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An Introduction to Cochlear Implants

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NYU Cochlear Implant Center
Department of Otolaryngology

Learner Objectives

Participants will be able to:

• 1. Describe current cochlear implants
• 2. Summarize current candidacy criteria
• 3. Discuss processing strategies
History of the Cochlear Implant

• Precursors
  • Vocoder- Homer Dudley (Bell Labs)
    • 1939- real time voice synthesizer that produced intelligible speech using circuitry designed to extract the F0 of speech, the intensity of its spectral components, and overall power. Components extracted with a series of 10 band pass filters- called a vocoder.
  • Cochlear Microphonic- Wever and Bray-
    • 1930- produced and described the electrical potentials in the cochlea that faithfully reproduced the sound stimulus
  • Electrophonic hearing- S.S. Stevens, et al
    • 1930’s described the mechanism by which the cochlear elements respond to electrical stimulation to produce hearing

History of the Cochlear Implant

Djorno and Eyries- 1957- first reported direct stimulation of the cochlear nerve - facial nerve graft-patient eventually could differentiate high v. low, environmental sounds, etc.

Chouard (Eyries lab)- credited with development the first multi-channel CI, in Europe.

CONTINUED
History of the Cochlear Implant

**US**

*William House* (L.A.)- 1959- received English translation of D&J work

1st CI January 1961- into the round window.

F. Blair Simmons (Stanford)- 1964

Robin Michelson (San Francisco)- single/multichannel
Mike Merzenich- UCSF (AB device)

By 1973- interest began to grow

1982- Graham Clark. Nucleus device in US

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**Auditory Function in Patients with Severe-to-Profound SNHL**

- Sensory receptors for audition (hair cells) are damaged or significantly diminished in number
- Some auditory nerve fibers survive
- Damaged hair cells are unable to transmit electrical impulses to surviving nerve fibers
- Auditory perception severely distorted or not possible
How Hearing Aids Work

• Hearing aids are designed to make sounds louder

• These amplified sounds are then sent through the damaged part(s) of the ear

• In some cases of sensorineural hearing loss, hair cell damage can be so extensive that these amplified sounds are too distorted to be useful for speech understanding

• For these patients, a cochlear implant may be the answer

Common Principles of all Cochlear Implant Systems

• In sensorineural deafness, viable auditory nerve tissue survives. Signals are not conveyed because the sensory receptors (hair cells) are damaged and unable to transmit electrical impulses to the nerves

• Cochlear implants are designed to bypass the damaged hair cells and stimulate the auditory nerves directly through the introduction of external electrical current.

• All implant systems share the same goal and, therefore, the same task.
• To convert the acoustic input signal into an electrical pattern that yields sound/speech clarity and allows speech recognition.

• All implant systems operate similarly-microphone > processor > antenna/transmitter > receiver/stimulator > electrode array

Design Features

• Transmission speed

• Electrode design

• Number of electrode contacts

• Number of channels

• Speech coding strategy
Speech coding strategy

- A set of rules for converting the acoustic signal into a stream of electrical stimulating waveforms applied by a cochlear prosthesis
Cochlear Implant
Evolution: *The Implantable Cochlear Stimulator (ICS)*

- **1.0**
  - Investigational
  - Prior to 1995

- **1.2**
  - CII Bionic Ear™
  - 1996

- **HiRes™ 90K**
  - 2001

- **HiRes™ 90K Advantage**
  - 2003

- **2012**

Evolution: *The Sound Processor*

- **Off the Ear**
  - CLARION™ 1.0
  - CLARION™ 1.2
  - S-Series™
  - Platinum Sound Processor™

- **Freestyle**
  - Neptune™

- **BTE**
  - CII BTE™
  - Platinum BTE
  - HiRes™ Auria™
  - Harmony™

- **Naida CI Q70 & Q90**
5th generation Nucleus® implant

- `86 CI22M
- `97 CI24M
- `99 Contour™
- `05 Freedom™
- `09 CI512

9th generation Nucleus® sound processor

- `83 WSP
- `89 MSP
- `94 Spectra
- `98 SPrint™
- `01 ESprint™
- `02 3G
- `05 Freedom™
- `09 CP810
- `13 CP910

continued
Processor advancements

Freedom device

Cochlear™ Nucleus® Electrode Portfolio

- CONTOUR ADVANCE™ ELECTRODE
- SLIM STRAIGHT ELECTRODE
- HYBRID™ L24 ELECTRODE
- STRAIGHT ELECTRODE
- DOUBLE ARRAY ELECTRODE
- AUDITORY BRAINSTEM ELECTRODE
SONNET and RONDO are compatible with all previous and current MED-EL implants

SONNET and RONDO are compatible with all previous and current MED-EL implants
MED-EL Electrode Arrays

Classic Series: Wave-shaped wires for atraumatic insertion properties

**STANDARD**
A 31.6mm electrode array designed for long cochlear duct lengths.

**MEDIUM**
A 24mm electrode array designed for cases where deep insertion is not desired or is not possible due to anatomic restrictions.

**COMPRESSED**
A 15mm electrode array designed for partial ossification or malformation of the cochlea.

MED-EL Electrode Arrays

FLEX Series: Further designed for structure preservation using FLEX Tip Technology

**FLEX28™**
A 28mm electrode array suitable for 98% of normal cochlear anatomies featuring FLEX-Tip technology. Optimised for insertion into the apical region (CCC).

**FLEX24™**
A 24mm electrode array featuring FLEX-Tip technology and designed for insertion less than 1.5 turns.
### Candidacy Evolution

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<td>Adults &amp; Children (2 yrs)</td>
<td>Adults &amp; Children (18 mo)</td>
<td>Adults &amp; Children (12 mo)</td>
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<td>Adults &amp; Children Pre &amp; Postling</td>
<td>Adults &amp; Children Pre &amp; Postling</td>
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<td><strong>Degree of SNHL</strong></td>
<td>Profound</td>
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<td>Severe-Profound Adults Profound Children</td>
<td>Severe-Profound Patients - 2 yrs &amp; older Profound Children - younger than 2 yrs</td>
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<td>0%</td>
<td>0%</td>
<td>40% or less (CID)</td>
<td>50% or less (HINT) in ear to be implanted with 60% or less in contralateral ear or binaurally</td>
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<tr>
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<td>Not candidates</td>
<td>0% open-set</td>
<td>Less than 20%</td>
<td>Lack of aud. Progress (HINT &lt; 30% important) (depending on age)</td>
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### Areas of Expansion

- Age at implantation
  - Younger than one year old
  - Adolescents and adults with prelingual deafness
  - Geriatric
- More residual hearing
- Long-term deafened
- Multiple disabilities and auditory neuropathy
- Bilateral implantation
- SSD
- EAS
- ABI for other than NF2

