Vanderbilt Audiology’s Journal Club: Effects of Hearing Preservation for Cochlear Implant Outcomes

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Expert e-Seminar

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Effects of Hearing Preservation for Cochlear Implant Outcomes

René H. Gifford, PhD
A few examples of “Bill’s Bar”

What’s the connection between “Bill’s Bar” and audiology?

A. Standard for the highest background noise SPL allowed on space shuttle
B. Bony shelf which is landmark in nVIII surgery
C. Narrow strip of the amygdala important for processing speech-in-noise
D. The term “BILL processing” (for hearing aids) was coined in Chicago’s Bill’s Bar
E. C.C. Bunch and Ray Carhart did Fuzzy Navel shots together in Chicago’s Bill’s Bar

The real “Bill’s Bar”

Fig. 1: CT, axial. Internal auditory canal. The bony-shaped structure protruding into its anterior fundus at this level is “Bill’s bar” named after Dr. William House. The facial nerve canal starts just anterior to Bill’s bar, and the short canal for the
Dr. William F. House, Inventor of Pioneering Ear-Implant Device, Dies at 84.

Photo from 1981

Ben Hornsby: 20 Years at Vandy!

4/30/2013
Has René experienced the "Hornsby Effect?"

THEN

NOW

Effects of Hearing Preservation for Cochlear Implant Outcomes

René H. Gifford, PhD

Early CI Patient

level (dB HL)

frequency (kHz)
Modern CI Patient

Modern CI Patient?

HA? CI? MEI? EAS/Hybrid?

- difficult to fit
- Vinay & Moore (2007):
  - 592 ears
  - For thresholds > 70 dB HL, 59% had dead regions
Conventional Cochlear Implant

Legend:
- Apex
- Base
- 500 Hz
- 1073 Hz
- 1483 Hz
- 2037 Hz
- 2777 Hz
- 3770 Hz
- 5100 Hz
- 6683 Hz

Combined Electric and Acoustic Hearing

Legend:
- Apex
- Base
- 500 Hz
- 1073 Hz
- 1483 Hz
- 2037 Hz
- 2777 Hz
- 3770 Hz
- 5100 Hz
- 6683 Hz

Cochlear Implants: Hearing Preservation

- Traditionally, any residual hearing would have been sacrificed during surgery.
- We are now seeing significant hearing preservation both with short and long electrode arrays.
Minimally traumatic surgery

- Cochleostomy location & size
- RW insertion
- Opening endosteum
- Hyaluronic acid (Healon®)
- Perilymph
- Insertion force and speed
- Steroids
  - Pre-, peri- and/or post-implant

Atraumatic electrodes

CI422

1. Surgical handle located opposite of the electrode contacts to assist with electrode orientation and atraumatic insertion
2. White marker at 25mm indicates maximum insertion depth
3. Tapered basal diffuser designed for smooth, single motion insertion and minimization of buckling
4. White marker at 20mm indicates end of the active portion of the electrode array
5. Base diameter 0.6mm
6. 22-micron lacing, half-bonded platinum electrode contacts, positioned over 25mm
7. Apical diameter 0.3mm
8. Suture for minimal insertion trauma

Atraumatic electrodes

- Standard
- Flex20
- Flex50
- Flex70

Multifrequency insertion

- Insertion depth range

<table>
<thead>
<tr>
<th>Standard</th>
<th>Flex20</th>
<th>Flex50</th>
<th>Flex70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insertion depth range</td>
<td>Insertion depth range</td>
<td>Insertion depth range</td>
<td>Insertion depth range</td>
</tr>
</tbody>
</table>
Atraumatic electrodes

Hybrid S8
Hybrid S12
Hybrid L24

Skeptics

Hearing preservation doesn’t matter because...
– The hearing is useless anyway.
– My patients do well.
– Surgery takes more time...
  – and it’s more difficult.
– Patients will lose hearing over time.
– We are setting ourselves up for failure.

Research Questions

Does HP improve speech recognition in realistic listening environments (e.g., diffuse noise and reverberation)?
Rader et al. (2013). Ear Hear. 34:324-32.

