# LM 212: Hearing Aids for Babies: Predicting Audiograms from ABR for Candidacy and Fitting

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2. The Ontario Infant Hearing Program
3. Our clinical audiology partners…(next slide!)

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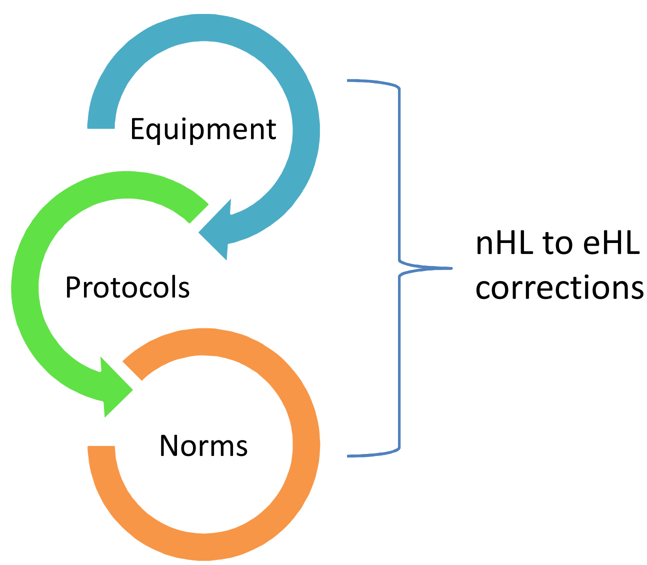
- Ontario Ministry of Children and Youth Services
- Vivosonic, Inc.

# Learning Objectives & Agenda for Today

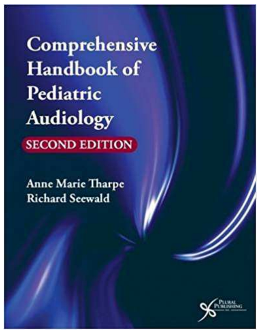
1. **Susan:** Rationale for correcting from nHL to eHL for the purposes of threshold estimation in infants prior to hearing aid fitting;
2. **Viji:** Review of research in the area of nHL to eHL corrections including current issues in this area; and
3. **Marlene:** New data on the validity and application of corrections within our program, clinical protocols.

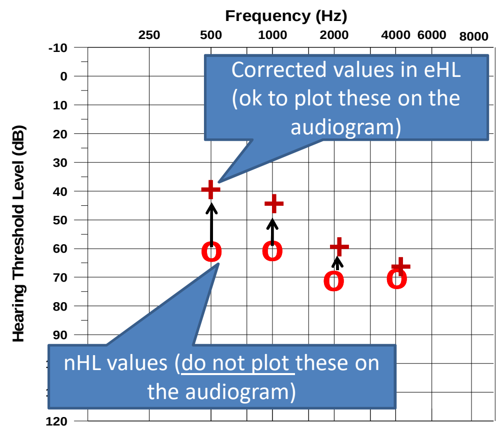
EHDI Programs support early identification of hearing loss, often for the purposes of supporting intervention.

*What do we need?*



The clinical impact of nHL to eHL corrections: the hearing thresholds will be too high if not corrected.



