Chirp-Evoked Auditory Steady State and Brainstem Responses

Lisa Hunter PhD
U. Cincinnati, Cincinnati Childrens Hospital Medical Center
Deborah Hayes, PhD
Children's Hospital Colorado
Pat Roush AuD
U North Carolina; UNC Health
Yvonne Sininger PhD
CNY Consultants, Santa Fe, New Mexico

New Technologies

- CE-CHIRPS
- ABR F_{mp} Noise and Signal Detection
- Bayesian Weighting
- Wide Band Tympanometry
- Next Generation ASSR

Next Generation ASSR is the main topic of our study

Investigation of Speed, Accuracy and Utility of Auditory Assessment Technologies

Funding granted to Yvonne Sininger by the Oticon Foundation in 2015

Overall goal: To evaluate/demonstrate clinical utility of these valuable techniques.

Specific Goals:

1) to determine if estimated behavioral thresholds (in dB HL) obtained by Next Generation ASSR (multiple frequency-binaural) are equivalent to those obtained with ABR (individual ear and test frequency). Hypothesis: thresholds determined by both methods will be equivalent.

2) to compare the time needed to complete an assessment with both techniques. Hypothesis: ASSR will reduce test time over ABR by ½ or more.

Study Specifics

Equipment:

Eclipse and Titan systems were provided by the Study, installed and calibrated at each site

Training and Monitoring:

Two or more training session at each site.

Conference calls at regular intervals.

Data Management/Analysis

Anonymized, encrypted data files emailed to Santa Fe.

Analyzed data point entered into REDCap at University of Colorado Medical Center

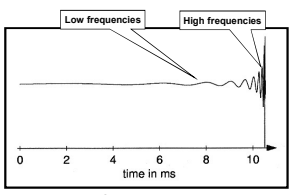
Data analyzed with SPSS

The CE-Chirp

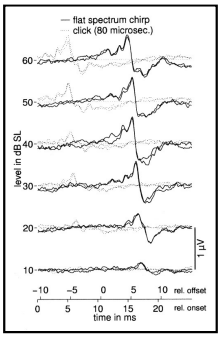
- Stimulus that reorganizes timing of spectral components to synchronize cochlear response.
- CE-Chirps are of the same energy and frequency composition as traditional stimuli- clicks and tone bursts.
- Produces neural response (ABR, ASSR,…) with up to 2X amplitude of traditional stimuli
- Greater amplitude enhances response detection
- Reduces time to automated detection
- Lowers threshold of response detection and reduces correction factors
- SEE HANDOUTS

5

Chirp vs Click-Evoked ABR

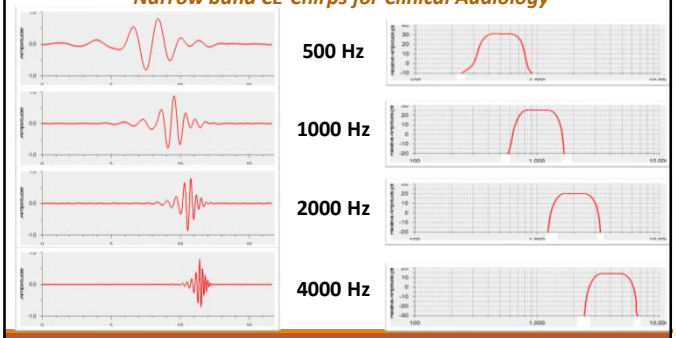


Chirp stimulus



Dau et al. 2000

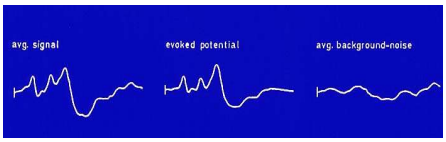
Narrow band CE-Chirps for Clinical Audiology



7

New Technologies

- ABR Noise and Signal Detection
- Bayesian Weighting

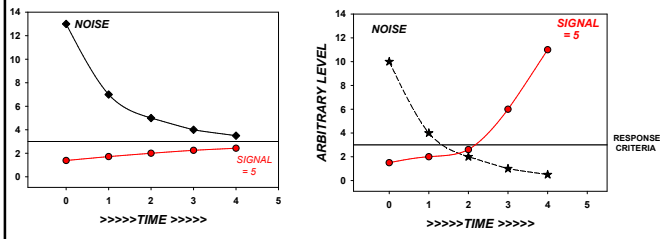


Average ABR = Neural Potential + Noise.