- n = 44
- Normal-hearing control (n = 22)
- Bilateral CI (n = 10)
- Hearing preservation (n = 12)
  - 11 FLEX\textsuperscript{eas}
    - Now marketed as the Flex 24
  - 1 FLEX 20
  - straight electrodes

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**Speech Perception With Combined Electric-Acoustic Stimulation and Bilateral Cochlear Implants in a Multisource Noise Field**

Tobias Rader,\textsuperscript{1} Hugo Froeh,\textsuperscript{1} and Uwe Brumme\textsuperscript{1}

**Background:** The aim of the study was to compare and contrast speech perception and tone identification scores of electric-acoustic stimulation (EAS) exposed to a hearing aid in the nonimplanted ear and a bilateral cochlear implant (BCI) using speech stimuli and multisource noise conditions. The study investigated the effects of different stimulus combinations on speech perception and tone identification abilities in normal-hearing subjects and patients with hearing loss.

**Methods:** Speech perception in noise was measured using a closed-set speech-in-noise test. The stimulation format (EAS) consisted of a 10-msec tone burst, with independent stimulus rates and single-electrode (FLEX\textsuperscript{eas}) or multiple-electrode (FLEX 20) stimulation. The speech-in-noise thresholds were measured for the AC and CI ears using different noise levels.

**Results:** Average speech perception thresholds in the CI group were significantly better than those in the EAS group.

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**Introduction:** Electric-acoustic stimulation (EAS) with hearing preservation is a two-implant form of CI with an internal microphone that allows for a more natural hearing experience. It was introduced by von Klugkist et al. (2018) as a consequence of improved hearing preservation with a microelectrode array design. This configuration is less invasive and enables better sound quality compared to traditional CI systems.

**Results:** Average speech perception thresholds in the CI group were significantly better than those in the EAS group.
Experimental details

- 2 noise conditions
  - S\textsubscript{0}N\textsubscript{0}
  - multi-source noise field
    - MSNF
    - 4-loudspeakers
      - ±45° and ±135°
  - Noise fixed:
    - 75 dB SPL for NH listeners
    - 65 dB SPL for CI listeners
LIMITATIONS

• Only tested the "best" condition for the EAS subjects
  
  • Did they need the hearing in the CI ear to achieve this level of performance?
  
• Small sample of both bilateral and EAS subjects

Research Questions

Does HP improve speech recognition in realistic listening environments (e.g., diffuse noise and reverberation)?

If so, what underlying mechanism may be responsible for the HP-related benefit?
Gifford et al. (2013). Ear Hear.

- n = 54
- Normal-hearing control (n = 16)
- Polish speaking (n = 17)
  - 17 Med El EAS
- English speaking (n = 21)
  - 2 Med El Sonata H
  - 2 Med El EAS
  - 10 Hybrid (6 S8, 4 L24)
  - 7 Nucleus 24 series or later [CI24RCA, CI24RE(CA), CI512]
    - Both short and long electrodes

LF PTA: 20-dB loss for both groups

CNC (% words)

n = 22
**Experiments**

- Restaurant simulation (8 loudspeakers)
  - Adaptive SNR, noise at 72 dBA
  - Fixed level SNR (+6 and +2 dB)
    - Polish: PMST
    - English: HINT
- Reverberant sentence recognition
  - 0.6 sec
  - AzBio & PSMT at 60 dBA
- ITD thresholds, acoustic only
  - $f_s = 250$ Hz

**Listening Conditions**

- Best aided EAS
  - CI + HA
  - HA

- Bimodal
  - CI + HA
  - NAL-NL1
  - HA verification
Adaptive SNR
Speech reception threshold (SRT)

\[ F_{1, 37} = 21.1 \ p < 0.001 \]
n = 9 S8 Hybrid

Fixed SNR, +6 and +2 dB
% correct
Reverberant Speech Recognition

\[ R_{T60} = 0.6 \text{ sec} \]

\[ \% \text{ correct} \]
Summary: noise & reverberation

- Preservation of acoustic hearing → significant benefit
- ~ 2.0 dB improvement in SNR for SRT
  - 6- to 12-percentage points (fixed-level noise & reverberation)

What is the underlying mechanism for the EAS-related benefit?