NYU School of Medicine

[Continued]
Areas of Expansion

• Bimodal stimulation
  • Knowledge of HA programming
  • CI + HA
  • CI + ABI
  • Manufacturer specific programming guidelines

Areas of Expansion

• Medical/Surgical Complicating Factors
  • Malformed and hypoplastic cochleae
  • Obstructed cochleae
  • Complicating diseases
    • HIV, severe conditions

• Streamlined fittings
  • Greater numbers of patients
  • Time, financial constraints
  • Self fitting
  • Group fittings
  • I techs
Evaluation Process

• History
• Audiologic battery
• Speech perception battery
• Medical, Otologic, Radiographic
• Vestibular
• Questionnaires
• Psychological, social work
• Counseling
• AT LEAST YEARLY EVALUATIONS POST-IMPLANTATION

Adult Candidacy

• 18 years of age or older

• Bilateral severe/profound sensorineural hearing loss (could be moderate in low frequencies)

• Limited benefit from amplification (<50% in the ear to be implanted and <60% in the opposite ear or binaurally on sentences)
Adult Preoperative Evaluation

- Unaided and aided thresholds
- Speech perception battery (words, sentences, quiet, noise, each ear, bilateral)
- Medical
- Otologic
- Radiologic
- Vestibular (?)
- ABR (?)
- Family/support
- Counseling
  - Realistic expectations
  - Device counseling

Pre and Post-operative Protocol

- Unaided audiogram, SDT, SRT, speech discrimination each ear
- Impedance
- Otoacoustic emissions
- Aided thresholds, SDT, SRT
- CNC words, HINT or AzBio sentences in quiet and noise presented at 48dBHL. HINT at SNR+10, AzBio at SNR+5

Evaluations are done in each ear individually and bilaterally.
Prelingual Adult

• Add or substitute as needed A, V, A+V and preop with hearing aids each ear and bilaterally (postop with implants)

• Tests: CID sentences, noise/voice, male/female, number of syllables, etc.

Bilateral Adult: simultaneous and sequential preop and postop

• Each ear separately and binaural

• Same tests adding the BKB-SIN test with speech coming from the front and noise front, right, left.
Other

• Localization testing for bilateral and unilateral candidates

Special Protocols

• Bilateral
• Hybrid
• Unilateral (SSD)
• Clinical Trials
Traditional CI vs. Hybrid Candidates

Current Indications for CI

Hybrid Candidacy Criteria

≤ 50% HINT sentences in ear to be implanted
≤ 60% HINT in contralateral ear or best aided condition

≤ 10% HINT in ear to be implanted
≤ 80% CNC in the contralateral ear

Pre-operative Evaluation (Pediatric)

- Case history
  - Medical, otologic, audiologic, communication, educational, and psycho-social factors
- Audiologic- unaided and aided testing
  - Behavioral measures
  - Objective measures
    - ABR, OAE
    - Age appropriate speech perception testing
- Medical
- Otologic
- Radiologic
- Assessment of speech and language development
- Assessment of cognitive development
- Family and school support
- Counseling- expectations
Choosing a Device

• It is the Center’s responsibility to provide accurate information re: all devices and answer questions
  • Reliability data, ease of use, etc.

• Patient then makes an informed decision

Common Questions

• Which is the best device? 50% will choose a device because it’s new, 50% will not choose a device because it’s new

• Reimbursement

• Know someone with a particular device

• Marketing

• Cosmetics

• MRI compatibility

• Battery life

• Ergonomics

• Customer support

• Company stability
Future Advancements

- Internal/external components e.g. waterproof
- Totally implantable
- New approaches to processing e.g. top-down, pre-processing
- Electrode design
- Surgery e.g. robotic
- Drugs
- Training
Cochlear Implant Predictors and Outcomes

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Co-Director, NYU Cochlear Implant Center

Learning Outcomes

Participants will be able to:

• 1. Identify variables affecting performance in children and adults
• 2. Describe outcomes in various populations including young children and older adults
• 3. Summarize the effects of plasticity, programming and intervention on performance
Postlingual CI ADULTS: 1970’s

• 1st USA Human Trial, Single Channel Electrode
• Post Lingual Deaf
• Safety, Efficacy
• Benefits
  • Sound Awareness
  • Aid to Lip Reading
  • Some Speech Understanding

CI ADULTS: 1980’s

• Multichannel electrode array superiority
• Modification of coding signals to different subsets of auditory fibers
  • simultaneous vs sequential stimulation
  • individual electrode vs pairs (bipolar)
  • waveform stimulus modification
• Multiple coding strategies
CI ADULTS: 1990’s

• Improved speech processing strategies
• Choices
• 70-100% open set word/sentence recognition for post-lingual deaf
  • telephone
  • professional, career activities
  • quality of life enhancement

CI ADULTS: 2000-present

• Improved technology: hardware, processing
• 90-100% open-set word/sentence recognition
• Improved speech understanding in noise
• Bilateral implantation
• Residual hearing
• EAS
• SSD
**Congenitally/Prelingually Deaf Adult**

- Can obtain speech understanding.
- Depends on many factors including: length of deafness, length of device usage, prior use of amplification, mode of communication.
- Improvement continues over time.
Cochlear Implants in the Geriatric Population

Predicted Increase in HL Incidence

• 50 million patients predicted to have HL by 2050
Central Auditory Function Declines in Older Patients

- Decreased temporal signal resolution with aging
- Decreased hearing acuity in noise
- Decreased hearing acuity with fast speech
- Decreased speech memory

These all occur in elderly patients with normal audiograms.


