Application of ABR in Infants and Young Children

- Rationale
- Tone burst (frequency specific) ABR
- Bone conduction ABR
- Auditory steady state response (ASSR)
- Sedation and anesthesia
Limitation of Tone Burst ABR in Severe-to-Profound Hearing Loss

- No ABR > 80 dB HL
- No ASSR > 120 dB HL
Diagnosis of Hearing Loss: Protocol for Confirmation of Hearing Loss in Infants and Toddlers (0 to 6 months)

Year 2007 JCIH Position Statement

- Child and family history
- Otoacoustic emissions
- ABR during initial evaluation to confirm type, degree & configuration of hearing loss
- Acoustic immittance measures (including acoustic reflexes)
- Supplemental procedures (insufficient evidence to use of procedures as “sole measure of auditory status in newborn and infant populations”)
  - Auditory steady state response (ASSR)
  - Acoustic middle ear reflexes for infants < 4 months
  - Broad band reflectance
- Behavioral response audiometry (if feasible)
  - Visual reinforcement audiometry or
  - Conditioned play audiometry
  - Speech detection and recognition
- Parental report of auditory & visual behaviors
- Screening of infant’s communication milestones
AUDITORY STEADY STATE RESPONSE (ASSR): Confusing Terminology

- Amplitude-modulation-following response (AMFR)
- Envelope-following response (EFR)
- Frequency-following response (FFR)
- Steady state evoked response (SSER)
- Steady state evoked potential (SSEP)
- 40 Hz response
- Auditory steady state response (ASSR)
ASSR: General Principles

- An electrophysiologic response, similar to ABR.
- Instrumentation includes:
  - Insert earphones
  - Surface electrodes
  - Averaging computer
- Stimuli are pure tones (frequency specific, steady state signals) activating cochlea and CNS
- ASSR is generated by rapid modulation of “carrier” pure tone amplitude (AM) or frequency (FM).
- Signal intensity can be as high as 120 dB HL
- ASSR phase or frequency is detected automatically (vs. visual detection)
Auditory Steady State Response (ASSR): Clinical Devices

- GSI VIASYS
  - Audera
  - Descendant of Melbourne Australia system (Field Rickards, Gary Rance, Barbara Cone-Wesson, et al)
- Bio-Logic Systems Inc.
  - MASTER
  - Descendent of Canadian system (Terry Picton et al)
- ICS
- HIS
- Others?
ASSR:
2000 Hz tone modulated at rate of 100 Hz

Modulated carrier
ASSR (Audera):
Significant phase coherence
ASSR (Audera):
No Response Condition
ASSR (Audera):
Test trials by frequency
ASSR (Audera): Estimated Audiogram
Four stimuli presented simultaneously to one ear

Sound

Cochlea

Brain

EEG + ASSR
ASSR, ABR, and Pure Tone Audiometry: Asking the clinically relevant question

*Not:* Which frequency-specific electrophysiologic technique is best ... tone burst ABR or ASSR?

*But:* How does the ASSR technique complement click and tone burst ABR techniques in the infant test battery?
# ABR (Click and Tone Burst) versus ASSR: Clinical Application

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ABR</strong></td>
<td><strong>Disadvantages</strong></td>
</tr>
<tr>
<td>Estimates normal</td>
<td>Can’t estimate profound HL</td>
</tr>
<tr>
<td>hearing thresholds</td>
<td></td>
</tr>
<tr>
<td>Ear-specific BC</td>
<td>Skilled analysis required</td>
</tr>
<tr>
<td>findings</td>
<td>Limited BC intensity levels</td>
</tr>
<tr>
<td>Diagnosis of AN</td>
<td></td>
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<tr>
<td><strong>ASSR</strong></td>
<td></td>
</tr>
<tr>
<td>Estimates severe-to-</td>
<td>No ear-specific BC findings</td>
</tr>
<tr>
<td>profound HL</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Requires sleep or sedation</td>
</tr>
<tr>
<td></td>
<td>Possible artifactual “response”</td>
</tr>
</tbody>
</table>
ASSR:
Is it possible to mistake an artifact for a response?

