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Update on Auditory Evoked Responses: Value of Chirp Stimuli in ABR/ASSR Measurement

Presenter: James W. Hall III, PhD

Moderator: Carolyn Smaka, AuD, Editor in Chief, AudiologyOnline

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Update on Auditory Evoked Responses: Value of Chirp Stimuli in ABR/ASSR Measurement

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Learning Objectives

- As a result of this Continuing Education Activity, participants will be able to:
- Describe concepts underlying chirp stimuli.
- Define the role of click versus tone burst stimulation in infant ABR measurement.
- Identify 3 advantages of chirp stimuli in infant ABR measurement.

Audiology Online Webinar: March 9, 2016
Update on Auditory Evoked Responses: Evidence-Based Protocol for Infant Hearing Assessment

- What do we mean by “evidence-based”?
- Historical perspective
- The “crosscheck principle” and ABR
- ABR stimulus parameters
- ABR acquisition parameters
- Saving precious test time
- Conclusions
- Questions and answers

Update on Auditory Evoked Responses: Value of Chirp Stimuli in ABR/ASSR Measurement

- What do we mean by “evidence-based”?
- Introduction to ABR stimulus parameters
- Role of click and tone burst stimulation in infant ABR measurement
- Definition of chirp stimuli
- Advantages of chirp stimuli in infant ABR recordings
- Review of selected recent research findings on chirps
- Questions and answers

Evidence-Based Practice (EBP) is Best Practice
Best Practice Follows Clinical Practice Guidelines

- **Evidence-based practice is "the integration of best research evidence with clinical expertise and patient values" (Sackett et al, Evidence-Based Medicine: How to practice and teach EBM. London: Churchill, 2000, p. 1)**
- **EBP is a five step process**
  - **Focused clinical question**
  - **Evidence is sought to answer the question**
  - **Clinician evaluates the quality of evidence**
  - **Clinician must integrate the evidence with the patient's clinical findings and preferred outcome to develop intervention plan**
  - **Document outcome and identify ways to improve it**

US Preventative Services Task Force:
Grades of Evidence
(www.fpnotebook.com/prevent/epi)

- **Level I: Randomized control trial**
- **Level II: Non-randomized control trial**
- **Level III: Cohort or case-control study**
- **Level IV: Ecological or descriptive studies**
- **Level V: Opinions of respected authorities based on**
  - **Clinical experience**
  - **Descriptive studies *or***
  - **Reports of expert committees**

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Evidence-Based Frequency-Specific ABR Test Protocol: *Stimulus Parameters*

Parameter	Selection	Rationale
Transducer	ER-3A inserts	Numerous infant advantages
	B71 or B81	Bone oscillator as needed
Type	Clicks	R/O ANSD
	Tone bursts	Available on all systems
	Chirp stimuli	Larger ABR amplitude
Mode of Presentation	Air-conduction	Always
	Bone-conduction	As indicated
Polarity	Rarefaction	Condensation as needed

Evidence-Based Frequency-Specific ABR Test Protocol: *Stimulus Parameters*

Parameter	Selection	Rationale
Rate	Click: 21.1/sec	Record wave I in less time
	TB: 37.7/sec	Record wave V in less time
Frequencies	.5, 1, 2, 4 K Hz	Sequence varies clinically
Duration	2-0-2 cycles	Equal intensities; < splatter
Ramping	Blackman	More frequency-specific
Intensity	dB nHL	Calibration in peRETSPL plus normal behavioral thresholds for each stimulus

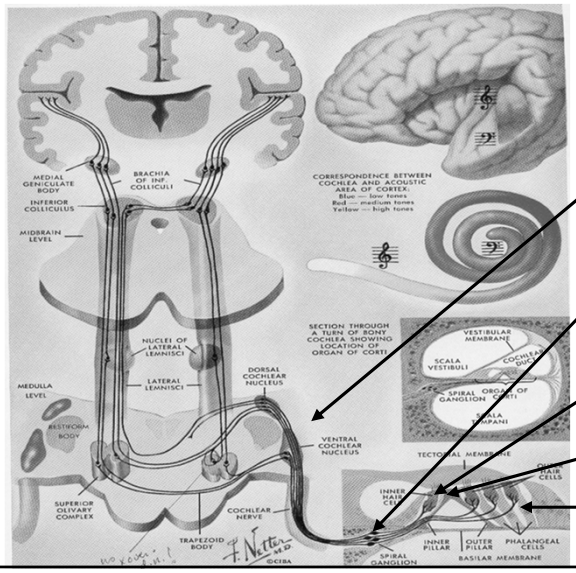
Update on Auditory Evoked Responses: Value of Chirp Stimuli in ABR/ASSR Measurement

- What do we mean by "evidence-based"?
- Introduction to ABR stimulus parameters
- Role of click and tone burst stimulation in infant ABR measurement
  - Stick with the click and…
  - Be the first with the bursts
- Definition of chirp stimuli
- Advantages of chirp stimuli in infant ABR recordings
- Review of selected recent research findings on chirps
- Questions and answers

Example of A Practice Guideline in Audiology: Year 2007 JCIH Position Statement Protocol for Evaluation for Hearing Loss In Infants and Toddlers from Birth to 6 months

