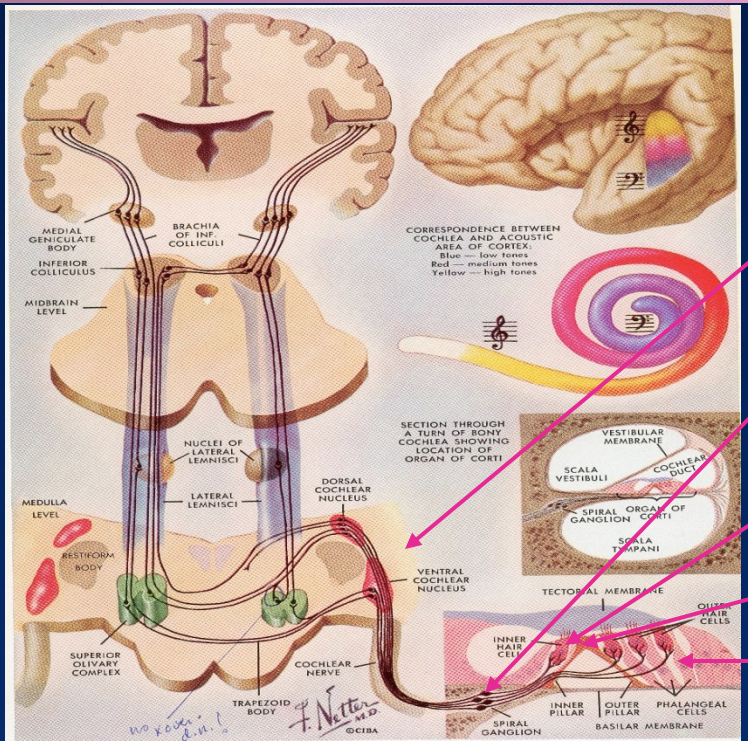
ABR and ASSR Measurement with Frequency Specific, Chirp, and Bone Conduction Stimulation

- Overview of Auditory Electrophysiological Procedures
- The Ongoing Importance of Click-Evoked ABR
- A Test Protocol for Frequency-Specific ABR
- Chirp Stimuli: What they are and their clinical value
- Bone Conduction ABR
- The Role of Auditory Steady State Response
- Un-Sedated versus sedated ABR and ASSR Measurement

ABR and ASSR Measurement with Frequency Specific, Chirp, and Bone Conduction Stimulation



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)

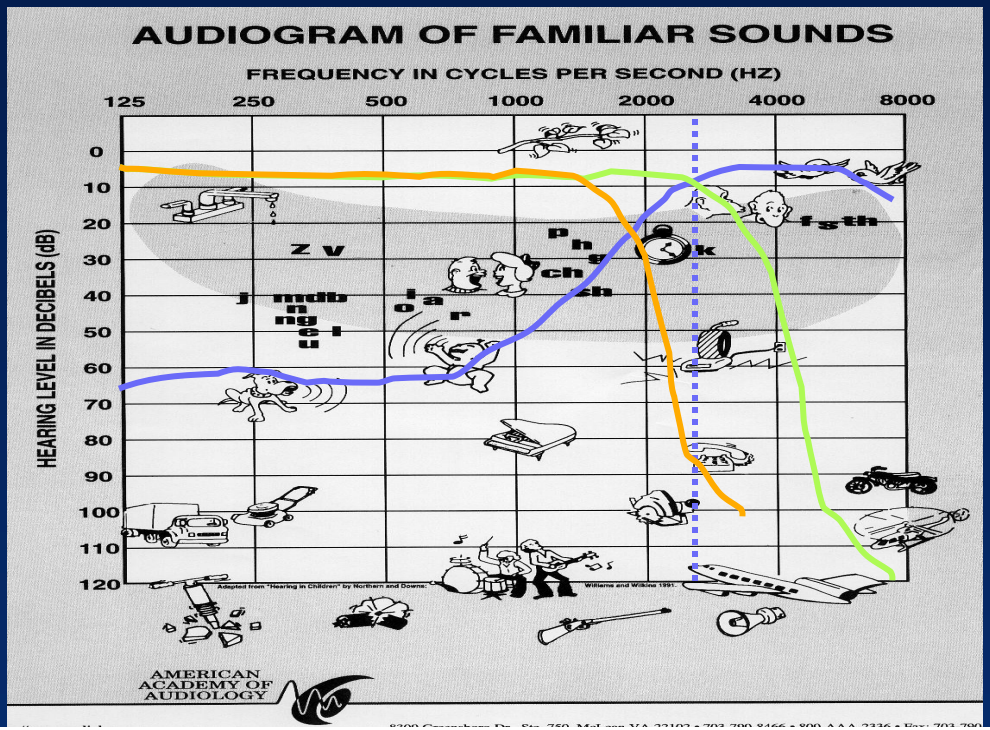
Year 2007 Joint Committee on Infant Hearing (JCIH): Protocol for Evaluation for Hearing Loss In Infants from Birth to 6 months

- Child and family history
- Evaluation of risk factors for congenital hearing loss
- Parental report of infant's responses to sound
- "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."*
- 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)
  - Otoacoustic emissions (distortion product or transient OAEs)
  - Tympanometry with 1000 Hz probe tone
  - Supplemental procedures, e.g.,
    - ✓ Electrocochleography (ECochG)
    - ✓ Auditory steady state response (ASSR)
    - ✓ Acoustic reflex measurement (for 1000 Hz probe tone)

Guidance for Auditory Brainstem Response Testing in Babies (Version 2.1) March 2013. NHSP Clinical Group

- Introduction
- Scope
- Patient Preparation
- Stimulus
  - Transducer
  - Air conduction stimuli
  - Bone conduction stimuli
- Data Collection and Analysis
- Calibration
- Artefacts
- Glossary
- Appendices

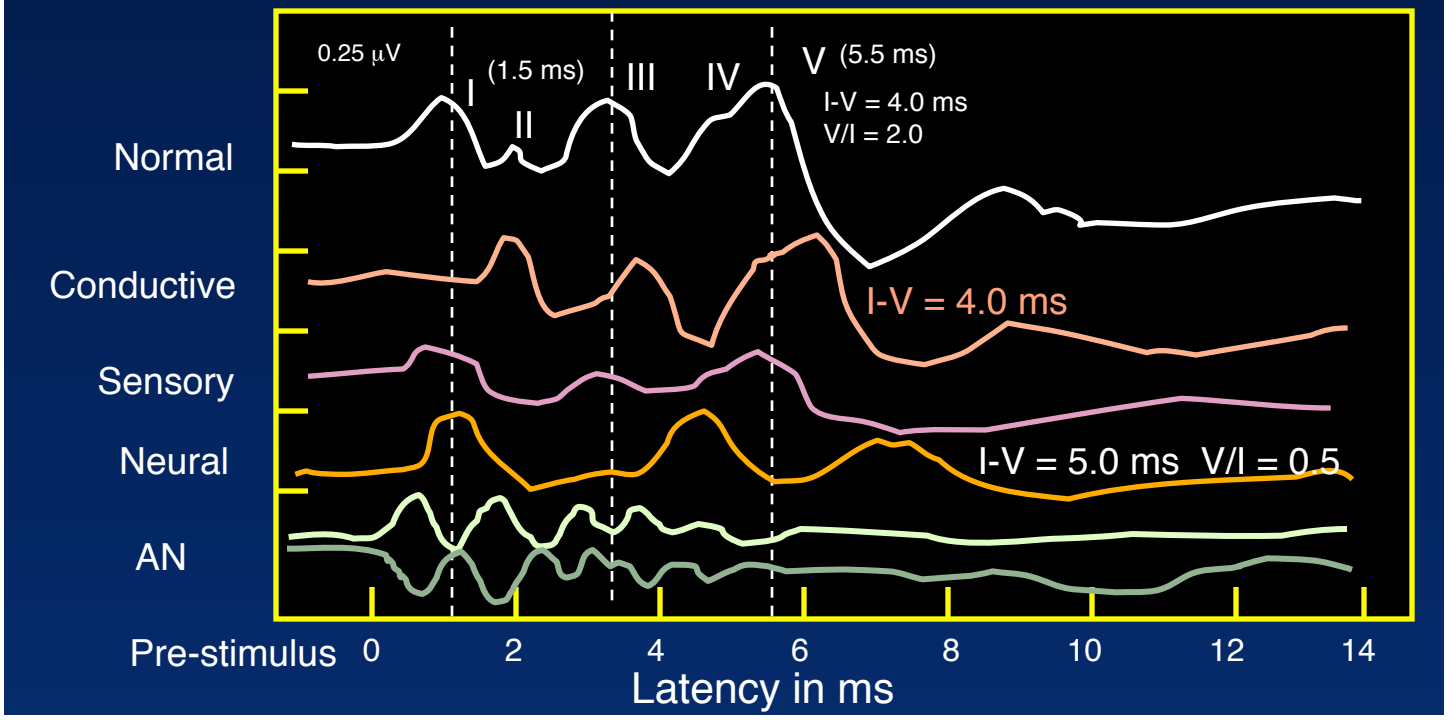
Limitation of Click-Evoked ABR: Lack of Frequency-Specificity



Normal click ABR

Abnormal or no click ABR

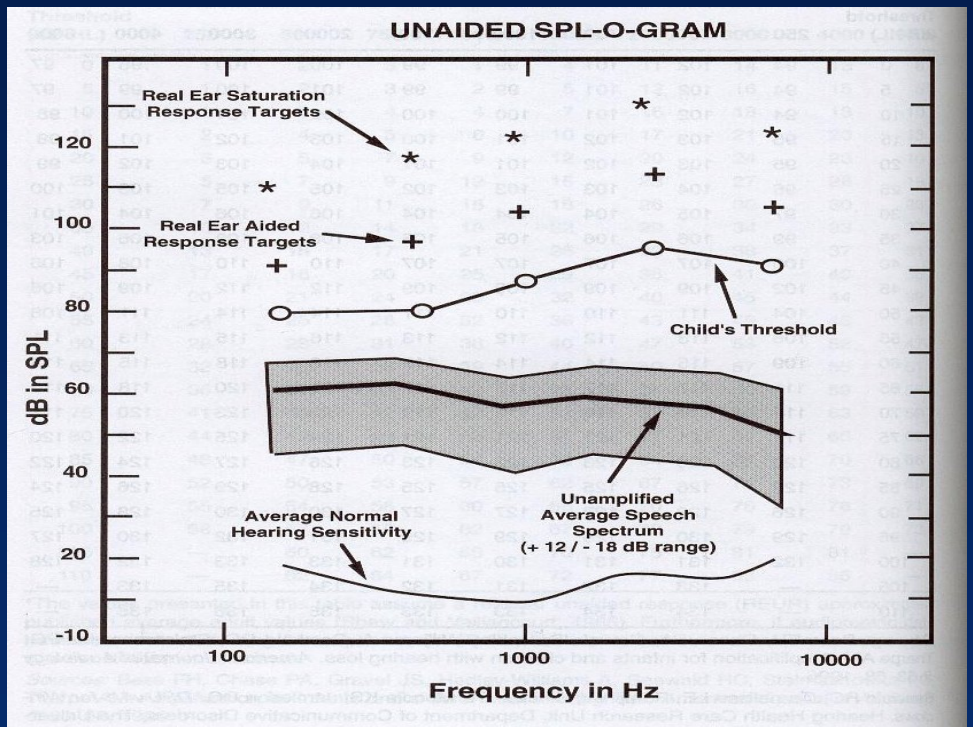
Diagnostic Value of the Click-Evoked ABR: Differentiation Among Types of Auditory Dysfunction



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

- Why it's a good strategy to begin the ABR assessment with click stimulation
  - 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, or tympanometry, or ASSR
  - Recommended by the
    - ✓ 2007 Joint Committee on Infant Hearing (USA)
    - ✓ 2013 NHS Guidance for ABR testing in babies (UK)

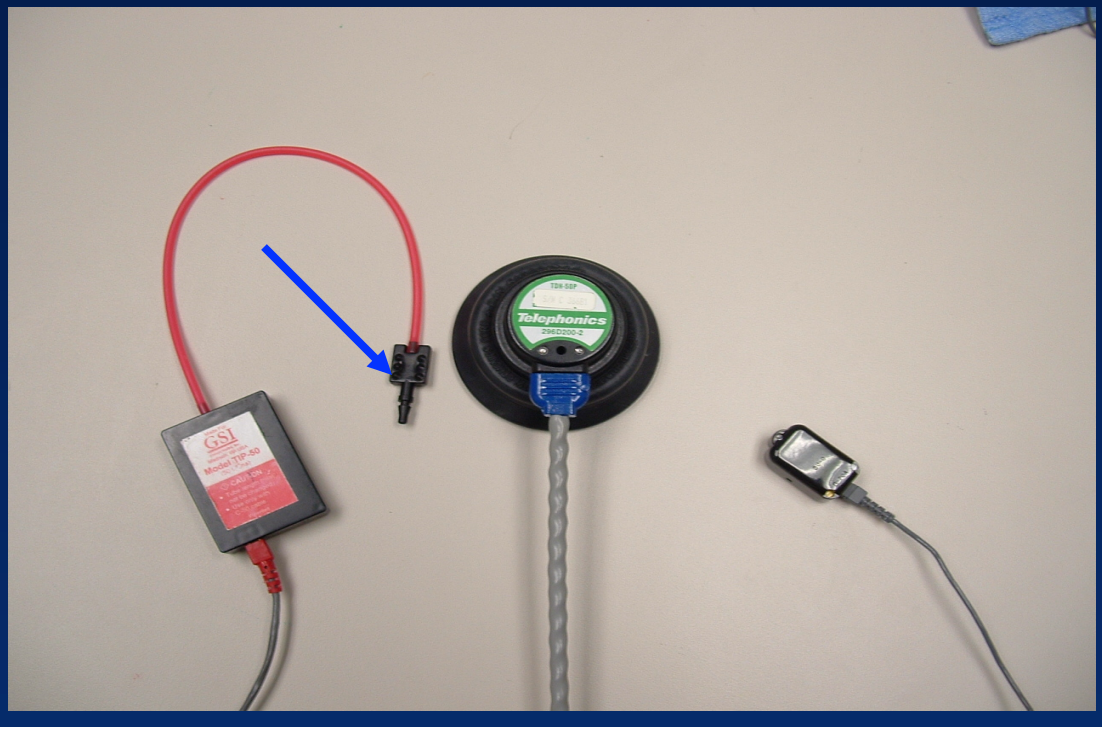
Estimation of Frequency-Specific Auditory Thresholds with Tone Burst ABRs: Initial Data Points for Hearing Aid Fitting



Evidence-Based Frequency-Specific ABR Test Protocol: Stimulus Parameters with Comparison to NHS Guidelines