Preservation of both hearing and binaural cues?
Interaural time differences (ITDs)

- most prominent < 1500 Hz

Do hearing preservation patients have preserved ITD cues?

ITD thresholds

- $f_s = 250$ Hz
  - 200 ms
- level = 90 dB SPL (10 to 40 dB SL)
- 2 down, 1 up tracking
  - 70.7% correct
- TASK: lateral position change

6 subjects in paper
12 subjects run to date!

SRT benefit (dB) vs. ITD
Is it a simple answer?

Do those with the best preserved hearing have the best ITD thresholds?
Multiple regression

**Dependent variable:** ITD threshold

**Independent variables:** LF PTA in CI ear and non CI ear

**Multiple regression**

Which variables contribute?

- LF PTA CI ear ($r^2 = 0.67$): $t = 3.04$, $p = 0.014$
- LF PTA non-CI ear ($r^2 = 0.39$): $t = 0.92$, $p = 0.38$
Those with better preop hearing tend to have the best preserved hearing and:

- Lowest (best) ITD thresholds
- Greatest degree of HP-related benefit

LIMITATIONS

- Bimodal condition with CI ear occluded was an acute condition
- Small sample for subjects in the ITD experiment

What needs to be done to ensure best hearing preservation?
Commodore Cornelius Vanderbilt

Commodore Vanderbilt Steamship (circa 1860)

Nice Job, Gunesh!
Rajan et al. (2012). Laryngoscope, 122: 190-195

• Prospective interventional study

• n = 34
  • All patients presenting for CI with measurable audiometric thresholds

• FLEX\textsuperscript{es} (n = 9) or FLEX\textsuperscript{soft} (n = 25)
  • 12 of the 25 FLEX\textsuperscript{soft} were in the "interventional" group

CONTROL group
• intravenous dexamethasone 4 mg
• Minimally traumatic surgery
• RW insertion

INTERVENTIONAL group
• intravenous dexamethasone 4 mg
• Minimally traumatic surgery
• RW insertion
• After intubation: transtympanic injection of 0.6 mL of methylprednisolone into the middle ear.
• Everything else consistent
Rajan et al. (2012)

TABLE II.
Our Proposed Classification System to Categorize Postoperative Hearing Preservation Rates for Comparison.

<table>
<thead>
<tr>
<th>Loss of Hearing after Implantation (Bone Conduction in dB)</th>
<th>Level of Hearing Preservation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10 dB</td>
<td>Level 1 (Complete Hearing Preservation)</td>
</tr>
<tr>
<td>10–30 dB</td>
<td>Level 2 (Partial Hearing Preservation)</td>
</tr>
<tr>
<td>&gt;30 dB</td>
<td>Level 3 (Minimal Hearing Preservation)</td>
</tr>
<tr>
<td>Complete loss of Hearing</td>
<td>Level 4 (Failure)</td>
</tr>
</tbody>
</table>
LIMITATIONS

- Study not conducted as a RCT
- Relatively small sample
### CONCLUSIONS

- Hearing preservation → better performance in complex listening environments
- Degree of preserved hearing impacts degree of EAS benefit
- Intratympanic steroid use → better rates of hearing preservation

### CONCLUSIONS

- Patients with best hearing preservation also have preserved binaural cues
  - ITD cues
  - CI ear best explains ITD thresholds…
  - …but those with better non-CI ear hearing tend to have better CI ear hearing

### QUESTIONS

- How much preserved hearing is needed?
- Amplified bandwidth?
  - More attention to LF amplification?
  - Targets for 125 Hz?
- Do patients really use binaural cues?
  - HAAGC → disrupt ILD and ITD cues?
  - Unilateral CI → disrupt ILD cues?
- Timing disruption b/tw electric and acoustic stimuli delivery?
Audiologic management of individuals with hearing preservation

Audiologic management

CI + HA

HA

Equipment check, otoscopy, real-ear measures, loudness balancing across ears, speech recognition, audiometry (if needed), device orientation counseling

Degree of electric & acoustic overlap?
Strictly judged by audiogram (slope/severity) or individual preferences?