Cochlear Implants: An Update on Technology and Outcomes

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- Non-financial Disclosure: I do not have any non-financial disclosures

Where did it all begin?

(Waltzman & Roland, 2006)

Where did we come from, where are we now, where are we headed?
What can we expect from children with today’s technology?
What is new? What is up and coming?

CI Technology Advancements

Where did it all begin?

(Waltzman & Roland, 2006)

Development of a Clinical Device
- Biocompatibility problems
- Lack of support
- Multiple electrodes
- New goals

Today's Devices

Body Worn Processors
Ear Level Processors

http://www.allhear.com/about.php
http://www.bionicear.org/About_the_CI.htm


http://www.allhear.com/about.php
ELECTROACOUSTIC HEARING

- Outcomes?
  - 50 subjects participated in clinical trials

- What if the hearing loss progresses?
  - 12% of clinical trial participants wound up receiving full array CIs

Hearing and Patient Satisfaction Among 19 Patients Who Received Implants Intended for Hybrid Hearing: A Two-Year Follow-Up.

- Mean hearing loss after surgery
- Mean changes in residual hearing 1 mo, 1 yr, 2 yr and 3 yrs (8 patients) post-op

(Erixon and Rask-Anderson, 2015)

Hearing and Patient Satisfaction Among 19 Patients Who Received Implants Intended for Hybrid Hearing: A Two-Year Follow-Up.

- Table showing patient satisfaction and speech discrimination scores

(Erixon and Rask-Anderson, 2015)
**Electroacoustic Hearing – Future Research**

(Gillespie et al. 2014)

**Back to Standard Cochlear Implants**

What can we expect today??

- Hearing
- Speech Production
- Language & Literacy
- Music

**Hearing - Thresholds**

![Audiogram of Speech Sounds](chart)

**Speech and Language**

- Study of speech skills has evolved as technology has improved
- 1980 – perception & articulation
- 1990 - higher level perception
- 2000 – higher order skills
- Tools used to assess skills have also evolved

**Speech Production**

- Relationship between perception and production
- Another measure of cochlear implant success
- Multiple contributors to success
- Questions to ask
- Let's look at some of the research...

**Emergence of Speech Production**

(Ertmer, Jung & Kloiber , 2013)
**Speech Production Accuracy**
- Young CI recipients vs. Typically Developing Peers

(From: Ertmer & Goffman 2011)

**Speech Intelligibility in Deaf Children After Long-Term Cochlear Implant Use**

- Increased focus on younger children
- Audiovisual speech perception
- Attention to speech
- Outcomes are increasingly improved
- Use of telephone
- Fully mainstreamed at younger ages

(Meining et al. 2014)

**Channel/Current Steering**
- Increased resolution due to addition of 'virtual' channels

[Image: Channel/Current Steering Diagram]


**Spectral Mapping**
- Frequency Spectrum is divided into frequency bands

- HiRes 120
- HiRes
- CIS, MNP, SAS

Frequency Spectrum 250-8000 Hz
**Current Steering**

How do we do it?
- Multiple current sources
- Active current steering is designed to deliver added spectral information between adjacent pairs of electrodes through accurately weighted simultaneous stimulation
- This is like having “virtual electrodes”

**ELECTRODE ARRAY**

- Spectral bands
- Neurons

**Conventional Spectral Resolution**

Filter response

- Filter 1
- Filter 2
- Filter 3
- Filter 4

Unresolved
Resolved

**ELECTRODE ARRAY**

- Current Source
- Electrode
- Nerve

100%
50%
30%
70%

**ELECTRODE ARRAY**

- Current Source
- Electrode
- Nerve

100%
50%
30%
**SPEECH VS. MUSIC**

- New technology boasts increased resolution (i.e. HiRes processing)

- **SPEECH**
  - How much resolution is needed?
  - Speech (Increasing Channels)
  - Speech (Decreasing Channels)

http://www.hei.org/research/shannon/simulations/

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**In summary...**

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**LANGUAGE/COMMUNICATION – PERSONAL OBSERVATIONS**

- Critical for literacy
- Vocabulary
- Grammar
- Social vs. Academic language
- Functional listening (passive learning)

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**LITERACY – WHAT IS THE ‘EVIDENCE’?**