- Child and family history
- Evaluation of risk factors for congenital hearing loss
- Parental report of infant's responses to sound
- Audiological assessment
  - Auditory brainstem response (ABR)
    - ✓Click-evoked ABR with rarefaction and condensation single-polarity stimulation if there are risk factors for auditory neuropathy
    - ✓Frequency-specific ABR with air-conduction tone bursts
    - ✓Bone-conduction stimulation (as indicated)
    - ✓Auditory steady state response (ASSR) is optional
  - Otoacoustic emissions (distortion product or transient OAEs)
  - Tympanometry with 1000 Hz probe tone
  - "Clinical observation of infant's auditory behavior. ***Behavioral observation alone is not adequate for determining whether hearing loss is present in this age group, and is not adequate for the fitting of amplification devices.***"

Diagnostic Value of Click-Evoked ABR: *Determining Site of Auditory Dysfunction*



Brainstem (ABR, ASSR, ARs)

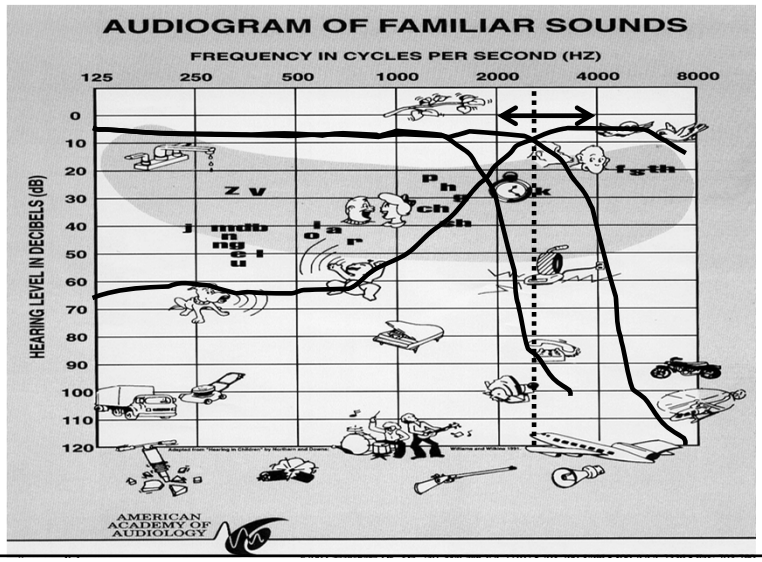
Spiral ganglion cells (ABR, ECochG)

IHC - 8th CN Synapse (ABR)

Inner hair cells (ECochG, ABR, ASSR, ARs)

Outer hair cells (OAE, ECochG, ARs)

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



Normal click ABR

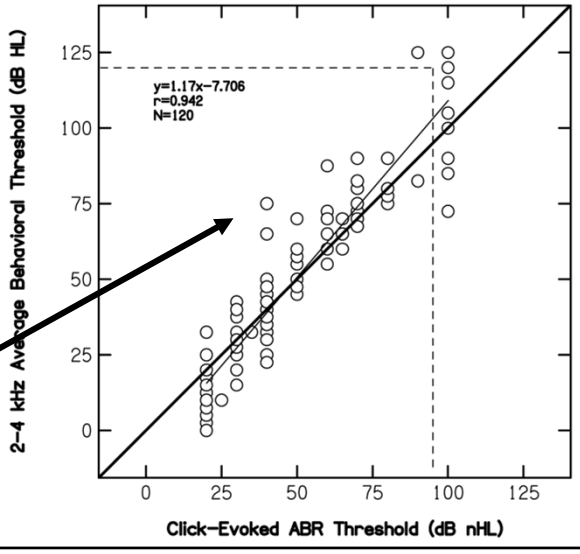
Abnormal or no click ABR

Gorga et al (2006). Using a combination of click- and toneburst evoked auditory brainstem response methods to estimate pure-tone thresholds. *Ear & Hearing, 27, 60-74*

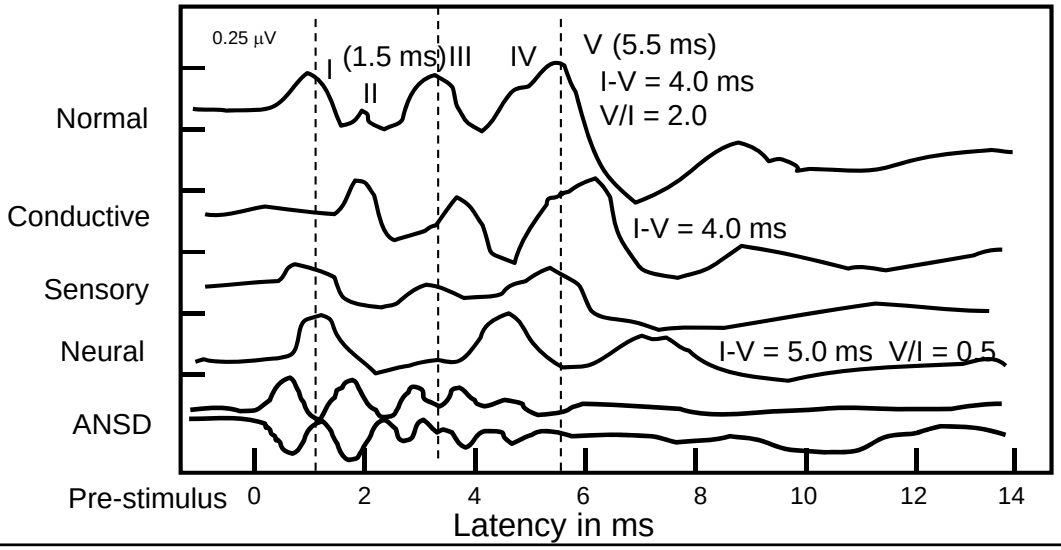
Click ABR Threshold versus Pure Tone Hearing Threshold (2 to 4 K Hz)

