Current developments and new directions in pediatric audiology:

Frequency specific auditory brainstem response audiometry - basis for habilitation

Suzanne C. Purdy
sc.purdy@auckland.ac.nz

Discipline of Speech Science, School of Psychology

International pediatric audiology Conference

April 11–13, 2014
Shanghai, China
Key points

• Click ABR and excellent screening tool but not suitable for estimating hearing thresholds
• Best practice guidelines have been developed
• Need careful attention to stimulus and recording protocols, rather than accepting manufacturer default settings
• Air and bone conduction ABR needed to estimate audiogram if AC toneburst ABR indicates a hearing loss
• Erroneous results can be obtained if people do not follow guidelines for reducing noise in recordings and accurately distinguishing responses from noise
Traditional ABR approach used click stimuli to determine objective hearing threshold in infants and other children that could not be tested behaviourally.

http://www.audiologyonline.com/articles/abr-illustration-auditory-dysfunction-through-12179
Click versus toneburst acoustic spectra

Sininger (1995)
Click ABR can miss hearing loss

Stapells & Oates (1997)
Toneburst ABR has become the gold standard for objectively estimating hearing thresholds in children

Relationship between toneburst ABR and behavioural thresholds


![Graph showing the relationship between toneburst ABR and behavioural thresholds across 500 Hz, 2000 Hz, and 4000 Hz. The graph includes data points for 73 ears at 500 Hz, 96 ears at 2000 Hz, and 51 ears at 4000 Hz. The correlation coefficients are r = .94, r = .95, and r = .97 respectively.](image-url)
Frequency specific ABR and aided CAEP in 7 month old
(Gravel et al., 1989)
Clinical Guidelines for toneburst ABR


- **Ontario** INFANT HEARING PROGRAM AUDIOLOGIC ASSESSMENT PROTOCOL Version 3.1, January 2008 [https://www.mountsinai.on.ca/](https://www.mountsinai.on.ca/)
Clinical Guidelines from United Kingdom

Includes sections ....

3. PATIENT PREPARATION

4. STIMULUS

5. DATA COLLECTION AND ANALYSIS ....

hearing.screening.nhs.uk/getdata.php?id=19345
<table>
<thead>
<tr>
<th>Stimulus</th>
<th>Recording</th>
</tr>
</thead>
<tbody>
<tr>
<td>• type</td>
<td>• electrodes</td>
</tr>
<tr>
<td>• duration</td>
<td>• time window</td>
</tr>
<tr>
<td>• polarity</td>
<td>• bandpass filter</td>
</tr>
<tr>
<td>• repetition rate</td>
<td>• number of averages</td>
</tr>
<tr>
<td>• masking</td>
<td>• number of repeats</td>
</tr>
<tr>
<td>• transducer</td>
<td>• electrode positions</td>
</tr>
<tr>
<td>• calibration</td>
<td>• number of channels</td>
</tr>
<tr>
<td></td>
<td>• number of repeats</td>
</tr>
<tr>
<td></td>
<td>• artifact reject</td>
</tr>
<tr>
<td></td>
<td>• gain/sensitivity</td>
</tr>
<tr>
<td></td>
<td>• notch filter</td>
</tr>
</tbody>
</table>
Recording Parameters

• **Time window**
  - 20-30 ms
  - Needs to be long enough to capture slow wave recovery ‘SN10’ (slow negative 10)

• **Response filtering**
  - Wide filter that includes low frequency energy in the response 30 - 3000 Hz

• **Electrode montage**
  - Vertex to enhance wave V
  - two channel for ABR to compare ipsi versus contra recordings
Tracking ABR response down to threshold

21 month old with normal hearing (behavioural thresholds at 24 months in parentheses)

Janssen, Usher and Stapells (2010)

- examined several hundred ABR assessments, half of which showed normal thresholds
- average sedated sleep 58 minutes (7.6 measures)
- average non-sedated sleep 49 minutes (6.2 measures)

Test first at levels where response is present in all infants with normal hearing: 35 dB nHL at 500 & 30 dB nHL at 1k, 2k, 4k Hz

| TABLE 3. Tone-ABR thresholds and detectability for normal-hearing group<sup>a</sup> |
|---------------------------------|--------|--------|--------------|
|                                 | 500    | 2000   | 4000         |
| Mean threshold (dB nHL)         | 23.6   | 12.9   | 12.6         |
| SD (dB)                         | 9.9    | 9.0    | 8.1          |
| N                               | 25     | 28     | 23           |
| Detectability (in percent):     |        |        |              |
| ≤10 dB nHL                      | 12     | 50     | 52           |
| ≤20 dB nHL                      | 52     | 96     | 100          |
| ≤30 dB nHL                      | 92     | 100    | 100          |
| ≤40 dB nHL                      | 100    | 100    | 100          |

<sup>a</sup> Results from group with bilateral normal hearing, with data from only one ear per subject included.