Study Group (n=72)       Control (n=45)

- AI=76y (70-88y)
- PTA=99 dB
- Length of severe/profound hl=8.9y (0-51)

- AI=45y (19-63y)
- PTA=106 dB
- Length of severe/profound hl=10.7y (0-38y)
Results: CNC Words & Phonemes

Conclusions

- Older patients derive *significant* hearing benefits following cochlear implantation.
- Elderly patients’ speech outcomes seem to plateau earlier and are slightly decreased compared to younger controls.
- Older patient’s speech understanding in noise shows a trend towards slightly poorer performance than controls.
- Right-sided implantation may lead to improved speech outcomes in elderly patients.
Emerging research has established an association between hearing loss and dementia 
• hearing loss independently associated with 40% rate of accelerated cognitive decline 
• this relationship may be linear: those with more severe hearing loss are at highest risk 
  • individuals with mild, moderate and severe HL had a 2, 3, and 5 fold increased risk of all-cause dementia over >10 yrs of follow-up

Recent data suggest that interventions for hearing loss may impact cognition in older adults

Subjects

• 7 postlingually deafened females
• Mean age = 73.6 (range = 67-81)
Methods

- Neurocognitive battery of 20 tests: intellectual function, learning, short and long term memory, verbal fluency, attention, mental flexibility and processing speed. Assessed preimplantation and 2-4.1 years (mean 3.7) following implantation
- CNC words preop and at regular intervals postop

Results

- Significant relationship between speech perception and cognitive function over time
- Post-CI improvements were observed in 14/20 (70%) of subtests, declines in 5 (25%)
- Improvements centered in verbal, memory, processing speed/mental flexibility domains
- All declines involved motor, vision
- 5 neurocog tests were predictive of improved speech perception over time:
  - WASI, vocabulary, matrix reasoning, Boston Naming Test, list learning at 2 and 3 yrs post-CI
Open-set speech understanding

Oral communication-do not exclude TC

Mainstream school

On track for age-appropriate speech production and oral language development

Second oral language capabilities
Multiply Handicapped Deaf Children: The Big Picture

• Approximately 40-60% of children with hearing loss have additional, identified special needs

• This does not include children with undiagnosed learning difficulties or different learning styles

• Can help children achieve to their maximum potential

• Results indicate slow variable progress depending on the level of involvement

Monitoring Progress

• Intervention and its effectiveness

• Educational placement and whether it is appropriate

• Support services available/provided

• Child’s progress and use of cochlear implant and other technology
Auditory Neuropathy/Dys-synchrony

- Outer hair cell function is ok but neural transmission in the auditory pathway is disordered. Alteration in neural synchrony and temporal encoding (?)…
- Thought to be in the spiral ganglion cells and/or 8th nerve not the brainstem–cortex.
- Mutations in OTOF gene
- About 7%-10% of permanent childhood hearing loss. % unknown for adults.
Associated with….

• Progressive, prelingual, bilateral (92%), moderate to profound SNHL (81% >70dBHL); Berlin 2010 says 30% have profound hearing loss

• Recordable otoacoustic emissions (normal outer hair cell function) with absent or atypical brainstem responses (lack of synchronous neural signal) and absent reflexes

• Speech understanding poorer than expected from degree of hearing loss especially in noise

Diagnosis

• Moderate, severe, profound hearing loss

• Speech understanding poorer than what might be predicted from degree of hearing loss on audiogram

• Recordable acoustic emissions with absent or atypical brainstem responses

• Normal radiography
Hearing Aid vs. Cochlear Implant

Some have suggested that hearing aids offer little to no benefit (Berlin, 1999) while others have shown that in some cases hearing aid use has proven beneficial (Rance et al 2004, Buchanan et al 2005).

Case Study
• Suspected hearing loss confirmed at 20 months of age

• Bilateral mild-to-moderate-severe sensorineural hearing loss

• No measurable waveform on ABR; on polarity inversion a large Wave I was noted

• Absent OAE

• Performance = with/without amplification
Preop MLNT = 30%
Preop LNT = 27%
1 month post-stim MLNT = 100%
1 month post-stim LNT = 100%

Speech intelligibility improved dramatically
Summary and Conclusions

• Cochlear implants are a viable option for the treatment of AN.
• Approximately 50% with AN can benefit from CI. Restores some degree of neural synchrony and temporal coding?
• Other confounding disabilities need to be taken into account.
• Team approach for treatment.
• CAUTION: RESOLUTION WITHOUT TREATMENT
• Newborn hearing screening has led to early ID of profound hearing loss.

• 85% - 99% of newborns are being screened within a day of being born, remainder within first few months.

• On average and over all degrees of hearing loss, children achieve higher levels in all areas when intervention commences within the first 6 months of life.

Implanting Under One

• Safety

• Candidacy
  • Certainty of testing and deafness
  • Programming issues

• Efficacy
  • Auditory
  • Linguistic
Summary

• Full insertions without perioperative complications.
• No difficulty with device programming.
• Developing auditory/oral language skills.

EXPERIENCED SURGEONS, CENTERS

• Implantation in children <12 months of age can be performed safely.
• Provides early and effective access to sound leading to functional benefit beyond what can be obtained with conventional amplification with trend towards better development than later implantation. Most are 9m+, some are 5-6 months.
• Must have accurate diagnosis and appropriate post-implantation intervention.
Cochlear Implantation in the Adolescent Population

Why wait until adolescence for CI?

• “Awaiting long-term data outcomes”
• “Saving the ear for new technology”
• “Hair cell regeneration is just around the corner”
• “I don’t want my child to have to change schools, social groups, etc.”

• Failure to identify hearing loss in childhood
• Progressive hearing loss
• Lack of access to health care/social support
Subjects

• 67 patients ages 10-17 undergoing unilateral CI from 1986-2009
• Congenital deafness or severe-profound bilateral hearing loss prior to age 3

• Mean age at implant = 12.9 years
• Mean duration of deafness = 11.5 years
• Mean follow-up = 60 months
Summary

• Significant improvement in speech perception can be obtained in prelingually deafened adolescents after unilateral CI

• Cause of deafness does not seem to affect outcomes

• Oral communicators perform significantly better after CI

Sequential Bilateral CI in the Adolescent Population

• To examine variables that affect outcome

• CNC, HINT-N

• Mean age CI2=13.5, mean interval between CI1, CI2=8.2 years neither of which correlated significantly with performance.

• 27 adolescents bil profound snhl, 22 received CI1 prior to age 10, all received CI2 between 10-17 years.
CI1, CI2 and Bilateral Speech Perception

Summary

- Subjects demonstrated improvement in CI2 scores over time
- Bilateral CI scores show small improvement due to ceiling effect
- Use of implant is closely tied to performance scores and improvement over time
Conclusions

• The focus of CI has been on very young children and patients with relatively short durations of deafness

• Early implantation has consistently yielded excellent results

• Initial cochlear implantation of prelingually deafened adolescents has benefits and should be considered a viable treatment option for patients with realistic expectations and positive motivation

• Bilateral sequential cochlear implantation leads to improved speech perception in the adolescent population even after a long duration of deafness / interimplant interval

Auditory Perception after ABI: Early Experience (Non-NF2 Pediatric Population)
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Performance Plateau in Prelingually and Postlingually Deafened Adult Cochlear Implant Recipients

Objectives

1. To characterize the performance plateau post CI in both prelingually and postlingually deafened adult CI recipients

2. To compare the plateau in these two patient groups
Summary

• CNC words:
  • Postlingual: significant improvement at 3 years post CI
  • Prelingual: significant improvement at 5 years post CI
Conclusions

• There is continued, though flatter, improvement to the end point of this study

• Change from currently reported 6-12 months

Conclusions for all populations

• Numerous factors affect ultimate outcome and the ability to predict performance

• Extensive preoperative counseling and individualized evaluation are critical to ensure patients and families understand the range of possible outcomes.