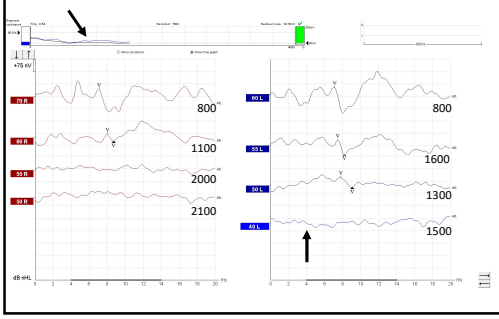
It is not possible to accurately determine how much of each is present, merely by looking.

Noise can obscure a response so it is important to know how much noise is present.

Same Signal (ABR) With Different Background Noise
High Noise Prevents Detection



BACKGROUND NOISE STOPPING RULE



- If noise is very low, any response present should have reached criteria.
- Stopping on low noise will avoid continuing to average to 6000 sweeps

40 dB Left stops at 1500 sweeps on low noise

- Study used noise stopping rule of 20 nV
- Better stopping rule is 15 nV for infants

Bayesian Weighting
What is it and why would I use it?

First proposed by Elberling & Wahlgren in 1985 as a method of noise reduction during averaging.

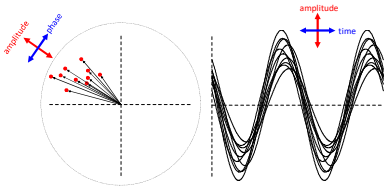
Rather than rejecting all sweeps with high amplitude (traditional noise rejection) Bayesian weighting assigns a "weight" to each block of sweeps based on estimated noise in the block.

When a block is quiet, it is given greater "weight" in the average than when a block is noisy. Almost nothing is discarded.

How are ASSR and ABR Alike, Different?

- ABR and ASSR both look at the same brainstem neural activity.
- ASSR modulates the stimulus at a known frequency.
- Response detection then searches for evidence of that frequency in the ongoing EEG.
- If the neurons are activated by the stimulus, there will be a spike in the frequency response of the EEG at the modulation frequency and the phase of the EEG will be synchronized with the stimulus onset.

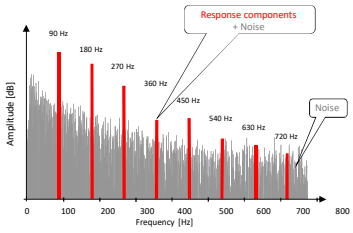
Traditional ASSR Detection Searches for Significant Amplitude and/or Phase Coherence of the Modulation Frequency



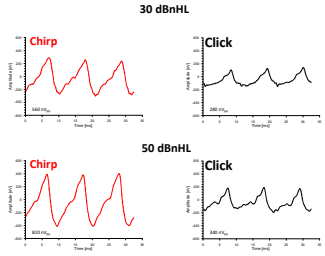
How is the "Next Generation" ASSR Different than the First Generation??

- ***Next Generation uses BOTH amplitude and phase information for detection.***
- ***Next Generation uses the fundamental and 20+ harmonics for response detection.***
- ***Next Generation ASSR uses Narrow Band CE-Chirps.***

Next Gen ASSR uses Response Detection (Phase and Amplitude) at Fundamental and 20+ Harmonics Compared to Fundamental Alone



Next Gen ASSR uses Narrow Band CE-Chirps as Stimuli Known to produce Larger Amplitude Responses And Lower Thresholds



Protocol Summary

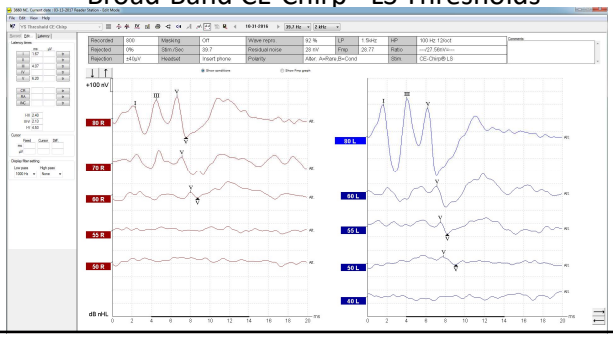
- Start with Wide-Band Tympanometry and DPOAE
- Get an ABR threshold in each ear using a Wide-Band CE Chirp
- Determine the order of electrophysiologic tests- randomized by subject number.
- ABR thresholds using NB CE-Chirps with reliance on Fmp.
- ASSR thresholds using Eclipse protocol.
- Bone Conduction by ABR if necessary