Parameter	Selection	Rationale
Transducer	ER-3A inserts	Numerous infant advantages
NHS 2013	TDH 39/49	Numerous disadvantages
Type	Tone bursts	Available on all systems
Polarity	Rarefaction	Produces optimal ABR
NHS 2013	Alternating	Failure to diagnosis ANSD
Ramping (window)	Blackman	Less spectral splatter
NHS 2013	Linear acceptable	More spectral splatter

ABR Transducer Options



Guidance for Auditory Brainstem Response Testing in Babies (Version 2.1) March 2013. NHSP Clinical Group *Transducer Guidelines*

- "Warning: Insert earphones should not be used above the maximum intensity levels given in the NHSP guidelines for early audiological assessment. This is because a baby has a much smaller ear canal which will lead to a 10-20 dB higher stimulus level compared to the same insert earphone used in an adult. This uplift is thought to diminish over the early months of life as the ear canal grows (see NHSP early assessment guidance for more details."
- Clinical Concerns with Guidelines
  - Supra-aural (TDH) earphones have numerous disadvantages for infant ABR assessment
  - Alleged increased intensity is theoretical and based on calibration cavities not infant ears
  - No evidence from clinical data for enhanced infant thresholds

ABR Measurement in Infants and Young Children: Advantages of Insert (ER-3A) versus Supra-Aural Earphones

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

Evidence-Based Frequency-Specific ABR Test Protocol: Stimulus Parameters with Comparison to NHS Guidelines

Parameter	Selection	Rationale
Rate	Click: 21.1/sec	Record wave I in less time
	TB: 37.7/sec	Record wave V in less time
NHS 2013	Click, 2K, 4K Hz: 45.1/s	
	1K and 500 Hz: 35.1/sec	
Frequencies	1, .5, 4, 2 K Hz	Sequence varies clinically
Duration	2-0-2 cycles	Equal intensities; < splatter
NHS 2013	2-1-2 cycles	
Intensity	dB nHL	Different criteria for NHS 2013

Calibration of Transient Stimulus Intensity in dB HL: Two Different Approaches

- Biological Verification
  - Determine 0 dB nHL in small group of normal hearing adults
- NHS Calibration
  - Physical calibration according to ISO 389-6 (2007) or NHSP-recommended calibration values for RETSPL (air conduction) or for RETFL (bone conduction)
  - Listener check before each test session
  - "Threshold ABR tests should ideally be performed in a sound-proofed room or environment which meets the same standards used in pure tone audiometry… Careful selection of the local test area or room may be necessary in order to achieve satisfactory environmental conditons."

Evidence-Based Frequency-Specific ABR Test Protocol: Stimulus Parameters with Comparison to NHS Guidelines

Parameter	Selection	Rationale
Artifact reject	On	Minimize muscle artifact
NHS 2013	+/-3 to +/- 10 υV peak-to-peak; start at +/- 5 υV peak	
Analysis time	15 ms	Click, 4000 Hz, 2000 Hz
	20 ms	1000 Hz and 500 Hz
		Encompass delayed wave V and SN10 after wave V
NHS 2013	20 ms	Click, 4000 Hz, 2000 Hz
	25 ms	1000 and 500 Hz

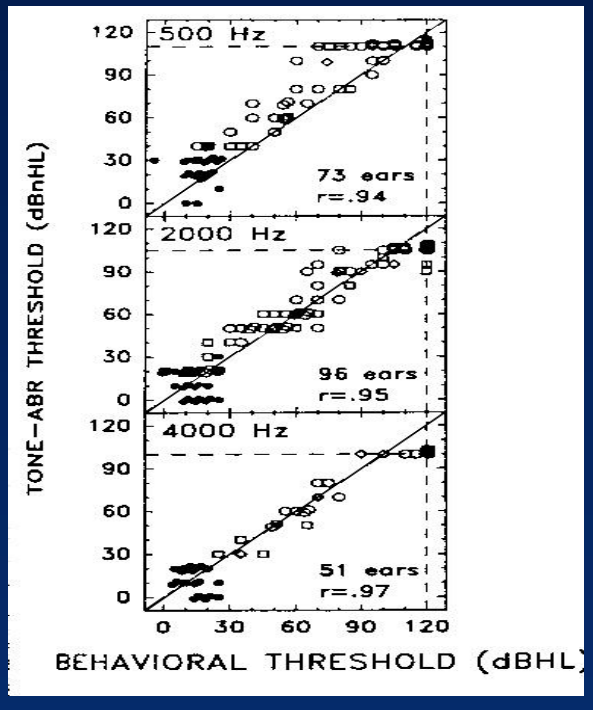
Evidence-Based Frequency-Specific ABR Test Protocol: Stimulus Parameters with Comparison to NHS Guidelines

Parameter	Selection	Rationale
Sweeps	Variable	To produce an SNR of 3:1 To increase test efficiency
NHS 2013	2000 click & chirp 3000 tone burst	Minimum 1500 click & chirp Minimum 2000 for tone burst
	See Appendix D: "…number of sweeps per average"	
Reliability	2 or 3 runs	"If it doesn't replicate, you must investigate!"

Evidence-Based Frequency-Specific ABR Test Protocol: Stimulus Parameters with Comparison to NHS Guidelines

Parameter	Selection	Rationale
Electrode type	Disc & ear clip or disposable	
Electrode location	Fz - Ai Fpz ground	Optimal infant response Good for BC stimulus Permits ipsi/contra meas't
Filter settings	30 - 3000 Hz No notch filter	Encompass infant spectrum
Artifact reject	On	Minimize muscle artifact

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



Frequency Specific Auditory Brainstem Response: Stimuli Made Simple

- 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: Stimuli Made Simple

- 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

Frequency Specific Auditory Brainstem Response: Stimuli Made Simple

- Factors influencing accuracy of auditory threshold estimation with ABR
  - Maturational factors
    - ✓ Latency, amplitude, and morphology of wave V
    - ✓ Changing size of the external ear canal
    - ✓ Changing properties of the external ear canal
    - ✓ Cognitive maturation of behavioral hearing thresholds
  - Technical factors
    - ✓ Patient movement interference (poorer signal to noise ratio)
    - ✓ Acoustic (ambient) noise in test room
    - ✓ Electrical noise
    - ✓ Accuracy of earphone placement
    - ✓ Electrode array (e.g., Larger wave V with a non-cephalic array)
    - ✓ Intensity increment (e.g., 10 versus 5 dB)

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

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	-10 dB

Note: According to Stapells (2000), ABR thresholds "overestimate" behavioral thresholds by 10 to 20 dB for normal hearers and 5 to 15 dB for patients with sensory hearing loss

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)

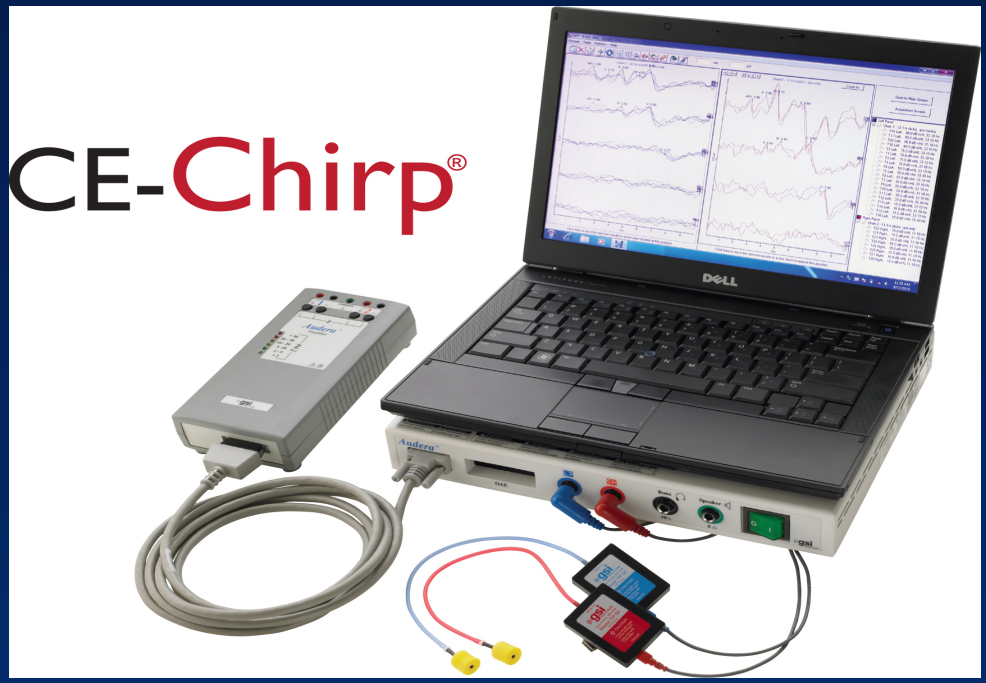
Steps in Accurate Estimation of Auditory Thresholds

- With ABR system, obtain average normal behavioral thresholds (from 3 to 5 normal hearing adults) for click and each tone burst signal
  - Minimally click plus 500, 1000, 2000, and 4000 Hz
  - Calculate “dial” reading that is equivalent to 0 dB nHL
  - With ABR system
  - In typical test environment (s)
- ABR thresholds in dB nHL are not equal to pure tone hearing thresholds in dB HL
  - Subtract 10 dB from ABR threshold to estimate auditory threshold (edB HL)
- Plot estimated auditory thresholds on “tone burst ABR audiogram”

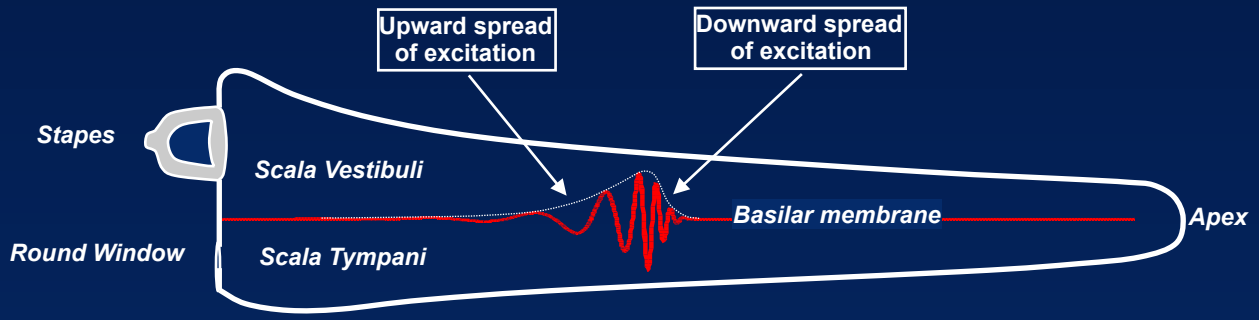
Advantages of CE-Chirp Stimulation of the Auditory Brainstem Response (ABR)

- Early identification, diagnosis, and intervention of infant hearing loss improves communication
- Accurate assessment of hearing in young children is standard of care
- Why it is important to record ABRs with click and also tone burst stimulation
- Protocol for tone burst (frequency specific) ABR
- Chirp stimuli in ABR measurement
- Summary of advantages of chirp-evoked ABR

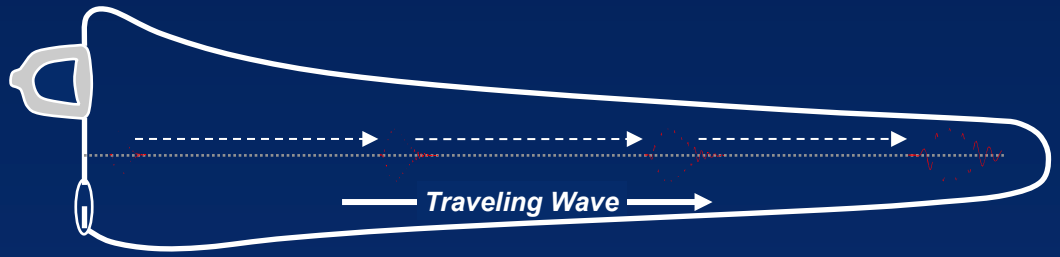
Chirp Stimuli in ABR Measurement: A Valuable Supplement to Traditional Stimuli