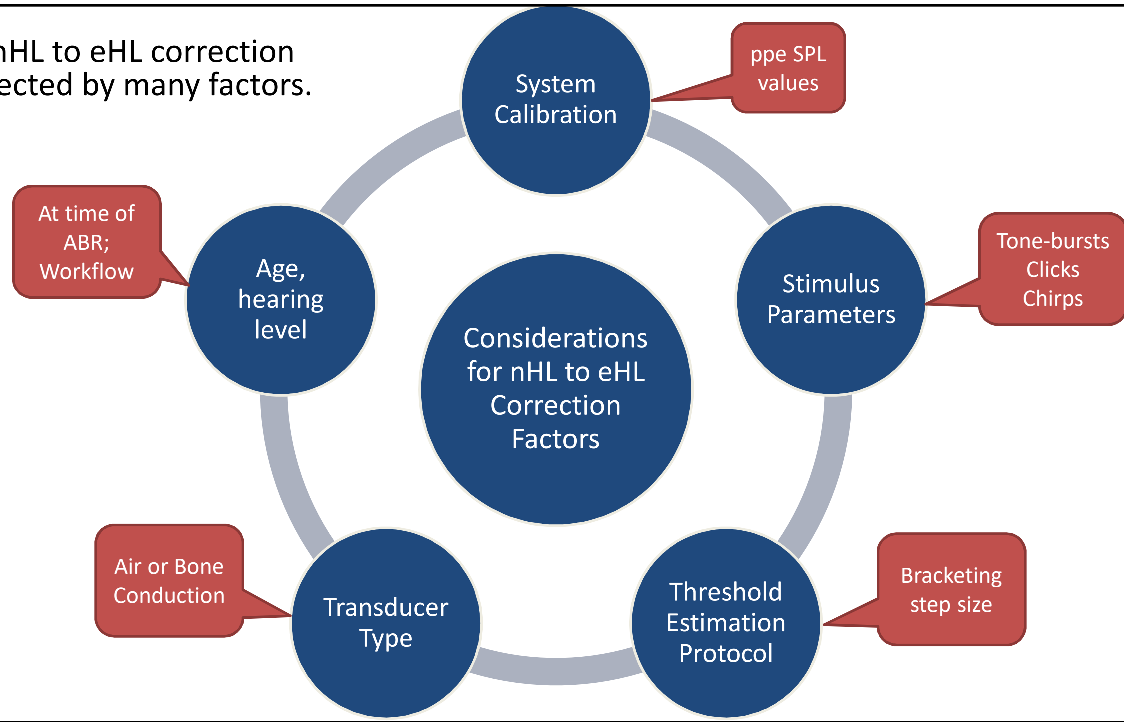

Chapter 25, figures 25-3

# What is an nHL to eHL correction anyway?

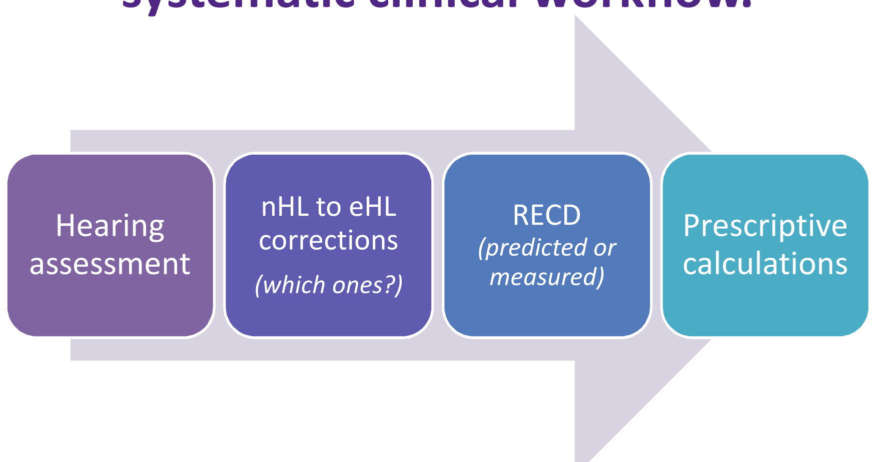
- Audiometric pure tones are calibrated in dB HL
- Frequency-specific ABR is calibrated in dB nHL
  - Various systems to define "normal" nHL levels exist & we'll review these.
- HL and nHL are not the same. nHL is typically higher than HL.
  - We can apply **corrections** to nHL to predict HL levels. The predicted units are designated with "eHL" for "estimated" HL so that record-keeping can distinguish between eHL and later HL audiograms from behavioural audiometry.

Bagatto et al 2005; 2010; Gorga et al 1993; McCreery et al 2015; Stapells et al 2005; Stapells 2000

The nHL to eHL correction is affected by many factors.




## We can apply nHL to eHL corrections in a systematic clinical workflow.




Ontario Infant Hearing Program 2016; 2016; American Academy of Audiology 2013

## In our EHDI program, we decided on a plan for how our corrections are applied.

- The **assessing audiologist** applies the correction before plotting results on an audiogram. All results are discussed in eHL (not nHL) to better link to later assessment.
  - We have program-level corrections that are used at all sites. These are specific to our equipment and calibration.
- The **amplification audiologist** is trained that the corrections should already be done (so that it doesn't happen twice!).

## WHY ARE THE CORRECTIONS NECESSARY AT ALL? A STORY OF STIMULI AND STANDARDS.

Volume 35, issue 4, 2014: audiometric calibration
Volume 36, issue 1, 2015: short tone calibration

## Some routinely-used measures use short-duration stimuli.

http://www.beaconaudiology.com/diagnostic-audiology/newborn-hearing

- Measurement of the **Auditory Brainstem Response**, requires a brief stimulus followed by a silent measurement interval.
  - **Brief clicks** are used for screening & neurologic ABR
  - **Brief tones** are used for a more frequency-specific ABR measurement, typically for estimating thresholds.
    - We detect brief tones at higher levels: they are so short that thresholds are actually higher if measured using behavioural audiometry! (Due to temporal summation).
- Measurement of the **Auditory Steady State Response** (ASSR) uses sustained, long-duration stimuli.

## Tonepips, or brief tones, or tonebursts, use a small number of cycles. They ramp on and ramp off. This means that the level varies across cycles.

