Bimodal Hearing: A Hearing Aid In Conjunction With A Cochlear Implant

Questions?
For any questions during this broadcast, please send an email to:
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Questions will be answered at the end of the presentation.

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Acoustic Auditory Pathway

Cochlear Implant Function
Cochlear Implant Candidacy
• FDA criteria first set in 1985 for adults
• Severe to profound hearing loss
• Limited benefit from amplification
  – Aided speech perception for sentences
  – <40 to 50% in implanted ear
  – <40 to 60% in “best aided condition”
• Assume loss of residual hearing

Today’s CI Recipients
• Different from earlier implant candidates?
• Expanding criteria
  – Improved outcomes with CIs
  – more patients implanted with more
    residual hearing in the non-implanted ear.
• “Off Label”

Changing Candidacy

Changing Candidacy

Changing Candidacy
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Unilateral Or Bilateral?

Need For Bimodal Stimulation?
- Majority of CI recipients have unilateral implant
- Consideration: Residual hearing in non-implanted ear
- Bimodal Stimulation
  - CI (electrical stimulation) in one ear
  - HA (acoustic stimulation) is used in the contralateral ear

CI & HA Mutually Exclusive?
- Common wisdom...
  - Two different kinds of signals
  - Hearing aid as a crutch?
- Experience with early implant users
  - Dooley et al., 1993
  - Lack of control of two independent devices
- Pitch or loudness mismatch
- Binaural interference
Why Bilateral Stimulation?

- Auditory system is designed to work with two sources of auditory input
- How long have binaural HAs been standard of care?
- Binaural advantage
  - Redundancy/summation
  - Head shadow
  - Binaural squelch

Benefits Of Binaural Hearing

- Binaural = input from both ears and coordination by the nervous system
- Sound localization
- Improved speech perception in quiet and/or noise
- Less listening effort
- “Naturalness” of sound

Why Does One Need Two?

- CI does not restore normal hearing
- Impact of unilateral deafness
  - Educational difficulties 10 x more likely
  - Increased chance of behavioral problems
  - Risk for speech-language delays
  - Difficulty hearing in noise and tracking conversation in groups
  - Poor localization abilities
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**Neuro-Biological Effects**
- Auditory deprivation effects
  - Retrograde degeneration
  - Auditory neurons and cortex
- Effects on binaural pathways
  - More extensive morphological changes than for bilateral loss
  - Imbalance in structures that receive binaural projections

**Bimodal Stimulation**

**CI And Contralateral HA**
- Growing body of research supports benefit of combining acoustic and electric stim
- Most listeners can integrate the two
  - Potential to restore some binaural auditory functions
  - Even if hearing aid has not been used for a longer period of time
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**Bimodal Stim vs. One CI Only**
- If recipient has residual hearing in non-implant ear...
  - Improved speech understanding in noise
  - Improved localization ability
  - Less listening effort
  - More “natural” sound quality
  - Improved “distinctiveness of voices”
  - Music perception/enjoyment/appreciation

**Bimodal Stim & Localization**
- Many subjects demonstrate improved horizontal localization ability in the bimodal condition vs. CI alone condition
- High degree of variability across individuals

**Benefits Of Low Frequencies**
- Is there a minimum amount of residual hearing needed to benefit from CI + HA?
- Enough residual hearing for speech perception with HA alone is NOT necessary
- Greatest increment of benefit from adding frequencies below 125 to 300 Hz
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**Benefits Of Low-Frequencies**
- Low-freq information is not well transmitted by cochlear implants
- “Complementarity” of acoustic signal
  - F0 and F1
  - Pitch cues & voice segregation
  - Formant transitions
  - Information about voicing and manner

**Low Frequency Acoustic Information**
- Zhang et al., 2010
- Buchner et al., 2009

**Typical Pattern Of Test Findings**
- Firstz, Reeder, & Skinner (2008)
- Speech perception - monosyllable words
- CI + HA is better than CI or HA alone
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Bimodal Studies - Speech Perception
- Gifford et al. (2007)
  - 11 adults with significant residual low-frequency hearing
  - Bimodal benefits in quiet and noise

Cost Effectiveness Rationale
- Compared to bilateral CI, it is less expensive & less invasive
- Is bimodal function as good as function with binaural CI?
  - Schafer et al., 2007
- Limited resources scenario: provide unilateral CIs to more patients vs. bilateral CIs to fewer patients.

Bimodal Trend
Growing percentage of CI recipients using a hearing aid in the non-implant ear
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Bimodal Stimulation

- Most CI recipients can integrate electric and acoustic input
- Some kind of device should be considered for the second ear of all unilateral implant recipients
- Results will obviously be more limited with minimal residual hearing

Bimodal Protocol?