N = 77
71 = < 5 years

Click ABR Threshold Better Than Pure Tone Threshold



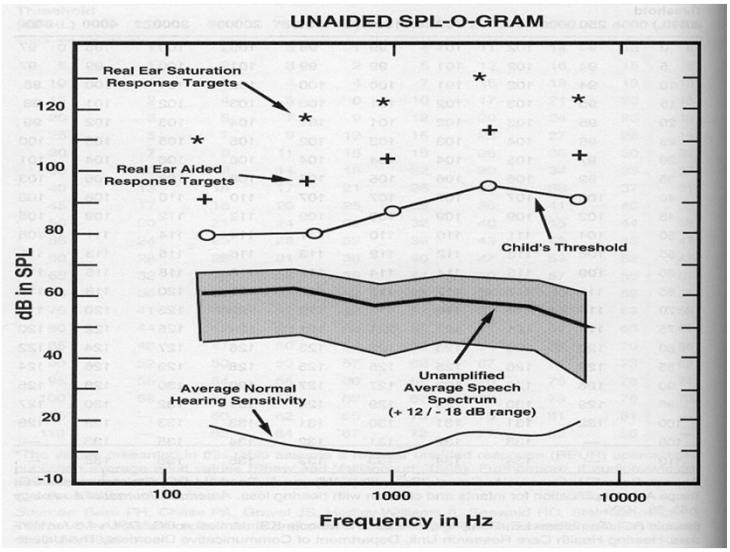
Diagnostic Value of the Click-Evoked ABR: Differentiation Among Types of Auditory Dysfunction



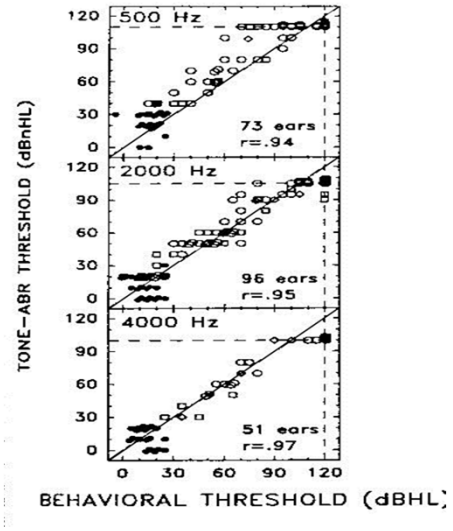
Diagnostic Value of the Click-Evoked ABR: Differentiation Among Types of Auditory Dysfunction

- **Recommend beginning an ABR assessment with click stimuli**
- **Only requires a few minutes of test time**
- **Analysis permits differentiation among types of hearing loss**
- **Waveform analysis indicates test ear (presence of wave I)**
- **Identification of auditory neuropathy spectrum disorder**
- **Findings help to determine next steps in the assessment, e.g.,**
  - **Bone conduction ABR**
  - **Tympanometry**
  - **ASSR**
- **Recommended by the:**
  - **2007 Joint Committee on Infant Hearing (USA)**
  - **International clinical guidelines (e.g., UK, Canada, Australia)**

Estimation of Frequency-Specific Auditory Thresholds with Tone Burst ABRs: *Initial Data Points for Hearing Aid Fitting or Cochlear Implant Candidacy*

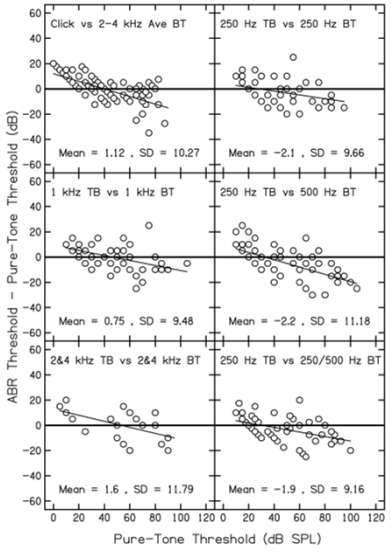


FREQUENCY-SPECIFIC AUDITORY BRAINSTEM RESPONSE (ABR): Relation to Audiogram (Oates & Stapells, 1998)



Gorga et al (2006). Using a combination of click- and toneburst evoked auditory brainstem response methods to estimate pure-tone thresholds. *Ear & Hearing, 27, 60*-74

N = 77
71 = < 5 years



Frequency Specific Auditory Brainstem Response: Selected References (1)

- **Bagatto M (2008). Baby waves and hearing aids: Using ABR to fit hearing aids to infants. *Hearing Journal, 61*, 10-16**
- **Beck, Samsson & Moodie (2009). Facilitating a smooth transfer from ABR to hearing aid fittings. *The Hearing Journal, 62*, 20-28**
- **British Columbia Early Hearing Program, BCEHP (2008). Diagnostic audiology protocol.**
- **Gorga et al (2006). Using a combination of click- and tone burst-evoked auditory brainstem response measurements to estimate pure-tone thresholds. *Ear & Hearing, 27*, 60-74**
- **Hall JW III (2007). *New Handbook of Auditory Evoked Responses*. Boston: Allyn & Bacon**
- **Lee et al (2007). Threshold of tone burst auditory brainstem responses for infants and young children with normal hearing in Taiwan. *J Formosan Med Association, 106*, 869-875**