- Tonepip ABR uses a 5 cycle tone: (aka 2-1-2 toneburst)
  - 2 cycles rise
  - 1 cycle peak
  - 2 cycles fall


  - Some use 2 0 2 … this can vary, and the stimulus properties vary with it.

## The more brief the tone, the more broad the energy spectrum.

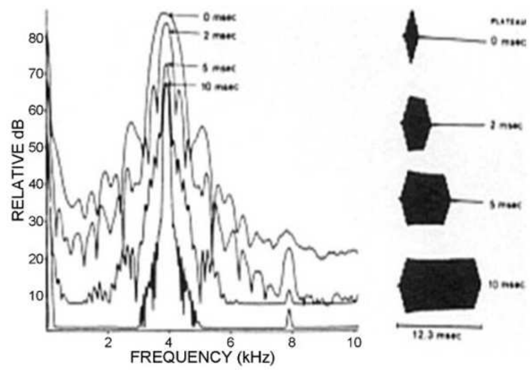
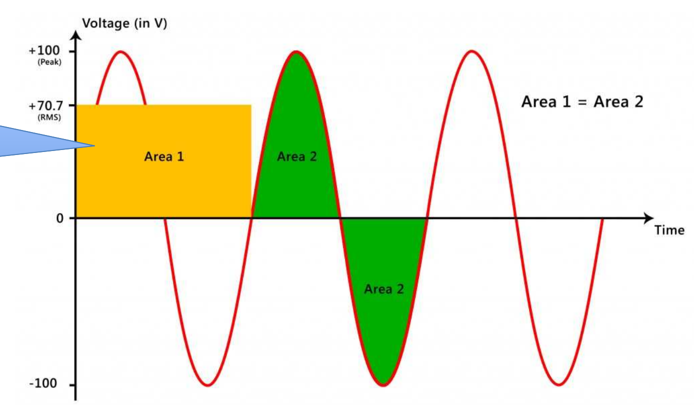



**Figure 3** The effects of tone-burst duration on spectrum. Reprinted from Burkard (1984)[9] with the permission of Elsevier.

Laukli & Burkard, 2015, Seminars in Hearing

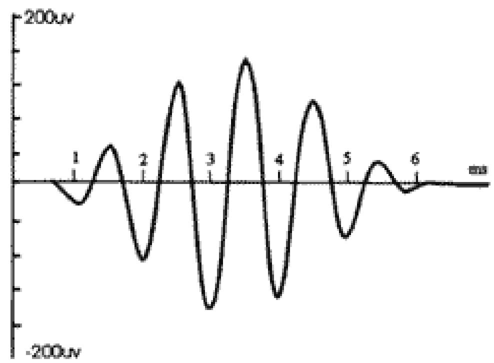
## For audiometric pure tones, sound level meters measure the level in dB RMS (yellow area). This is ok to do, because the peak level doesn't change across cycles.

The energy in the yellow area is equivalent to the green areas.




http://proaudioblog.co.uk/2015/04/pa-power-ratings-1-know-whats-watt/

Unfortunately, RMS measurement for a tonepip doesn't really work.




- The level of the tone changes over the rise/fall time of the pip.
- The peak is stable, the rest are changing.
- A different strategy is therefore used…

Instead, we match the peak level of the tonepip to the peak level of a long-duration tone. Measure the long-duration tone in dB RMS.

- This is called the peak to peak equivalent sound pressure level (Haughton, Lightfoot, & Stevens, 2003).
- Abbreviate this as: *dB ppe SPL*.

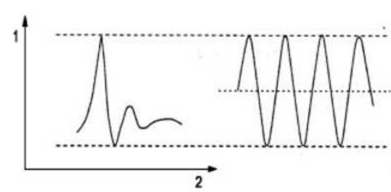



**Figure 4** A schematic of peak-to-peak peak-equivalent sound pressure level measurement. (1 indicates the amplitude axis; 2 indicates the time axis.) The authors thank the International Electrotechnical Commission for permission to reproduce information from its International Standard IEC 60645–3 ed. 2.0 (2007).

Laukli & Burkard, 2015, Seminars in Hearing, IEC (2007) 60645-6

## Early standards are now available for some protocols with short stimuli. But…

- For program-level nHL to eHL corrections, we still need to characterize typical responses for infants who have hearing loss.
  - *Even with new standards, nHL to eHL corrections may be specific to infant age & hearing loss equipment type, stimulus type, filter settings, window settings, repetition rate, type of averaging, and stopping rules.*