Cochlear Excitation Patterns for Click versus Narrow Band Stimulation

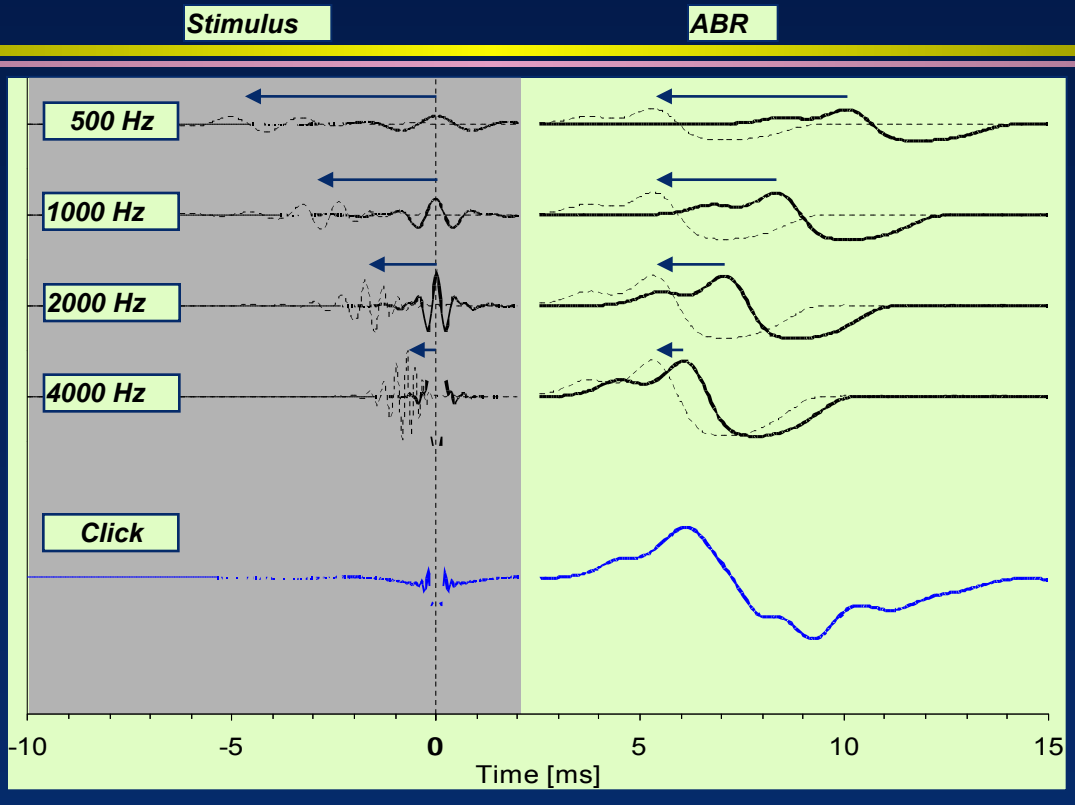


Continuous, narrow band stimuli

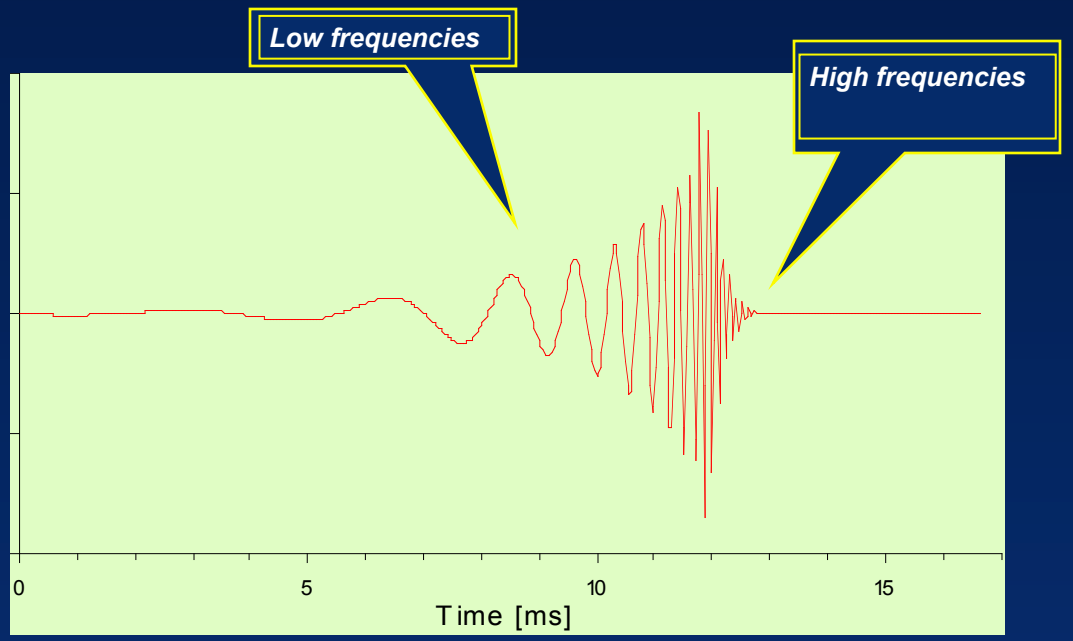


Transient, broad band stimuli

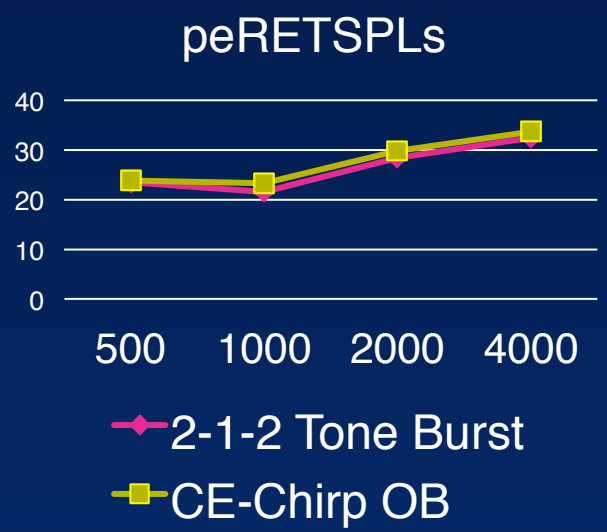
Temporal Compensation via Input Compensation (Courtesy of Claus Elberling)



Chirp Temporal Waveform



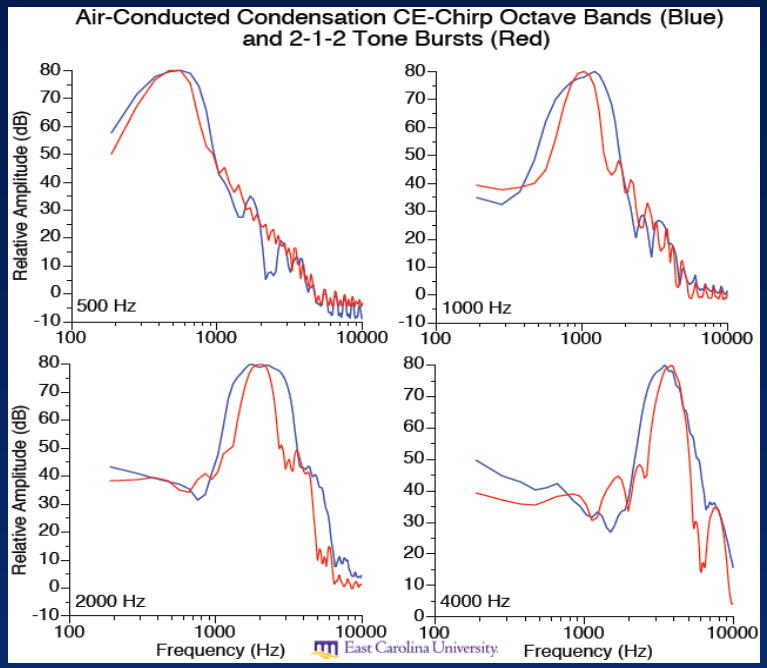
peRETSPLs:
CE-Chirp Octave Bands vs. Tone Bursts



- 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

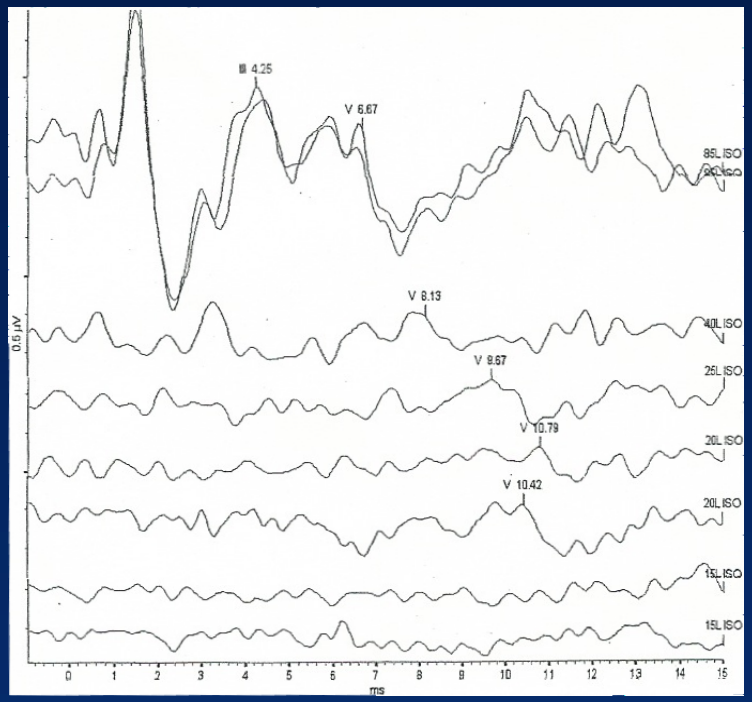
Acoustic Spectrum:
CE-Chirp Octave Bands vs. Tone Bursts



