Update on Asymmetric and Unilateral Hearing Loss Studies: What Have We Learned?

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Disclosures

• Financial:
  — Employed by WUSM—salary
  — NIH (research funds)
  — Cochlear Americas, Advanced Bionics (consulting relationship and audiology advisory board member, research funds)

• Nonfinancial:
  — Serve as treasurer for the American CI Alliance (ACIA)
Overview of Presentation

- Case Study
- Unilateral Hearing Loss (UHL) (No CI)
- Effects of UHL/AHL from listener perspective
- Asymmetric Hearing Loss (AHL) (With CI)
- Primary focus today: Speech recognition in noise and Localization
- Variables: Length of deafness & Age at onset
Individual Subject (S11)

• Hearing history
  - Mumps age 7 yrs, profound HL (LE)
  - Acoustic neuroma age 47, profound HL (RE)
  - 1 mo later, CI in LE, the ear without direct peripheral stimulation for 40 years
Word and Sentence Recognition
In Quiet

Word and Sentence Recognition
In Noise

Firszt et al, 2002
EABR
El #1
100% of DR
All subjects

Firszt et al, 2002
EMLR
EI #1
100% of DR
All subjects

Firszt et al, 2002
El N1-P2
El #1
100% of DR
All subjects

Firszt et al, 2002
Individual Subject (S11)

- Did having sound in one ear help to maintain the opposite poor ear for a good outcome?
- Was having hearing in both ears until age 7 and establishing binaural pathways the main reason?
Studies underway at WUSM/SLCH

We are studying several patient populations with varied asymmetry between ears

- All have one deaf ear, rely on one better ear
- All are unilateral listeners

Normal or Near-normal hearing

Some hearing loss
Uses amplification

Severe to profound hearing loss
Uses Cochlear implant

Better Ear

Poor Ear
We Hear with Our Brain, Not Just Our Ears

• Contrast of
  – Bilateral normal hearing
  – Bilateral hearing loss
  – Asymmetric hearing loss
Normal Hearing

Results in

- Stronger contralateral activation (opposite side) (dark colors)
- Weaker ipsilateral activation (same side) (light colors)
Symmetric HL

Results in

• Reduced overall activation
• Similar balance remains
  — Stronger contralateral
  — Weaker ipsilateral
Unilateral HL

Results in
• Loss of balance
• Stronger ipsilateral
• Altered binaural interactions
• Creates aural dominance
UHL Adults
Unilateral Hearing Loss (UHL) Study in Adults

Purpose:

• Quantify auditory deficits in adults with UHL
  – Need to quantify when considering treatment
• Identify sources of variability in outcomes
• Compare results with NH bilateral listeners
• Compare results with NH unilateral listeners
  – Introduce the condition of UHL acutely

UHL Study

Participants

- Adults with UHL
  - Tested with one NH ear
- NH matches for each UHL participant (age and gender)
  - One NH match tested with one ear (other ear plugged & muffled)
    - NH-Plugged
  - One NH match tested with both ears
    - NH-Bilateral

*Firszt et al, 2017, in press*
## UHL Study – Demographics

<table>
<thead>
<tr>
<th></th>
<th>Mean (SD) Range</th>
<th>Age (years)</th>
<th>PTA (dB HL) from .25-8 kHz (tested ears)</th>
<th>PTA (dB HL) from .25-8 kHz in deaf ear</th>
<th>Age Onset SPHL (years)</th>
<th>Length of Deafness (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UHL (n=26)</td>
<td></td>
<td>49.1 (12.9)</td>
<td>13.2 (7.1) 0.0 – 29.3</td>
<td>110.2 (10.5) 78.3 – 121.3+</td>
<td>27.3 (22.7) 0 - 61</td>
<td>21.9 (21.8) &lt;1 - 72</td>
</tr>
<tr>
<td>NH - Plugged (n=25)</td>
<td></td>
<td>48.8 (13.7)</td>
<td>11.8 (11.8) 3.0 – 23.1</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>NH - Bilateral (n=23)</td>
<td></td>
<td>49.7 (11.6)</td>
<td>12.2 (12.2) 2.5 – 26.1</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