IEC (2007) 60645-6

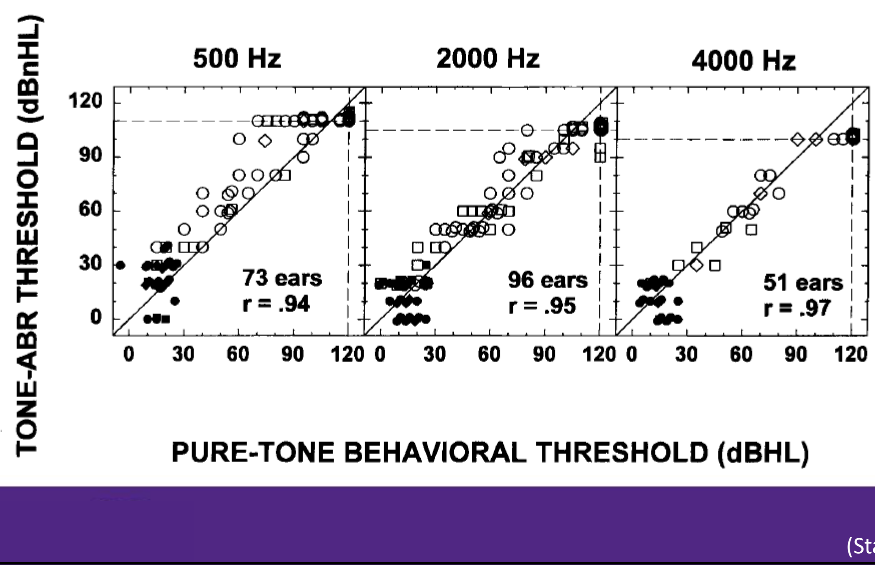
## Our goals for the project we'll share today:

- Perform an updated review of the literature on frequency-specific ABR thresholds versus behavioural thresholds.
  - What are the differences?
  - Do they vary with degree of hearing loss?
  - Do they vary with equipment type or parameters?
  - Is a "universal" correction approach possible?
- Perform an on-the-ground review of our 2016 protocol's performance for nHL to eHL corrections, and assess if and how they are impacted by a change to new equipment.

# LESSONS FROM THE LITERATURE

Viji Easwar, Ph.D., University of Wisconsin-Madison

## Early work evaluating the relationship between ABR and behavioural thresholds




(Stapells et al., 1995)

# Meta-analysis by Stapells et al (2000)

32 studies

Table 5. Summary of Mean Thresholds, Standard Errors, and 95% Confidence Intervals for Tone-ABR Thresholds (in dB nHL) in Participants With Normal Hearing as a Function of Frequency.

| | 500 Hz | 1000 Hz | 2000 Hz | 4000 Hz |
|---|---|---|---|---|
| **Adults** | | | | |
| Mean Threshold (dB nHL) | 20.4 | 16.2 | 13.4 | 11.8 |
| Standard Error (dB) | 0.8 | 0.6 | 0.5 | 0.5 |
| 95% Confidence Interval (dB nHL) | 18.8 - 21.9 | 14.9 - 17.4 | 12.3 - 14.4 | 10.7 - 12.8 |
| Number of Participants | 271 | 271 | 216 | 258 |
| **Infants and Young Children** | | | | |
| Mean Threshold (dB nHL) | 19.6 | 17.4 | 13.6 | 15.5 |
| Standard Error (dB) | 0.5 | 0.7 | 0.9 | 0.7 |
| 95% Confidence Interval (dB nHL) | 18.8 - 20.5 | 16.0 - 18.7 | 11.8 - 15.5 | 14.1 - 16.8 |
| Number of Participants | 369 | 78 | 65 | 209 |

Table 6. Summary of Mean Difference Scores, Standard Errors, and 95% Confidence Intervals for Tone-ABR Estimation of Pure-Tone Behavioural Threshold in Participants With Sensorineural Hearing Loss as a Function of Frequency.

| | 500 Hz | 1000 Hz | 2000 Hz | 4000 Hz |
|---|---|---|---|---|
| **Adults** | | | | |
| Mean Threshold (dB nHL) | +13.4 | +10.3 | +8.4 | +5.2 |
| Standard Error (dB) | 1.2 | 0.9 | 1.0 | 1.4 |
| 95% Confidence Interval (dB nHL) | 11.0 - 15.8 | 8.4 - 12.1 | 6.3 - 10.3 | 2.4 - 8.0 |
| Number of Participants | 85 | 167 | 100 | 84 |
| **Infants and Young Children** | | | | |
| Mean Threshold (dB nHL) | +5.5 | +4.9 | +0.6 | -8.1 |
| Standard Error (dB) | 1.3 | 1.3 | 1.1 | 2.0 |
| 95% Confidence Interval (dB nHL) | 3.0 - 8.0 | 2.4 - 7.3 | -1.6 - +2.7 | -12.1 - -4.1 |
| Number of Participants | 125 | 118 | 110 | 35 |