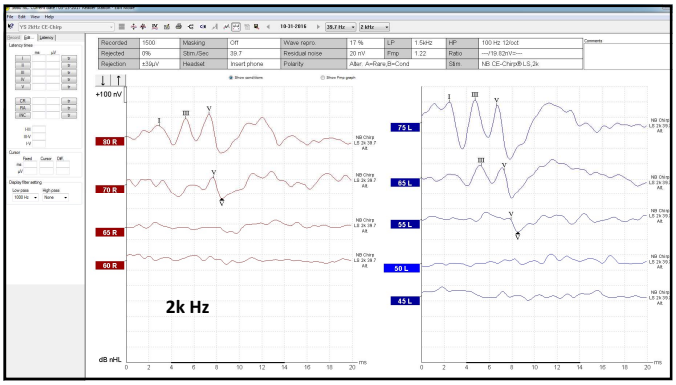
ABR Protocol-- Testing

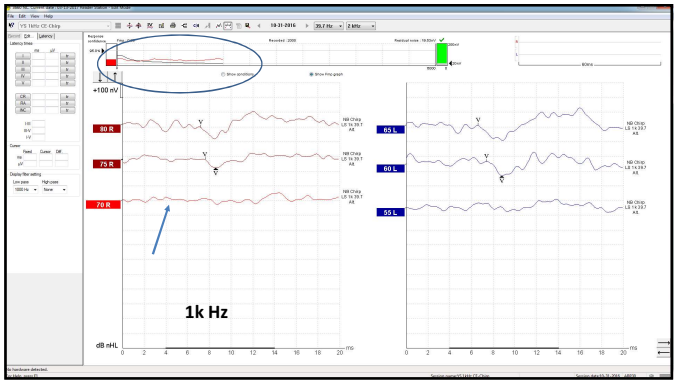
- Establish Threshold for BB CE-Chirp LS in each ear before Frequency-Specific testing (ASSR or ABR).
- Order of frequency presentation or ear is at the discretion of the tester.
- Begin the threshold search just above the BB Chirp threshold.
- Test each level once unless special circumstances.
- If a response to level X is fast (800-1200 sweeps) and response large (>100 nV) use a large descending step size (20 or greater)

Broad-Band CE-Chirp® LS Thresholds

Broad-Band CE-Chirp® LS Thresholds





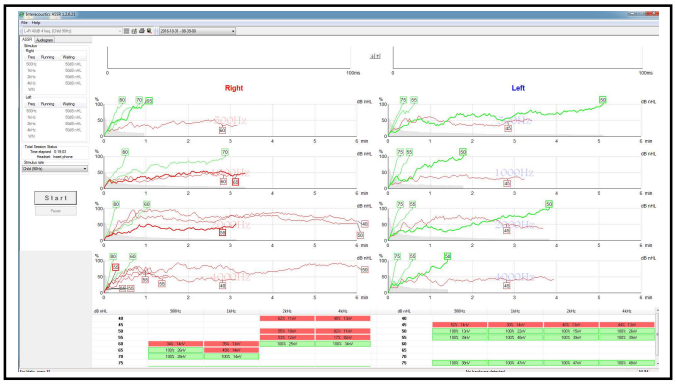


ASSR Protocol

- Default is 4 frequencies per ear all running simultaneously.
- Starting Level is determined by tester, can be individually chosen.
- Each frequency has a unique modulation frequency that is close to 90 Hz.
- Background noise and response detection criteria are automatically updated for each frequency/ear.
- New stimulus level can be implemented for any of the eight conditions at any time. The others continue to run.

ASSR Protocol

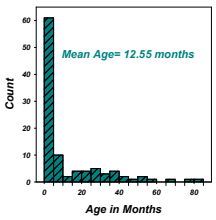
- Noise rejection level is set to 40 nV.
- Insert ER3-A Earphones used.
- Test will stop at 95% confidence of response or 6 minutes.
- Test time can be extended for any particular condition if needed.
- YS stopping rule. If detection is at or below 50% and noise is <= 15 nV, the test can be stopped by the user as a no response.
- Test levels are determined as with ABR with concentration on test speed. A response met quickly warrants a large decrease in level and vice versa.