*Firszt et al, 2017, in press*
UHL Study

Test Protocol addressed two known deficits

• Listening in noise
• Localization
HINT Sentences in Restaurant Noise

R-Space™

- 8 loudspeakers surround the listener
- Sentences from the front
- Restaurant noise from all loudspeakers
- Adaptive measure: Noise at 60 dB SPL, speech level is varied
- Participants repeat the sentence
- SNR-50 score (SNR at which the patient scores 50% correct)

Illustration from Revit et al, 2002
Lower is better

HINT Sentences in R-Space™

SNR-50 (dB)

UHL  NH-plugged  NH-bilateral

NH significantly better; no difference in Unilateral groups

Firszt et al, 2017, in press
Localization Methods

• CNC words (100) presented randomly via loudspeaker array
• 15 speakers; 10 active, 5 inactive
• 140 degree arc, speakers 10 degrees apart
• Roved at 60 dB SPL (+/- 3 dB)
• Asked to identify word and speaker location
Localization Methods

- Identify loudspeaker location
- Localization ability was scored as degrees of error (RMS) between source loudspeaker and participant response (0° = perfect localization)

Scored as degrees of error (RMS)
10° between each speaker
Localization

Lower is better

RMS error (degrees)

A - Total Loudspeaker Array

NH
significantly
teacher;
Unilateral
groups differ

UHL  NH-plugged  NH-bilateral

Firszt et al, 2017, in press
Localization Based on Side of Presentation

Loudspeakers on Good Side

Loudspeakers on Poor Side

Firszt et al, 2017, in press
Result

• NH considerably better than either unilateral group—need NH norms for all measures

• UHL affected localization differently than listening in noise
  – Localization better for UHL than NH-plugged
  – R space results show no differences between unilateral groups
Effects of Experience with UHL

Among the UHL participants:

• 9 had recent onset of SPHL (onset within 3 yrs of study)
  – Recent AAO

• 8 had childhood onset of SPHL (onset by 3 yrs of age)
  – Young AAO
Localization by Age at Onset

Total loudspeaker array

RMS Error (degrees)

Lower is better

Recent AAO
Young AAO

Firszt et al, 2017, in press
HINT Sentence in R-Space by Age at Onset

Firszt et al, 2017, in press
Result

• Localization better for Young AAO versus Recent AAO
  – Those with early onset of SPHL in one ear appear to have learned strategies to improve localization but this did not transfer to speech understanding in noise
Effects of Training

• If experience helps with localization, can training improve localization ability in those with UHL?
  – Pilot study with 11 adults with UHL, 5 training sessions
  – Assessed pre and post training with three stimuli

Pre- and Post-Training Results

Lower is better

Error bars = +/- 1 SEM

Firszt et al, Hear Res, 2015
Localization Training

Mean Reported Location (degrees azimuth)

Words  Spectral RSS  Temporal RSS

Pre-training  Post-training

Source Location (degrees azimuth)

error bars = ± 1 standard deviation
*p < 0.05, **p < 0.01, ***p ≤ 0.001

Firszt et al, Hear Res, 2015
Result

• Pre and post-training results showed improvement

• Considerable individual variability

• Future work
  – Are some individuals predisposed to have better localization or to benefit more from training?
  – Does training generalize to everyday situations?
UHL Children
Introduction

• Aims of pediatric study:
  – Identify abilities of children with UHL on measures that address known deficits, and quantify deficits on these measures
  – Investigate sources of variability
  – Compare performance and variability to gender matched peers of similar ages

# UHL Children and NH Matches

<table>
<thead>
<tr>
<th>Mean (Range)</th>
<th>Age at Test (years)</th>
<th>Unaided FF PTA (dB HL)</th>
<th>Age SPHL Onset (years)</th>
<th>Length of Deafness (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UHL</strong> (n = 20)</td>
<td>12.0 (6.9 – 16.3)</td>
<td>100.8 (61 – 120+)</td>
<td>6.6 (-2 – 20)</td>
<td>1.0 (0.0 – 7.9)</td>
</tr>
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<td><strong>NH</strong> (n = 20)</td>
<td>12.0 (7.5 – 17.8)</td>
<td>4.2 (0 - 17)</td>
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*Reeder et al, Audiol Neurotol, 2015*
# UHL Children and NH Matches