Frequency Specific Auditory Brainstem Response: Selected References (2)

- Rance, Tomlin & Rickards (2006). Comparison of auditory steady-state responses and tone-burst auditory brainstem responses in normal babies. *Ear and Hearing, 27*, 751-762
- Stapells DR (2000) Threshold estimation by the tone-evoked auditory brainstem response: A literature meta-analysis. *J Speech-Language Pathology & Audiology, 24*, 74-83
- Stapells DR (2011). Frequency-specific threshold assessment in young infants using the transient ABR and brainstem ASSR. In *Comprehensive Handbook of Pediatric Audiology*. R Seewald & Tharpe AM (eds). San Diego: Plural Publishing, pp. 409-448
- Vander Werff, Prieve & Georgantas (2009). Infant air- and bone conduction tone burst auditory brainstem responses for classification of hearing loss and the relationship to behavioral thresholds*. Ear and Hearing, 30*, 350-368
- McCreery et al (2014). The impact of degree of hearing loss on auditory brainstem response predictions of behavioral thresholds. *Ear & Hearing*

Air Conduction Tone Burst ABR Thresholds Minus Behavioral Thresholds in Infants and Young Children with Hearing Loss

Adapted from Stapells (2011)

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)

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- Questions and answers

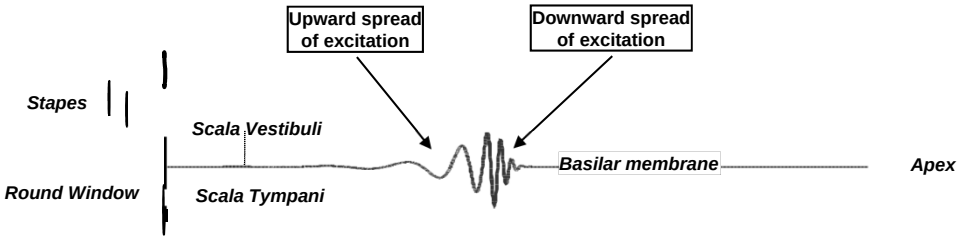
Chirp Stimuli in ABR Measurement: *Now Available on Selected Clinical Devices*

Evidence-Based Clinical Applications of Chirp Evoked ABRs and ASSRs: *"Early" Chirp Literature*

- Elberling C & Don M (2008). Auditory brainstem responses to a chirp stimulus designed from derived-band latencies in normal-hearing subjects. *Journal of the Acoustical Society of America, 124*, 3022-3037
- Elberling C (2010). A direct approach for the design of chirp stimuli used for the recording of auditory brainstem responses. *JASA, 128,* 2955-2964
- Elberling, C, Callø J & Don, M (2010). Evaluating auditory brainstem responses to different chirp stimuli and three levels of stimulation. *Journal of the Acoustical Society of America*, *128,* 215-223

NOTE: CE-Chirp refers to Danish scientist Claus Elberling (CE)

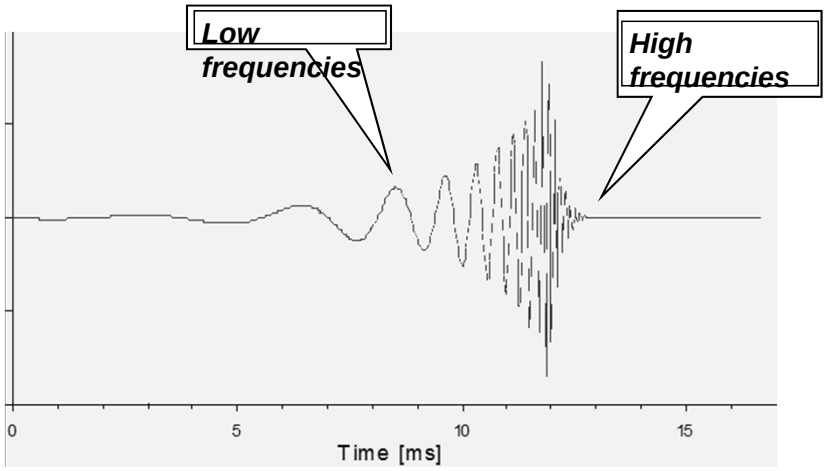
Cochlear Excitation Patterns for Click versus Narrow Band Stimulation