Clinical expertise

Patient values

Best research evidence

EBP
CHALLENGES FOR ACQUIRING LITERACY

- Limited language base
  - Limited access to language
- Limited relationship between sound and print

Hart and Risley (1995) Meaningful Differences in the Everyday Experience of Young American Children

STAGES OF READING PROFICIENCY

1. Birth – 6-7 yrs control of syntax and semantics; develop sound/letter assoc and written words have meaning
2. 7-8 yrs; decoding to fluency
3. 8-14 yrs reading to learn stage. Top down and bottom up processing skills develop.
4. 14-18 yrs. Comprehend reading from different viewpoints.
5. 18 yrs. Analyze and synthesize with higher level reasoning

Note: many school curricula now push these expectations up.

APPLICATION TO CHILDREN WHO ARE D/hh??

- Need solid language to master stage 1
- Plateau often at stage 3
- Our visual language (reading and writing) parallels spoken language

S PENCER, BARKER & TOMBLIN (2003) EXPLORING LANGUAGE AND LITERACY OUTCOMES OF PEDIATRIC COCHLEAR IMPLANT USERS

- Compared prelingually deafened CI users with Hearing Peers
- Significant Difference were found for:
  - Formulated sentences
  - Concepts and directions
  - Reading comprehension
  - Writing – total words, t-units, also CI group had more errors

TO TAKE HOME MESSAGES?

- Not seeing a year’s growth in a year’s time
- Therefore gap widens
- However, in this study the CI group was less than a year behind compared to hearing group. This is an improvement from other previous studies
- Ideas for remediation
  - Sentence formulation
  - Use common academic vocabulary eg spelling words
- May continue to see improvements in gap as children implanted younger

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DESDARDIN, AMBROSE, & EISENBURG (2008, 2011)

- Predictors of success
  - Ability to manipulate phonemes; phonologic awareness e.g. rhyming
  - Segmenting, blending
  - Vocabulary
  - Language experiences
- Family involvement
  - Types of questions parents ask important
  - How can we have parents as teachers and still avoid the closed ended question?
Research questions

- What is the strength of the relationships between children’s receptive and expressive language skills at Time 1 (T1) and their literacy outcomes 3 years later T2?

- Are mother’s facilitative language techniques during storybook interactions at T1 associated with their children’s later phonological awareness and reading abilities at T2? And

- What specific early child (age etc.) or maternal factors (family income etc.) contribute to literacy outcomes for this population of young deaf children with ciscs?

Coding of samples

- Higher level
  - Parallel talk
  - Open-ended questions/phrase
  - Expansion
  - Recast

- Lower level
  - Imitation
  - Label
  - Closed-ended question
  - Linguistic mapping
  - Directive
  - Comment – nonspecific “good”

RESULTS

- #1 – relationship between expressive language at T1 and phonological awareness at T2. Directly related to rhyming, segmentation, deletion. Receptive language not related to T2. T1 skills related to reading.
- #2 – Mother’s use of open-ended questions related to later literacy/phonological awareness.
- #3 – factors that related to later phonological awareness include expressive language and higher facilitation techniques by moms.
- Features of group to consider – educated moms, higher SES, early implant recipients. Limited cultural diversity.

TAKE HOME MESSAGES?

- Need to understand importance of early intervention and literacy facilitation.
- What should the audiologist tell parents?
- Language rich environment critical

HEARING – 1 OR 2 IMPLANTS?

- Risk for POORER educational, speech-language, and social-emotional outcomes
  - Lieu, Tye-Murray, and Fu 2012
    - Cohort of UHL, ages 6 to 12
    - Standardized cognitive achievement, and language testing at yearly intervals for 3 years.
    - Improvement over time, but persistent problems
  - Lieu 2013
    - Cohort of UHL children compared to NH siblings
    - Controlling for “environmental” factors UHL significantly lower in oral language and verbal IQ

UNILATERAL HEARING LOSS

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  - Lieu, Tye-Murray, and Fu 2012
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http://www.usemyears.com/
http://www.healthyhearing.com
CHILDREN WITH UHL COMPARED TO NH SIBLINGS

