Innovations in the Electrophysiologic Evaluation of Infant Hearing Part II Cost- Benefit Analysis

James Dean AuD
Linda Norrix, Ph.D.
David Velenovsky, Ph.D.
Barbara Cone, Ph.D.

University of Arizona
Summary 2009 National CDC EHDI Data, on referrals for diagnostic evaluations

Documented refer for DX
56,794

Permanent Hearing Loss
(5,073)
8.96%

No Hearing Loss
(22,124)
39%

No documentation of a diagnosis
(29,597)
52%
• Additional medical referrals for diagnostic audiologic evaluations will be made for infants and young children with...

  – Children with Special Health Care Needs
    • (NICU grads, chronic health conditions)
  – Non-typical auditory behaviors
    • ASD
  – Trauma
  – Infants & children identified with no pass on inpatient screen and **no OP screen** on routine visits and surveillance
  – Concerns related to risks for late onset hearing loss
    • CMV
  – Developmental delays
Cost modeling example:

- For each noisy infant/child being evaluated the kalman-filtered EEG/ABR improves the chance of obtaining a response at near threshold levels by up to 35%.
  - Induced motor noise raised threshold by 10-20 dB in adults.
  - Kalman-filtering application reduced noise interference by 10-20 dB in 25-35% of subjects.
- What does this mean in terms of costs?
What’s it worth to you?

• 10 dB closer to true threshold?
  – Hearing aid fitting
  – Other diagnostic procedures

• 35% increased likelihood of obtaining a response?
  – Covert that to audiology time: estimate saving 10 minutes per patient
  – If cost of an eval is $600/hour (all overheads considered) then that is $100/patient.
Other costs

- Cost of general anesthesia ABR = $5,000.00
- Cost of parental anxiety about procedure?
  - No shows, missed appointments
- What percentage of “natural sleep” ABRs are in your caseload?
  - If you start your test at 20 or 30 dB nHL, and get a response, even while the child is awake, how much is that worth to you?
A conservative example

- 3 natural sleep ABRs/day @ $600.00/test
- Advanced signal processing (kalman+*in-situ* amplifier) results in a 40% increased likelihood of being able to obtain a near threshold response during steady or intermittent noise.
- This could translate to 10 minutes of time saving/test.
- $300.00 savings/day.
A less conservative example

• 35% higher likelihood of obtaining a near threshold response translates to 20 minutes of time savings/test
• 1 hour saved per day=$600.00

• What is your time worth?
• 1 more subject/day = shorter wait lists
The Jackpot

• For every patient that can be tested without sedation/anesthesia, the cost savings is up to $5,000.00/test.
  – Given your case-load, how many patients/month would be eligible for natural sleep (or moderately quiet wakefulness) ABRs?
Case Example

- Dr. Norrix will present a case that illustrates how the “experimental” system was used to obtain results in a child who would otherwise not be able to be tested with sedation/anesthesia owing to her medical condition.
<table>
<thead>
<tr>
<th><strong>Jane</strong></th>
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<tbody>
<tr>
<td>• 9 months of age, full term at birth</td>
</tr>
<tr>
<td>• Cardio pulmonary disease and failure to thrive</td>
</tr>
<tr>
<td>• 6 month stay in PICU</td>
</tr>
<tr>
<td>• Heart surgery</td>
</tr>
<tr>
<td>• Currently ventilator dependent via tracheostomy</td>
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<tr>
<td>• GI tube</td>
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<td>• Significant developmental delays including motor, cognitive, speech &amp; language</td>
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Behavioral Audiologic Evaluation

• Normal acoustic admittance but wide tympanometric widths, AU
• DPOAEs – “refer” but noisy
• BOA – eye widening, smiling, rudimentary heard turn at 75 dB HL in each ear
Better ear

Rarefaction

Click Results

dBnHL

Equivalent Sweeps
861
3609
2883
1400
2200
3544
2464
Other scenarios

• Ability to obtain an ABR at 20-30 dB nHL in a moderately wakeful may result in cost savings if combined with:
  – Tympanometry results
  – OAE results

• If a “pass” for these quasi-screening results, then it may be more appropriate to follow the infant using behavioral methods.
Features of the system we did not test

- Wireless connection (blue-tooth)
- 1 vs. 2 channels
Mid-late 1970’s: Brainwaves in response to sound are used to test newborn hearing----could these be used for screening all infants?

University of Texas at Dallas, Parkland Hospital ca 1978
How much cost-savings from use of wireless connection of amplifier to computer?