Courtesy of East Carolina University

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

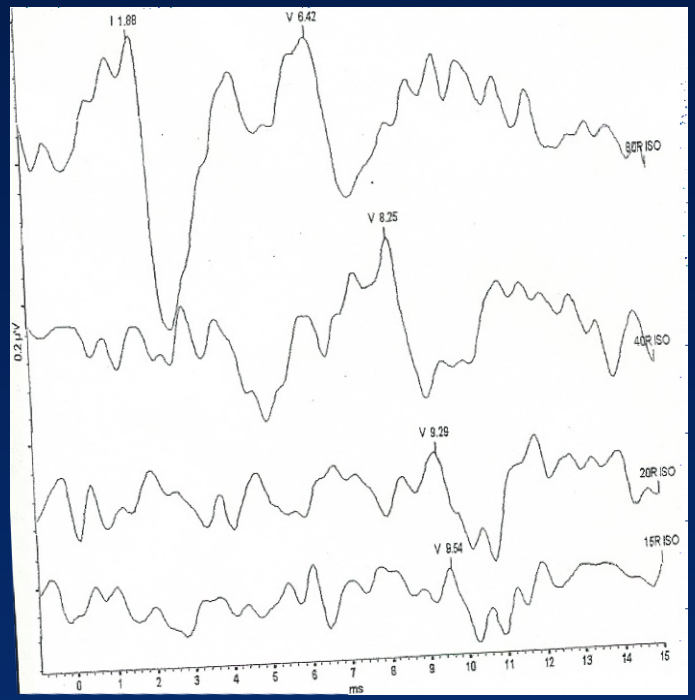
15 dB nHL Click

15 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

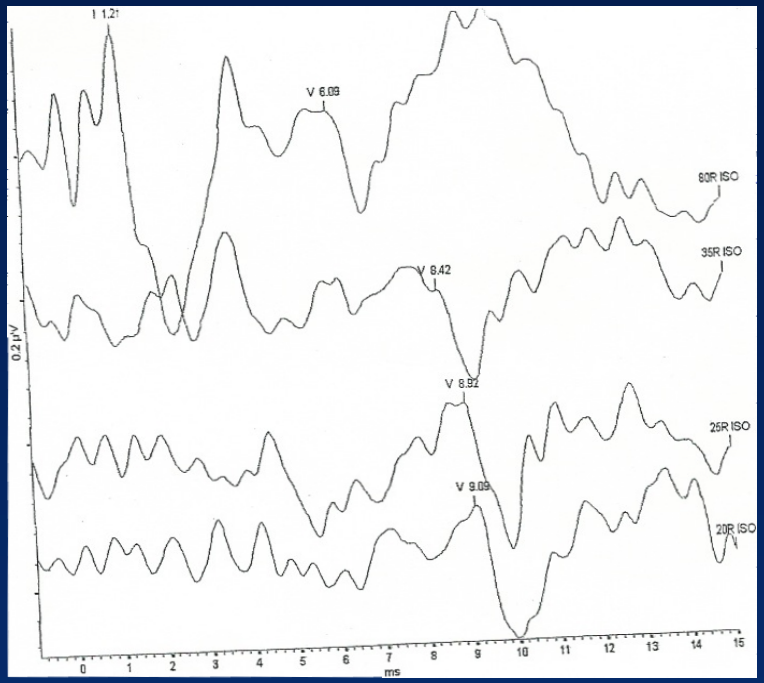
20 dB nHL
570 sweeps

15 dB nHL
912 sweeps

2000 Hz Chirp Evoked ABR

Stimulus rate = 37.7/sec

Total sweeps = 2318 ; Total test time = 61 seconds



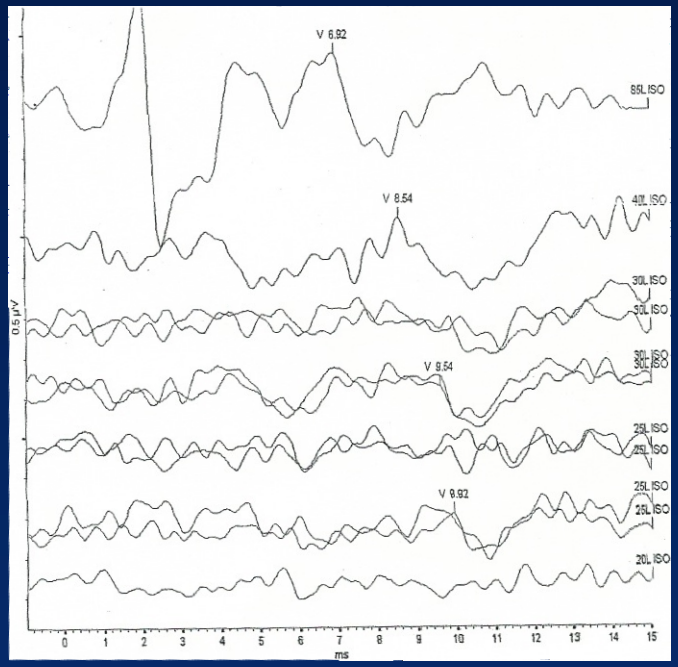
80 dB nHL
722 sweeps

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

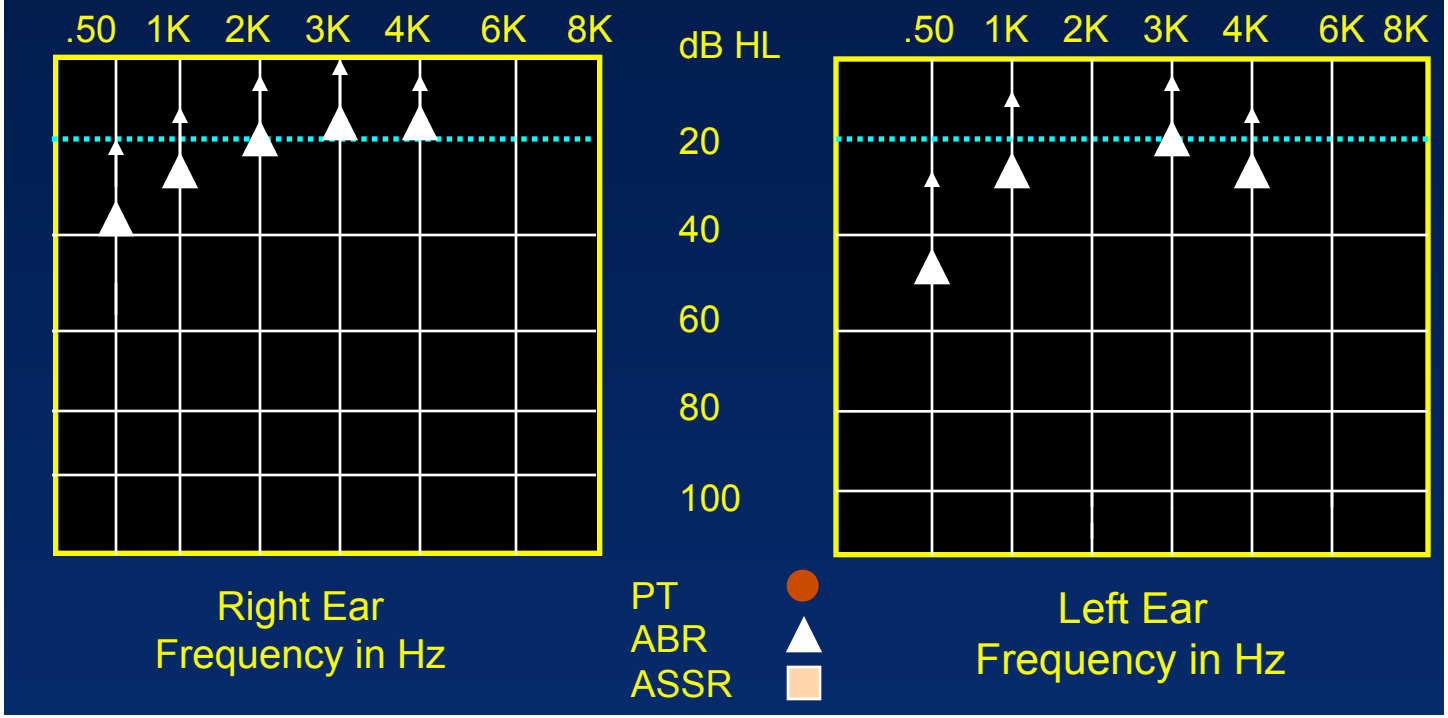
30 dB nHL, Chirp Tone Burst

25 dB nHL, Tone Burst

25 dB nHL, Chirp Tone Burst

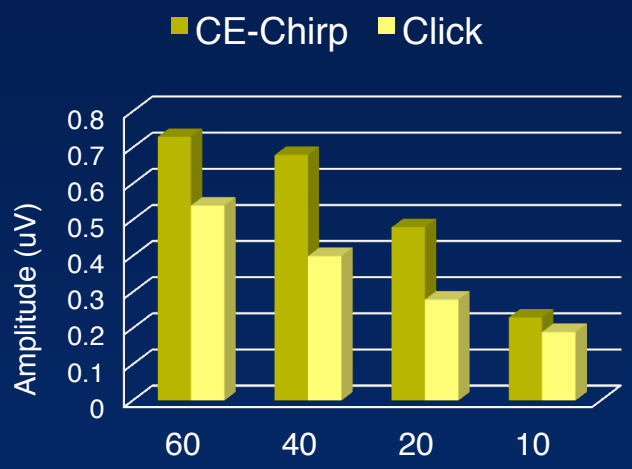
15 dB nHL, Chirp Tone Burst

Electrophysiologic Estimation of the Audiogram: One year 4 month boy



Adults:
CE-Chirp Amplitudes

Amplitude Comparison

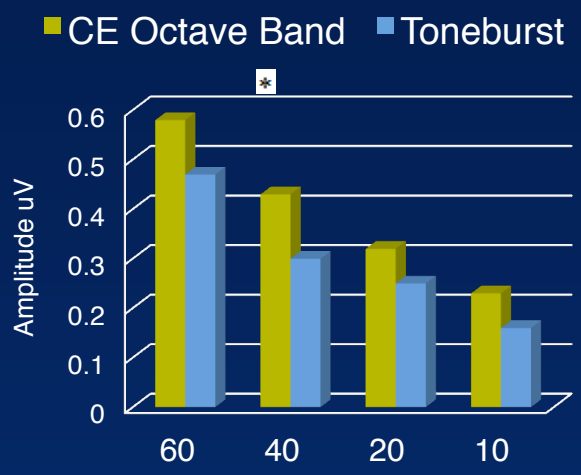


- **Wave V amplitudes were significantly greater at 60, 40, 20 dB nHL**
- **Greater amplitudes are consistent with previously published research**

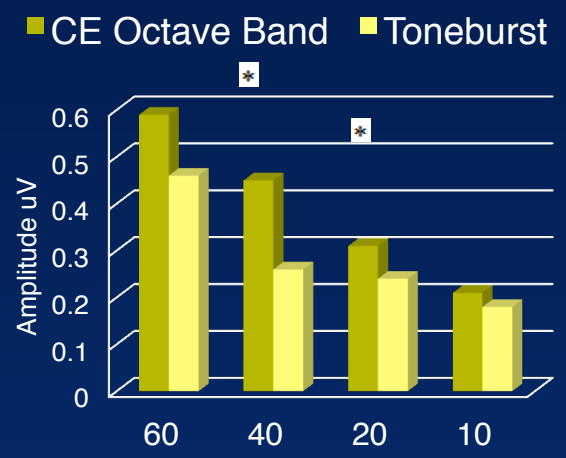
Stangl S, Rentmeester L, Hood LJ. (2013). Auditory brainstem responses to clicks, chirps, tonebursts, and octave-band chirps. Poster presented at the 2013 Meeting of the American Auditory Society, Scottsdale, Arizona.

Adults:
CE-Chirp Octave Bands

4000 Hz



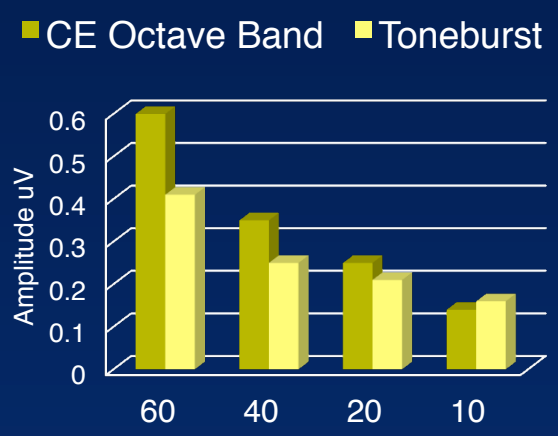
2000 Hz



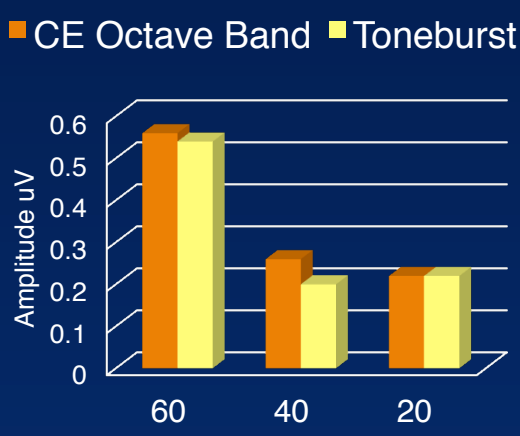
Stangl S, Rentmeester L, Hood LJ. (2013). Auditory brainstem responses to clicks, chirps, tonebursts, and octave-band chirps. Poster presented at the 2013 Meeting of the American Auditory Society, Scottsdale, Arizona.

Adults: CE-Chirp Octave Bands

1000 Hz



500 Hz

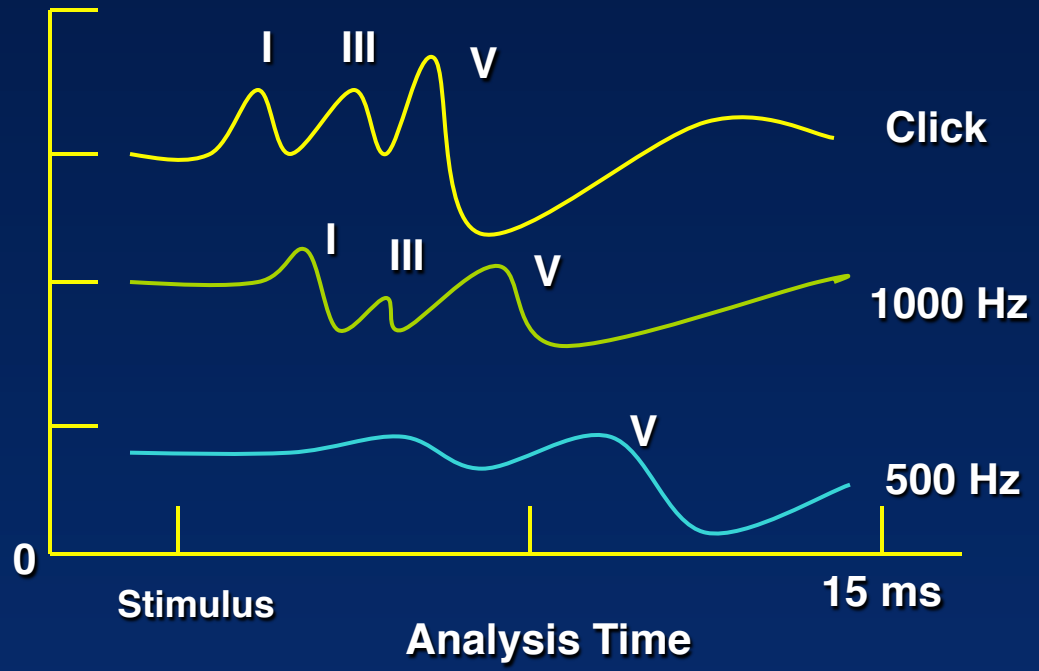


Stangl S, Rentmeester L, Hood LJ. (2013). Auditory brainstem responses to clicks, chirps, tonebursts, and octave-band chirps. Poster presented at the 2013 Meeting of the American Auditory Society, Scottsdale, Arizona.

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

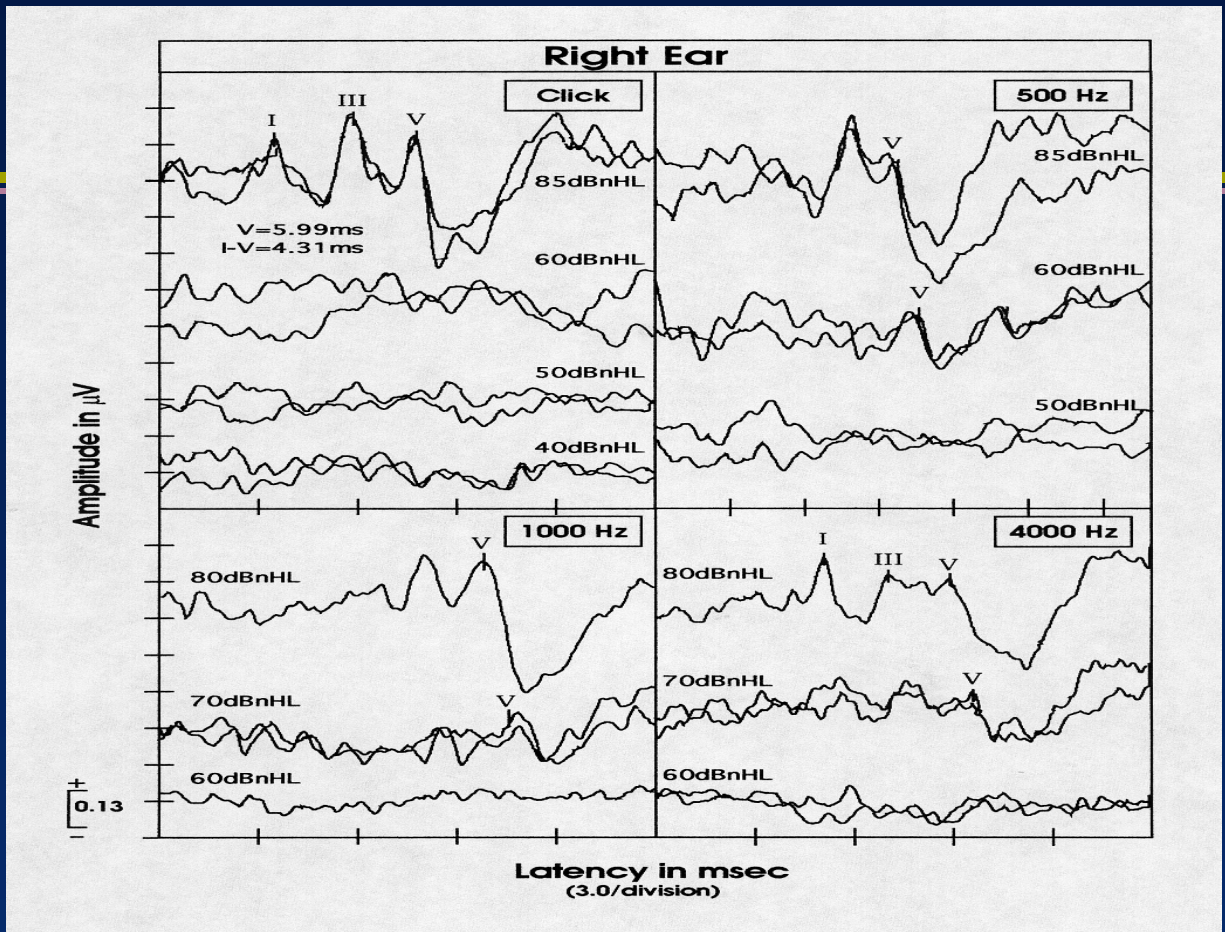
- ABR amplitude is larger for chirp stimulation
- Larger amplitude contributes to:
  - More confident identification of wave V
  - Shorter test time is needed to identify wave V
  - Reduced test time for each stimulus frequency permits more complete estimation of auditory threshold in speech frequency region
  - More accurate thresholds are sometimes possible with chirp stimulation

Waveform Analysis:
Click versus Tone Burst ABRs

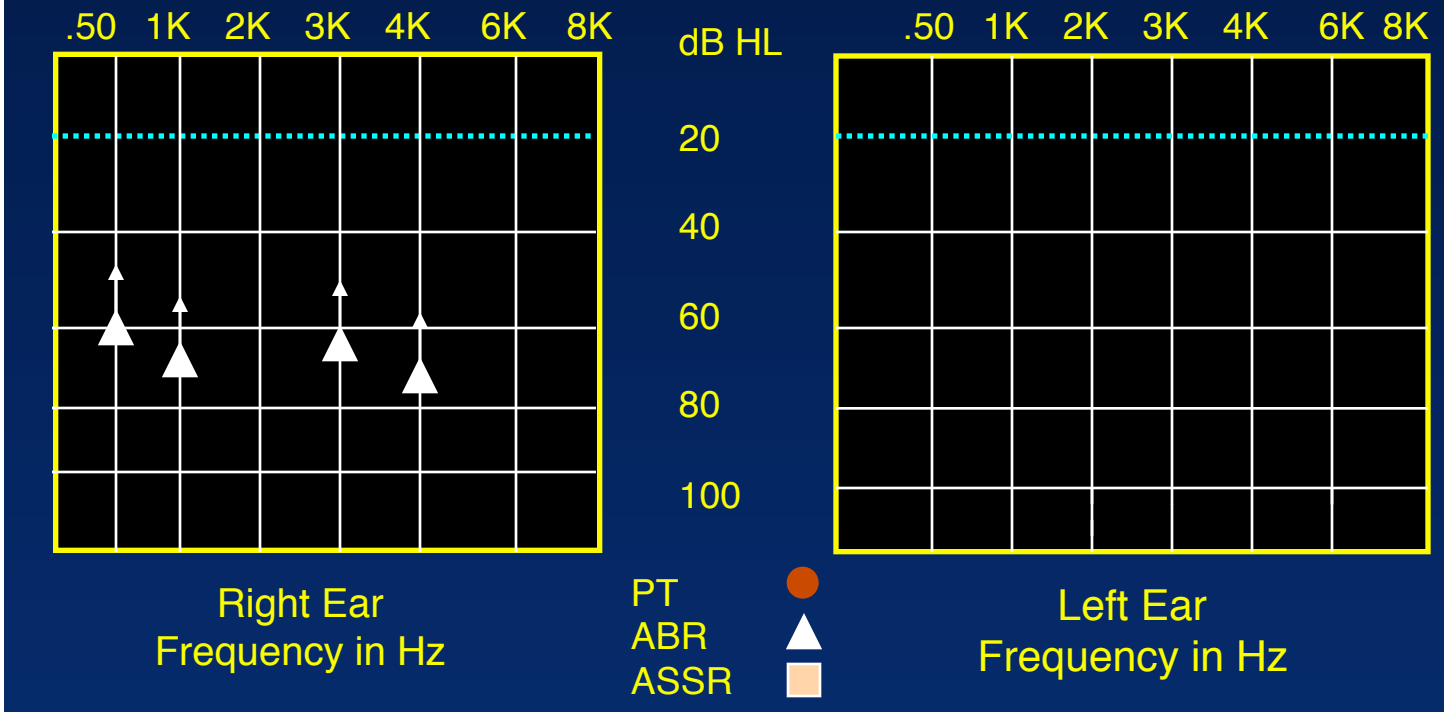


Keys To Confident Analysis of ABR Waveforms

- Minimize background (residual) noise in ABR measurement
  - Quiet preferably sleeping patient (low myogenic noise)
  - Lowest possible electrical artifact
- Maximize the ABR (the signal)
  - High stimulus intensity level
  - Optimal stimulus characteristics
- Confident identification of a clear response
  - SNR of 3:1
  - Replicability
  - "… as well as meeting the 3:1 signal to noise criteria the waveforms must show the expected characteristics in terms of amplitude, latency, and morphology (NHS, 2013)."