• WIDE RANGE OF PERFORMANCE
Variables Affecting Performance

- Length of deafness
- Technology
- Speech processing strategies
- Electrode design
- Neural survival/plasticity
- Age at implantation
- Other disabilities

Variables (cont’d)

- Medical/Surgical issues
- Programming: Subjective/Objective (NRT, reflexes)
- Length of device usage
- Communication mode, education, intervention (post-op training)

ALL INTERACT
Future Advancements

• Totally implantable/internal, external components

• New approaches to processing e.g. top-down, pre-processing

• Electrode design

• Drugs

• Training

NYU Cochlear Implant Center

• Co-Directors of the Cochlear Implant Center
  • J. Thomas Roland Jr., MD
  • Susan B. Waltzman, PhD

• Surgeons
  • J. Thomas Roland Jr., MD
  • Daniel Jethanamest, MD
  • David Friedmann, MD
  • Otol/Neurotol Fellow

• Cochlear Implant Audiologists
  • William Shapiro, AuD – Supervisor
  • Betsy Bromberg, MA
  • Janet Green, AuD
  • Laurel Mahoney, AuD
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  • Alison Singleton, AuD
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  • Jonathan Neukam, AuD
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Thank you!

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Cochlear Implantation: Results and Considerations for Asymmetric Hearing Loss & Single Sided Deafness

Jill B. Firszt, Ph.D.
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Director, Cochlear Implant Program

22nd Appalachian Spring Conference
June 9, 2016

Learning Objectives

• Participants will be able to:
  — Identify audiometric profiles for individuals with asymmetric hearing loss/single sided deafness (SSD)
  — Name 2 benefits of cochlear implantation for adults with asymmetric hearing loss/SSD
  — Identify one demographic variable that affects cochlear implant performance in individuals with asymmetric hearing loss/SSD
Overview of Presentation

• Case study
• Unilateral hearing loss in Adults (UHL), no CI
• Effects of unilateral input and mode of hearing: From the listener perspective
• Asymmetric HL in Adults (AHL), with CI
• Single Sided Deafness (SSD), with CI

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
Individual Subject (S11)

- Did having sound in one ear help to maintain the opposite 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
- All are unilateral listeners

Normal or Near-normal hearing

Some hearing loss
Uses amplification

Severe to profound HL
Uses cochlear implant

UHL Adults
Unilateral Hearing Loss (UHL) Study in Adults

Purpose:
- Quantify auditory deficits in adults with UHL
- Identify sources of variability in outcomes
- Compare results with NH bilateral listeners
- Compare results with NH unilateral listeners
  - Introduce the condition of UHL for NH listeners that have not adapted to UHL

<table>
<thead>
<tr>
<th></th>
<th>Mean (SD)</th>
<th>Age (years)</th>
<th>PTA (dB HL) from .25-8 kHz in ear(s) tested</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>49.1 (12.9)</td>
<td>25 - 71</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>48.8 (13.7)</td>
<td>22 - 71</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>49.7 (11.6)</td>
<td>22 - 67</td>
<td>12.2 (12.2) 2.5 - 26.1</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>
UHL Study

Test Protocol

• Speech recognition in noise
  – HINT sentences presented in the R-Space™

• Localization
  – CNC monosyllabic words presented from an array of 15 loudspeakers

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
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 (+/- 6 dB)
- Asked to identify word and speaker location
Localization

A - Total Loudspeaker Array

Lower is better

RMS error (degrees)

### Localization Based on Side of Presentation

Loudspeakers on Good Side

Loudspeakers on Poor Side

Firszt et al, submitted
Summary: UHL Adult Study

- Both unilateral groups (UHL and NH-plugged) worse than NH-Bil on all measures (localization, speech in noise)
- Localization better for UHL than NH-plugged
- R space results show no differences between unilateral groups

Closer Look at UHL Group

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

Test Measures
- Localization
- HINT sentences in the R-space
Localization by Age at Onset

- Total loudspeaker array
- Lower is better
- RMS Error (degrees)

Recent AAO  | Young AAO
---|---

HINT Sentence in R-Space by Age at Onset

- SNR-50 (dB)
- Lower is better

Recent AAO  | Young AAO  | NH
---|---|---

Firszt et al, submitted
Recent AAO versus Young AAO

Summary

• Localization better for Young AAO vs 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

• Experience with unilateral input affected localization differently than speech in noise

Can Training Improve Localization Ability?

• Pilot study, 11 adults with UHL

• Attended 5 training sessions, using spectral and temporal sounds

• Pre and post-training assessments using words, and spectral and temporal sounds
  – Group mean RMS error scores improved for all stimuli
  – Those with poorest RMS scores prior to training improved the most, those with the best RMS scores pre-training improved the least

*Firszt et al, 2015, Hear Res*
Localization Training

Source Location (degrees azimuth)

Mean Reported Location (degrees azimuth)

error bars = ± 1 standard deviation

* $p < 0.05$, ** $p < 0.01$, *** $p \leq 0.001$

Fiszt et al, 2015, Hear Res

Listener Perspective
Listener Perspective

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

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
- Emphasis on dynamic, diverse listening environments

(Gatehouse and Noble 2004)
SSQ-Three 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?

Study Objectives

• Quantify effects of unilateral input using the SSQ
• Compare results with adults who had bilateral normal hearing and were of similar ages

Dwyer et al, 2014, Ear Hear
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)

---

**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, 2014, Ear Hear

Results – Spatial Hearing

Dwyer et al, 2014, Ear Hear
Results – Qualities of Hearing

* \( p < 0.05, ** \ p < 0.01, *** \ p < 0.001 \)

Dwyer et al, 2014, Ear Hear

Conclusions

• 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, are at a disadvantage in many aspects of everyday listening and communication
Asymmetric Adults

Asymmetric Hearing Loss Study

• One ear SPHL
  One ear uses a HA (moderate HL)
• What are the measured deficits of asymmetric hearing loss?
• What are the benefits of cochlear implant treatment?
Asymmetric Hearing Loss Study in Adults

Purposes

• To determine the benefits of cochlear implantation
• To compare the better ear with a HA to bimodal (HA + CI)
• To determine the relation between variables and outcomes with a CI
  – length of deafness, HA use, residual hearing

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

Firszt et al, 2012, Ear Hear
Group Demographics
Postlingual Participants (n = 20)