- We did not test this feature in our lab or clinic-based verification studies.
- The comparison data are obvious
  - 100% performance for wireless system
  - 0% performance for conventional hard-wired system.
- How many times did you wish you could test an infant while driving them around in a car to induce sleep??
  - N= 1 (me)
  - About 1,000,000
Other features

• Currently, the wireless system is limited to 1-channel.

• Does the benefit of wireless out-weigh the cost of having only 1 channel?
  – How often do you use information from the second channel?
  – Put a $$ value on that and compare it to your estimated value of the wireless connection.

• Positive or negative net effect?
Cost-Modeling Summary

• Costs and benefits must be considered on a “practice-pattern” basis.
• Costs and benefits can be modeled using strict or lax criteria.
  – Strict criteria = conservative estimate of savings
  – Lax criteria = greater estimate of savings
• Empirical data suggests up to a 35% “advantage” for kalman-filtered + in-situ amplifier (2 features of Vivosonic) ABR.
• Other features (e.g. wireless) may result in additional benefits/cost-savings but should be calculated with respect to limitations (e.g., 1-channel).
Innovations

• in the electrophysiologic assessment of infant hearing.
• Funded by AUCD
• Purpose is to investigate 3 innovative methods for estimating threshold using evoked potentials.
  – 40 Hz ASSR
  – Chirps
History of ASSR for Infant Hearing Tests

• Based upon fundamental research concerned with the brain’s response to complex sounds.
• Brain response “follows” the stimulus modulation.
• Brain response is analysed in the frequency domain.
  – Spectral analyses
  – Analyses of phase coherence.
2000 Hz CF, 50 Hz MF
ASSR Characteristics

• Present at near threshold levels.

• Present for a wide range of modulation frequencies, from less than 10 Hz to over 150 Hz.

• Responses for rates $\geq 80$ Hz have many response characteristics similar to ABR.
ASSR Amplitude as a function of modulation frequency
Generators

• Dependent upon modulation frequency.

• For MF<20, same as for CAEP:
  – Primary auditory cortex and association areas.

• For MF <40 Hz, same as for MLR:
  – sub-cortical (brainstem, medial geniculate) and primary auditory cortex.
  – For rates>60 Hz, same as for ABR:
    – brainstem auditory system but may also have some contribution from primary auditory cortex.

• For rates>120 Hz, CAP: + brainstem.
  • Need to consider limits of neural rate-following at different levels of auditory system
ASSRs: 80 Hz and 40 Hz
Figure 4. Comparison of AMFR development at 40-Hz and 80-Hz modulation frequencies at 50-dB stimulation level. To characterize the development, the regression lines of the 50-dB representations from Figures 1 and 3 are used. On the SNR graph, the age to the right of the intersection of the more steeply increasing 40-Hz line with the flatter 80-Hz line is interpreted as the age at which the 40-Hz modulation frequency seems more suitable for AMFR recording for audiological purposes. Upper part: development of the AMFR amplitude. Lower part: development of the SNR.
40 Hz ASSR

- The 40 Hz ASSR is generated at the level of the auditory cortex.
- It has a larger amplitude than 80 Hz ASSR (generated at the brainstem).
- 40 Hz ASSR can be obtained in quiet wakefulness in older children or adults.
40 Hz ASSR in infants

• Are 40 Hz ASSR present in infants tested while awake?
• Are ASSRs present in infants at lower modulation rates?
• How do these differ from those found in adults?
Stimuli for ASSRs

<table>
<thead>
<tr>
<th>Time</th>
<th>Frequency</th>
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</tr>
</thead>
<tbody>
<tr>
<td>AM</td>
<td></td>
<td>sin(^3)</td>
<td></td>
</tr>
<tr>
<td>FM</td>
<td></td>
<td>tone</td>
<td></td>
</tr>
<tr>
<td>MM</td>
<td></td>
<td>noise</td>
<td></td>
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25 ms 0 2000 Hz
Time domain waveforms

3-80R(A)

2-80R(A)

1-80R(A)
40 Hz ASSR

Frequency, Hz
20 Hz ASSR
Age = 12 months

40 Hz

20 Hz

10 Hz

8.00uV

3-80R(A)

2-80R(A)

1-80R(A)
Age = 4.5 months

Frequency:
- 40 Hz
- 20 Hz
- 10 Hz
Some thoughts about these data

• The 80 Hz harmonic is present even when response to the fundamental (20 or 40 Hz) is of low amplitude.
• Harmonic at 80 Hz indicates dominance of brainstem generators.
• At this age (<12 months) the transient cortical response demonstrates rapid adaptation even for stimulus rates as low as 1 or 2 Hz.
  – We cannot rule out brainstem generation site at this time.
• Large amplitude responses, detection in the frequency domain may allow more efficient estimates of threshold in awake babies.