***Note.*** *Difference score = Tone-ABR threshold (in dB nHL) minus Pure-Tone Behavioural Threshold (in dB HL).*

Since then…

9 - adults with NH

5 - adults with HL

11 - children with NH

8 - children with HL

*studies including multiple groups have been counted repeatedly

# Recent studies support the good correspondence between ABR and behavioural thresholds

*In children (in dB HL)*

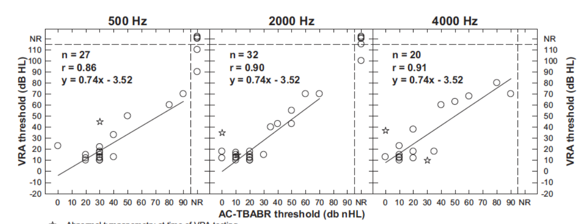
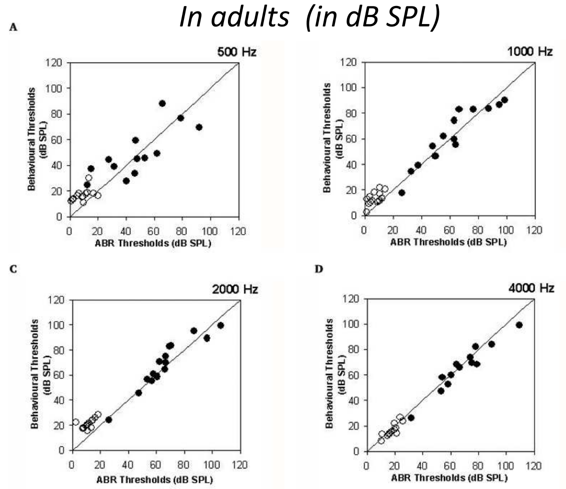



Fig. 6. Relationship between AC-TBABR and behavioral thresholds obtained by VRA for infants categorized as NH or SNHL at the time of ABR testing for each frequency. Values outside to the right or above the dotted lines represent infants with no response at the limits of either ABR or VRA equipment, respectively. These data are not included in the regression, which is shown by the solid line in each panel. In addition, data from infants with possible middle ear dysfunction on the day of behavioral testing (as evidenced by abnormal tympanometric results) were not included in the regression but are represented in this figure by the star symbols in each panel. The number of infants contributing to the regression, correlation coefficients, and regression equations for each frequency is shown in each panel.

*In adults (in dB SPL)*




Correlations between 0.91 to 0.99

(Vander Werff et al., 2009)

(Bagatto et al., 2005)

# Hearing loss degree impacts magnitude of correction

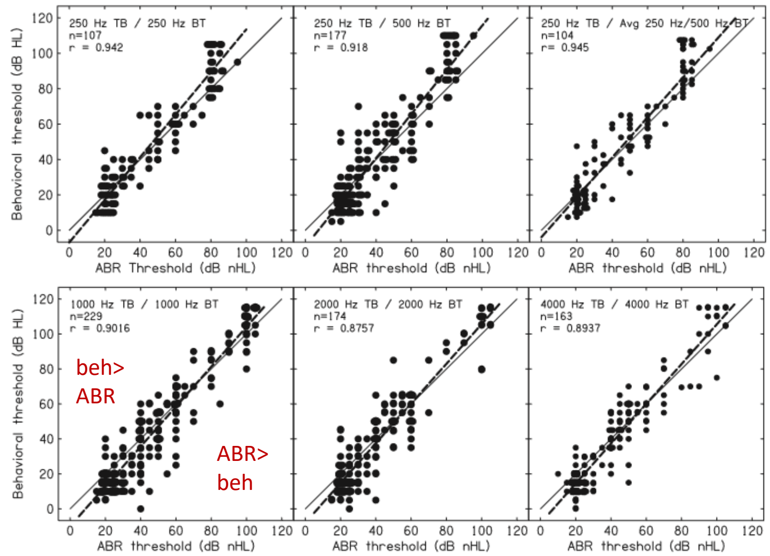



Fig. 2. Behavioral thresholds (BT) as a function of auditory brainstem response (ABR) thresholds for 1000 Hz (left), 2000 Hz (middle), and 4000 Hz (right). The number of observations (*n*) and the correlations are provided within each panel. The solid thin line is provided as a reference and has a slope of one. The dashed line represents a best-fit line to the data in each panel, and has a slope greater than one.