Right Ear
Click
500 Hz
1000 Hz
4000 Hz
I
III
V
85dBnHL
60dBnHL
50dBnHL
40dBnHL
V=5.99ms
I-V=4.31ms
80dBnHL
70dBnHL
60dBnHL
Amplitude in μV
0.13
Latency in msec
(3.0/division)

Electrophysiologic Estimation of the Audiogram



Estimation of Auditory Sensitivity with Auditory Brainstem Response (ABR)*

Date of Visit: _____ Diagnosis: _____

Reason for Evaluation: _____

History / Medical Complications: _____

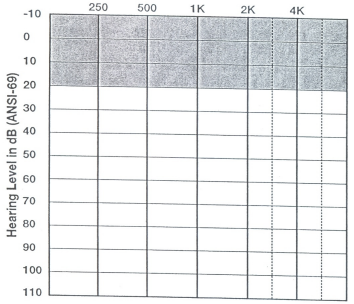
Pain Scale (1 - 10): _____

☐ Pt without new complaints

☐ Pain commensurates with dx / condition

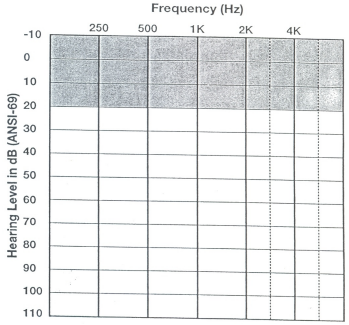
RIGHT EAR

Frequency (Hz)



LEFT EAR

Frequency (Hz)



○ = Air Conduction (AC) Threshold
△ = Bone Conduction (BC) Threshold
● = Masked AC Threshold
▲ = Masked BC Threshold
T = Estimated Behavioral Threshold

**Click and tone burst stimulation used to elicit the ABR. Auditory thresholds are approximately 10 dB better than minimum intensity levels producing an ABR wave V.*

Results / Impressions: _____

Recommendations: _____

Referred by: _____ Audiologist: _____ Provider #: _____

Patient Name: _____ Patient Identification #: _____

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Speech and Hearing Center
Department of Communicative Disorders
352-392-8888

Rev. 5/5/06
PS61941

ABR and ASSR Measurement with Frequency Specific, Chirp, and Bone Conduction Stimulation

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  - Otoacoustic emissions (distortion product or transient OAEs)
  - Tympanometry with 1000 Hz probe tone
  - Supplemental procedures, e.g.,
    - ✓ Electrocochleography (ECochG)
    - ✓ Auditory steady state response (ASSR)
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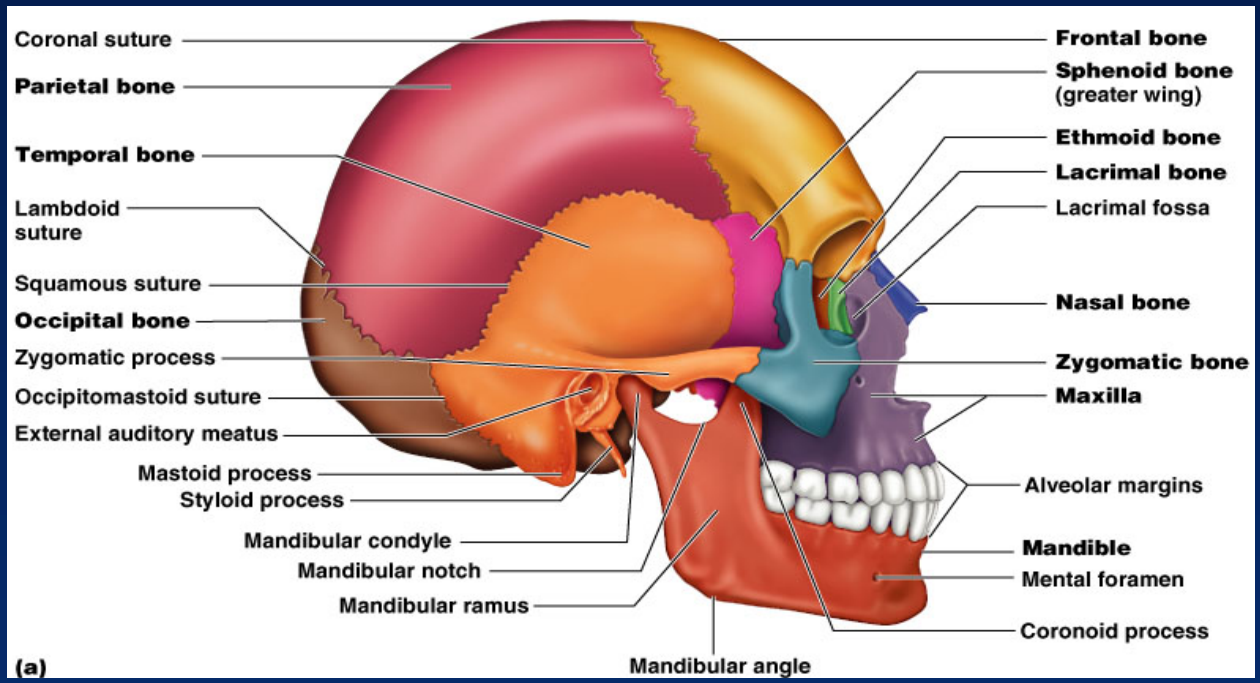
Ear Specific Bone Conduction Auditory Assessment is Feasible with ABR

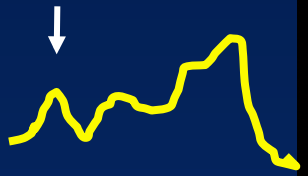


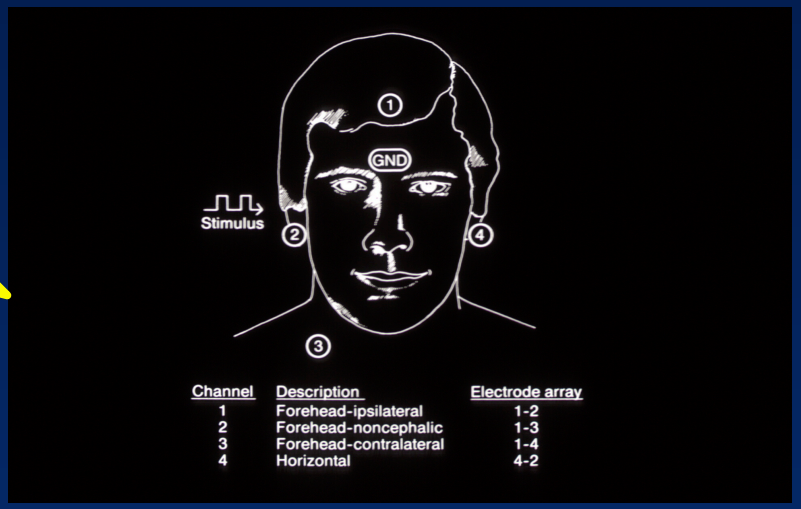
Maturation of Bone Conduction ABR: Increased Inter-Aural Attention in Infants

- Yang EY, Rupert AL & Moushegian G (1987). A developmental study of bone conduction auditory brainstem responses in infants. Ear & Hearing, 8, 244-251
- Small SA & Stapells DR (2008). Normal ipsilateral/contralateral asymmetries in infant multiple auditorysteady-state responses to air- and bone conduction stimulation. Ear & Hearing, 29, 185-198
- Conclusion: Bone conduction stimulation up to 30 dB nHL in infants will activate only the ipsilateral cochlea

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

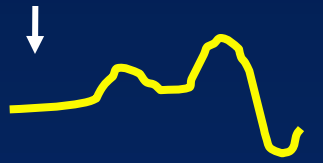
Ipsi Channel
Wave I





Channel	Description	Electrode array
1	Forehead-ipsilateral	1-2
2	Forehead-noncephalic	1-3
3	Forehead-contralateral	1-4
4	Horizontal	4-2

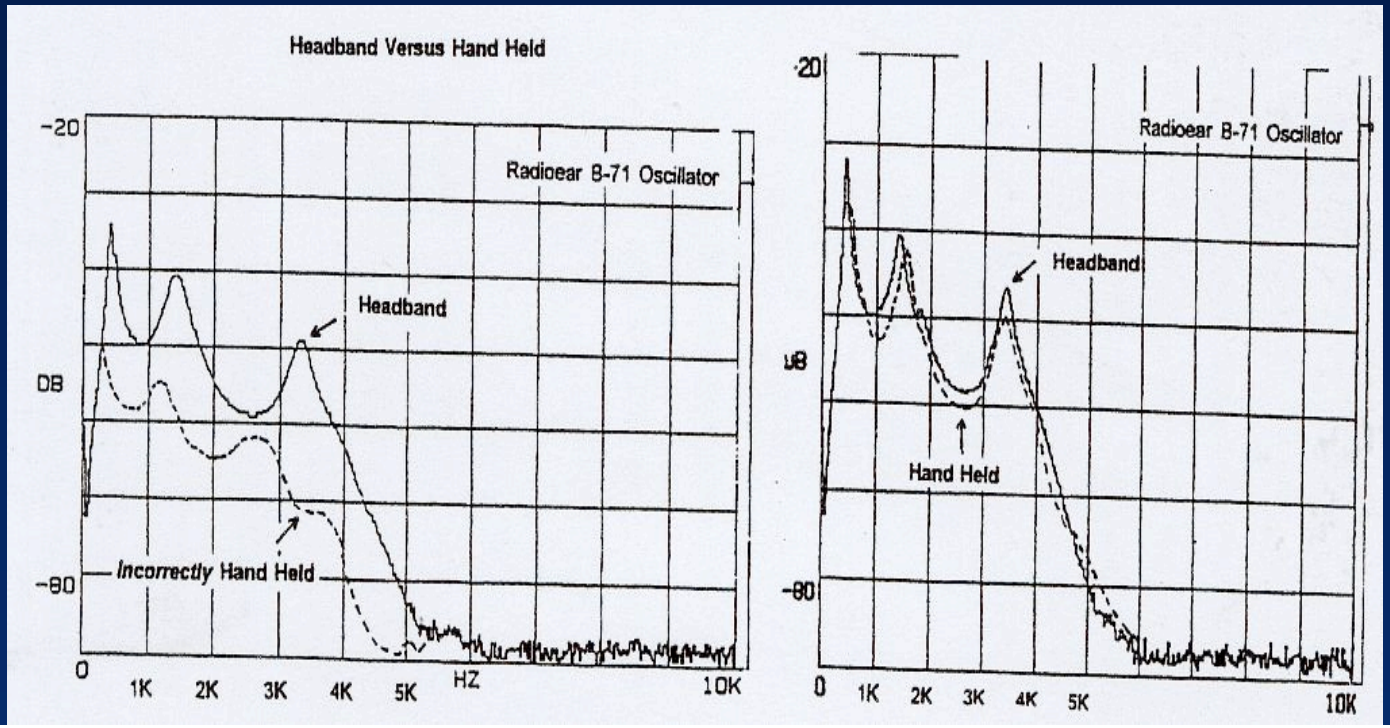
Contra Channel
No Wave I



ABR: Protocol for Bone Conduction

- B-70 or B-71 bone vibrator
- Mastoid placement
  - 10 dB increase in intensity
  - Less electrical interference with recording electrodes
- Leave insert earphones in ear canals after air conduction ABR
- Increased distance between inverting electrode and transducer
- Alternating click stimuli to minimize stimulus artifact
- Slower rate (e.g., 11.1/sec) as needed to enhance wave I
- 30 to 3000 Hz (low frequencies enhance response amplitude)
- Begin near maximum intensity level (about 50 dB nHL)
- Identify wave I in ipsilateral array to verify test ear
- Plot latency/intensity function for wave V for BC vs. AC

Bone Conduction:
Effect of Transducer Factors



Bone Conduction:
Head Band Placement for Infants

Posterior Placement Away from Electrodes

Adjusting the Head Band for Infants

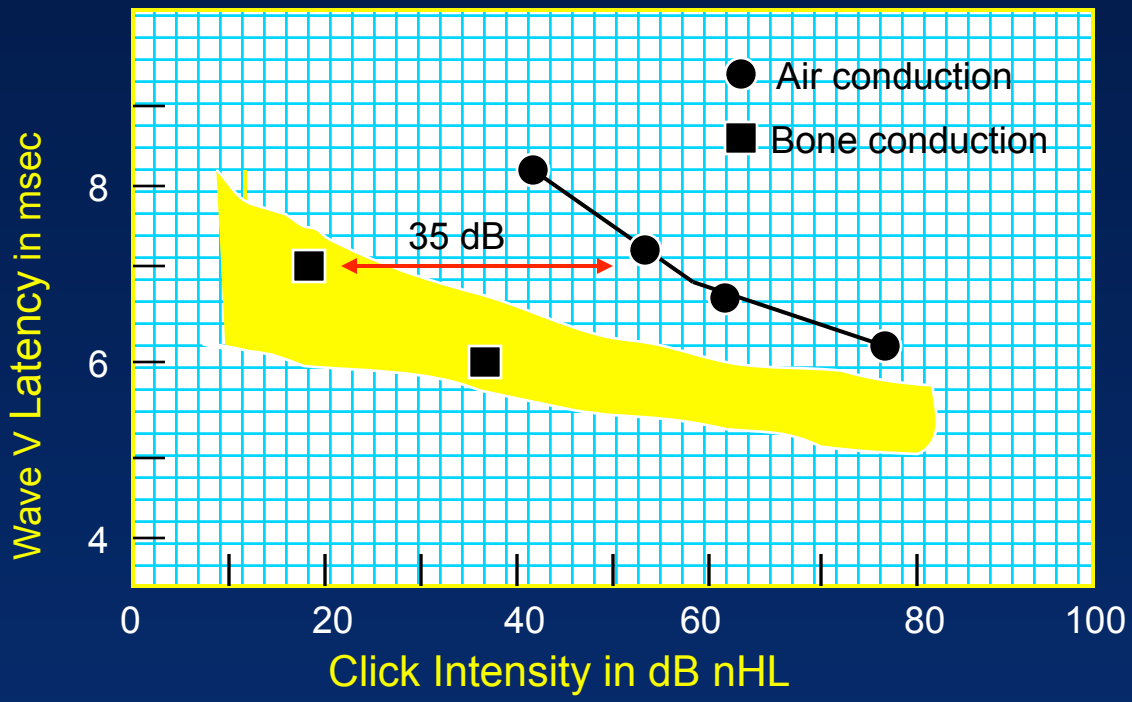
Clinical Measurement and Applications of Bone Conduction ABR: Standard of Care in Diagnostic Assessment of Infants and Young Children