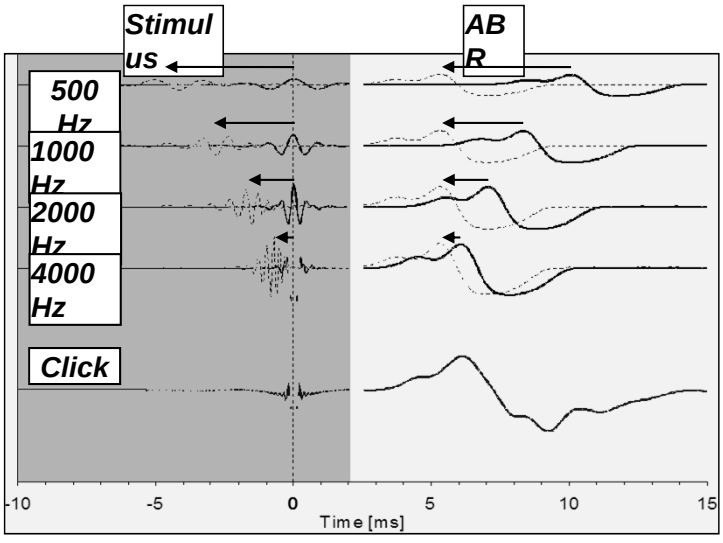
Continuous, narrow band stimuli

Transient, broad band stimuli

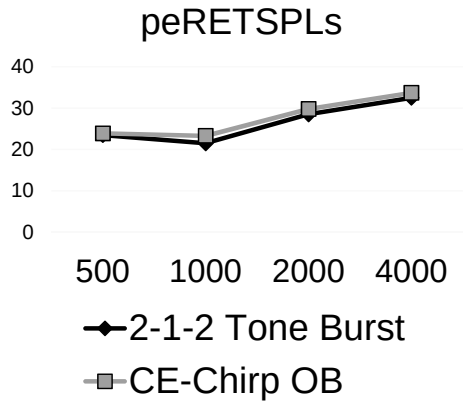
Chirp Temporal Waveform



Temporal Compensation via Input Compensation (Courtesy of Claus Elberling)



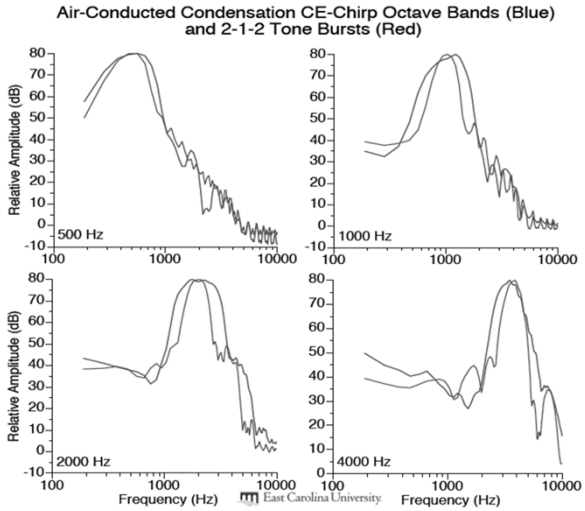
peRETSPLs:
CE-Chirp Octave Bands vs. Tone Bursts



- **ISO 389-6: 2-1-2 Tone Burst peRETSPLs (blue = tone bursts)**
- **3A Insert Earphones using 711 ear simulator**
- **Range of 0.4 to 1.8 dB difference**

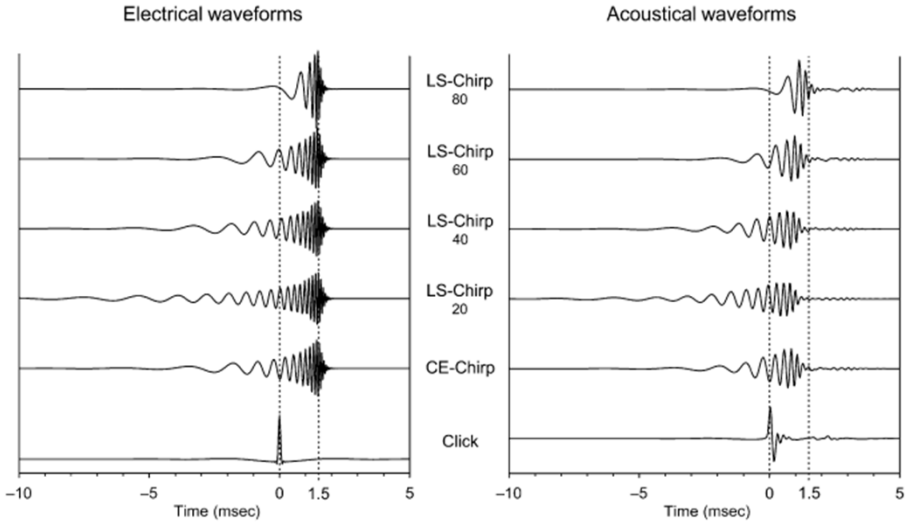
Reference: Gotsche-Rasmussen, Poulsen, Elberling, Reference Hearing Threshold Levels for Chirp Signals Delivered by an ER-3A Earphone, International Journal of Audiology, 2012, Early Online: 1-6

Acoustic Spectrum:
CE-Chirp Octave Bands vs. Tone Bursts

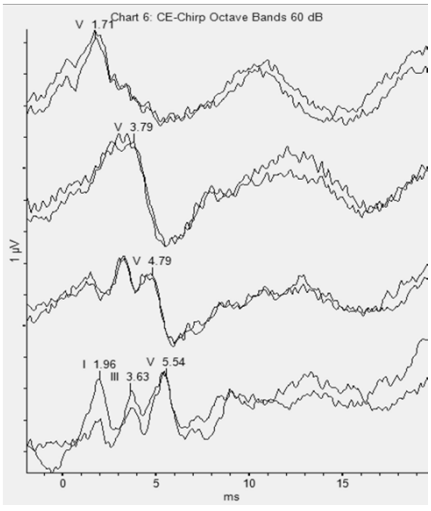


Courtesy of East Carolina University

Kristensen & Elberling (2012). Auditory brainstem responses to level-specific chirps in normal-hearing adults. *J American Aacademy of Audiology, 23,* 712-721