- Special considerations?
- Independent or interdependent?
- No widely accepted protocol or practices
- Some published recommendations
  – Ching et al., 2004
  – Mok et al., 2006
  – Ullauri et al., 2007
  – Kielman et al., 2010

Ching Et Al.(2004) Procedure

- 2-step procedure:
  – Paired comparisons between frequency responses to determine preferred one for speech
    • NAL-RP
    • More low-freq gain
    • Less low-freq gain
  – Loudness balancing procedure
    • Adjust overall HA gain
    • Compare HA to CI loudness
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**Alternative Frequency Response**

<table>
<thead>
<tr>
<th>Gain by Frequency</th>
<th>250 Hz</th>
<th>500 Hz</th>
<th>1000 Hz</th>
<th>2000 Hz</th>
<th>4000 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Freq Boost</td>
<td>+7 dB</td>
<td>+4 dB</td>
<td>+0 dB</td>
<td>-6 dB</td>
<td>-12 dB</td>
</tr>
<tr>
<td>NAL</td>
<td>NAL gain</td>
<td>NAL gain</td>
<td>NAL gain</td>
<td>NAL gain</td>
<td>NAL gain</td>
</tr>
<tr>
<td>Low Freq Cut</td>
<td>-11 dB</td>
<td>-5 dB</td>
<td>-1 dB</td>
<td>+5 dB</td>
<td>+8 dB</td>
</tr>
</tbody>
</table>


**HA Fitting Considerations**

- **Ching et al. (2004):**
  - greater bimodal benefit (speech perception and localization) when HAs were fine-tuned or “optimized”
  - Start with NAL-RP and compare to alternate frequency responses
  - balance loudness for live speech

**Desired Sensation Level (DSL)**

- Focuses on audibility of speech signal
- Allows visualization of audibility low-frequency component
- Does not require input from patient
- Has not been directly compared to NAL-RP in study with bimodal users
- Keilmann et al., 2010; Park et al., 2012
Keilmann Et Al. (2010) Procedure

- Hearing aid set with DSL prescriptive method
- CI and HA optimized separately, then tested together
  - Speech audiometry
  - Loudness scaling
- Procedure not well-detailed
**Bimodal Fitting Procedure**
- Differing procedures are in use
- Most studies of bimodal stimulation demonstrate a benefit
- Loudness balancing may be difficult to perform
- Further study is needed to determine if there is a “best” procedure

**Bimodal Stimulation**

**Case Example: Adult Patient**

**Case Example: Background**
- Female
- First seen at age 53
- Progressive loss, unknown etiology
- Explored multiple options
  - Conventional amplification
  - Frequency compression
  - FM
- Difficulty communicating well enough to perform her job in sales
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**Audiometric History**

[Graph showing audiometric history with data points]

**Aided Speech Perception**

<table>
<thead>
<tr>
<th>Tests Administered</th>
<th>CNC Words: Phonemes</th>
<th>HINT Sentences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scores by Test Condition</td>
<td>Right Aid</td>
<td>Left Aid</td>
</tr>
<tr>
<td>CNC Words</td>
<td>DNT</td>
<td>DNT</td>
</tr>
<tr>
<td>HINT Sentences</td>
<td>45%</td>
<td>66%</td>
</tr>
</tbody>
</table>
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1 Month Post-Op

Thresholds: CI & Left Ear

Speech Audibility
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Speech Audibility

- Audibility of speech spectrum up to ≈1800 Hz.
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Pre-CI vs. Post-CI

Current Speech Perception

Patient Comments

• “I don’t even ask for assistive listening devices any longer. It just doesn’t occur to me like it used to...”

• “I need both the CI and the hearing aid for the best clarity of speech...”
Bimodal Stimulation

Case Example: Pediatric Patient

Background

- Female, first seen at age 3;9
- Family primarily Spanish speaking
- Concerns for unintelligible speech
- Hx of 2 previous audiograms WNL
- DPOAEs absent 1500-8000 Hz, bilaterally
- Initial ABR indicated severe to profound bilateral hearing loss

Behavioral Audiogram
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Amplification Fitting

- No high-frequency audibility
- Based on “estimated” thresholds

CI Candidacy Evaluation

- No Response

CI Right at Age 4:6
Benefit from Bimodal Stim?

Aided Audibility

- Audibility of LTASS up to above 1.1 - 1.5 kHz
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CI and HA

First Year Post-Op CI

- Consistent use of CI and HA
- Subjectively performs better bimodally than CI alone
- Total Communication program in school
- English skills surpassing Spanish
- Progress in auditory skills per ESP

Auditory Skills Development
Summary

- Cochlear implants do have application in patients with residual hearing.
- Acoustic signal from a hearing aid can be used to supplement the electrical signal from a cochlear implant.
- Bimodal benefits may show up best in noisy listening situations.

Summary

- Subjects report on “real-life” advantages (even those with no measurable speech perception benefit).
- HAAs may need to be adjusted to optimize performance.
- Bimodal benefits may be immediate or may evolve over time.
- Even patients who have not used amplification for a few years may receive bimodal benefit.

Summary

- Research suggests that bimodal fitting should be considered for patients with CIs who have useful residual hearing in the non-implanted ear.
- Bimodal stimulation is recommended for patients with residual hearing and good HA performance in non-CI ear, those who want to restore binaural hearing and all young children.
References


References


References


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References

- Zhang T, Dorman MF, Spahr AJ. (2010). Information from the voice fundamental frequency (F0) region accounts for the majority of the benefit when acoustic stimulation is added to electric stimulation. Ear & Hearing, 31, 63-69.

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