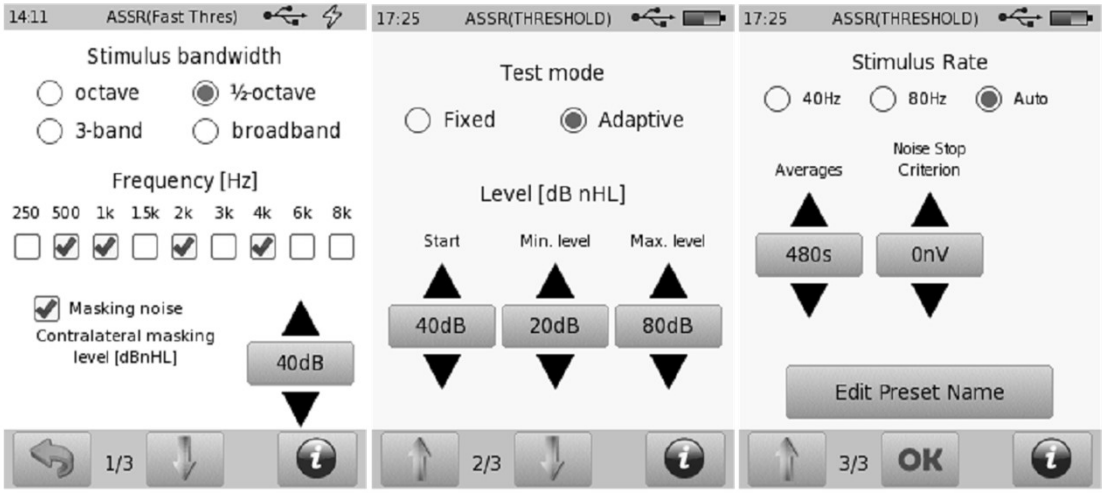
- **0-10 mins: Rationale for Infant ABR Assessment**
- **11-30 mins: Evidence-Based ABR Protocol**
- **31-35 mins: Pediatric ABR Measurement and Analysis**
- **36-45 mins: Strategies for Minimizing Test Time**
- **46-50 mins: Role of ASSR in Infant Assessment**
- **51-55 mins: ABR within an Objective Test Battery**
- **56-60 mins: Summary and Conclusion**



Presented in Partnership with

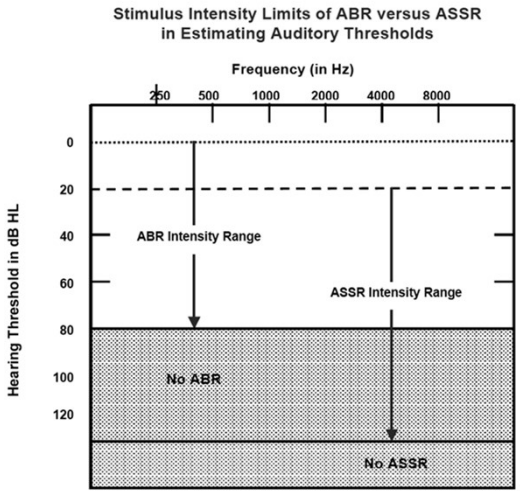
continued

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment: *Role of ASSR in Infant Assessment*



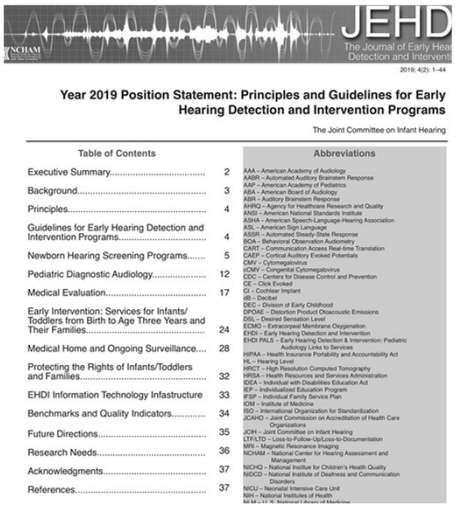
Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment: *Role of ASSR in Infant Assessment*

- **ABR and ASSR recorded with same equipment, electrodes, and transducers**
- **Differences between ABR and ASSR**
  - **ABR: transient stimulus at moderate rates**
  - **ASSR: AM and FM modulated pure tones presented at very fast rates**
  - **Manual vs. automated analysis**
- **Advantages of ASSR vs. ABR along**
  - **Estimation of thresholds in severe to profound hearing loss**
  - **Crosscheck ABR threshold estimations**
  - **Automated analysis**
- **Disadvantages of ASSR vs. ABR**
  - **No waveform for neuro-diagnostic analysis**
  - **Patient must be asleep or very quiet**



Presented in Partnership with

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment: *Role of ASSR in Infant Assessment*



JEHD
The Journal of Early Hearing Detection and Intervention
2019; 4(2): 1-44

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

The Joint Committee on Infant Hearing

Table of Contents

Abbreviations

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
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
NICHQ – National Institute for Children's Health Quality
NIDCD – National Institute of Deafness and Communication Disorders
NICU – Neonatal Intensive Care Unit
NIH – National Institutes of Health
NLM – National Library of Medicine

Although toneburst ABR is the gold-standard for estimating hearing thresholds in the infant, other evoked-response protocols, stimuli, and technologies are emerging that demonstrate frequency specificity, as well as equivalent, if not superior test efficiency (e.g., ABR or Automated Steady-State Response [ASSR] using puretone or broadband [chirp or click-evoked-chirp stimuli], Cebulla & Elberling, 2015; Cebulla, Lurz, & Shehata-Dieler, 2014). Any technology, protocol or stimulus used for objective determination of frequency-speci c hearing thresholds should be rigorously and independently validated for the ability to accurately predict behavioral hearing thresholds in infants and young children of all ages and all types and degrees of hearing loss.