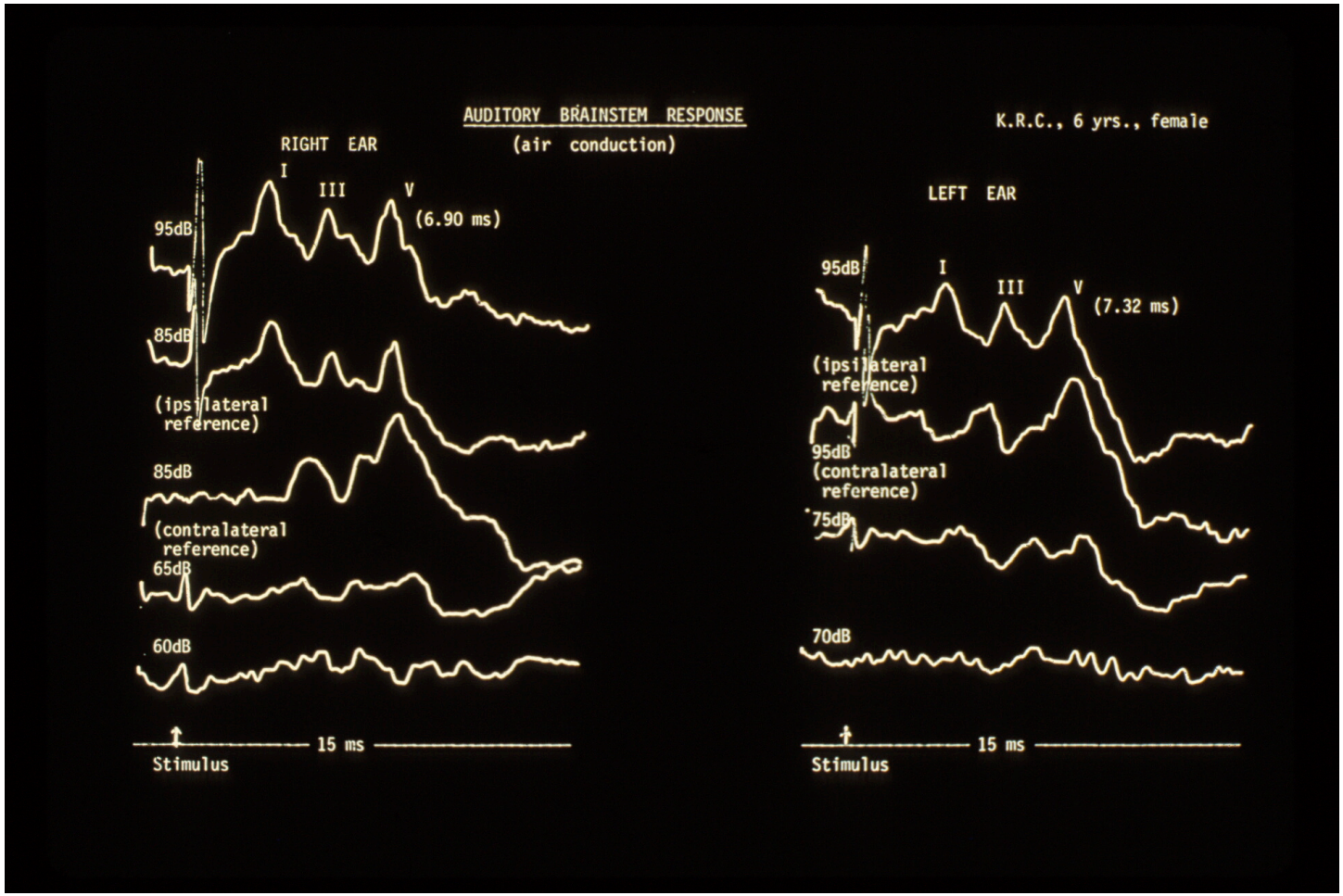
- Indications for bone conduction ABR
- Resolving the dreaded masking dilemma
- Bone conduction ABR test protocol
- Click or tone burst bone conduction stimulation
- Illustrative cases
- Conclusions

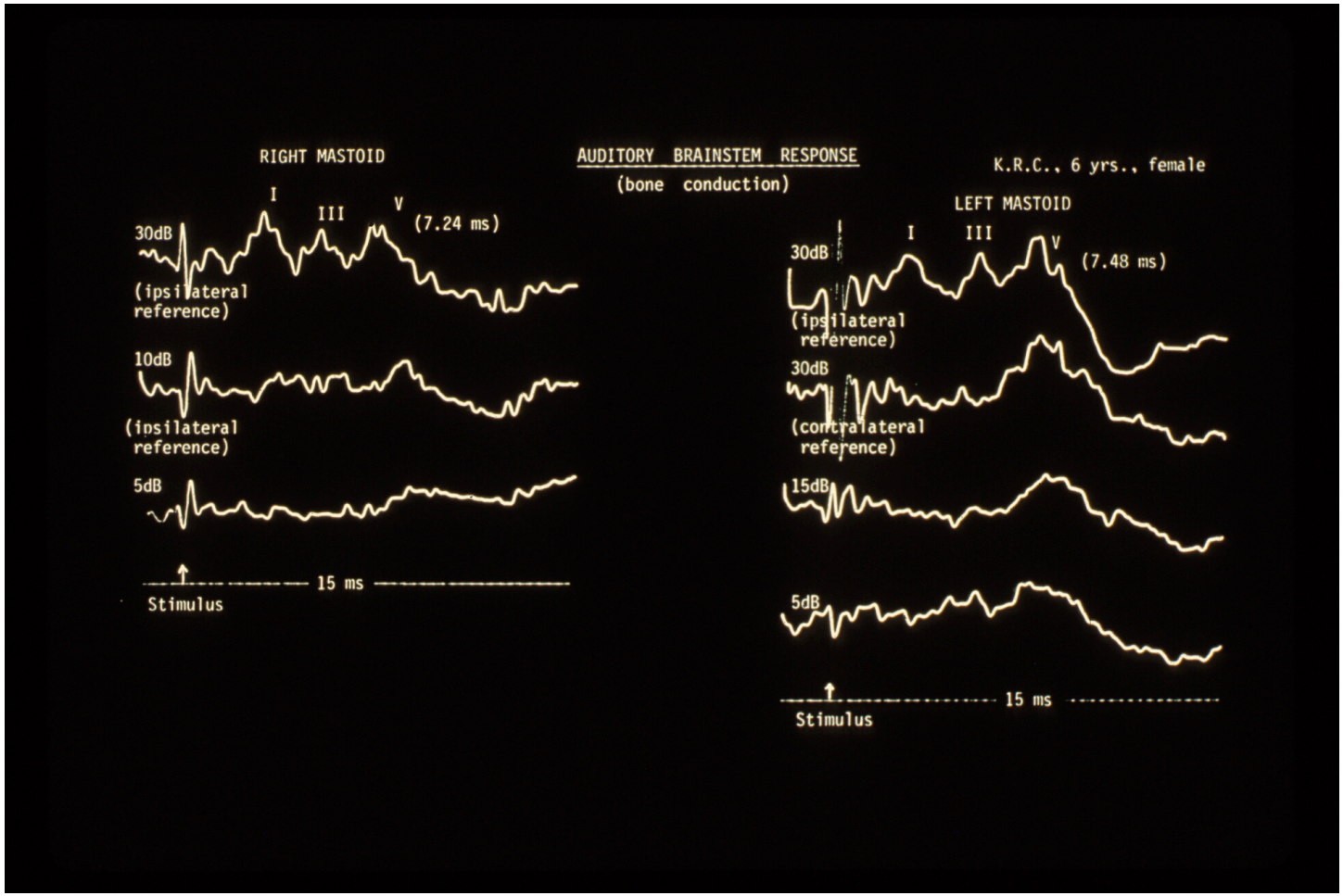
Clinical Measurement and Applications of Bone Conduction ABR: Click or Tone Burst Bone Conduction Stimulation

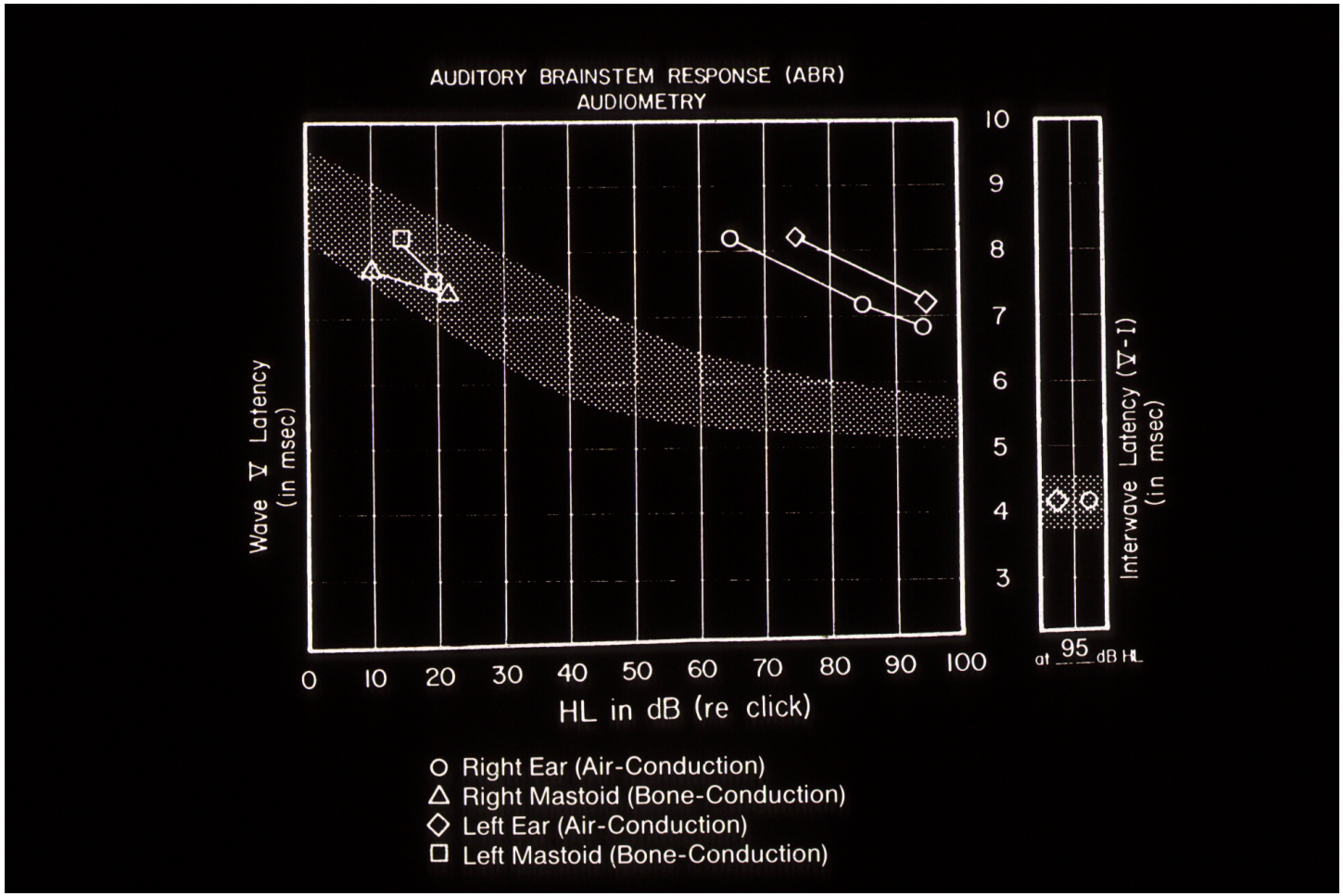
- Rationale for click only
  - Air conduction tone burst information is most useful
  - Test time is unacceptably lengthy with addition of tone burst bone conduction recordings
  - Confident identification of ABR is more likely with click versus tone burst stimulation
  - Provides information needed for management decisions
- Rationale for tone burst stimulation
  - Consistent with protocol for behavioral audiometry
  - Click stimulation may underestimate conductive component
    - ✓ Only estimates air-bone gap in the high frequency region
    - ✓ Conductive hearing loss is usually greatest in low frequency region

Example of Estimation of Air-Bone Gap with ABR




AUDITORY BRAINSTEM RESPONSE
(air conduction)
K.R.C., 6 yrs., female
RIGHT EAR
I
III
V
(6.90 ms)
95dB
85dB
(ipsilateral reference)
85dB
(contralateral reference)
65dB
60dB
15 ms
Stimulus
LEFT EAR
95dB
I
III
V
(7.32 ms)
(ipsilateral reference)
95dB
(contralateral reference)
75dB
70dB
15 ms
Stimulus


AUDITORY BRAINSTEM RESPONSE
(bone conduction)
K.R.C., 6 yrs., female
RIGHT MASTOID
I
III
V
(7.24 ms)
30dB
(ipsilateral reference)
10dB
(ipsilateral reference)
5dB
15 ms
Stimulus
LEFT MASTOID
I
III
V
(7.48 ms)
30dB
(ipsilateral reference)
30dB
(contralateral reference)
15dB
5dB
15 ms
Stimulus


AUDITORY BRAINSTEM RESPONSE (ABR)
AUDIOMETRY
Wave V Latency
(in msec)
10
9
8
7
6
5
4
3
0
10
20
30
40
50
60
70
80
90
100
HL in dB (re click)
Interwave Latency (V-I)
(in msec)
at 95 dB HL
Right Ear (Air-Conduction)
Right Mastoid (Bone-Conduction)
Left Ear (Air-Conduction)
Left Mastoid (Bone-Conduction)

Clinical Measurement and Applications of Bone Conduction ABR: Click or Tone Burst Bone Conduction Stimulation