• Age at onset of SPHL poorer ear
  – Mean 52.6 yrs (range = 4-76 yrs)

• Length of deafness in poorer ear
  – Mean 12.3 yrs (range = 1-40 yrs)

• Age at implant
  – Mean 65 yrs (range 25-84 yrs)

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
Adult Asymmetric Hearing Loss Study

• Testing before CI surgery
  – Better ear only, aided
  – Poorer ear only, aided (better ear plugged/muffed)
  – Everyday listening condition
    – Bilateral HAs for 3 participants, HA in better ear for all others

• Testing after CI surgery
  – 1, 3, 6, 9, 12, and 24 months
  – HA ear only, CI ear only, Bimodal

Unaided Hearing Thresholds

![Graphs showing unaided hearing thresholds for poorer and better hearing ears.](image)
Implanted/Aided
Sound-field Thresholds

Poorest Hearing Ear
CI SF Thresholds

Better Hearing Ear
HA SF Thresholds

<table>
<thead>
<tr>
<th>Frequency (Hertz)</th>
<th>Hearing Level (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>125</td>
<td>-10</td>
</tr>
<tr>
<td>250</td>
<td>10</td>
</tr>
<tr>
<td>500</td>
<td>20</td>
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<td>1000</td>
<td>30</td>
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<td>2000</td>
<td>40</td>
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<tr>
<td>4000</td>
<td>50</td>
</tr>
<tr>
<td>8000</td>
<td>60</td>
</tr>
</tbody>
</table>

Fixed Level Speech Recognition (n=20)

CNC Word Scores

HINT Sentences in Noise (+8 SNR)
Adaptive HINT in Restaurant Noise: R-Space (n=20)

Lower scores are better

Error bars = + 1 SEM; **p < 0.01; ***p < 0.001

Localization (n=20)

Lower scores are better

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

![Graph showing average ratings for SSQ (n=20) with greatest ability and least ability on the y-axis, and pre-implant and 6 months on the x-axis. The graph indicates a significant increase in average ratings over time.]

**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 High Fever</td>
<td>3 / 3</td>
<td>Never / 3</td>
<td>25</td>
</tr>
<tr>
<td>P2</td>
<td>28 Unknown/EVA</td>
<td>Birth / 23</td>
<td>Never / 28</td>
<td>23</td>
</tr>
<tr>
<td>P3</td>
<td>26 Meningitis</td>
<td>7m / 7m</td>
<td>Never / 1</td>
<td>25</td>
</tr>
<tr>
<td>P4</td>
<td>43 Unknown</td>
<td>Birth / Birth</td>
<td>3** / 3</td>
<td>40</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)

Pre 1m 3m 6m 9m 12m 24m

Percent Correct

P1 P2 P3 P4

Test Interval

Pre-Lingual Results: HINT Sentences

HINT Sentences in Noise

Pre 1m 3m 6m 9m 12m 24m

Percent Correct

P1 P2 P3 P4

Test Interval
Pre-Lingual Results: Localization

Pre-Lingual Results: SSQ
Adult Asymmetric Hearing Loss Study

• What is the relation between length of deafness & use of a HA and CI outcomes?

• 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
Summary: Adult Asymmetric HL Study

• Distinct patterns for recipients with prelingual versus postlingual asymmetric SPHL
• Length of deafness did not correlate with outcomes in postlingual group
• Study is ongoing: Gathering longitudinal data on more participants

Feasibility Study of the Cochlear Nucleus Implant System in Adults with Single-Sided Deafness (SSD)

Jill B. Firszt, Laura Holden, Gail Neely,
Sig Soli, William Slattery,
Susan Waltzman, J. Thomas Roland,
Camille Dunn, Bruce Gantz, Lori O’Neill
Study Overview

- Four center feasibility study (FDA approved study with IDE, indication not currently approved)
  - House Research Institute, CA
  - New York University, NY
  - University of Iowa, IA
  - Washington University in St. Louis, MO
- 10 newly implanted patients
- Evaluated pre-implant, 3, 6 & 12 mos post-implant

Study Overview

- The research questions addressed by this feasibility study were to understand if:
  - Restoration of hearing sensation, electrically, results in improved speech understanding (in poor ear)
  - Restoration of hearing sensation using both ears results in:
    - Improved spatial hearing, especially for speech in noise
    - Improved hearing performance and quality of life
Inclusion Criteria

• Adults with one poor ear, one better ear:
  — Poorer ear (ear to be implanted):
    • Severe to profound sensorineural hearing loss, defined as thresholds 80 dB HL or greater for .5, 1, 2, 3, and 4kHz; Duration ≤ 10 years
    • CNC word score ≤ 10%
  — Better ear (contralateral ear):
    • Normal or near-normal hearing, defined as no poorer than 30 dB HL for .25, .5, 1, 2 and 3 kHz; no poorer than 40 dB HL at 4 kHz
    • CNC word score ≥ 90%

Demographics

<table>
<thead>
<tr>
<th>Gender</th>
<th>Implanted Ear</th>
<th>Mean Age (SD) Yrs</th>
<th>Duration (SD) Yrs</th>
<th>Etiology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male = 3</td>
<td>Left = 6</td>
<td>52.8 (11.3)</td>
<td>3.2 (3.4)</td>
<td>Unknown - 5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Meniere’s - 2</td>
</tr>
<tr>
<td>Female = 7</td>
<td>Right = 4</td>
<td></td>
<td></td>
<td>Bell’s Palsy - 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Viral - 2</td>
</tr>
</tbody>
</table>
CNC Word Recognition

<table>
<thead>
<tr>
<th>Listening Condition</th>
<th>Preoperative N=10</th>
<th>3 Months N=10</th>
<th>6 Months N=10</th>
<th>12 Months N=10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Better Ear</td>
<td>95.7% (SD = 2.5%)</td>
<td>94.4% (SD = 5.3%)</td>
<td>95.1% (SD = 5.8%)</td>
<td>94.3% (SD = 5.6%)</td>
</tr>
<tr>
<td>CI Ear</td>
<td>0.0% (SD = 14.7%)</td>
<td>51.3% (SD = 10.9%)</td>
<td>56.9% (SD = 14.1%)</td>
<td>54.2% (SD = 14.1%)</td>
</tr>
<tr>
<td>Bilateral</td>
<td>NA</td>
<td>96.8% (SD = 3.0%)</td>
<td>97.1% (SD = 2.2%)</td>
<td>96.5% (SD = 2.8%)</td>
</tr>
</tbody>
</table>

Pre-op HINT SF: CROS vs Better Ear

- CROS presents subjects with a 3.6 dB disadvantage (p<.05) when noise is presented towards the poorer ear
- No advantage when noise is directed to the better ear alone or from the front
6m Post HINT DC: Bilateral vs Better Ear

- Bilateral presents subjects with a 1.24 dB advantage (p=0.013) when noise is presented towards the better ear.
- No decrement when noise is directed towards the implanted ear (unlike CROS).