- Literature: Air conduction
  - Gorga et al, 2004: found apparent ASSRs for stimulus intensity levels > 100 dB HL in patients with cochlear implants (deseabled)
  - Picton & John, 2004
  - Small & Stapells, 2004

- Literature: Bone conduction
  - Dimitrijevic et al, 2002
  - Small & Stapells, 2005

- Explanations and conclusions
  - Aliasing in measurement when signal is sampled at a rate less than twice its frequency
  - Problem was apparently limited to research or early clinical version of MASTER system
  - Based on clinical experience, it is clearly possible to perform ASSR measurement at intensity levels up to 120 dB HL without detection of a response (with Audera device)
Role of ASSR in Frequency-Specific Estimation of Hearing Sensitivity in Infancy

OAE/ABR Screening
Refer Outcome

Normal?
Wave I
Wave I-V
20 dB nHL

Tone Burst
ABR or OAEs

Click ABR

Delayed
Wave I?

Bone Conduction
ABR

Abnormal ABR
or No Response

Wave I only?
CM only?

ASSR

Auditory Neuropathy
Auditory Steady State Responses (ASSRs): Pros and Cons for Clinical Use

- **Advantages (Pros)**
  - Reasonably frequency specific stimuli
  - Can be used for electrophysiologic assessment of severe to profound degree of hearing loss in infants and young children
  - Clinical devices now available
  - Automated analysis

- **Potential disadvantages (Cons)**
  - Require very quiet state of arousal
  - Less accurate in normal hearing (especially low frequencies)
  - Limited anatomic site specificity
  - Analysis difficult with bone conduction stimulation
ASSR: Lingering Clinical Questions

- Are the neural generators for the ASSR well defined?
- Are there maturational effects on ASSR from premature infants through childhood?
- Is test time equivalent for ASSR vs. tone burst ABR?
- Can ASSR be recorded from non-sedated patients?
- What is the effect of sedation and anesthesia on ASSR?
- How closely correlated are ASSR and pure tone hearing thresholds?
- Can ASSR be used in estimation of bone conduction auditory thresholds?
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ABR in the Clinic with Conscious Sedation
(e.g., chloral hydrate)
American Academy of Pediatrics Guidelines for Conscious Sedation (WWW.AAP.org/policy)

*Pediatrics* 89, **1992**, p 1110-1115

Guidelines for Monitoring and Management of Pediatric Patients During and After Sedation for Diagnostic and Therapeutic Procedures

*Pediatrics* 110, **2002**, pp 836-838

Guidelines for Monitoring and Management of Pediatric Patients During and After Sedation for Diagnostic and Therapeutic Procedures: Addendum
ABR in the Operating Room with Light Anesthesia (e.g., propofol)
<table>
<thead>
<tr>
<th>Setting</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinic</td>
<td>Less expensive</td>
<td>Limited sedation options</td>
</tr>
<tr>
<td></td>
<td>Near or in audiology</td>
<td>Limited medical support</td>
</tr>
<tr>
<td></td>
<td>Scheduling ease</td>
<td>Increased liability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Uncertain success/&gt; time</td>
</tr>
<tr>
<td>O.R.</td>
<td>Medical (ENT) support</td>
<td>More expensive</td>
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<tr>
<td></td>
<td>Ideal patient state</td>
<td>Remote location</td>
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<td></td>
<td>Controlled sedation</td>
<td>Noisy environment</td>
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<td></td>
<td>Limited liability</td>
<td>Complicated scheduling</td>
</tr>
</tbody>
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Disadvantages of Anesthesia for in ABR Assessment of Children

- Delayed diagnosis (many months) due to problems with scheduling time in the operating room with medical support team (e.g., anesthesiologist)
- Ten fold increase in cost (>4000 versus $400) associated with services in the operating room
- Medical risk of anesthesia and related procedures (e.g., intubation)
- Possible secondary neurological and cognitive deficits of anesthesia in children at risk for learning problems
- Inability to conduct a full auditory assessment in remote location outside of the audiology clinic
Thank you!

Questions?