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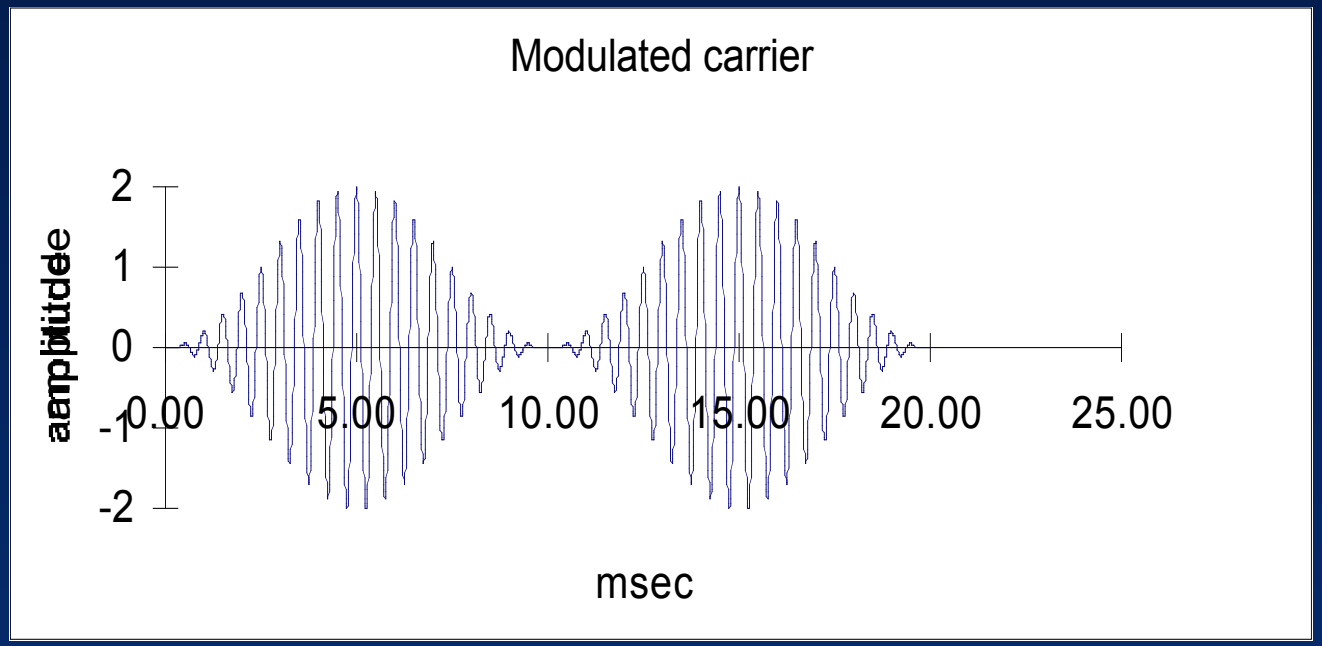
  - Otoacoustic emissions (distortion product or transient OAEs)
  - Tympanometry with 1000 Hz probe tone
  - Supplemental procedures, e.g.,
    - ✓ Electrocochleography (ECochG)
    - ✓ Auditory steady state response (ASSR)
    - ✓ Acoustic reflex measurement (for 1000 Hz probe tone)

Role of Auditory Steady State Response (ASSR) in Infant Hearing Assessment

Auditory Steady State Response (ASSR): 2000 Hz tone modulated at rate of 100 Hz



ASSR: General Measurement Principles

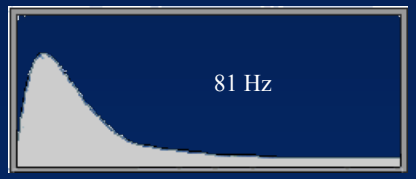
- An electrophysiological response, similar to ABR.
- Instrumentation includes:
  - Insert earphones
  - Surface electrodes
  - Averaging computer
- Stimuli are pure tones (frequency specific, steady state signals) activating cochlea and CNS
- ASSR is generated by rapid modulation of “carrier” pure tone amplitude (AM) or frequency (FM).
- Signal intensity can be as high as 120 dB HL
- ASSR phase or frequency is detected automatically (vs. visual detection)

Modulated Stimuli Produce Frequency-Specific Steady-State Responses at the Modulation Frequency

Carrier at 1 kHz
100% AM
81Hz modulation frequency

Activation at 1 kHz region of basilar membrane

Steady-State response at the modulation frequency



Frequency Spectra – EEG & ASSR

Sound

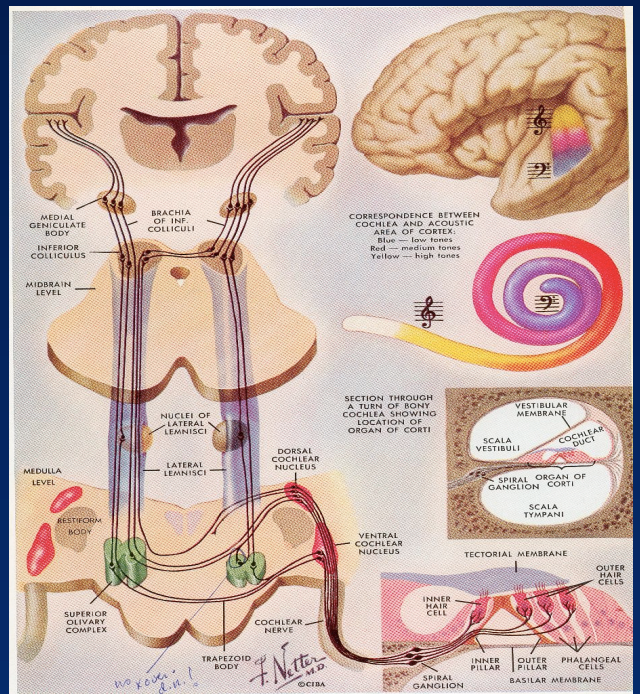
Cochlea

Brain

Anatomy & Physiology of ASSR: Generators (Kuwada et al, 2002

Slower modulation rates (< 80 Hz) = Cortical regions

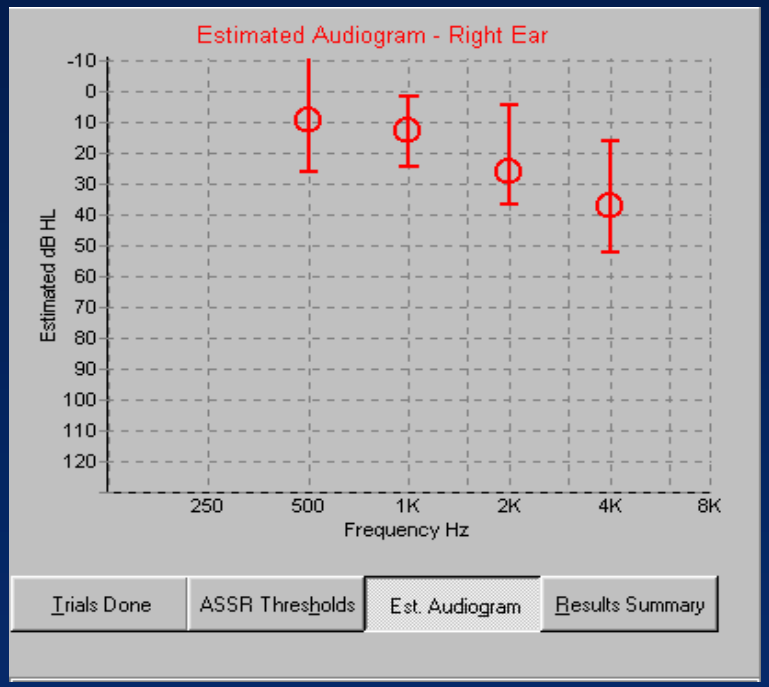
Faster modulation rates (> 80 Hz) = Brainstem



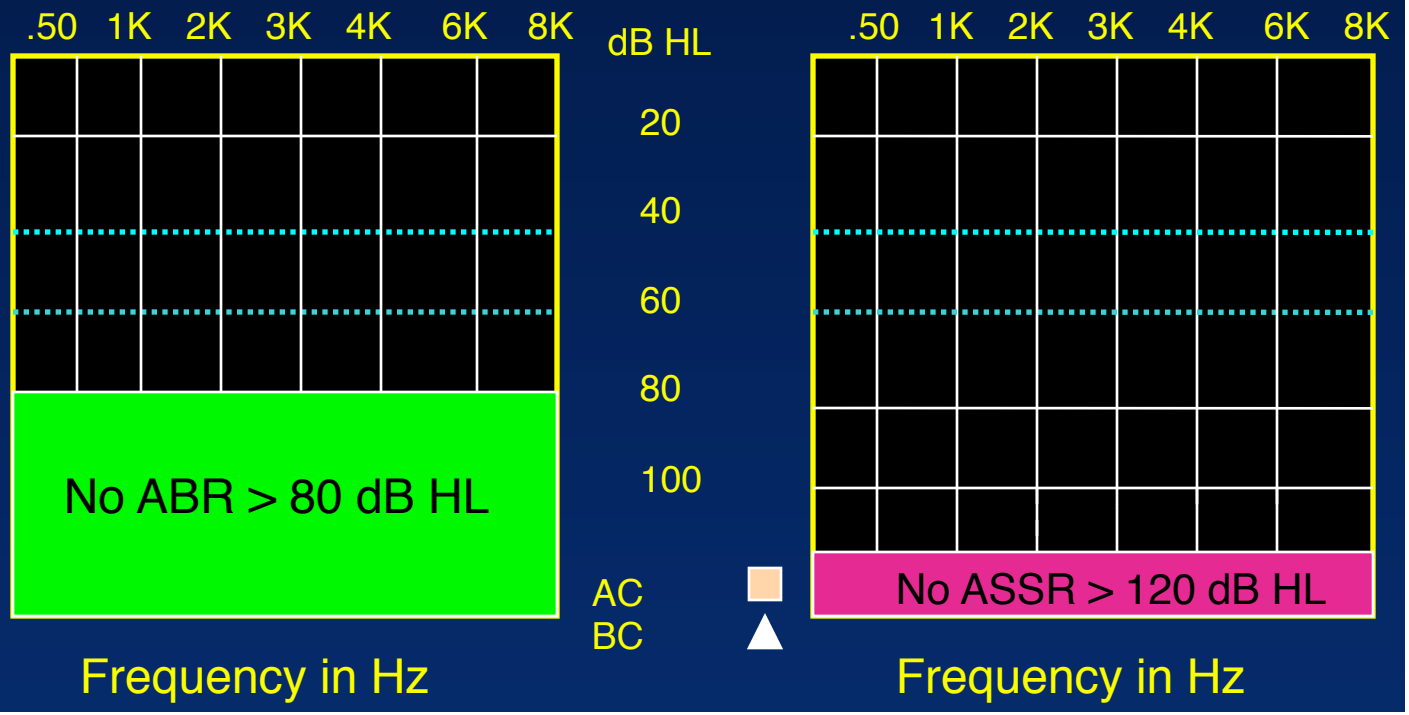
AUDITORY STEADY STATE RESPONSE (ASSR) IN INFANT HEARING ASSESSMENT AND MANAGEMENT: *Recent Research on Multiple versus Single Stimuli*

- Ishida & Stapells. Multiple-ASSR interactions in adults with sensorineural hearing loss. *International J Otolaryngology*, 2012
  - Studied effects of single versus multiple simultaneous stimuli on the 80 Hz and 40 Hz ASSR in adults with normal hearing or SNHL
  - Results showed:
    - ✓ Decreased amplitudes for ASSRs for multiple versus single stimuli in one ear
    - ✓ For 40 Hz ASSR there were further decreases in amplitudes for multiple stimuli in 2 ears versus 1 ear
    - ✓ Effects were comparable for normal versus SNHL ears
    - ✓ Multiple stimuli are of clinical value, but there are likely situations where it's more efficient to use single stimuli

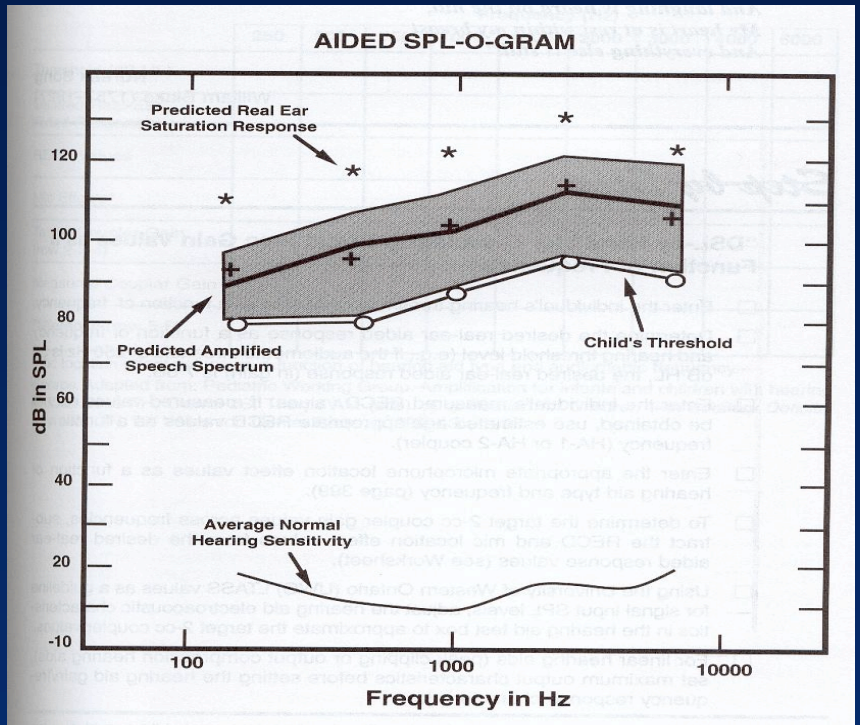
Estimating the Audiogram with ASSR



Limitation of Tone Burst ABR in Severe-to-Profound Hearing Loss



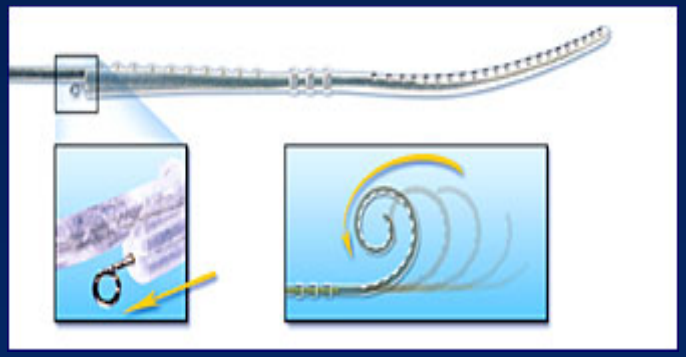
Estimation of Frequency-Specific Auditory Thresholds with Auditory Electrophysiology: DSL Hearing Aid Fitting



Auditory Steady State Responses (ASSRs): Pros and Cons for Clinical Use

- Advantages (Pros)
  - Reasonably frequency specific stimuli
  - Can be used for electrophysiological assessment of severe to profound degree of hearing loss in infants and young children
  - FDA-approved clinical devices available
  - Automated analysis
- Potential disadvantages (Cons)
  - Requires *very* quiet state of arousal
  - Sedation or anesthesia is often necessary
  - Limited anatomic site specificity
  - Analysis difficult with bone conduction stimulation

ASSR Contributes to Timely Management of Infant Hearing Loss: Determining the Need for Cochlear Implants and Confirmation of 8th Nerve Integrity in ANSD



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Un-sedated Pediatric ABR Measurement: Techniques

- Non-medical techniques
  - Sleep deprivation
  - Record ABR immediately after feeding
  - Bean bag “bed” to minimize movement
  - Benedryl (with pediatrician approval)
  - Melatonin
    - ✓Schmidt et al. Melatonin is a useful alternative to sedation in children undergoing brainstem audiometry with an age dependent success rate: A field report of 250 investigations. *Neuropediatrics 38: 2-4, 2007*.