(McCreery et al., 2015)

# Why is the nHL-HL relationship hearing loss-dependent?

- Calibration (Gorga et al., 1993; McCreery et al., 2015)
- Temporal integration reduces as hearing loss degree increases (Reed et al., 2009)
  - Difference between long and brief tones are smaller in individuals with hearing loss

# Two approaches for nHL to eHL correction:

I. <u>Constant</u>
- o Same for all degrees of hearing loss

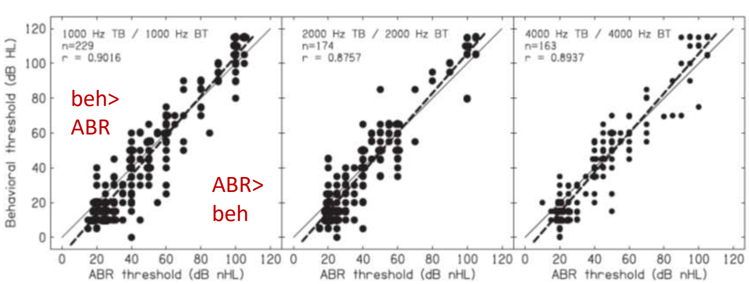
| AIR CONDUCTION | | | | |
|---|---|---|---|---|
| Frequency (Hz) | 0.5k | 1k | 2k | 4k |
| Minimum Level (dB Dial) | 35 | 35 | 30 | 25 |
| Correction Factor (dB)* | -10 | -10 | -5 | 0 |

*CF to be added to ABR threshold in nHL

Appendix I (Ontario Infant Hearing Program ABRA Protocol, 2016)

# Two approaches for nHL to eHL correction:

II. <u>Level-dependent</u>
- o Different depending on degree of hearing loss




eHL (1000 Hz)=-0.13(ABR threshold at 1000 Hz) + 8.32

**TABLE 4. Linear regression equations and correction factors for each test frequency**

| | | Examples of Corrections for Specific ABR Thresholds | | | |
|---|---|---|---|---|---|
| | Equation | 20 dB nHL | 40 dB nHL | 60 dB nHL | 80 dB nHL |
| 500 Hz | y = –0.22x + 5.90 | 5 | –3 | –7 | –12 |
| 1000 Hz | y = –0.13x + 8.32 | 5 | 3 | 0 | –2 |
| 2000 Hz | y = –0.14x + 7.31 | 5 | 2 | –1 | –4 |
| 4000 Hz | y = –0.16x + 9.32 | 6 | 3 | 0 | –3 |

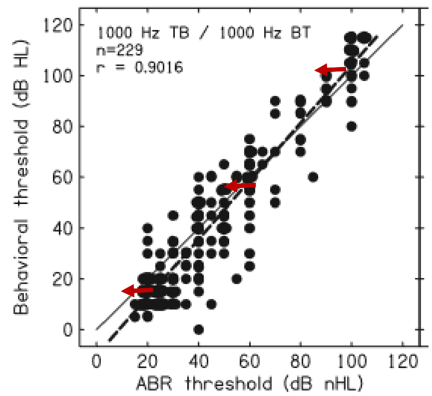
*Correction factors to be subtracted from auditory brainstem response threshold to predict behavioral threshold.*

(McCreery et al., 2015)

# Impact of difference in correction approaches

- Possible ”overcorrection” and therefore underestimation of eHL with constant correction

- But, this is not replicated in many datasets
  – Including our data




# To sum up…

- Frequency-specific nHL to eHL correction factors may vary by
  – Degree of hearing loss
  – Stimulus parameters
  – Physiological maturation
  – Equipment calibration and collection parameters

  – So, correction factors are less likely to be universal

# Estimating Audiograms from the ABR for Infant Hearing Aid Fittings: Data from the Ontario Infant Hearing Program

Marlene Bagatto, Au.D., Ph.D., University of Western Ontario

## Current Work: Rationale

Ontario Early Hearing Detection and Intervention (EHDI) program has adopted several ABR correction factors over the years

- Equipment updates
- Calibration changes
- Improved ABR threshold estimation skills

1) Assess accuracy of current ABR corrections
2) Evaluate ABR system new to the Ontario program
3) Inform future protocols

# Ontario ABR Assessment Protocol

- AC ABR toneburst thresholds at 500, 2000, and 4000 Hz
  - also at 1000 Hz when indicated
- BC ABR toneburst thresholds at 500 and 2000 Hz
  - when indicated
- Click ABR to assess cochleo-neural status (as needed)
- Diagnostic DPOAE for cross check (discretional) and neuropathy (mandatory)
- Tympanometry with 1000 Hz probe
- Ipsilateral reflexes at 1 kHz with a 1000 Hz probe

Bracketing Step Size:
No larger than 10
5 dB if ≥ 70 dB eHL

Ontario Ministry of Children and Youth Services 2008; 2016

# Frequency-Specific Corrections (Ontario, 2016)

| | AIR CONDUCTION | | | | BONE CONDUCTION | |
|---|---|---|---|---|---|---|
| **Frequency (Hz)** | 0.5k | 1k | 2k | 4k | 0.5k | 2k |
| **Minimum Level (dBnHL)** | 35 | 35 | 30 | 25 | 25 <1 yr<br>30 ≥1 yr | 30 |
| **Correction Factor** | -10 | -10 | -5 | 0 | 0 | -5 |

Correction factors are applied to ABR nHL values to obtain estimates of behavioural thresholds (eHL)

https://www.mountsinai.on.ca/care/infant-hearing-program/documents/protocol-for-auditory-brainstem-response-2013-based-audiological-assessement-abra

Ontario Ministry of Children and Youth Services 2016

## Research Question - 1

How well do the current Ontario ABR corrections predict behavioural thresholds?

