Optimizing Diagnostic Auditory Brainstem Response and DPOAE

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• Newborn is referred for repeated OAE or ABR failure:
  – Is hearing loss present?
  – If so, sensorineural, conductive or neural?

• Possible sources of information:
  – Otoscopy
  – Toneburst Air/Bone ABR
  – 1000 Hz Tympanometry
  – Acoustic Reflexes
  – TE or DPOAEs
Natural Sleep

• ABR testing ideal conditions
  – During natural sleep
  – Under sedation if they have prior failure or older than 5 months
  – Can be done in most infants under 5 months of age
  – Practice is to try without sedation up to 6 months, then try behavioral first
Ideal Testing Condition
Appropriate Conditions for Testing

- Ensure infant arrives for testing in an appropriate state
- Instructions critical
- Infant should be tired (not overtired)

**Delay sleep**
- Hungry on arrival
- Keep infant awake for at least 1 hour prior to testing
- Provide accommodations for breast or bottle
- Rocking chair, infant swing or seat
Infant support to encourage sleep
Recommended Test Sequence

• Upon arrival:
  – Do otoscopy first
  - Put on electrodes
  - Feed child

• Do tympanometry and OAEs
  - wait…….

Never wake a sleeping infant!
Click ABR

- Useful for hearing screening
- Neurological evaluation, diagnosing auditory neuropathy spectrum disorder
- Misses hearing loss when there are frequencies with normal sensitivity.
- Equal contributions from 500Hz to 4000Hz

Tone ABR

- Used for threshold evaluation
- Useful for determining frequency-specific hearing levels to fit HAs
- Stimuli from 500 Hz to 4000 Hz
Person holding the bone oscillator must be well trained in applying a constant and appropriate force.

No significant difference in adult behavioral or infant ASSR BC thresholds using the two techniques.

**Compare benefits:**
- **elastic band** - an assistant is not required.
- **hand-held** - faster and more comfortable for the infant - much less likely to wake up the infant.

So, use what works best for you!

Small, Hatton & Stapells, 2007
Residual Noise

- **RN measure** is an online measure of the largest peak-to-peak amplitude
- Present in the noise estimate (the "+/-" response is used as the noise estimate)
- As such it is somewhat conservative, overestimating the noise present in the response.
Residual Noise

- May be used several ways
- The best way is to always record to a specific RN level that is quiet enough to be confident that IF a response were present, you would be able to see it because you recorded a quiet wave.
- Reasonably quiet = value of $0.15-0.20\mu V$
- If the RN is not below the criterion (such as $0.15\mu V$), one can’t say "no response".

Stapells, 2004
Toneburst ABR Protocol

- System: Vivosonic Integrity V500
- Stimulus rate: 37.1 (stimuli/s)
- Windowing: Blackman 2-0-2
- Averaging: Kalman weighted
- High pass filter cutoff frequency: 30 Hz
- Low pass filter cutoff frequency: 3000 Hz
- Tone-burst frequencies 0.5, 1, 2, 4 kHz.
- Cond/Rare with correlation $\geq 0.7$ for wave V threshold.
Bone Conduction Recording

- High forehead to ipsilateral mastoid recording montage.
- ER-3A insert earphones.
- Hand-held B-71 vibrator at temporal bone, contralateral masking.
Air and Bone Conduction Click and Tone-Burst Auditory Brainstem Thresholds Using Kalman Adaptive Processing in Nonsedated Normal-Hearing Infants

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• Ear and Hearing, March 2015
• Normative study using Kalman weighted adaptive processing
• 145 Infants who passed newborn screening and follow-up DPOAE
• Includes air and bone conduction norms for clicks, 500, 1000, 2000 and 4000 Hz tonebursts
• Shows no effect of sleep state in quiet infants
Air Cond Toneburst– Clicks and 4000 Hz

Modified from Elsayed, Hunter, Keefe et al, 2015
Air Cond Toneburst – 1000 Hz

Modified from Elsayed, Hunter, Keefe et al, 2015
Bone Cond Toneburst– 4000 Hz

Modified from Elsayed, Hunter, Keefe et al, 2015
Bone Cond Toneburst – 1000 Hz

Modified from Elsayed, Hunter, Keefe et al, 2015
Average AC & BC TB-ABR latencies

- 500 Hz: no significant difference between AC and BC latencies.
- 1000 Hz: no significant difference except at 30 dB nHL.
- 2000 and 4000 Hz: significant differences at 10-30 dB nHL.

