Identification of Infants and Children with Auditory Neuropathy #2

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What is the impact of Auditory Neuropathy on Clinical Audiology

• Data from several sources indicates that approximately 1 in 10 children with permanent, sensorineural hearing loss and 3 of 1000 children enrolled in an NICU will have Auditory Neuropathy. (30 PubMed in 2006)

Auditory Neuropathy

Typical Profile

• Hearing Loss - sensorineural pattern - any degree
• Poor speech perception *
• Absent or severely abnormal ABR *
• Cochlear Microphonic present
• Otoacoustic Emissions present but sometimes disappear *
• No Acoustic (middle ear muscle) Reflex *

* out of line with degree of hearing loss if cochlear
Speech Awareness Threshold (SAT):
Right Ear = 85 dBHL
Left Ear = CNE

Tympanometry: WNL Bilaterally
Ipsilateral Acoustic Reflex Thresholds:
Absent Bilaterally

Auditory Brainstem Response
Click 80 dBnHL 11/s Insert Earphones

Auditory Neuropathy in Children
< 2 Years of Age
Average Hearing Loss

Auditory Neuropathy
Speech Discrimination re PTA

Neuropathy Speech Discrimination Score
Expected Speech Discrimination Score
Sound is generated by mechanical vibrations. This sets up oscillations of air molecules that propagate through the air and strike the TM.

The Organ of Corti

- Inner Hair Cell: mechanoelectrical transducer to report signal to the brain.
- Outer Hair Cell: mechano-electro-mechanical amplifier that pumps mechanical energy back into the moving basilar membrane.
The electrical polarity change with incoming sound is the source of the Cochlear Microphonic (CM).

Outer Hair Cells contract and expand to amplify local basilar membrane motion. This is the source of the Otoacoustic Emission.
Potential Sites of Lesion in AN
Based on Symptoms

CM present from either IHC OHC or both OAE (outer hair cells) functioning
Inner hair cell function or synapse could be involved.
ABR Wave I Abnormal (Peripheral Auditory Nerve Involved (?))
Drug-induced spiral ganglion cell death: a model for AN

Schmidt et al., 2002 JARO 03:223-233.

Other studies found that Quabain destroys ABR leaving OAE and CM intact.

Wang et al Chin Med J, 2006 119:12, 974 Cochlear function after selective spiral ganglion cells degeneration induced by quabain.


OTOF mutations can explain 3.5% of non-syndromic deafness.

Otoferlin involved in vesicle membrane fusion.

Auditory Nerve

Cross-section of auditory nerve taken post-mortem from a patient with AN. Notice dramatic decrease in number of fibers and evidence of axonal degeneration.
Hair cells and Organ of Corti were found to be intact in this cochlea of a patient with confirmed AN.

How does auditory nerve involvement lead to:

- Poorly formed ABR?
- Poor Speech Perception?
- Absent Acoustic and Olivocochlear Reflex?
Synchrony

Synchrony is exhibited when the timing of nerve spikes is matched (simultaneous) across a population of nerve fibers. In the auditory system the timing is synched with the initiating sound and occurs in populations of primary auditory neurons. Dys-synchrony describes neural activity that is not time-locked to the auditory stimulus. This will happen when conduction properties of the nerve are altered.
Cat ABR with stimulus trigger (top) and with jittered stimulus (bottom). Neural jitter will do the same thing: obliterate the ABR even if activity is present.

**Auditory Brainstem Response in Auditory Neuropathy**

- **Normal ABR**
- **AN ABRs**
- **CM Prominent**
- **Neural peaks absent!**

**Gap Detection**

- Gap duration is varied to determine shortest “perceptible” gap.
- Human gap detection thresholds is 2-3 ms
**Temporal Modulation Measures**

Unmodulated Noise VS Modulated Noise

Moderation depth in dB

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**Psychoacoustic Measures Indicate a Primary Temporal Processing Disorder**


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**Human Speech is Characterized by Rapid Transitions**

“circuits”
Poor encoding of temporal information by a diseased auditory nerve will disrupt speech perception in unpredictable ways!
Clear Speech
Conversational Speech


- Study of children AN (4 - 10.7 years) SNHL and controls.
- Some methodological differences with Zeng.
- Most results similar some discrepant
- Poor temporal resolution as measured by TMTF
  (TMTF correlates with speech perception)
- Near Normal Frequency Resolution
  used a notched noise technique
- Poorest AN subjects (speech) show poor frequency discrim
- Considerable inter-subject variability
Rance et al (as Zeng and others) find TMTF a good predictor of speech perception.

Acoustic Reflex

Olivo-cochlear Reflex

Both involve the auditory nerve which can explain their absence in patients with AN.

How to Handle AN

- Whenever possible start assessment with OAES
- Begin ABR with HF Tone Burst (2 or 4k)
- If NR at highest level
  - Switch to click 80 dB
  - Measure ABR with both polarities
  - Superimpose responses to inspect for CM
- If present CM in either ear OAEs if not done.
- If no CM proceed with TB ABR for threshold.
**IMPORTANT**

- **HEARING THRESHOLDS CANNOT BE DETERMINED FROM ABR WHEN AN IS PRESENT.**
- **BEGIN EARLY INTERVENTION WITHOUT AMPLIFICATION AND WORK TO OBTAIN BEHAVIORAL THRESHOLDS AS QUICKLY AS POSSIBLE!**

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**LM 5 Months Old**

- C-section due to fetal distress
- Multiple blood transfusions
- 10 days in NICU
- Bilateral Refer at birth Screening ABR
- Tested in natural sleep (4 test sessions)

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[Graph showing cochlear microphonics for LM Click LE]
Results from initial test session.
Normal tymps and OAEs were present at that time.
Fit with mild gain amplification. Discontinued use at 9 months.
Making good progress with AVT therapy.
BM 15 Months Old