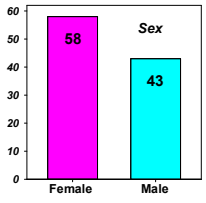


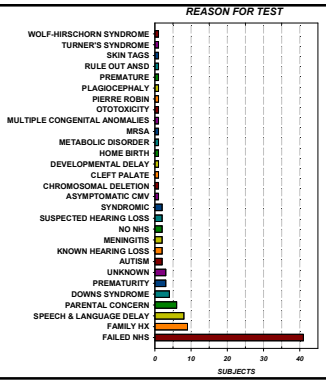
PRELIMINARY RESULTS

Santa Fe STAMP Threshold by Auditory Multiple Procedures

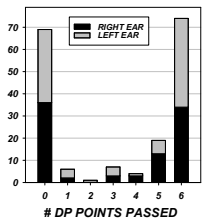
102 Subjects Enrolled

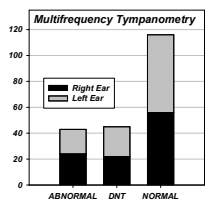


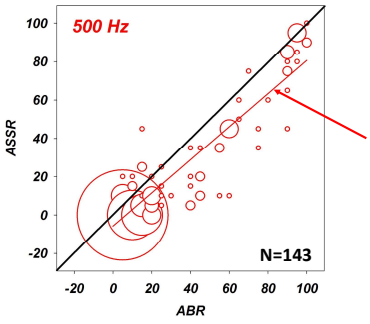




Middle Ear/ DPOAE



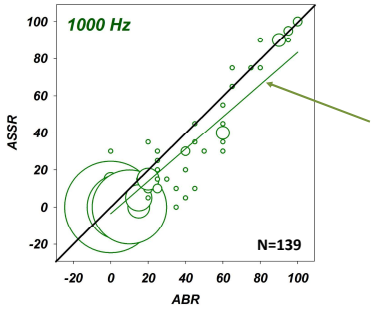




Mean Difference 9.54 dB
p< 0.001

Regression:

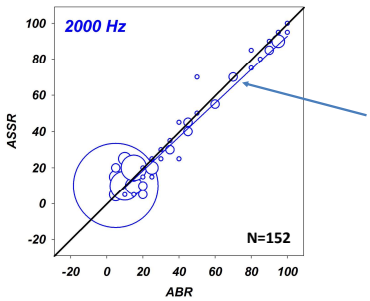
Slope: 0.86
R^2: 0.863
Difference: 5.77



Mean Difference 6.39 dB
p< 0.001

Regression:

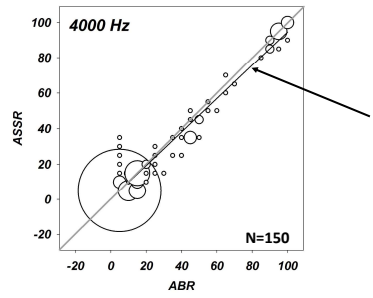
Slope: 0.87
R^2: 0.852
Difference: 3.49



Mean Difference 1.74 dB
p= 0.001

Regression:

Slope: 0.93
R^2: 0.954
Difference: 0.21

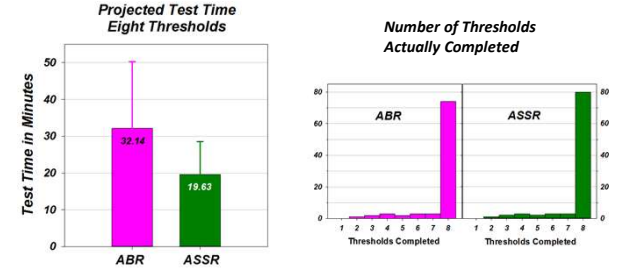


Mean Difference 0.81 dB
p= 0.09 (non significant)

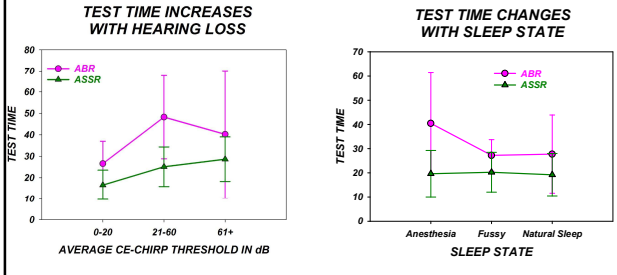
Regression:

Slope: 0.94
R^2: 0.956
Difference: 0.40

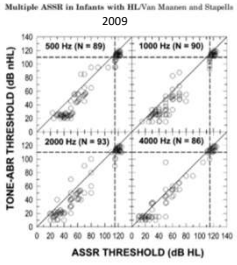
TEST TIME



TEST TIME



RESULTS SUMMARY
Next Gen ASSR far more sensitive re ABR



Note: Reversed Axes

- Most recent similar study- "old generation ASSR v standard ABR
- Amplitude F-test at modulation frequency.
- ASSR used cosign3 windowed tones, modulation rates of 81-100 Hz.
- ABR used Blackman- windowed tones, 39-sec.