## Procedure - 1

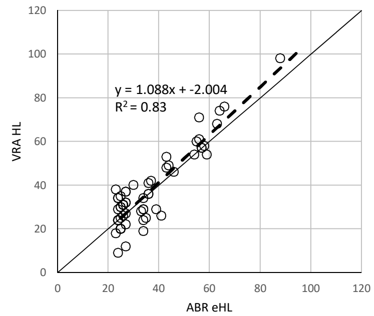
### Clinical File Review

- 4 Ontario IHP sites provided retrospective data from a total of 43 infants (84 ears)
- Age range: 1 to 21 months
- For each infant:
  - ABR threshold estimations (10 then 5 dB step sizes)
  - Behavioural (VRA) thresholds (10 then 5 dB step sizes)
  - Insert earphones coupled to foam eartips
  - Varying degrees of SNHL

# Results - 1

Data cleaning:
Max ABR levels
Progressive
Conductive overlay

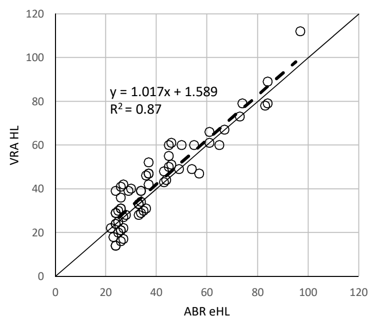
500 Hz
N = 59



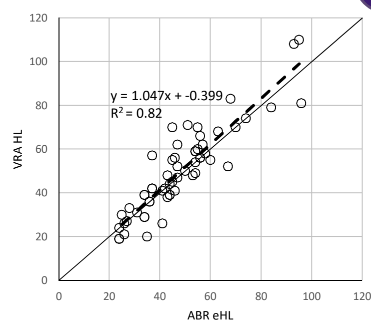

2016 ABR Corrections:
500 Hz = -10
2000 Hz = -5
4000 Hz = 0

Converted to SPL at the eardrum using age-based RECD predictions: Relationship improves

2000 Hz
N = 64




4000 Hz
N = 59




# Conclusions - 1

- Current Ontario ABR corrections provide good predictions of behavioural thresholds
  - Largest VRA-ABR difference = 2.26 dB at 2000 Hz
- Step size matters
  - No need for level-dependent corrections
- Application of ear canal acoustics improves prediction of behavioural thresholds from the ABR
  - Important for individualizing hearing aid prescription

## Research Question - 2

What is the impact of infant ABR collection parameters on correction factors?

## Procedure - 2

**Evaluation of ABR collection parameters and their impact on current corrections**

- 7 Ontario IHP sites (10 Audiologists) provided data from a total of 82 infants (101 ears)
- Parameters evaluated:
  - Participant age
  - Hearing level
  - System type

Ontario IHP purchased new ABR equipment. Required evaluation for infants with hearing loss.

## Procedure - 2

- Clinical sites executed Ontario ABR Assessment Protocol (2016) with current equipment (Biologic NavPro) during a clinical appointment

- When time and test conditions permitted, used new IHP system (Vivosonic Integrity) to estimate ABR thresholds with same infant
  - Weighting of recordings (versus unweighted averaging) main parameter difference