<table>
<thead>
<tr>
<th>Mean (Range)</th>
<th>Age at Test (years)</th>
<th>Unaided FF PTA (dB HL) Poorer Ear</th>
<th>Better Ear</th>
<th>Age SPHL Onset (years)</th>
<th>Length of Deafness (years)</th>
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<td><strong>UHL</strong> (n = 20)</td>
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<td>9.7 (0.3 – 15.3)</td>
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<td><strong>UHL</strong> (n = 11)</td>
<td>10.5 (6.9 – 13.4)</td>
<td>95.2 (61 – 120+)</td>
<td>5.9 (-2 – 20)</td>
<td>1.3 (0.0 – 7.9)</td>
<td>8.2 (0.3 – 12.1)</td>
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</tbody>
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<tr>
<th>Mean (Range)</th>
<th>Age at Test (years)</th>
<th>Unaided FF PTA (dB HL) Right Ear</th>
<th>Left Ear</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NH</strong> (n = 20)</td>
<td>12.0 (7.5 – 17.8)</td>
<td>4.2 (0 - 17)</td>
<td>4.9 (-1 – 16)</td>
</tr>
<tr>
<td><strong>NH</strong> (n = 10)</td>
<td>10.4 (7.5 – 15.5)</td>
<td>4.4 (0 – 17)</td>
<td>4.7 (-1 – 12)</td>
</tr>
</tbody>
</table>

*Reeder et al, Audiol Neurotol, 2015*
Mean NH Adults = -5 dB

Reeder et al, Audiol Neurotol, 2015
Localization

Lower scores are better

RMS Error (degrees)

<table>
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<tr>
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<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>UHL (n = 11)</td>
<td>28.1°</td>
<td>13.5°</td>
</tr>
<tr>
<td>NH (n = 10)</td>
<td>6.0°</td>
<td>3.7°</td>
</tr>
</tbody>
</table>

*** p < 0.001

Mean NH Adults = 3 degrees

Reeder et al, Audiol Neurotol, 2015
Result

• Results poorer for UHL than NH - most measures

• Considerable variability on all measures with UHL
  – Some UHL children had scores within the range of NH children

• Localization – older children performed better, had more experience. No relation to listening in noise

• Low frequency hearing in the better ear correlated with listening in noise but only for UHL children— a few dB may have a greater impact for UHL than NH
Listener Perspective

How do adults with asymmetric hearing perceive their hearing and communication abilities?

Participants

UHL group (n=30)  One deaf ear
- Mean PTA 13 dB HL (0 - 27 dB HL)
- Mean age 51 yrs (25 - 76 yrs)

Cl group (n=20)  One deaf ear
- Mean PTA 20 dB HL with Cl (13 - 33 dB HL)
- Mean age 53 yrs (33 - 75 yrs)

HA group (n=16)  One deaf ear
- Mean PTA 40.0 dB HL with HA (29 - 52 dB HL)
- Mean age 60 yrs (26 - 77 yrs)

NH group (n=21)
- Mean bilateral PTA 10 dB HL (4 - 23 dB HL)
- Mean age 50 yrs (27 - 73 yrs)
Speech, Spatial and Qualities of Hearing Scale (SSQ)

- 49-item questionnaire designed to evaluate the effects of hearing loss in terms of function
- Uses a 10-point scale (0-10), where “0” indicates great difficulty and “10” indicates no difficulty
- Focus on realistic, daily life communication functioning

(Gatehouse and Noble 2004)
Three SSQ Domains

**Speech Domain**

- You are in a group and the conversation switches from one person to another. Can you easily follow the conversation without missing the start of what each new speaker is saying?

**Spatial Domain**

- Can you tell how far away a bus or a truck is from the sound?