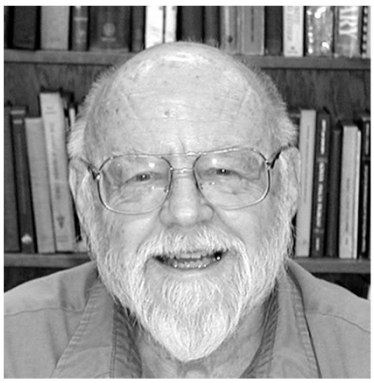
Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment: Time Ordered Agenda

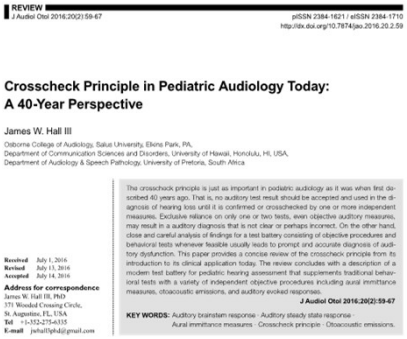
- **0-10 mins: Rationale for Infant ABR Assessment**
- **11-30 mins: Evidence-Based ABR Protocol**
- **31-35 mins: Pediatric ABR Measurement and Analysis**
- **36-45 mins: Strategies for Minimizing Test Time**
- **46-50 mins: Role of ASSR in Infant Assessment**
- **51-55 mins: ABR within an Objective Test Battery**
- **56-60 mins: Summary and Conclusion**

Presented in Partnership with

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment: *The Cross-Check Principle in for Diagnosis of Hearing Loss in Children*

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





REVIEW
J Audiol Otol 2016;20(2):59-67
pISSN 2384-1621 / eISSN 2384-1710
http://dx.doi.org/10.7874/jao.2016.20.2.59

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

James W. Hall III

Osborne College of Audiology, Salus University, Elkins Park, PA,
Department of Communication Sciences and Disorders, University of Hawai, Honolulu, HI, USA,
Department of Audiology & Speech Pathology, University of Pretoria, South Africa

Received July 1, 2016
Revised July 13, 2016
Accepted July 14, 2016

Address for correspondence
James W. Hall III, PhD
171 Wooded Crossing Circle,
St. Augustine, FL, USA
Tel +1-352-275-6335
E-mail jwhallIIIphd@gmail.com

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.

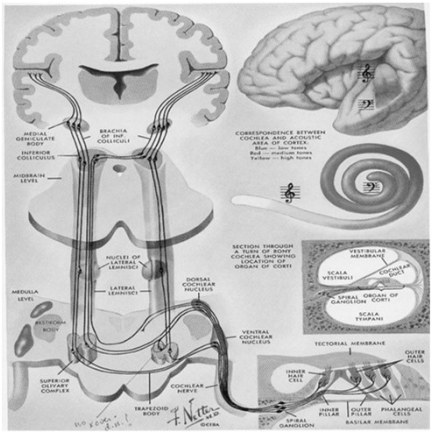
"We have found than simply observing the auditory behavior of children does not always yield an accurate description of hearing loss"…

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

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment: *The Cross-Check Principle in for Diagnosis of Hearing Loss in Children*

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

- **Behavioral Audiometry**
- **Aural Immittance Measurements**
  - **Tympanometry**
  - **Acoustic Reflexes**
- **Otoacoustic Emissions (OAEs)**
- **Auditory Brainstem Response (ABR)**
  - **Air- and Bone Conduction Click Stimuli**
  - **Tone Burst**
  - **Broadband and Narrow Band Chirp Stimuli**
- **Auditory Steady State Response (ASSR)**
- **Electrocochleography (ECochG)**
- **Cortical Auditory Evoked Responses**



Presented in Partnership with

CONTINUED

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment: Time Ordered Agenda

- 0-10 mins: Rationale for Infant ABR Assessment
- 11-30 mins: Evidence-Based ABR Protocol
- 31-35 mins: Pediatric ABR Measurement and Analysis
- 36-45 mins: Strategies for Minimizing Test Time
- 46-50 mins: Role of ASSR in Infant Assessment
- 51-55 mins: ABR within an Objective Test Battery
- 56-60 mins: Summary and Conclusion

Simple and Evidence-Based ABR Protocol for Infant Hearing Assessment: *Summary and Conclusion*

- ABR is the preferred technique for estimation of hearing level (eHL) in infants and young children
  - Recommended by 2019 JCIH
  - Almost 50 years of clinical research and experience
- Efficient and accurate auditory assessment with ABR is feasible with an appropriate test protocol and strategy
  - Evidenced-based test protocol + quiet patient = Optimal ABR
  - Complete diagnostic and threshold estimation ABR in $\leq$ 30 minutes is feasible
- ABR is NOT a test of hearing. Use a test battery including
  - Aural immittance (high frequency tympanometry and acoustic reflexes)
  - Otoacoustic emissions
  - Supplemental procedures as indicated
    - ✓ ASSR for assessment of severe-to-profound hearing loss
    - ✓ ECochG for diagnosis of ANSD