Un-Sedated ABR Measurement: Techniques

- Sleep deprivation
  - 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

Un-sedated Pediatric ABR Measurement: Techniques

Un-sedated Pediatric ABR Measurement: Techniques

- Selected publications on use of melatonin to induce sleep in medicine
  - Brzezinski A. (1997) Melatonin in humans. *N Engl J Med, 336*, 186-195.
  - Dodge NN & Wilson GA. (2001). Melatonin for treatment of sleep disorders in children with developmental disabilities. *J Child Neurol, 16*, 581-584.
  - Johnson et al. (2002). The use of melatonin as an alternative to sedation in uncooperative children undergoing an MRI examination. *Clin Radiol, 57*, 502-506.
  - Milstein V et al. (1998). Melatonin for sleep EEG. *Clin Electroencephal, 29*, 49-53.
  - Seabra et al. (2000). Randomized, double-blind clinical trial, controlled with placebo, of the toxicology of chronic melatonin treatment. *J Pineal Res, 29*, 193-200.
  - Wassmer E et al. (2001). Melatonin is useful for recording sleep EEGs: a prospective audit of outcome. *Dev Med Child Neurol, 43,* 735-738.

Un-Sedated ABR Measurement: Melatonin

- Hormone naturally produced by pineal gland (small gland in center of the brain)
- Controls circadian rhythm
- Inhibited by light
  - Exposure at night to incandescent light for 39 minutes reduces melatonin by 50%)
  - Chronic reduction in melatonin linked to cancer risk
- Enhanced by darkness
- Strong antioxidant activity
- Exogenous melatonin (synthetic, e.g., tablets) causes rapid sleep induction without sedation
- Peak serum concentration reached in about 60 minutes
- Concentration declines within 4 hours

Un-Sedated ABR Measurement: Melatonin

- Schmidt et al. Melatonin is a useful alternative to sedation in children undergoing brainstem audiometry with an age dependent success rate: A field report of 250 investigations. *Neuropediatrics 38: 2-4, 2007*.
- N = 250 children age 1 month to 13.7 years (mean =2.2 years
- Oral administration of melatonin dissolved in water
  - 5 mg for children < 1 year
  - 10 mg for children between 1 and 6 years
  - 20 children for children > 6 years
- ABR recordings
  - ✓Click + tone burst (4000, 2000, 1000 & 500 Hz)
  - ✓Began at intensity level of 45 or 55 dB (max 100 dB nHL)
  - ✓Testing between 10 am and 2 pm

Un-Sedated ABR Measurement: Melatonin

- Schmidt et al. Melatonin is a useful alternative to sedation in children undergoing brainstem audiometry with an age dependent success rate: A field report of 250 investigations. *Neuropediatrics 38: 2-4, 2007*.
- Results
  - 230 children fell asleep in average time of 32 minutes
  - Click evoked ABR successfully completed in 216 children
  - Tone burst ABR successfully completed in 115 children for at least two frequencies
  - Melatonin reduced need for anesthesia for ABR from 74 per year to 12 per year (> 80%)

Un-Sedated ABR Measurement: Melatonin Decreases Need for Anesthesia

(Schmidt et al, 2007)

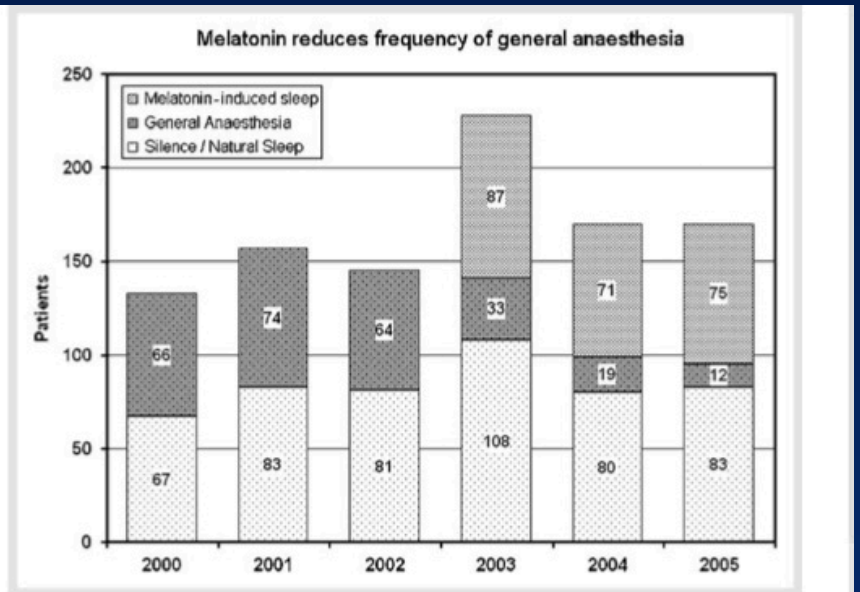


Fig. 1 Melatonin reduces the frequency of general anaesthesia performed for ABR investigations. From 2001 to 2005, we reached a decrease of >80%.

Un-Sedated ABR Measurement: More Successful for Younger Children

(Schmidt et al, 2007)

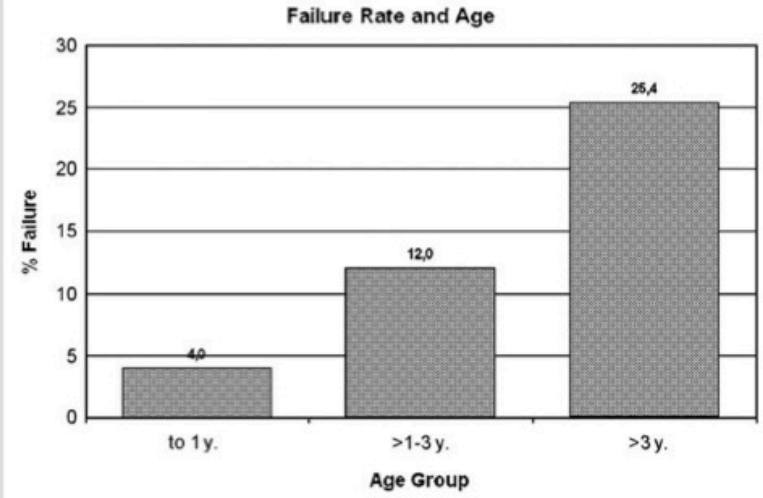
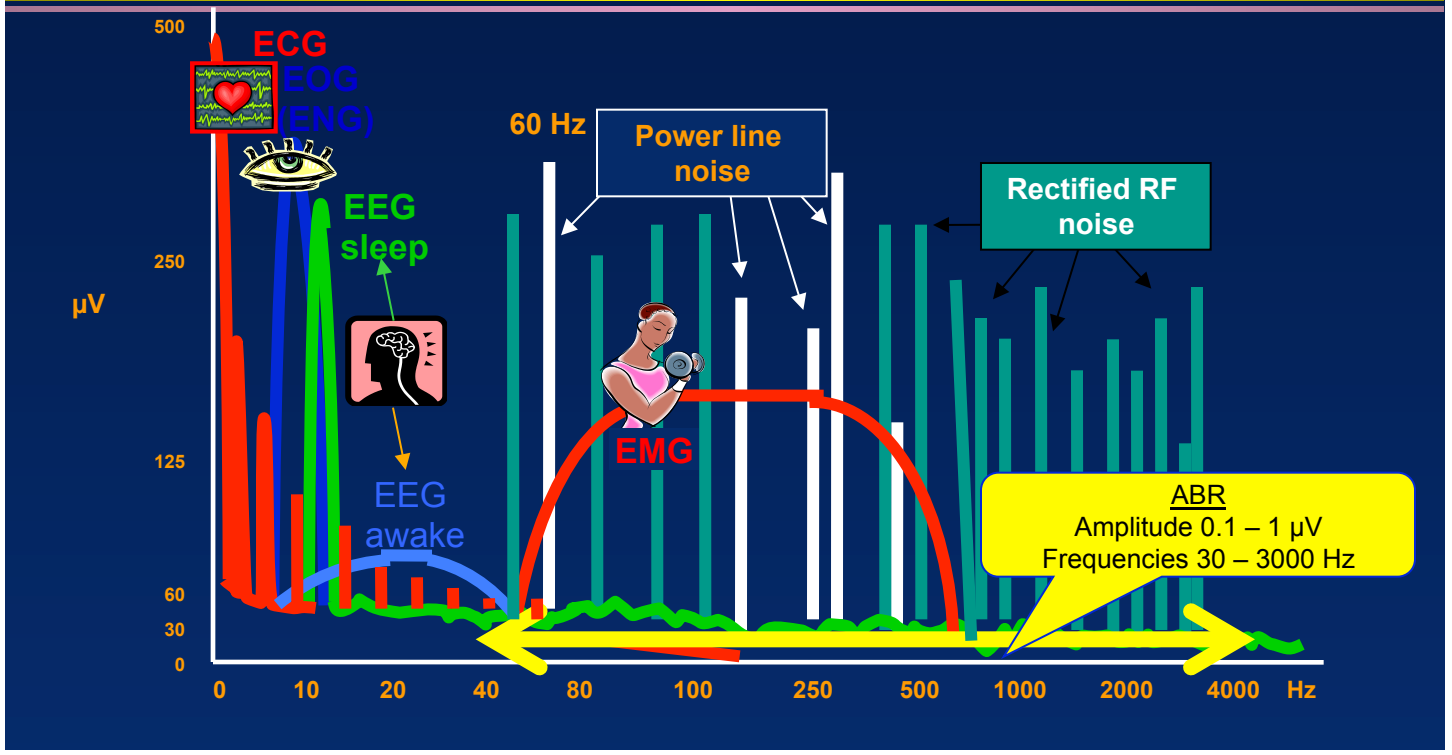


Fig. 2 Age distribution of failure rate in children undergoing ABR with melatonin. Children up to the age of one year showed the lowest (4%), children elder than three years the highest (25.4%) failure rate.

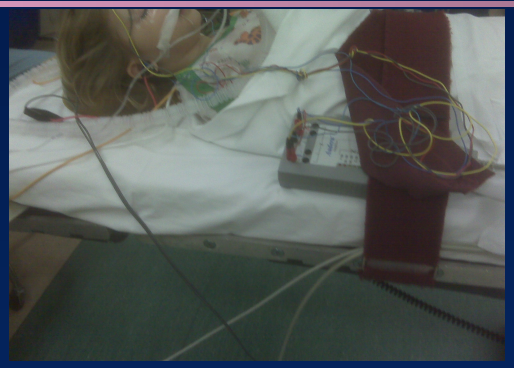
Spectrum of Noise in ABR Measurement



ABR in the Clinic with Conscious Sedation (e.g., chloral hydrate)

ABR in the Operating Room with General Anesthesia

ABR in Ambulatory Surgical Center with Light Anesthesia (e.g., Propofol)



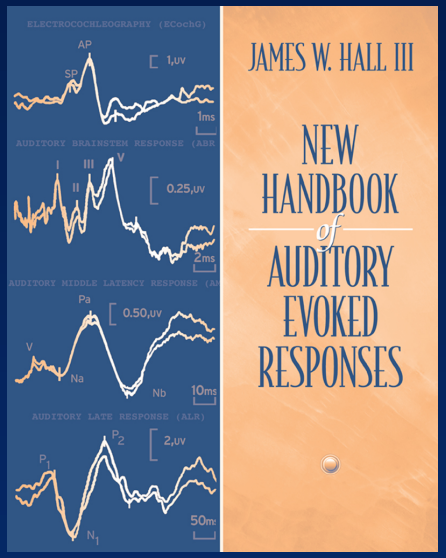
SEDATION OPTIONS:
Clinic versus Operating Room

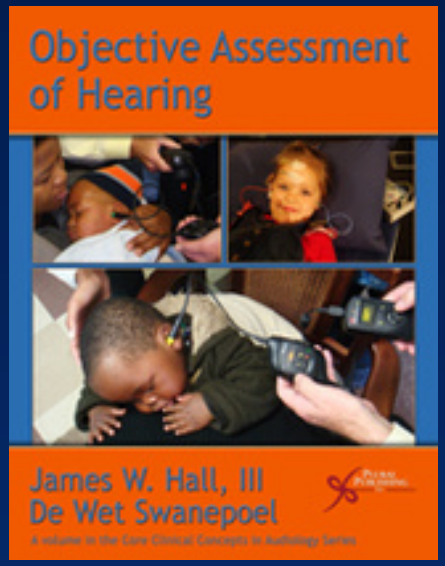
Setting	Advantages	Disadvantages
Clinic	Less expensive Near or in audiology Scheduling ease	Limited sedation options Limited medical support Increased liability Uncertain success/> time
O.R.	Medical (ENT) support Ideal patient state Controlled sedation Limited liability	More expensive Remote location Noisy environment Complicated scheduling

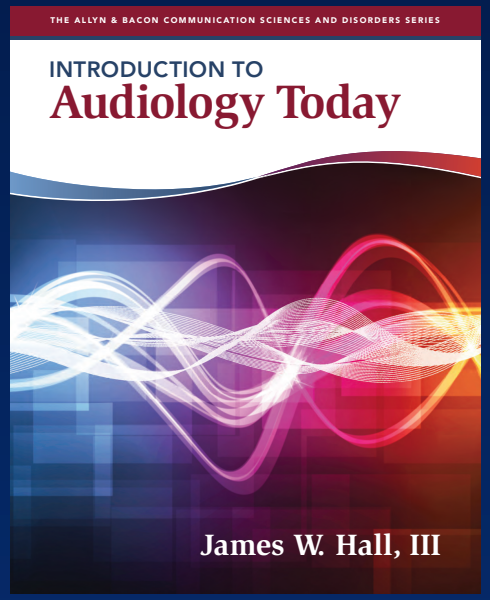
Disadvantages of Anesthesia for in ABR Assessment of Children

- Delayed diagnosis (many months) due to problems with scheduling time in the operating room with medical support team (e.g., anesthesiologist)
- Ten fold increase in cost (>$4000 versus $400) associated with services in the operating room
- Medical risk of anesthesia and related procedures (e.g., intubation)
- Possible secondary neurological and cognitive deficits of anesthesia in children at risk for learning problems
- Inability to conduct a full auditory assessment in remote location outside of the audiology clinic

Thank You!
Questions?







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