**Qualities Domain**

- Can you easily judge another person’s mood from the sound of their voice?
Ten Subscale Analysis
Gatehouse and Akeroyd (2006)

SiQ = speech in quiet
SiN = speech in noise
SiSCont = speech in speech contexts
MultStream = multiple speech stream processing and switching
Loc = localization
DisMov = distance and movement
SegSnds = segregation of sounds
IdSnd = identification of sound and objects
Qlty = sound quality and naturalness
Eff = listening effort
Results – Speech

Dwyer et al, Ear Hear, 2014

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Results – Spatial Hearing

Dwyer et al, Ear Hear, 2014

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Results – Qualities of Hearing

* p < 0.05, ** p < 0.01, *** p < 0.001

Dwyer et al, Ear Hear, 2014
Result

• The 3 groups with one deaf ear, did not differ in their perceived hearing disability for 6 of 10 subscales

• In other words, NH in only one ear was as disabling as listening with a unilateral CI or a unilateral HA

• Adults reliant on a single ear, irrespective of the mode of hearing, report difficulties in many aspects of everyday listening and communication
Parent Perspective

How do parents rate the abilities of their children with UHL when listening in everyday situations?

Reeder et al, 2015, Audiol Neurotol
(Pediatric) Speech, Spatial, and Qualities of Hearing Scale (SSQ)

Pediatric SSQ: Galvin et al 2007

Reeder et al, 2015, Audiol Neurotol
Result

• Parents ratings for UHL significantly poorer than ratings of children with NH

• Among UHL, Qualities ratings highest (7.2), followed by Speech (6.2) and then Spatial (4.3)
  – Similar pattern to that of UHL Adults (Qualities 6.5, Speech 5.5, Spatial 3.6)

• Parents report their children have difficulties in real-world environments
Asymmetric Adults: Treatment with CIs
Adult Asymmetric Hearing Loss Study

- What is the relation between length of deafness & use of a hearing aid in the poorer ear and outcomes with a CI?
  - Speech Recognition in Quiet
  - Speech Recognition in Noise
  - Localization
Study in Adults with Asymmetric Hearing Loss

• All have:
  • One poorer ear that meets CI criteria, the poorer ear is implanted
  • One better ear that uses a hearing aid (HA)
  • N = 24
    – 20 = Postlingual
    – 4 = Prelingual
Group Demographics
Postlingual Participants (n = 20)

• HA use
  • Better ear -- All wore a HA
  • Poor ear
    – 11/20 had never worn a HA
    – 9/20 had worn a HA for some time
      • Only 3/9 were wearing a HA at the time of implantation
Unaided Hearing Thresholds

Poorer Hearing Ear

Better Hearing Ear

Frequency (Hertz)

Hearing Level (dB)

ANSI - 2004
Implanted/Aided
Sound-field Thresholds

**Poorer Hearing Ear**
CI SF Thresholds

**Better Hearing Ear**
HA SF Thresholds

[Graphs showing hearing level (dB) across different frequencies (Hertz).]
Speech Recognition-Postlingual (n=20)

CNC Word Scores

Average Percent Correct

Pre-Implant 6 months

Poorer/CI Ear
Better/HA Ear

Note: Protocols to optimize fitting of HA and CI prior to testing

When testing CI ear, Better ear is plugged and muffed
Adaptive HINT in Restaurant Noise: R-Space (n=20)

Mean NH Adults = -5 dB

Error bars = + 1 SEM; **p < 0.01; ***p < 0.001
Localization (n=20)

Mean NH Adults = 3 degrees

Error bars = + 1 SEM; **p < 0.01; ***p < 0.001
SSQ (n=20)