ABR Latency Values: CE-Chirp Octave Bands



500 Hz

1 kHz

2 kHz

4 kHz

CE-Chirp octave bands are derived from CE click chirps where low frequencies are presented before high frequencies. Therefore, wave V latencies for low frequency octave bands (e.g. 500 Hz) appear earlier than the high frequency octave bands (e.g. 1000, 2000, or 4000 Hz)

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- ❑ Definition of chirp stimuli
- ❑ Advantages of chirp stimuli in infant ABR recordings
- ❑ Review of selected recent research findings on chirps
- ❑ Questions and answers

Kristensen & Elberling (2012). Auditory brainstem responses to level-specific chirps in normal-hearing adults. *J American Aacademy of Audiology, 23,* 712-721

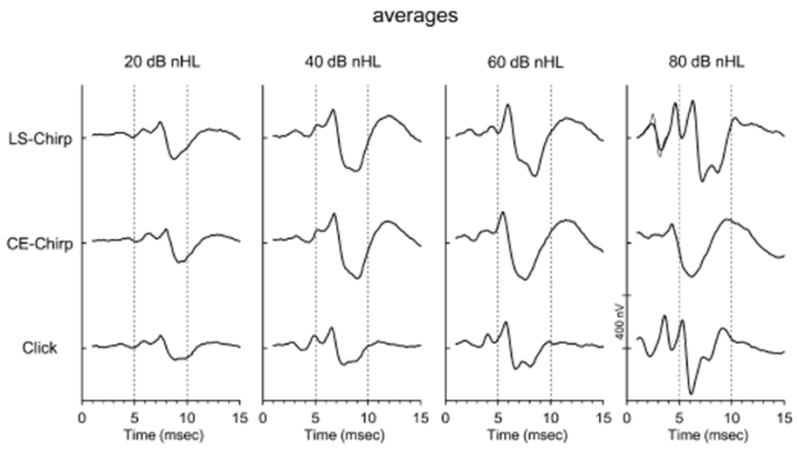
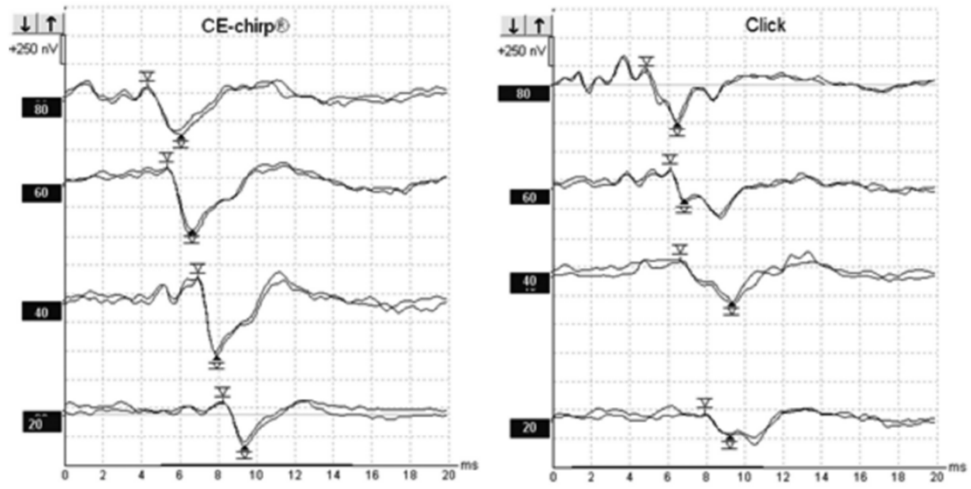


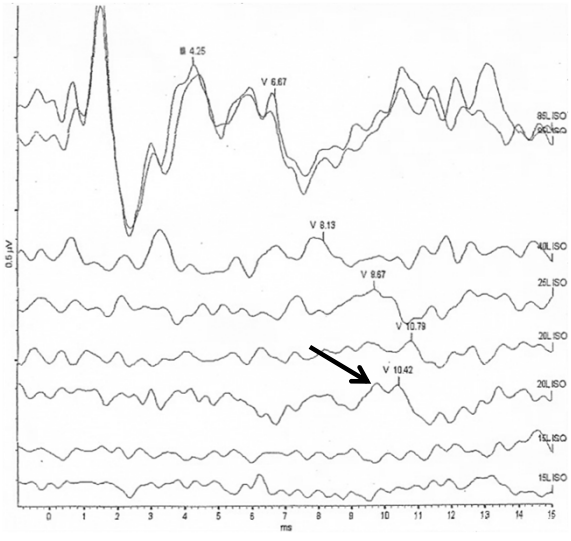
Figure 6. Grand Average ABR waveforms from N = 20 ears. The Grand Averages are obtained by time-shifting the underlying individual waveforms according the wave V latency. The thin line in the LS-Chirp/80 dB nHL condition shows a small part (corresponding to wave I) of the Grand Average obtained by using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

Rodrigues and Lewis (2012). Comparison of click and CE-chirp stimuli on brainstem auditory evoked potential recording. *Rev Soc Bras Fonoaudiol, 17*, 412-416



Conventional Click versus CE Chirp Evoked ABR

(1 year 4 month old boy with speech & language delay who failed hearing screening in nursery. Parents do not speak English)



