The Power of a OAE and ABR
Newborn Hearing Screening Strategy

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The Power of a OAE and ABR Newborn Hearing Screening Strategy
NEWBORN HEARING SCREENING WITH ABR: Early Events

- 1979: Schulman-Galambos C. & Galambos R. Brain stem evoked response audiometry in newborn hearing screening. *Archives of Otolaryngology* 105:
Marion Downs
“Grandmother of Newborn Hearing Screening”
Robert Galambos
Newborn Hearing Screening with Auditory brainstem response (ABR)

Beginning in 1974
UNIVERSAL NEWBORN HEARING SCREENING WITH AUTOMATED AUDITORY BRAINSTEM RESPONSE (AABR): A MULTI-SITE INVESTIGATION

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*Baptist Memorial Hospital East*  
*Memphis, Tennessee*
# NEWBORN HEARING SCREENING WITH AABR

## Test Performance and Outcome

<table>
<thead>
<tr>
<th>SITE</th>
<th>WBN</th>
<th>ICN</th>
<th>Refer % D/C</th>
<th>Refer Lost F/U</th>
<th>False Pos</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boulder</td>
<td>98%</td>
<td>2%</td>
<td>2%</td>
<td>16%</td>
<td>2%</td>
</tr>
<tr>
<td>Louisville</td>
<td>&gt;99%</td>
<td>&lt;1%</td>
<td>1%</td>
<td>45%</td>
<td>.35%</td>
</tr>
<tr>
<td>Memphis</td>
<td>&gt;99%</td>
<td>N=1</td>
<td>3%</td>
<td>13%</td>
<td>2.5%</td>
</tr>
<tr>
<td>Huntsville</td>
<td>93%</td>
<td>7%</td>
<td>1%</td>
<td>21%</td>
<td>.05%</td>
</tr>
<tr>
<td>Nashville</td>
<td>0%</td>
<td>100%</td>
<td>6%</td>
<td>32%</td>
<td>2%</td>
</tr>
<tr>
<td>N = 11,711</td>
<td></td>
<td></td>
<td>2%</td>
<td>28%</td>
<td>0.9%</td>
</tr>
</tbody>
</table>

AAP < 4% < 5% < 2%
David Kemp
“Discoverer of OAEs”
Otoacoustic Emissions (OAEs)
NEWBORN HEARING SCREENING: OTOACOUSTIC EMISSIONS

  - 53,121 babies underwent screening (NICU = 5130)
  - average initial failure rate = 10%
  - failure rate for rescreens at 2 to 6 weeks = 14.7%
  - over failure (refer) rate = 1.2%
  - 111 infants identified with permanent hearing loss
  - average age of intervention (amplification) = 5.7 months
EARLY IDENTIFICATION OF AND INTERVENTION FOR HEARING IMPAIRMENT IN CHILDREN

- Hearing loss of 30dB HL and greater in the frequency region important for speech recognition will interfere with the normal development of speech and language.
- Techniques used to assess hearing of infants must be capable of detecting hearing loss of this degree in infants by age three months and younger.
- Two physiologic measures...auditory brainstem response (ABR) and otoacoustic emissions (OAE)...show good promise for achieving this goal.

Joint Committee on Infant Hearing 1994 and 2000 Position Statements
Early Identification and Intervention for Hearing Impairment in Children: Important Steps

Pass?
- Parent Info
  - Progressive factor?

Fail?
- Diagnostic audiometry to define hearing loss
- Hearing loss?
  - Hearing aid fitting and habilitation (by 6 mos.)
- Secondary screening within 3 months (optional)
Newborn Hearing Screening with a Combined Automated OAE and ABR Technique

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Gerald Popelka, Ph.D.
Everest Biomedical,
St. Louis, Missouri, U.S.A.

(Journal of American Academy of Audiology, August 2004)
Rationale for Combined OAE/ABR Screening

- In ear calibration of signal intensity (OAE and ABR)
- Lower refer (< 2%) and false-positive rates (< 0.2%)
- Minimal parental anxiety
- Fewer diagnostic follow-ups with lower costs
- Less hearing impaired infants lost to follow-up
- Differentiation of conductive vs. sensory vs. neural auditory dysfunction
- Quicker and more appropriate management
- Identification of auditory neuropathy
- Earlier identification of hearing impairment
## Combination OAE/ABR Screening: Differentiation of Peripheral Auditory Dysfunction

<table>
<thead>
<tr>
<th>Type of dysfunction</th>
<th>OAE</th>
<th>ABR</th>
</tr>
</thead>
<tbody>
<tr>
<td>External/middle ear</td>
<td>abnormal</td>
<td>normal</td>
</tr>
<tr>
<td>Sensory (OHC)</td>
<td>abnormal</td>
<td>abnormal</td>
</tr>
<tr>
<td>Neural</td>
<td>normal</td>
<td>abnormal</td>
</tr>
</tbody>
</table>