Example: recording 500 Hz ABR using IHS equipment

Play video from 08:12 to 10:44

1. 40 dB nHL
2. 40 dB nHL
3. 50 dB nHL
4. 10 dB nHL

Note:
1. Replication
2. Growth
3. Baseline
Choice of stimuli

- Unilateral refer: 2k, 500, 4k Hz, then test other ear
- Bilateral refer: 2k 1\textsuperscript{st} ear, 2k 2\textsuperscript{nd} ear, 500, 500, 4k, 4k

500 Hz toneburst

2000 Hz toneburst

40 dB nHL

30 dB nHL

30 dB nHL

20 dB nHL
Conductive hearing loss – diagnosis should not be based on latency intensity function

Stapells et al (1985)
Steep high frequency SNHL – latency intensity function looks like a conductive loss

Stapells et al (1985)
Conductive versus sensorineural hearing loss

- Immittance audiometry
- Bone conduction audiometry
Bone conduction toneburst ABR

- Normal Skull of the Newborn
  - Frontal Bones
  - Metopic Suture
  - Anterior Fontanelle
  - Coronal Suture
  - Sagittal Suture
  - Parietal Bones
  - Posterior Fontanelle
  - Lambdoid Suture
  - Occipital Bone

Reference:
- Stuart et al (1990)
- Fox & Stapells (1993)

Electrode

Bone vibrator

Electrode
Bone conduction toneburst ABR: two-channel recording (reference to left and right mastoids)

Purdy and Kelly 2014
Stimulus artifact

- Click has 100 μs duration – artifact very brief at beginning of trace
- 2-1-2 cycle (rise-plateau-fall) 500 Hz tonepip lasts 4-2-4 ms, artifact can contaminate first 10 ms of trace
- 2-1-2 cycle 2000 Hz toneburst lasts 1-0.5-1 ms, artifact can contaminate first 2.5 ms of trace
- early peaks prior to wave V difficult to identify if there is stimulus artifact – not a problem as the focus is on wave V
Stimulus artifact needs to be distinguished from cochlear microphonic
Response Detection Difficulties

2000 Hz, 20 dB nHL

2 X 2000

3 X 2000

4 X 2000

2 X 4000

SUBJECT: N.B. (2 yrs)

(Stapells 2000)
Considering the quality (noisiness) of the recording when making judgements about ABR presence

1. United Kingdom guidelines

Example of a clear response (CR), satisfying the 3 to 1 signal to noise criterion

Figure 1
Scales:
150nV / div
2 ms / div
2. Ontario guidelines

- response-positive decision may be made on basis of single average if **location & shape of the waveform are appropriate** AND the presumed-response amplitude exceeds 250 nV (half Y-axis mark) AND Residual Noise Level 40 nV or less.

- If any **residual noise level** (RNL) is less than 20 nV, given at least 2000 sweeps, a subjective decision about response presence or absence usually may be made with confidence.

Owen (1988)
3. British Columbia guidelines

- reasonable latency (depends on frequency and intensity)
- prominence of peak relative to fluctuations in the remainder of the average
- reproducibility
- peak-to-peak amplitude of supposed response to the residual noise level (should be 3-4 times size of residual noise)
Calibration

ISO 389-6 standard describes method for electroacoustic and biological calibration

Acoustics — Reference zero for the calibration of audiometric equipment —
Part 6: Reference threshold of hearing for test signals of short duration
Calibration

• Regular calibration needed
• Use approved calibration facility to check peak to peak equivalent SPL – do not rely on default manufacturer settings without checking
• Normative reference threshold levels reported by Stapells
  http://www.courses.audiospeech.ubc.ca/haplab/ThreshABR.html

• United Kingdom: NHSP Guidelines for ERA Equipment Calibration
Estimating hearing thresholds from ABR thresholds *correction factor for little ears (≤3 months)

<table>
<thead>
<tr>
<th></th>
<th>500 Hz</th>
<th>1kHz</th>
<th>2kHz</th>
<th>4kHz</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABR threshold</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>dB HL (dial)</td>
</tr>
<tr>
<td>Add 5 dB only for babies ≤ 3 months</td>
<td>55</td>
<td>55</td>
<td>55</td>
<td>55</td>
<td>dB HL</td>
</tr>
<tr>
<td>Correction factor to be subtracted*</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>dB</td>
</tr>
<tr>
<td>Estimated HL (HL)</td>
<td>50</td>
<td>50</td>
<td>55</td>
<td>55</td>
<td>dB eHL</td>
</tr>
</tbody>
</table>

* Subtract these values from air conduction ABR threshold in dB nHL to obtain eHL.

Questions to ask

- What frequency?
- Latency norms?
- System calibrated?
- Is Wave V present or is it noise?
- How old is child – what corrections needed to estimate dB eHL?
- Is this conductive or sensorineural?
Conclusions

• If clinical guidelines are followed behavioural hearing thresholds can be reliably estimated from toneburst ABR thresholds for air and bone conduction
• Specialised training and supervision is recommended to ensure accurate results
• Partnerships between clinicians, calibration labs, manufacturers needed to ensure calibration is appropriate and standardised across clinics
Thank you all for your participation today

謝謝你們今天的參與

sc.purdy@auckland.ac.nz