Greatest Ability

speech

Spatial

Qualities

Least Ability

Pre-Implant 6 months

Average Rating

*** (all sections)

***

**

*
## Individual Demographics

### Pre/perilingual Participants

<table>
<thead>
<tr>
<th>AAI</th>
<th>Etiology</th>
<th>AAO HL (P/B)</th>
<th>Age Began HA Use (P/B)</th>
<th>Duration SPHL CI Ear</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>28</td>
<td>High Fever</td>
<td>3/3</td>
<td>Never/3</td>
</tr>
<tr>
<td>P2</td>
<td>28</td>
<td>Unknown/EVA</td>
<td>birth/23</td>
<td>Never/28</td>
</tr>
<tr>
<td>P3</td>
<td>26</td>
<td>Meningitis</td>
<td>7m/7m</td>
<td>Never/1</td>
</tr>
<tr>
<td>P4</td>
<td>43</td>
<td>Unknown</td>
<td>birth/birth</td>
<td>3**/3</td>
</tr>
</tbody>
</table>

**Stopped wearing HA in poor ear 10 years prior to CI**
Pre-Lingual Results: CNC Words

CNC Words (60 dB SPL)

Test Interval

Percent Correct

P1

P2

P3

P4

Poorer/CI Ear
Bimodal
Better/HA Ear
Pre-Lingual Results: HINT Sentences

HINT Sentences in Noise

Percent Correct

Test Interval

Poorer/CI Ear
Bimodal
Better/HA Ear
Pre-Lingual Results: Localization

Localization

Lower is better

CI Ear
Bimodal
HA Ear

Average Error (RMS)
Pre-Lingual Results: SSQ

SSQ Scale

Average Rating

Greatest Ability

Least Ability

0 2 4 6 8 10

Pre 6m 12m 24m

P1 P2 P3 P4

Speech
Spatial
Qualities
CNC Word Scores-CI Ear

Participants Ordered by Length of Deafness and HA Use (years)

<table>
<thead>
<tr>
<th>LOD</th>
<th>1</th>
<th>2</th>
<th>6</th>
<th>8</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>10</th>
<th>33</th>
</tr>
</thead>
<tbody>
<tr>
<td>HA Use</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>5</td>
<td>6</td>
<td>18</td>
</tr>
<tr>
<td>AAI</td>
<td>45</td>
<td>25</td>
<td>77</td>
<td>72</td>
<td>47</td>
<td>78</td>
<td>59</td>
<td>65</td>
<td>35</td>
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<tr>
<td></td>
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<td>72</td>
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<td></td>
<td>84</td>
<td>80</td>
<td>77</td>
<td>28</td>
<td>28</td>
<td>26</td>
<td>25</td>
<td>40</td>
<td>29</td>
</tr>
</tbody>
</table>

Some HA Use in Poorer Ear

No HA Use in Poorer Ear

Prelingual HL

Percent Correct
Participants Ordered by Length of Deafness and HA Use (years)

| LOD | 1 | 2 | 6 | 8 | 9 | 10 | 10 | 33 | 1 | 1 | 6 | 6 | 7 | 8 | 9 | 15 | 32 | 34 | 40 | 23 | 25 | 25 | 40 |
|-----|---|---|---|---|---|----|----|----|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HA Use | 1 | 1 | 1 | 7 | 8 | 9 | 5 | 6 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 29 |
| AAI | 45 | 25 | 77 | 72 | 47 | 78 | 59 | 65 | 35 | 62 | 68 | 71 | 82 | 72 | 65 | 68 | 68 | 84 | 80 | 77 | 28 | 29 | 26 | 43 |

CNC Word Scores-CI Ear

- Some HA Use in Poorer Ear
- No HA Use in Poorer Ear
- Prelingual HL
CNC Word Scores Each Ear

Participants Ordered by Length of Deafness and HA Use (years)

<table>
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<tr>
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<td>35</td>
</tr>
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Some HA Use in Poorer Ear

No HA Use in Poorer Ear

Prelingual HL

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<td>65</td>
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<tr>
<td>Percent Correct</td>
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</table>

Legend:
- HA
- CI
Result

• All postlingual participants had open-set speech recognition in the CI ear, even those with long periods of deafness (32-40 yrs) and no HA use.