- 2 months in NICU
- Hx of ventilator support
- Daily Dialysis for congenital kidney condition
- No Birth Hearing Screening
- Several behavioral attempts yielded responses to speech stimuli in the mild hearing loss range
- ABR under sedation
- OAEs present and robust bilaterally
BM- Bilateral AN

<table>
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<tr>
<th>Thresholds</th>
<th>CM</th>
<th>.5kHz</th>
<th>1kHz</th>
<th>2kHz</th>
<th>4kHz</th>
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<tr>
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<td>RE</td>
<td>Present</td>
<td>40 dB</td>
<td>60 dB</td>
<td>90 dB</td>
<td>80 dB</td>
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<tr>
<td>UMB</td>
<td>30 dB</td>
<td>&gt;60 dB</td>
<td></td>
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</tbody>
</table>

Referred to outside provider for behavioral assessment and amplification.
Hx:
Hearing loss identified at age 17 years.
Primary difficulty with speech understanding ability, especially in background noise situations and with multiple speakers.
Developed excellent speech reading skills.
Has tried several hearing aids but reports no significant benefit.
Previous evaluations revealed severe-to-moderate low frequency hearing loss, abnormal ABR, present TEOAEs bilaterally.

Subject: FZ
Age: 27 years

AUDIOGRAM

Age: 27 years
Speech Discrimination:
Right Ear = 40%
Left Ear = 64%

Tympanometry:
WNL Bilaterally
Ipsilateral Acoustic Reflex
Thresholds:
Absent or Elevated Bilaterally

Right Ear
Left Ear
Auditory Brainstem Response
Clicks 80 dBnHL 25/s Insert Earphones
Right Ear

GAP DETECTION

TEMPORAL MODULATION TRANSFER FUNCTION
Subject: KC  
DOB: 10/96  
Age at Exam: 16 months

Hx:
Older brother identified with profound hearing loss.
ABR at 20 days old revealed no response at equipment limits (105 dBnHL).
ABR repeated at 4 months revealed no response bilaterally.
Soundfield audiometry at 4 months old indicated no response at equipment limits.
Hearing aids were fit at 2 months old, however have not been worn consistently. Benefit from amplification is minimal.
Communicates primarily via sign language. Has sign vocabulary of >70 words and can put 3 words together in a sentence.

Speech Awareness Threshold (SAT):  
Right Ear = 85 dBHL  
Left Ear = CNEL

Tympanometry: WNL Bilaterally

Ipsilateral Acoustic Reflex Thresholds:  
Absent Bilaterally
Subject: KC
DOB: 10/96
Age at Exam: 16 months
Auditory Brainstem Response
Click 80 dBnHL 11/s Insert Earphones
Right Ear
Rarefaction
Condensation
Rarefaction & Condensation Overlaid

DOB: 10/96
Age at Exam: 16 months

Subject: LC
DOB: 10/93
Age at Exam: 4 years, 3 months
Hx:
Younger sister identified with profound hearing loss.
Parents suspected hearing loss at approximately 10 months old.
Recurrent otitis media from birth to two years.
ABR evaluation at 1 year old revealed no response bilaterally;
oboaoustic emissions were present bilaterally;
soundfield audiometry was consistent with severe-to-profound hearing loss.
Hearings aids fit bilaterally at 15 months of age;
hearing aid use has been inconsistent.
TEOAEs at 3 years, 10 months revealed absent emissions bilaterally.
Has sign vocabulary of >200 words and can combine 3-4 words in a sentence.

Subject: LC
DOB: 10/93
Age at Exam: 4 years, 3 months
AUDIGRAM
Speech Awareness Threshold (SAT):
Right Ear = 80 dBnHL Left Ear = CNT
Tymanometry: WNL Bilaterally
Ipsilateral Acoustic Reflex Thresholds:
Absent Bilaterally
**Subject: LC**
DOB: 10/93  
Age at Exam: 4 years, 3 months

**Subject: JD**
DOB: 11/94

**Hx:**
Parents suspected hearing loss at 1 year old. ABR at 19 months old indicated bilateral severe-profound hearing loss. Behavioral audiological evaluation at 21 months old consistent with severe-profound hearing loss. Aided bilaterally at 22 months. Minimal benefit from hearing aids - no pattern perception. Oral communication skills did not progress despite consistent hearing aid use/therapy. Oral pre-school program, received speech therapy through school district. Cochlear implant pre-evaluation revealed TEOAEs absent left ear; present right ear. Left ear implanted at 3 years, 3 months old with Cochlear CI24M device utilizing SPEAK processing strategy.
Speech Awareness Threshold (SAT):
Right = 85 dBHL          Left = 85 dBHL
Tymanometry: WNL Bilaterally
Ipsilateral Acoustic Reflex Thresholds:
Absent Bilaterally

Subject: JD
DOB: 11/94

Speech Awareness Threshold (SAT):
Right = 85 dBHL          Left = 85 dBHL
Tymanometry: WNL Bilaterally
Ipsilateral Acoustic Reflex Thresholds:
Absent Bilaterally

Subject: JD
DOB: 11/94

Auditory Brainstem Response
Clicks 11/s  82 dBnHL  Insert earphones
Rarefaction & Condensation Overlaid

Subject: JD
DOB: 11/94

Auditory Brainstem Response
Clicks 11/s  82 dBnHL  Insert earphones
Rarefaction & Condensation Overlaid
Summary

- Audiologic findings in patients with AN include abnormal ABRs, larger than normal CM, sometimes OAEs, poor hearing and speech perception.
- This group of symptoms has many causes but the most common sites of lesion will be the IHC synapse and primary auditory nerve.
- No good evidence of isolated IHC disorder exists for humans.

Thanks for Listening