ABR Threshold – ASSR Threshold (Mean)

	500	1000	2000	4000
Sininger et al	9.54	6.39	1.74	0.81
Van Maanen & Stapells	-10.67	-9.47	-9.25	-6.28
Difference	20.21	15.86	10.99	7.09

This improved sensitivity is due to the improved detection! We also expect overall a reduction of 5 dB in thresholds by both techniques, due to the CE-Chirp Stimuli

RESULTS SUMMARY

- Next Gen ASSR Thresholds are NOT equivalent to ABR except at 4k Hz. They are lower. This is due to advances in detection technology.
- Average test time difference shows ASSR is faster by 12.5 minutes (for 4 frequencies in each ear).
- Using our protocol, both ABR @ 32.14 and ASSR @ 19.63 minutes are quite fast and feasible for non-sedated infants. The CE-Chirp stimuli is responsible for some of the increased test speed.

QUESTIONS??

STAMP Santa Fe Threshold by Auditory Multiple Procedures

39

CASE PRESENTATIONS

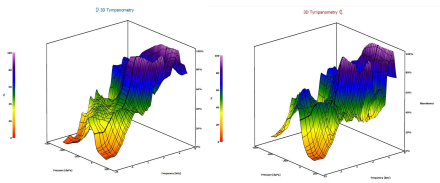
STAMP Santa Fe Threshold by Auditory Multiple Procedures

40

6514

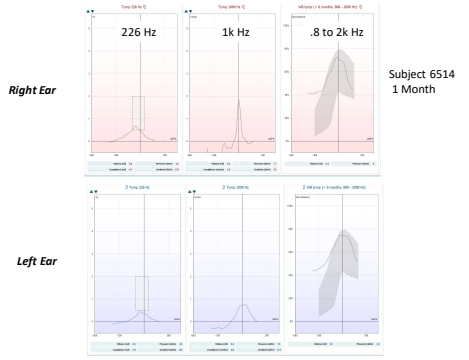
1 month old
Natural Sleep
Failed NHS- no other risks