*minor dysfunction*
DPOAE Protocol (1)

- 4 test frequencies presented
  - 2000, 3000, 4000, & 5000 Hz
  - important speech frequencies

- Stimulus calibration tolerance = +/- 2 dB

- Minimum 6 dB S/N (DP to NF) ratio for PASS outcome

- Criteria for 3 frequencies required for PASS outcome
DPOAE Protocol (2)

- Real ear measures determine
  - Level for $f_1$ and $f_2$ test frequencies
    - $L_1 = 65$ dB SPL
    - $L_2 = 55$ dB SPL

- $f_2/f_1$ ratio = 1.20

- DP and noise floor (NL) levels measured
  - Level of noise floor at dB frequency ($N_{dp}$)
  - Level of distortion product emission
    - $L_{dp}$ at $2f_2 - f_1$
    - $L_{dp}$ relative to $N_{dp}$ (DP – NF difference)
DPOAE Screen PASS

Right Ear

Emission

Noise
AABR Protocol

- Stimulus type = rarefaction clicks
- Stimulus intensity level = 35 dB nHL
- Stimulus rate = 37.1/sec
- Number of stimulus repetitions = 3000
- Probe tip for stimulus delivery (same tip for OAE)
  - Electrodes placed on high forehead and each earlobe
    - Maximum Impedance < 12 kOhm
    - Maximum Impedance mismatch < 5 kOhm
- Filter settings
  - high pass filter = 100 Hz
  - low pass filter = 1500 Hz
- Pass/fail criteria = Fsp > 3.1
AABR Analysis Approach
(Fsp is most common automated ABR analysis criterion)

- **Fsp (variance ratio)**
  - Ratio of signal to noise
  - $Fsp = \frac{\text{Variance}_{\text{signal}}}{\text{Variance}_{\text{noise}}}$
  - Magnitude of response
    - $\sim 1.0 = \text{no response.}$
    - $> 3.1 = \text{response present.}$

<table>
<thead>
<tr>
<th>Fsp</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
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PASS Criterion 4
AABR Screen
Combination OAE/AABR Study: Subjects

- N = 300 infants (600 ears)
- All babies underwent OAE and ABR screening
- Newborns that failed first DPOAE or ABR were re-screened prior to discharge
- Newborns discharged with ‘refer’ result returned within 2 to 3 weeks for follow-up diagnostic audiologic evaluation
Combine OAE and AABR Study:
Results (N = 600)

<table>
<thead>
<tr>
<th>Diagnostic Outcome</th>
<th>Screening Outcome</th>
<th>Pass</th>
<th>Refer</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td></td>
<td>590</td>
<td>2</td>
<td>592</td>
</tr>
<tr>
<td>Hearing Impaired</td>
<td></td>
<td>0</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td><strong>N</strong></td>
<td>590</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

Sensitivity = 100.0%
Refer Rate = 1.7%
Specificity = 99.7%
Positive Predictive Value = 80.0%
<table>
<thead>
<tr>
<th>Diagnostic Category</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>2</td>
<td>NA</td>
</tr>
<tr>
<td>Conductive</td>
<td>3</td>
<td>0.5%</td>
</tr>
<tr>
<td>Sensorineural</td>
<td>5</td>
<td>0.8%</td>
</tr>
<tr>
<td>Total hearing impaired</td>
<td>8</td>
<td>1.3%</td>
</tr>
</tbody>
</table>
Potential Sites of Auditory System Abnormality

- Blockage
- Dysfunction
- Abnormal development
- Abnormal structure
Combination OAE/ABR: Optimizing Early Identification and Diagnosis of Infant Hearing Loss

OAEs/ABR

<table>
<thead>
<tr>
<th>Normal?</th>
<th>Abnormal?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk factor? CNS</td>
<td>Threshold ABR Tympanometry</td>
</tr>
<tr>
<td>Neurodx ABR</td>
<td>Delayed Wave I? Abn tymp?</td>
</tr>
<tr>
<td>Rule out Auditory Neuropathy</td>
<td>BC ABR (conductive)</td>
</tr>
<tr>
<td>Healthy Infant?</td>
<td>Severe-Profound SNHL?</td>
</tr>
<tr>
<td>Pass Hearing Screening</td>
<td>ASSRs</td>
</tr>
</tbody>
</table>
Combined OAE/ABR Screening:
Summary of Clinical Advantages

- In ear calibration of signal intensity for OAE and ABR
- Lower refer (< 2%) and false-positive rates (< 0.2%)
- High sensitivity and specificity
- Fewer diagnostic follow-ups with lower overall cost for early identification of infant hearing loss
- Differentiation of auditory dysfunction at birth
  - conductive
  - sensory
  - neural (e.g., auditory neuropathy)
- Quicker and more appropriate management
- Earlier intervention hearing impairment