12m Post HINT DC: Bilateral vs Better Ear

- Bilateral presents subjects with a 2.04 dB advantage (p=0.008) when noise is presented towards the better ear.
- No decrement when noise is directed towards the implanted ear (unlike CROS).
Localization Test Set-Up

- Simulates an arc, locations spaced 15° apart, range from 97.5 to 262.5 in rear hemi-field
- Participants provided with diagram that divided the space behind the head into 12 segments
- Prior to testing, participants familiarized with the stimulus locations
- Tested using Direct Connect (DC), identify the location of the stimulus

Direct Connect Localization

[Diagram showing RMS error (degrees) over different intervals: Preop, 3 Mos, 6 Mos, 12 Mos for Better Ear, CI Alone, Bilateral]
Speech, Spatial & Qualities of Hearing Scale (SSQ)

- **Speech Section**
  - Probes speech recognition in a variety of listening environments and visibility of talkers

- **Spatial Section**
  - Examines spatial hearing: sound direction, distance, movement

- **Qualities Section**
  - Considers segregation of sound, naturalness, effort

*Gatehouse & Noble 2004*

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**SSQ**

**Speech, Spatial & Sound Qualities (SSQ) Questionnaire**

<table>
<thead>
<tr>
<th></th>
<th>Preoperative</th>
<th>3 Months Postactivation</th>
<th>6 Months Postactivation</th>
<th>12 Months Postactivation</th>
<th>N = 10</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Speech/Hearing</strong></td>
<td>0.0</td>
<td>1.0</td>
<td>2.0</td>
<td>3.0</td>
<td>4.0</td>
</tr>
<tr>
<td><strong>Spatial</strong></td>
<td>0.0</td>
<td>1.0</td>
<td>2.0</td>
<td>3.0</td>
<td>4.0</td>
</tr>
<tr>
<td><strong>Quality</strong></td>
<td>0.0</td>
<td>1.0</td>
<td>2.0</td>
<td>3.0</td>
<td>4.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>0.0</td>
<td>1.0</td>
<td>2.0</td>
<td>3.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>
Iowa Tinnitus Handicap Questionnaire

- 27 questions to assess the impact on tinnitus perception
- Rate from 0 to 100
- 0 = strongly disagree; 100 = strongly agree
- Example items:
  - I cannot concentrate because of tinnitus
  - Tinnitus causes stress
  - I feel uneasy in social situations because of tinnitus

Kuk et al 1990
Dizziness Handicap Inventory

- 25 questions to assess the impact on dizziness
- Answer as Yes, Sometimes, No
- Example items:
  - Does looking up increase your dizziness
  - Does your dizziness significantly restrict your participation in social activities
  - Does your dizziness interfere with your job or household responsibilities

*Jacobson, Newman 1990*

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**Dizziness Handicap Inventory**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative</td>
<td>3 Months</td>
</tr>
<tr>
<td>Rating</td>
<td>Rating</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
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<td>8</td>
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<td>290</td>
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<tr>
<td>64</td>
<td>310</td>
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</table>

**Tinnitus Handicap Questionnaire**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative</td>
<td>3 Months</td>
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<td>Rating</td>
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<td>90</td>
<td>90</td>
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<tr>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
Key Conclusions

- CI for SSD restored speech understanding to the poor ear
- CROS results showed a significant disadvantage for hearing in noise when noise was towards the poor ear
- CI added benefit when noise was towards the better ear
- CI did not detract from performance in the bilateral condition
- Localization – bilateral condition provided benefit compared to the better ear alone
- Perceived hearing abilities were improved

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
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

Future Considerations

• Continued study of asymmetric input & cochlear implant
  — Congenital versus postlingual hearing loss

• Consider the implications of unilateral input, when this occurs early in life, and whether binaural abilities can be accessed later

• CI Candidacy requirements should be modified to allow treatment to each ear rather than requiring bilateral hearing loss for cochlear implantation
Future Considerations

- We have two ears for a reason
- The auditory system is designed to be binaural
- Should we change our description from “One normal hearing ear and one deaf ear” to better reflect “An abnormal binaural system”
- It’s a system….rather than two individual ears operating separately. What happens to one ear affects the system. We should treat the system by treating each ear.

Acknowledgements

- NIH/National Institute on Deafness and Other Communication Disorders
  - R01 DC009010
  - P30 DC04665

- We thank our participants for their time and commitment to our studies, and our colleagues
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What Happens If My Patient Loses Hearing Following Hybrid Cochlear Implantation?

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Department of Otolaryngology—Head and Neck Surgery

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Learner Objectives

1. As a result of this activity, the participant will be able to identify appropriate candidates for the hybrid technology.
2. As a result of this activity, the participant will be able to describe the hearing preservation outcomes for those implanted.
3. As a result of this activity, the participant will be able to describe the speech perception benefits for those with different amounts of hearing loss.
Outline of Talk

- Hearing loss statistics
- Basics of a CI
- Cochlear Implant Types
- Hybrid
  - Candidacy Considerations
  - Counseling
  - Outcomes
    - Hearing Preservation
    - Speech Perception
    - Programming

Does one predict the other?

Hearing Loss Statistics

- In 2015, those suffering hearing loss will exceed 700 million
  - billion by 2025 (Hear-it Organization, 2012)
- WHO estimates that HL is more prevalent than any other disabling condition (2008)
- Many with HL are unserved or underserved
  - Why?
    - Poor awareness
    - Shortage of professionals
    - Geographic barriers
    - Lack of reimbursement policies
Who is a “traditional” candidate?

- Guidelines for pediatric cochlear implantation:
  - at least 12 months of age
  - profound, bilateral hearing loss
  - Lack of auditory progress with bilateral hearing
  - receive minimal “benefit” from hearing aids

- Guidelines for adult implantation:
  - profound, bilateral hearing loss
  - receive minimal “benefit” from hearing aids
  - speech recognition scores \( \leq 50\% \) (private insurance) and \( \leq 40\% \) (Medicare)

New Indications:
Nucleus® Hybrid™ Cochlear Implant
What is a Hybrid Cochlear Implant?