Broad Band Tympanometry



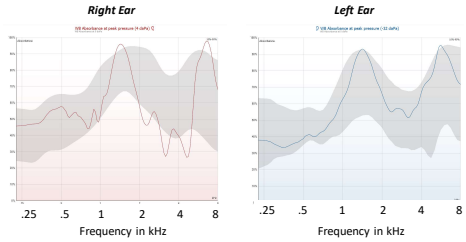
Left Ear Right Ear

Subject 6514 1 Month



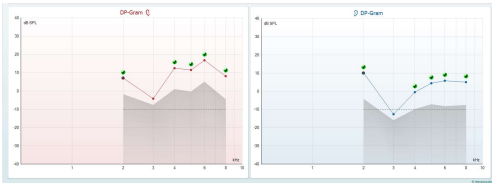
Subject 6514
1 Month

Wide Band Absorbance



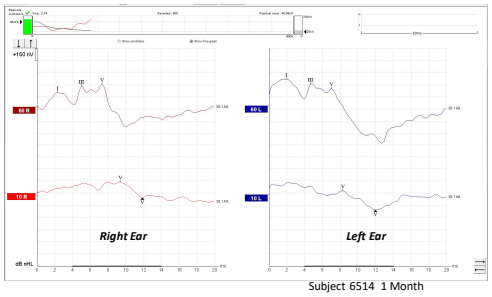
Subject 6514 1 Month

DPOAEs



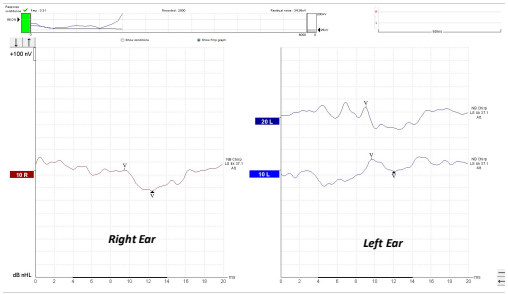
Subject 6514 1 Month

Broad Band CE-Chirp ABR Threshold <10 dB Both Ears



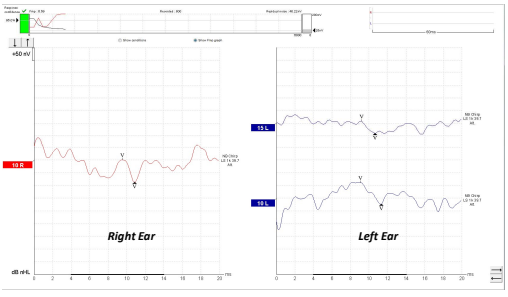
Subject 6514 1 Month

4k Hz <10 dB Both Ears



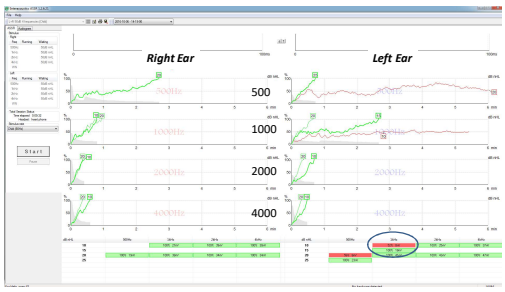
Subject 6514 1 Month

1k Hz < 10 dB Both Ears

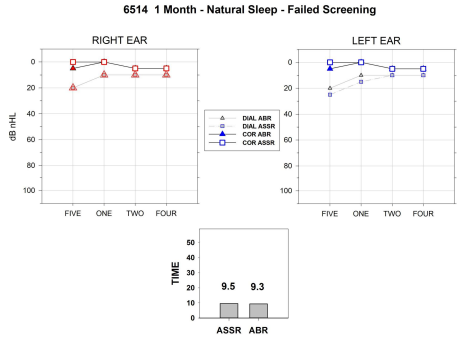


Subject 6514 1 Month

ASSR



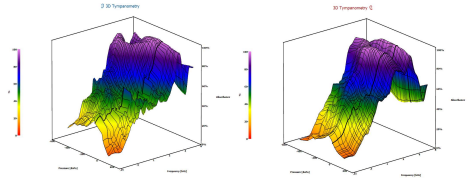
Subject 6514 1 Month



2672

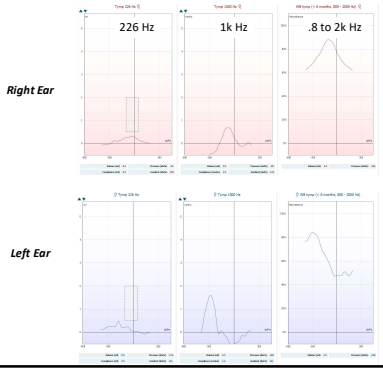
- 3-months-old at time of study visit
  - 3rd ABR evaluation at CCHMC
- Failed NBHS in both ears
- Full-term birth via emergency c-section due to failure of labor progression
- No known risk factors for hearing loss
- At 3 weeks: Mild SNHL, normal tymps, absent DPs, ? Air bone gap?
- At 7 weeks: Mild Conductive Loss, ? Bone, Neg Pressure tymps