85 dB nHL Click, rarefaction, 21.1/sec
I = 1.46 ms
V = 6.67 ms
I-V = 5.21 ms

45 dB nHL Click

25 dB nHL Click

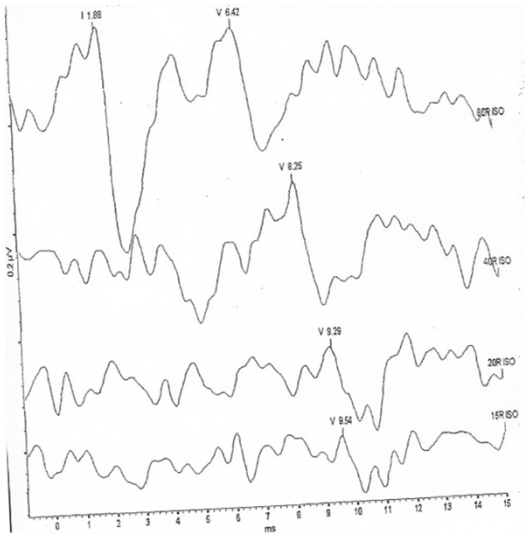
20 dB nHL Click

20 dB nHL CE Chirp

4000 Hz Chirp Evoked ABR

Stimulus rate = 37.7/sec

Total sweeps = 2622; Total test time = 69.5 seconds



Right Ear
80 dB nHL
684 sweeps

40 dB nHL
456 sweeps

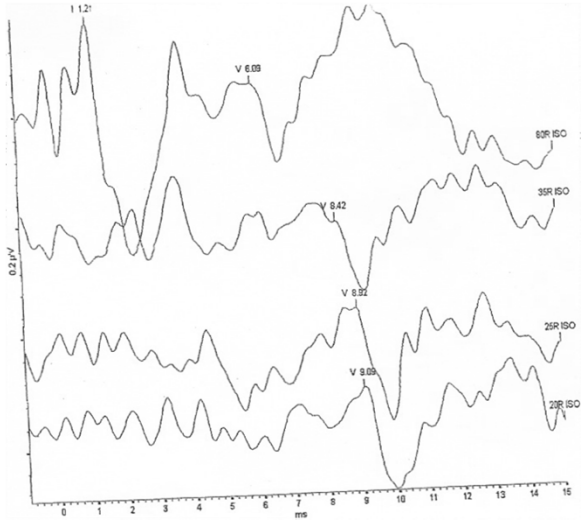
20 dB nHL
570 sweeps

15 dB nHL
912 sweeps

2000 Hz Chirp Evoked ABR

Stimulus rate = 37.7/sec

Total sweeps = 2318 ; Total test time = 61 seconds



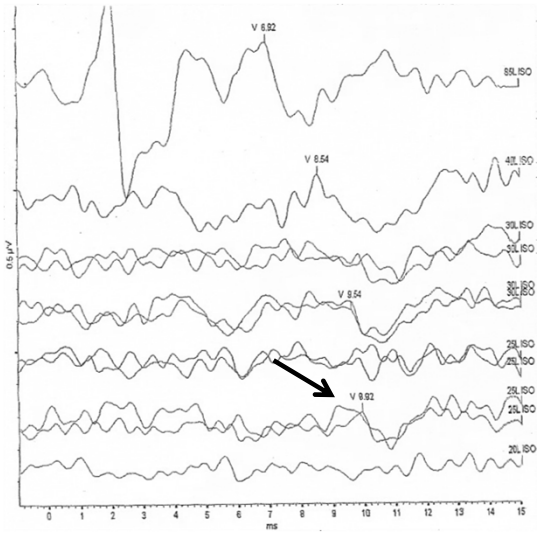
80 dB nHL
722 sweeps

35 dB nHL
570 sweeps

25 dB nHL
456 sweeps

20 dB nHL
570 sweeps

4000 Hz Conventional versus Chirp Evoked ABR



Left Ear
85 dB nHL
Tone Burst

40 dB nHL
Tone Burst

30 dB nHL
Tone Burst

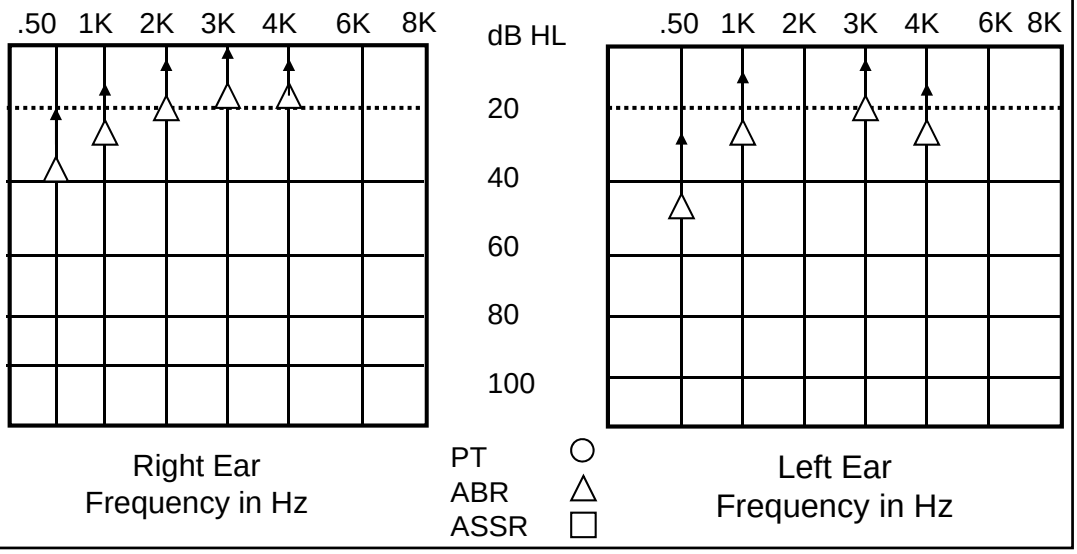
30 dB nHL, Chirp Tone Burst

25 dB nHL, Tone Burst

25 dB nHL, Chirp Tone Burst

15 dB nHL, Chirp Tone Burst

Electrophysiologic Estimation of the Audiogram:
One year 4 month boy



Advantages of CE-Chirp Stimulation of the Auditory Brainstem Response (ABR): *Advantages of Chirp Stimulation*