- Shorter electrode array than traditional cochlear implant
  - Only stimulates the basal end (10-16 mm, 195-250 degrees) of the cochlea
- Hybrid allows individuals with steeply sloping HF hearing losses an alternative to traditional cochlear implantation
  - Designed to protect and preserve cochlear structures
  - Allows for combined acoustic and electrical stimulation in the same ear

Hybrid History

- 1999: 2 Different Approaches
  - Von Illberg publishes 1st report of preserving hearing with standard-length electrode and combines acoustic and electric hearing.
    - Coins Electro-Acoustic Stimulation (EAS)
  - Iowa Team implants 6mm Hybrid electrode in subjects with near normal low-frequency hearing.
    - 1999: 3 subjects, hearing preserved, but unpleasant high pitch, 10mm electrode developed
    - Gantz et al publication 2003 with 6 patients
Benefits of A+E Hearing

- Benefits of hybrid hearing
  - Improved quality vs. traditional CI
  - Improved speech perception abilities (Gantz & Turner, 2004, 2003; Gantz, Hanson, Turner, Oleson, Reiss, & Parkinson, 2009).
  - Better frequency selectivity, which helps with understanding speech in environments with background noise (Turner, et al., 2007).
  - Maintains localization abilities (Dunn, et al., 2010; Gifford, et al., 2014).

Nucleus Hybrid Electrode Arrays

- S8:
  - 10mm in length
  - 6 electrodes
  - Used to preserve low-frequency hearing
- S12:
  - 10mm in length
  - 10 electrodes
  - Used to preserve low-frequency hearing
- L24:
  - 16mm in length
  - 22 electrodes
  - 4 electrodes disabled
  - Used to preserve low-frequency hearing
- Standard device:
  - 19mm in length
  - 22 electrodes
  - Stabilizing “wing”

FDA Approved
How it works

How does a Hybrid implant work?

/01 The acoustic component amplifies low frequency sounds and sends them through the normal hearing pathway.

/02 At the same time, the sound processor converts high frequency sounds to digital signals and sends them to the implant.

/03 The implant bypasses the damaged inner ear and sends sound information directly to the hearing nerve.

/04 The nerve response is sent to the brain where it’s combined with the amplified sounds and turned into the sound you hear.

Candidacy Considerations
Common Candidacy Questions

- How do I know if I should consider a Hybrid for my patient?
- Are there people who I shouldn’t consider a Hybrid candidate?
- Other questions?

How do I know if I should consider a Hybrid?

- Audiogram
- Speech Recognition Scores
- Medical Considerations
- Hearing History & Etiology
- Lifestyle & Demographics

(continued)
Candidacy Considerations: Audiogram

**Implanted Ear:**
- Low-frequency residual hearing ≤ 60 dB HL 125 – 500 Hz
- PTA of 2k, 3k, 4k > 75 dB HL

**Opposite Ear:**
- PTA of 2k, 3k, 4k > 60 dB

Poorer ear is generally implanted

Candidacy Considerations:

**Speech Recognition Scores**

- CNC words were used in the clinical trial
  - Candidacy has been based on these scores
  - Aided word score between 10% and 60% in the ear to be implanted
    - Aided word score no better than 80% in the opposite ear

- What about sentence scores?
  - We also test AzBio Sentences in noise and in quiet as a connected speech test for insurance purposes.
  - **Candidacy is based on the word scores and not on the sentence scores**
**Candidacy Considerations:**

**Hearing History and Etiology**

- Stable or progressive loss
- Hearing aid use
- Cause of hearing loss
  - Noise induced
  - Congenital
- Duration of hearing loss
- Duration of profound high frequency hearing loss

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**Candidacy Considerations:**

**Lifestyle and Demographics**

- Patient age
- Cognitive status
- Patient expectations and lifestyle
- Quality of life and subsequent life demands
  - Patients who have considerable listening demands, e.g. music, noise, etc, are great candidates for EAS
**Candidacy Considerations: Medical**

- Reservations with certain types of medical issues
  - Dementia
  - Brittle diabetes
  - Progressive loss
  - Autoimmune
- These patients are still implant candidates, but might change device recommendation

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**What happens if I lose my hearing?**
What happens if I lose my hearing?

- Plan for all possible outcomes of hearing:
  - Use of acoustic and electric if hearing is preserved
    - Even if it only at 125 and 250 Hz
  - Electric only if complete loss of functional acoustic hearing
    - 16 mm
    - Do not necessarily have to explant and put in a longer electrode.
      - Most patients who’ve lost hearing still have good outcomes

Preservation of Hearing Outcomes

- Outcomes
  - 3 possible outcomes for hearing preservation:
    1. Good preserved residual hearing—functional hearing at and below 500+Hz
    2. Some preserved residual hearing—functional hearing at 125 and 250 Hz
    3. Loss of all residual hearing—loss of all functional hearing
  - 3 possible outcomes for speech perception:
    1. Above median
    2. Median
    3. Below median

- Outcomes for hearing preservation does NOT necessarily predict outcomes for speech perception benefit
Preservation of Hearing Outcomes

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    2. Median
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- Outcomes for hearing preservation does NOT necessarily predict outcomes for speech perception benefit
23/29 with Functional Hearing 79%
Summary of Preservation of Residual Hearing

• Most maintain functional acoustic hearing
• ~20% lose the hearing between 1-6 months post-activation
  - Delayed immune reaction
  - Response to electrical current and amplification
    • Excitotoxic Stress Reaction-loss of IHC-SGN synapse
  - Inner Ear Fibrosis
  - Other
• Recently have begun to use steroids at time of activation

Speech perception outcomes
Speech Perception Testing

- CNC Word Recognition Assessment
- AzBio Sentences in Noise at +5dB SNR (0° azimuth)

Test Conditions Terminology

1. **Combined**: bilateral HA in addition to the CI

   ![Combined Diagram]

2. **Hybrid**: CI and the HA ipsilaterally, but no HA on the contralateral ear

   ![Hybrid Diagram]
Preservation of Hearing Outcomes

• Outcomes
  – 3 possible outcomes for hearing preservation:
    1. Good preserved residual hearing—functional hearing at and below 500+Hz
    2. Some preserved residual hearing—functional hearing at 125 and 250 Hz
    3. Loss of all residual hearing—loss of all functional hearing
  – 3 possible outcomes for speech perception:
    1. Above median
    2. Median
    3. Below median
Combined CNC by Hearing Preservation

- **Percent Correct**
  - Good
  - Some
  - None
  - Standard Bimodal

- **Medians**
  - F = 54
  - E = 54.5
  - HE = 82

- **Means**
  - Freedom: N=53, Mean = 53.6
  - Hybrid E Only: N=50, Mean = 50
  - Iowa Hybrid E Only: N=25, Mean = 51

CNC Word Recognition

- Freedom
- Hybrid E Only
- Iowa Hybrid E Only
• A lot of variability in performance with this group
  – Typical of cochlear implant data

• Why do some do well and others not so well?