Broad Band Tympanometry



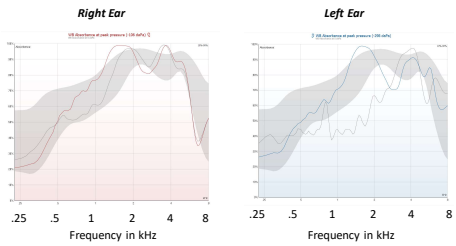
Left Ear Right Ear

Subject 2672 3 Months



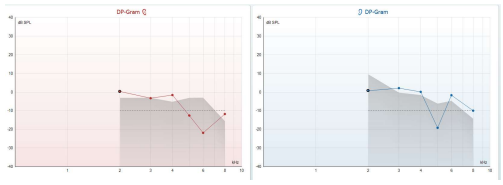
Subject 2672
3 Months

Wide Band Absorbance



Subject 2672 3 Months

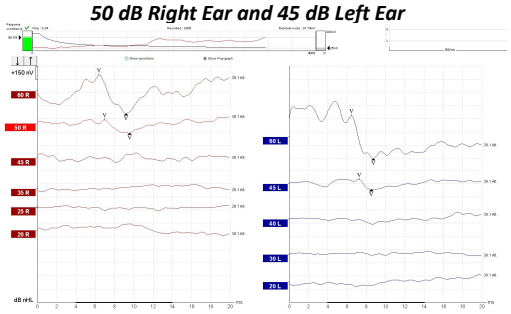
DPOAEs



Right Ear Left Ear

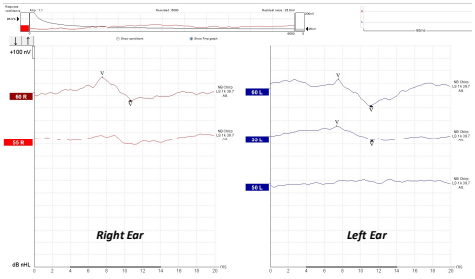
Subject 2672 3 Months

Broad Band CE-Chirp ABR Threshold 50 dB Right Ear and 45 dB Left Ear



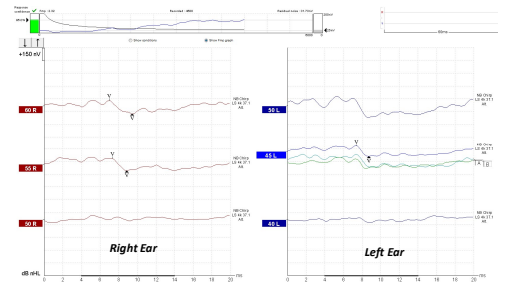
Subject 2672 3 Months

1k Hz 60 dB Right Ear and 55 dB Left Ear



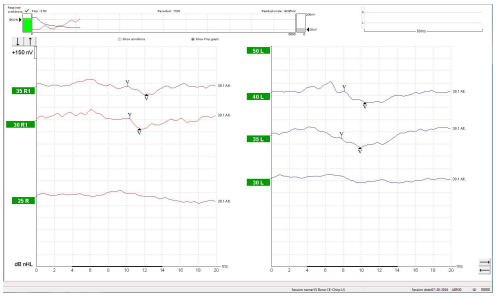
Subject 2672 3 Months

4k Hz 55 dB Right and 45 dB Left



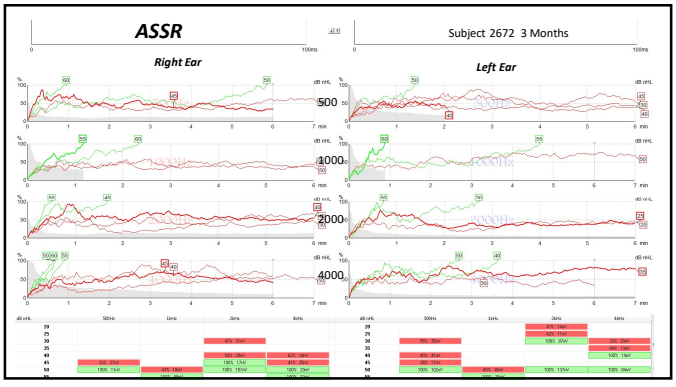
Subject 2672 3 Months

BB Chirp Bone Threshold = 30 & 35 dB

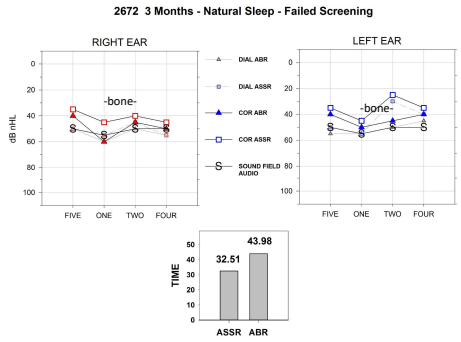


Subject 2672 3 Months

ASSR

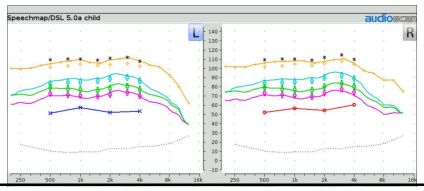


Subject 2672 3 Months



2672: 4-months-old

- HA Fitting
  - Phonak Sky V50 P BTEs
  - Verified using DSL targets and measured RECD
  - Dad very skeptical of hearing loss



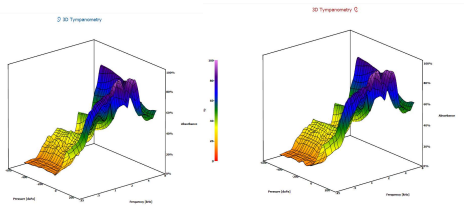
2672: 5-months-old

- MRI Completed
  - Bilateral mild bulbous appearance of the vestibules and mild enlargement of the endolymphatic ducts/sacs
  - Probably incomplete partitioning of the middle/apical turns of the cochlea
  - Mild left modiolus deficiency
- ENT Ordered OtoSeq Genetics Testing
  - 2 mutations in *SLC26A4* gene → Pendred syndome