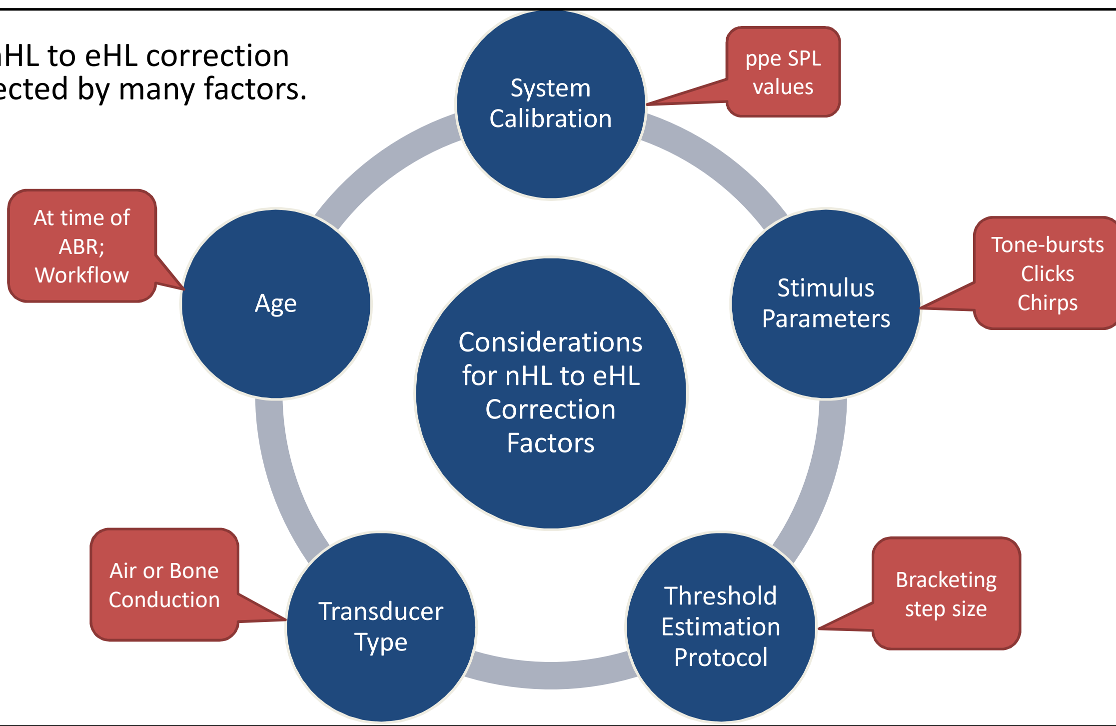
## Results - 2

- When ABR assessment parameters are closely matched to Ontario 2016 protocol, Vivosonic Integrity predicts ABR thresholds in infants similar to Biologic NavPro
  - Largest Bio-Viv difference = 4.24 dB at 2000 Hz
- Need more sampling of infants with hearing losses >70 dB nHL
- Minor changes to Ontario ABRA protocol to account for system differences prior to provincial implementation

## Clinical Implications

- Corrections to ABR threshold estimates used in Ontario predict behavioural thresholds well
  - Variation in step sizes at high levels supports frequency-dependent correction only
- Application of RECD to assessment information is still necessary for individualizing hearing aid fittings in infants
- Using an alternative ABR system with current Ontario protocol has little impact on accuracy of threshold estimation in infants with hearing loss

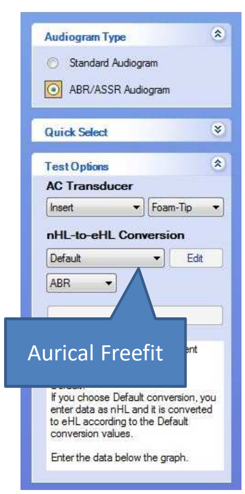
The nHL to eHL correction is affected by many factors.

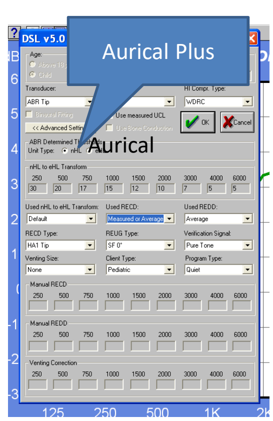


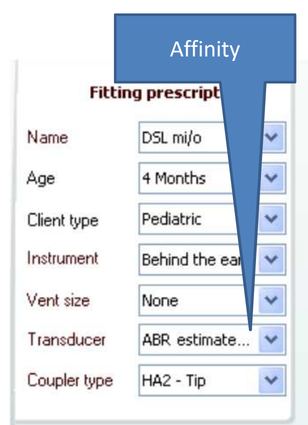
# What corrections should I use?

- If you use FS-ASSR, the correction is likely already built in. Check.
- If you use FS-ABR:
  - Default DSLv5 corrections are 20, 15, 10, 5: these were established some time ago and intended for Stapells' recommended settings and mainly used on the Biologic Nav-Pro. The 20 dB correction at 500 Hz may be larger (will give a lower audiogram) than experienced ABR clinicians require. This is a **highly conservative** approach.
  - Our 2016 corrections of 10, 10, 5, 0 seem to work well with NavPro or Vivosonic systems at the parameters used in this study. This includes a **varying step size** with smaller steps above 70 dB nHL. The 2008 correction of 15, 10, 5, 0 are similar and slightly more conservative – might be better if equipment or clinicians are new.
  - The McCreery corrections worked well for their (different) system parameters and a **fixed step size**. If this matches your protocol, it is also an evidence-based choice.

## Remember that the default corrections can be accessed in commercial systems. You can usually override these if you choose a different nHL to eHL correction.



# For Monday Morning

- The most important thing is to use a correction at all.
- The second most important thing is to make sure it is not applied twice. Who will do it and how?
- The third most important thing is to use a correction that is appropriate for your system and collection parameters.