• Current outcome tools do not fully measure the
efficacy of CI as a treatment option.

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**Human Ecology**

• In hearing health care, success with
  intervention is as much related to the anatomy/
  physiology of the individual as it is to the
  *environmental* and *personal* (i.e., ecological)
  factors that make each individual unique from
  the next*.

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*Wu YH, Bentler RA. Do older adults have social lifestyles that place fewer
International Classification of Functioning, Disability and Health

- International Classification of Functioning, Disability and Health, known more commonly as ICF
- Model of health suggests that psychological and lifestyle factors are intertwined with physical health and well-being of the individual

Hearing Loss

Body Functions & Structure
- Loss of hearing in one ear
- Increase in tinnitus
- Dizziness
- Spatial awareness
- Cortical reorganization

Activity Restriction
- Hearing in noise
- Localizing sounds
- Resisting during conversation
- Listening effort increased
- Reduction in quality of life

Participation Restriction
- Withdrawal from social situations
- Withdrawal from social interactions
- Change of job duties
- Community, social, and civic life
- Depression

Contextual Factors

Environmental
- Work place environment
- Attitudes
- Family support during interactions
- Insurance limitations

Personal
- Socio-economic Status
- Personality
- Education Level
- Age
- Other health issues
Goal

- Characterize the relative contributions and change in functioning and disability associated with hearing loss and CI as an intervention.
  - Investigate this longitudinally
- Characterize the influence that contextual (e.g. personality, cognition) factors have on outcomes.

Summary of Speech Perception

- There is variability amongst hybrid benefit
  - Similar to what is seen with a standard CI
- In cases where hearing is maintained minimally or not all at, patients can still benefit from a shorter array cochlear implant.
- Performance for those that have not maintained residual hearing do similarly to bimodal users who have a standard electrode.
- Need to start to understand variability by looking at the person and what might predict outcomes.
What have we learned over the years?

What have we learned over the years: Picking the right patient!
What have we learned over the years: Fitting!

- We always fit the electric and acoustic hearing on the day of activation.
- **Fitting steps:**
  1. Complete an audiogram using air conduction (125-8000 Hz) and bone conduction (250-4000 Hz).
  2. Fit the acoustic component.
  3. Verify the acoustic component via real-ear.
  4. Perform impedance measures.
  5. Program electrical hearing, setting the electric boundary at the point where the acoustic threshold exceeds 70 or 75 dB HL.
  6. Confirm via soundfield audiogram that the subject is getting at least a threshold of 30 dB HL in their low-frequencies with their AC. (plug contra ear)
    - Will want to go back and increase gain with the AC or move the electric boundary down if this isn’t the case.
  7. Consider the contralateral ear. Verify the fitting of that HA as needed.

What have we learned over the years: Verify the acoustic fitting!

- Custom sound software does not show you exactly what the acoustic component is providing. You must verify!!!

![Graph showing acoustic fitting](image)

Looks like gains are set out to 900Hz.

Comparison to speechmap shows patient is not matching target at 900Hz.
What have we learned over the years: Verify the acoustic fitting!

- Custom sound software does not show you exactly what the acoustic component is providing. You must verify!!!
- Speechmap supports our CI Frequency Boundary
- So why doesn’t the CI frequency boundary and gain settings in Custom Sound not match?
- In order to get enough gain and meet targets in the lower frequencies, you sometimes have to add an extra acoustic channel to change the shape of the fit.
- Estimated output in Custom Sound is higher than speechmap by 5dB or more.

What have we learned over the years: Impedance and Hearing Loss!

- Impedance changes and hearing loss seems to occur synchronously.
  - Indicative of changes intracocheal?
What have we learned over the years: Impedance and Hearing Loss!

7/8/14

• Pulsewidth increased on multiple electrodes to keep electrodes within compliance.
• Lower frequency boundary set to 188 Hz.
• Patient prescribed a course of prednisone.

What have we learned over the years: Impedance and Hearing Loss!

9/8/15
What have we learned over the years: Impedance and Hearing Loss!

9/23/15
- Pulsewidth changed back to 25µs, consistent with mAP prior to hearing loss.
- Lower frequency boundary set to 563 Hz.

10/27/15
- Patient came to clinic reporting that she is not hearing well with her current cochlear implant settings.
- Pulsewidth increased to 62µs.
- Lower frequency boundary set to 188 Hz.
What have we learned over the years: A little goes a long way!

- **Post-Op Audiogram**
  - Plan ahead: order an acoustic component when doing the device consult. Then fit the acoustic component......
    - If post-operative thresholds at 125 Hz and greater and are aidable.
    - Generally speaking, fit the acoustic component at frequencies where the threshold does not exceed 75 dB HL.
    - Exceptions can be made.
- You can get a lot of benefit out of just a little bit of acoustic hearing.

Things we still need to learn: Prescriptive method!

- **Using NAL might not be the right prescriptive methodology.**
  - The aim of NAL-NL1 and NAL-N2 is to maximize speech intelligibility above the compression threshold, while keeping the overall loudness of speech at or below normal overall loudness.
  - NAL-NL2 prescribes relatively more gain across low and high frequencies and less gain across mid-frequencies than NAL-NL1.
  - NAL-NL2 provides slightly higher compression ratios for those with mild or moderate hearing loss.
- **NAL wasn’t designed in the context of EAS. It is a good starting point, but deserves more research.**
- **We need to consider the goal of NAL vs our goal of fitting the acoustic component.**
Things we still need to learn: Cross-over frequency!

- In the past, we have been confined to the protocol associated with the clinical trial.
  - We attempted to provide the broadest amplified bandwidth for low-frequency acoustic hearing.
  - Electric cutoff was based on the low-frequency hearing threshold.
- Studies have shown mixed results for meet vs overlap fitting.
  - Overlap: Kiefer et al. (2005); Gifford et al. (via presentation)
  - No difference: Fraysse et al. (2006); Simpson et al. (2009)

Final Thoughts

- Candidacy is determined by a number of factors for standard CI and Hybrid candidates
  - Audiogram
  - Speech perception
  - Etiology
  - Demographic factors
- There is variability amongst hybrid benefit
  - Similar to what is seen with a standard CI
- Verification of the acoustic component through real-ear testing is important.
- In cases where hearing is maintained minimally or not all at, patients can still benefit from a shorter array cochlear implant.
  - Performance for those that have not maintained residual hearing do similarly to bimodal users who have a standard electrode
Acknowledgement

• Research grant 2 P50 DC00242 from the National Institutes on Deafness and Other Communication Disorders -- National Institutes of Health

• The Lions Clubs International Foundation and the Iowa Lions Foundation.

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