- ABR amplitude is up to two times larger for chirp stimulation
- Larger amplitude contributes to:
  - More confident identification of wave V
  - Shorter test time is needed to identify wave V
  - Reduced test time for each stimulus frequency permits
    - ✓ More complete estimation of auditory threshold in speech frequency region
    - ✓ Possibility of infant ABR assessment in natural sleep without the need for sedation or anesthesia
  - More accurate thresholds are sometimes possible with chirp stimulation

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- Questions and answers

Evidence-Based Clinical Applications of Chirp Evoked ABRs and ASSRs:
Selected Recent Literature (N = > 45 articles via PubMed)

- **Kristensen S & Elberling C (2012). Auditory brainstem responses to level-specific chirps in normal-hearing adults. *JAAA, 23,* 712-721**
- **Rodrigues, Ramos & Lewis (2013). Comparing ABRs to toneburst and narrow band CE-chirp in young infants. *Int J Pedi ORL, 77*, 1555-1560**
- **Rodrigues & Lewis (2014). Establishing ASSR thresholds to narrow band CE-chirps in full term infants. *Int J Pedi ORL, 7*8, 238-243**
- **Cebulla, Lurz & Shehata-Dieler (2014). Evaluation of waveform, latency and amplitude values of chirp ABR in newborns. *Int J Pedi ORL, 7*8, 631-638**
- **Xu, Cheng & Yao (2014). Prediction of frequency-specific hearing threshold using chirp ABR in infants with hearing loss. *Int J Pedi ORL, 7*8, 812-816**

Evidence-Based Clinical Applications of Chirp Evoked ABRs and ASSRs:
Selected Recent Literature (N = > 45 articles via PubMed)

- **Stuart & Cobb (2014). Effect of stimulus and number of sweeps on the neonate ABR. *Ear & Hearing, 35*, 585-588**
- **Venail et al (2015). Refining the audiological assessment in children using narrow-band CE-chirp evoked ASSRs. *Int J Audiol, 54*, 106-113**
- **Zim et al (2014) Comparison between ABR with click and narrow band chirp stimuli in children. *Int J Pedi ORL, 7*8, 1352-1355**
- **Di Scipio & Mastronardi (2015). CE-chirp ABR in cerellopontine angle neuromonitoring: technical assessment. *Neurosurg Rev, 38,* 381-384**
- **Maloff & Hood (2014). A comparison of ABR elicited by click and chirp stimuli in adults with normal hearing and sensory hearing loss. *Ear & Hearing, 35,* 271-282**

Evidence-Based Clinical Applications of Chirp Evoked ABRs and ASSRs: *Selected Recent Literature (N = > 45 articles via PubMed)*

- **Muhler et al (2014). 40-Hz multiple ASSR to narrow-band chirps in sedated and anesthetized infants. *Int J Pedi ORL, 7*8, 762-768**
- **Ferm & Lightfoot (2015). Further comparisons of ABR amplitudes, test time, and estimation of hearing threshold using frequency-specific chirp and tone pip stimuli in newborns: Findings at 0.5 and 2K Hz. *Int J Audiol, 54,* 745-750**
- **Bargen GA (2015). Chirp-evoked ABR in children: A review*. Am J Audiol, 24*, 573-583**
- **Zhou et al (2015). Study on the relationship between tone burst ABR and CE-chirp ASSR in infants with profound sensorineural hearing loss*.* *Zhonghua Er Bi Yan Hou Tou Jing Wai Ke Za Zhi. 50,* 551-5.**
- **Wilson et al (2016). Assessment of low-frequency hearing with narrow band chirp-evoked 40-Hz sinusoidal ASSR. Int J Audiol, *55,* 239-247**

Evidence-Based Clinical Applications of Chirp Evoked ABRs and ASSRs

- **Enhanced diagnostic assessment with ABRs elicited with CE-chirp air conduction click stimuli**
  - **Larger amplitude of wave III and wave V**
  - **Larger amplitude of wave I**
- **Faster estimation of frequency-specific air-conduction ABR and ASSR thresholds**
  - **Up to 50% reduction in overall test time**
  - **Detection of an ASSR in 10 – 15 seconds with fast rate**
- **Better detection of ABR and ASSR with low frequency stimuli**
- **More confident detection of bone conduction ABR**
- **Intra-operative monitoring with response detection in less time**

Resource

- **eHandbook of Auditory Evoked Responses (2015)**
- **Procedures and protocols for recording ECochG, ABR, ASSR, AMLR, ALR, and P300**
- **eBook available from Kindle Direct Publishing (Amazon.com)http://www.amazon.com/dp/B0145G2FFM**