Modified from Elsayed, Hunter, Keefe et al, 2015
Comparison of AC thresholds

- Current Study
- Vander Werff et al. (2009)
- Stapells (2000)
- Stapells et al. (1995)

Mean Threshold (dB nHL)

Frequency (Hz)
Mean AC wave V TB Threshold
+ 1 Std Dev

Modified from Elsayed, Hunter, Keefe et al, 2015
Comparison of the BC thresholds with previous studies in infants

Mean Threshold (dB nHL)

Frequency (Hz)
Mean BC wave V TB Threshold + 1 Std Dev

Current Study
Vander Werff et al. (2009)
Fox and Stapells (1993)

Modified from Elsayed, Hunter, Keefe et al, 2015
Summary – Tone Burst ABR

• Normative newborn threshold study completed using Kalman weighting and Bluetooth pre-amplifier.
• Low intensity thresholds successfully obtained for masked BC with hand-held bone vibrator over the temporal bone in infants.
• Large sample size across frequencies (500 Hz-4000 Hz).
• AC and BC TB-ABR were easily recorded in infants 2-12 weeks old under natural sleep.
DPOAE in Infants

- Normative DPOAE data are not available for infants after birth and up to one year of age.
- Normative data currently used clinically are based on studies in older children and adults (1-90 years of age), established by Gorga and colleagues.
- The majority of these norms are for adults.
Study Goals

• To provide normative DPOAE data for infants from birth to 18 months age.
• The study differs from others in that it provides longitudinal data over the first year of life.
• Outcome variables were distortion product level (DP), noise floor (NF), and signal-to-noise ratio (SNR).
• Age, risk factors, ear, birth weight, birth type, race, and gender were studied as covariates.
Methods

• 110 infants were included in the study.
• All infants passed newborn screening, diagnostic ABR at $\leq$ 30 dB nHL, and visual-reinforced audiometry at $\leq$ 25 dB nHL.
• DPOAE testing was performed at average ages of 1, 6, 9, and 12 months of age.
• Vivosonic Integrity DPOAE system was used with stimuli of 65 & 55 dB SPL between 1-8 kHz.
Age at Follow-up Visits
DPOAE Level Decreases from Birth to 12 Mos
Noise Level Increases from Birth to 12 Mos
SNR decreases from birth to 12 Mos
DPOAE SUMMARY

• This study has implications for diagnosis of hearing in infants birth to age 16 months.
• DP SNR is only valid for frequencies at 2 kHz and above due to high noise floor in lower frequencies.
• Acceptable SNR of at least 3 dB at each frequency is needed to ensure an interpretable response.
• DP levels should fall above the 20th percentile for at least 3 out of 5 frequencies between 2 and 8 kHz.
Case Study: Baby Girl 2003

- Enrolled from NICU, 38 week gestational age, >3000 gms
- Treated with Gentamicin
- Screening in NICU:
  - Referred on ABR and OAE Left Ear
  - Passed ABR and OAE Right Ear
DPOAE: High noise level, both ears
No significant S/N Ratio at any frequency

What are some possible reasons for the absent OAEs?
Wideband Tympanograms

Normal Right Ear

Abnormal Left Ear

Right Ear has negative pressure. Absent OAE in left associated with abnormal absorbance.

Cincinnati Children’s
Air (top) and Bone (bottom)
Conduction 1 kHz Toneburst ABR

1000 Hz: Air-Bone Gap = 20 dB

Clicks 70 dB nHL
40 dB nHL
20 dB nHL
Air and Bone Conduction Toneburst ABR

4000 Hz: Air-Bone Gap = 0 dB
Left Air Conduction ABR

500 Hz = 50 dB, 1000 Hz = 30 dB, 2000 Hz = 50 dB
Left Bone Conduction ABR

500 Hz ABG = 40 dB, 1000 Hz ABG = 10 dB
Take Home Messages

- Normative data with Kalman filtering shows slightly better thresholds than published studies.
- No effect of sleep state in quiet infants.
- DPOAE testing needs to use age-appropriate norms for infants.
- Combination of DPOAE and wideband tympanometry is a powerful diagnostic tool for audiologists.
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