• The prelingual participants had little speech recognition with similar lengths of deafness, but early age at onset.
Asymmetric Children: Treatment with CIs
Participants

- 5 children/teens with asymmetric hearing loss (ages 10-19 years)
- P1 - P3 had more favorable hearing history with more CI experience
- P4 & P5 had profound SNHL in the poorer ear from birth, were never aided in that ear, and have only 6 mos CI experience

### Demographic Information

<table>
<thead>
<tr>
<th></th>
<th>Age (y)</th>
<th>Etiology</th>
<th>AAO SPHL (P)</th>
<th>Age Began HA Use (P/B)</th>
<th>AAI (P)</th>
<th>Length CI Use (y;m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>11</td>
<td>EVA</td>
<td>8</td>
<td>4 / 4</td>
<td>8</td>
<td>3;2</td>
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<tr>
<td>P2</td>
<td>10</td>
<td>Unknown</td>
<td>Birth</td>
<td>2 / 2</td>
<td>5</td>
<td>5;2</td>
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<tr>
<td>P3</td>
<td>19</td>
<td>Unknown</td>
<td>4</td>
<td>4 / 4</td>
<td>14</td>
<td>5;4</td>
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<td>Birth</td>
<td>Never / 4</td>
<td>12</td>
<td>0;6</td>
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<td>P5</td>
<td>15</td>
<td>Unknown</td>
<td>Birth</td>
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<td>0;6</td>
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</tbody>
</table>

_Cadieux et al, 2013, Otol Neurotol_
Pediatric Participant Audiograms

Cadieux et al, 2013, *Otol Neurotol*
CNC Words in Quiet and Noise

Quiet at 50 dB SPL

Noise (60 dB SPL +8 SNR)

* p<0.05

Cadieux et al, 2013, Otol Neurotol
Cadieux et al, 2013,
Otol Neurotol
Result

• Some children with AHL show significant benefit from CI in the poorer ear

• Effects of congenital AHL requires further investigation

• Consider the implications of unilateral input, when this occurs early in life, and whether hearing abilities in the poor ear can be accessed later, or whether binaural abilities can be achieved
UHL (SSD) Adults: Treatment with CIs
Speech Recognition in Cochlear Implant Recipients with SSD (St. Louis VA)

• Inclusion criteria
  – Severe to profound sensorineural HL in the poor ear and WRS ≤ 40%
  – Normal or near-normal hearing in other ear with 3 frequency PTA (.5, 1, 2 kHz) ≤ 30 dB HL; at 3 kHz and above, thresholds above 30 dB allowable
  – Adult onset of SPHL
  – Duration of deafness < 20 years
  – Previously tried CROS, BiCROS or Baha softband
VA Participants

• P1: Age 50, sudden SPHL
  – Implanted age 52 (Med-El)
  – Length of deafness 17 mos

• P2: Age 58, sudden SPHL
  – Implanted age 65 (Nucleus)
  – Length of deafness 7 years

• P3: Age 53 SPHL, but not sudden (prior HL)
  – Implanted age 63 (Adv Bionics)
  – Length of deafness 10 years
High frequency threshold levels with the CI (green) are better than his high frequency threshold levels in his good ear (red).

AAI = 52 years  
LOD = 17 mos  
Med-El

WRS = 0% LE
VA Participant 2 - Audibility in dB HL

Again, high frequency threshold levels are better with the CI than thresholds in the good ear.

AAI = 65 years
LOD = 7 yrs
Nucleus

WRS = 0% LE
VA Participant 3 - Audibility in dB HL

Very poor speech discrim in LE, NU6 word score of 8% at 100 dB HL

AAI = 63 years
LOD = 10 yrs
Adv Bionics

Very poor speech discrim in LE, NU6 word score of 8% at 100 dB HL
Scores with CI only. Better ear plugged and muffed.
Scores with CI only. Better ear plugged and muffled.
Cl only Perception in Quiet

Cl only scores. Better ear plugged and muffled for testing.
Localization

Large improvement at 3 and 12 months post-op in the bilateral condition (using good ear and CI) over his pre-op condition.
Better localization scores with CI and good ear (3 and 12 mos post-op) than with good ear alone (pre-op).
Localization

Better localization scores with CI and good ear (3 and 12 months post-op) than pre-op condition.
BKB Sentences in Noise