3513

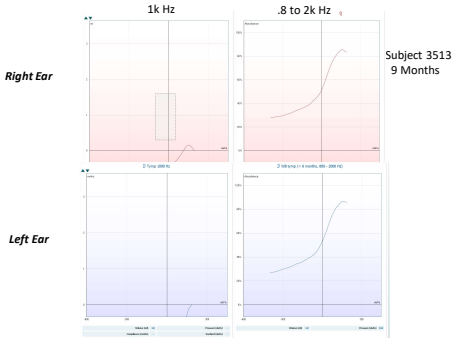
9 months old
Anesthesia/MRI
Failed NHS

Broad Band Tympanometry

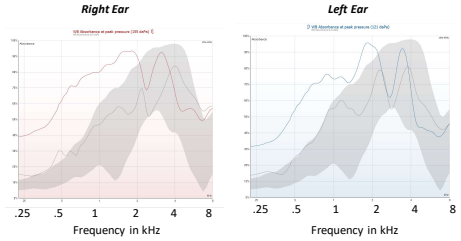


Left Ear Right Ear

Subject 3513 9 Months

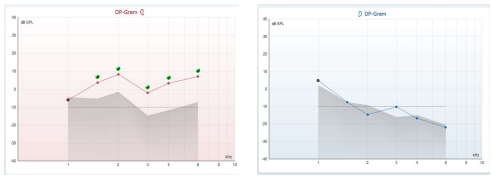


Wide Band Absorbance



Subject 3513 9 Months

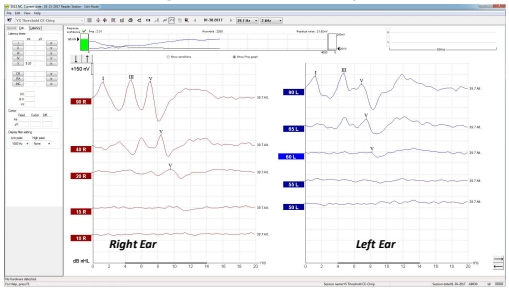
DPOAEs



Right Ear Left Ear

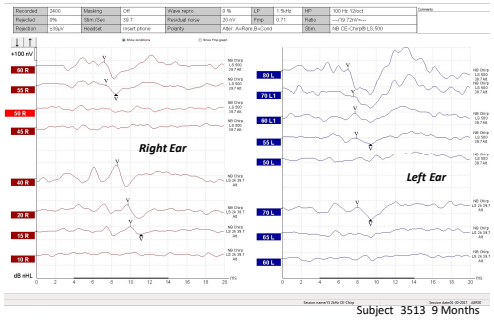
Subject 3513 9 Months

Broad Band CE-Chirp ABR Threshold
20 dB Right Ear and 60 dB Left Ear



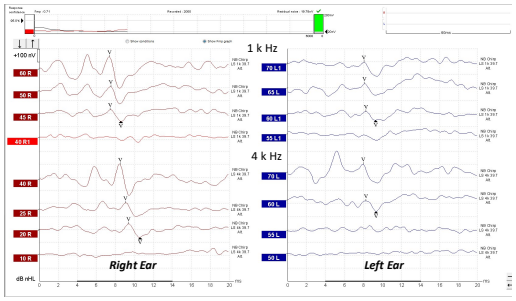
Subject 3513 9 Months

500 Hz 55 dB Both Ears
2k Hz 15 dB Right and 70 dB Left Ear



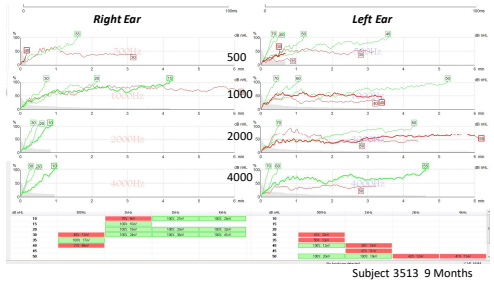
Subject 3513 9 Months

1k Hz 45 dB Right and 60 dB Left
4k Hz 20 dB Right and 60 dB Left



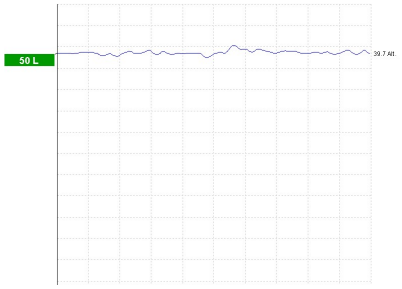
Subject 3513 9 Months

ASSR

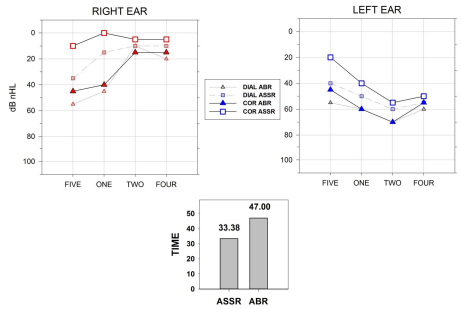


Subject 3513 9 Months

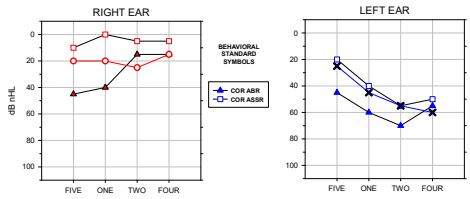
Masked BB Chirp Bone > 50 dB Left Ear



Subject 3513 9 Months



ABR, ASSR and Behavioral Thresholds



SUMMARY QUESTIONS??

STAMP
Santa Fe
Threshold by Auditory Multiple Procedures

76