When noise is to the good ear (R), adding the CI improves the SNR score. When noise is to the bad ear (L), adding the CI does not improve the SNR score but doesn’t make it worse.
When noise is to the good ear (R), adding the CI slightly improves the SNR score. When noise is to the bad ear (L), adding the CI does not improve the SNR score.
When noise is to the good ear (R), adding the CI does not change the SNR score. Essentially the same when noise is to the bad ear (L).
Participant Comments

• Examples of when CI is most helpful
  – Localization
  – Hearing and understanding family
  – Understanding in everyday situations
  – Hearing environmental sounds

• Examples of when CI is least helpful
  – Movie theatres too loud; Some restaurants

• I wear the processor all day, everyday. I hate taking it off. It’s like taking off an ear. I feel lost. (P2)

• I don’t feel that there is a situation in which the implant is detrimental. (P2)

• The CI has opened up a whole new world for me. (P3)
Counseling Recommendations

Based on results and discussions with participants, pre-implant counseling important:

- Improvements may be realized in some but not all listening environments
- Sound quality from CI will differ from acoustic hearing; may need additional time to adjust
- CI alone practice is essential to maximize CI benefit (direct connect to CI or better ear plugged)

All patients commit to post-op rehabilitation for 8-10 weeks—emphasis on programming optimization of CI ear and training
Programming Comments

• Protocol—similar to traditional CI users
  — Plug the better ear, especially for balancing and Ts

• Loudness—difficulty determining volume
  — Set CI volume with BE plugged, may be too loud with BE + CI. When evaluating CI alone and BE ear plugged, CI volume may be too soft

• Subjective feedback—some have more difficulty giving feedback re programming changes, small differences not as apparent (better ear dominant)

• Acclimatization—seems to take longer to adjust, longer to reach maximum performance
Patient Selection Recommendations

- Hearing history
  - Any unaided thresholds in poor ear
  - Age at onset (sudden vs congenital)
  - Cochlear anatomy
  - Previous trials with other devices

- Communication needs
  - Work environment
  - Family and Social environment

- Motivation and realistic expectations

- Commitment to rehab process

Careful selection is needed to avoid non-use in the future
Overall Summary

- UHL poorer than NH-Adults and children
- Tremendous variability, some score within the NH range
- Experience helps with localization but not listening in noise
  - Adults with acute UHL vs UHL; UHL Adults Young AAO vs Recent AAO, Older UHL children
  - Different mechanisms involved??
Overall Summary

• Length of deafness a significant factor in traditional CI performance
  - For bilateral SPHL
  - For 2<sup>nd</sup> ear of sequential bilateral recipients

• Length of deafness does not appear to have the same impact for AHL

• Age at onset is a critical factor with respect to treatment with a CI, even w/one opposite good hearing ear
Issues to Consider

• If we assume UHL deprives binaural processes, and we need bilateral input...
  – We do recommend bilateral HAs, bilateral CIs, and bimodal (HA+CI) at young ages

• We know from sequential CIs, bilateral input is needed in a timely manner—can’t wait too long

• If younger is better, how do we identify deficits early? How do we determine recommendations for treatment? And how do we measure benefit?
Issues to Consider

• If not all children have a deficit, how to identify those that do

• Maybe all children have a deficit and we need different measures

• Those with performance comparable to NH peers, how are they doing it? Using other resources? Greater cognitive load? Some other work around?
Issues to Consider

• There will still be deficits with a CI
• Is there the potential to decrease performance?
• If so, who is at risk for poorer performance?
• Does etiology play a bigger role? Children with UHL have higher risk of cochlear anomalies
• Many unanswered questions...
Future Considerations: Raise the Bar for Bilateral Input

- Consider treatment for each ear with hearing loss, be it acoustic or electric
- The auditory system is designed to be binaural. We should treat the system by treating each ear
- CI Candidacy requirements should be modified to allow treatment to each ear rather than requiring bilateral hearing loss for cochlear implantation
- At the same time, we need to be thoughtful as we strive for optimal outcomes for each person
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