<table>
<thead>
<tr>
<th>Outcome measures</th>
<th>UHL Mean (SD)</th>
<th>NH Mean (SD)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal IQ</td>
<td>100.9 (14.3)</td>
<td>102.7 (14.6)</td>
<td>0.040</td>
</tr>
<tr>
<td>Performance IQ</td>
<td>99.4 (14.4)</td>
<td>102.8 (14.3)</td>
<td>0.108</td>
</tr>
<tr>
<td>Full scale IQ</td>
<td>100.7 (12.2)</td>
<td>104.2 (13.3)</td>
<td>0.012</td>
</tr>
</tbody>
</table>

Lieu, 2014

BILATERAL CI BECOMING MORE COMMON

- 2005 – three major manufacturers report ~ 2800 bilateral implantees worldwide
- As of 2010 estimated 5% of CI patients worldwide are bilateral

BINAURAL LISTENING ADVANTAGES

- Head shadow effect
- Interaural time difference
- Interaural level difference
- Interaural loudness balancing/centering

LIMITATIONS TO BINAURAL ADVANTAGES WITH BILATERAL CI?

- Surgical
- Physiological/Pathological
- ITD sensitivity
- Interaural Loudness Balancing/Centering

(Kan & Litovsky 2015)

INTERAURAL PLACE MATCHING

(Kan & Litovsky 2015)
Bilateral vs. Unilateral CI (Children)

- Do children with Bilateral CI really do better than their unilateral CI peers?
- Different factors play a role
  - Age of acquisition of CI
  - Parental involvement
  - Family reading habits!

Countless Variables

- Age of acquisition of hearing loss
- Amplification history/amount of auditory deprivation
- Cochlear/CANS integrity
- Age at implantation
- Device integrity
- Family support/follow through
- Support services
- Non-verbal IQ
- General health/cognitive function

Cochlear Implants for Single Sided Deafness???

Off Label Use of Cochlear Implants
**Off Label Use of Cochlear Implants**
- Tinnitus
- Vertigo
- Unilateral Deafness**

**Systematic Review #1**
- 17 studies included (108 patients with SSD)
- Weaknesses in research
  - Short term followup (majority 1 yr or less)
  - Evaluation protocols not standardized
  - Self-selection bias of population
- Outcomes positive
  - Speech in noise
  - Localization
  - Subjective benefits
  - Tinnitus improvements

(Vlastarkos et al. 2014)

**Systematic Review #2**
- Outcomes considered:
  - Speech in noise
  - Sound localization
  - Quality of life
- 9 studies (N=112) used in analyses
- Variable results
  - Heterogeneity between studies
  - Benefits in all areas noted
- Conclusion – need larger high quality studies

(van Zon et al. 2015)

**Additional Advances in Auditory Prostheses**
- Auditory Brainstem Implants
- Auditory Midbrain Implants

**Success Across Devices**
- Early researchers never expected cochlear implants to work
- Current CI users have open set speech recognition & use the telephone
- Outcomes for ABI are improving
- Promise for MBI

**I Have a Bilateral Severe-Profound SNHL, Can I Benefit from a Cochlear Implant?**
- You don't need working hair cells for a cochlear implant so a 'sensory' or cochlear loss is OK
- but you DO need a working connection to auditory nerve fibers so a 'neural' or retrocochlear hearing loss is NOT OK
**WHEN MIGHT THE AUDITORY NERVE BE AFFECTED?**

- Surgical procedures related to acoustic neuromas
- Auditory Neuropathy Spectrum Disorder (only cases of true neuropathy)

**NEUROFIBROMATOSIS TYPE II**

- Genetic
- Bilateral SNHL as a result of bilateral acoustic neuromas (vestibular schwannomas)
- In cases like this, bypassing the hair cells is not enough, we need something that will bypass the affected 8th nerve

**AUDITORY BRAINSTEM IMPLANT**

- Electrode array

Only approved for adults and children 12 yrs or older

**VITAL VIDEO SUMMER 2013 – 1st child in US Clinical Trial to receive an ABI**

- Grayson Update:
AUDITORY MIDBRAIN IMPLANT

AUDITORY MIDBRAIN IMPLANT CLINICAL TRIAL 1 OUTCOMES
- Poor temporal coding
- Limited Speech Perception
- Animal Studies → New clinical trial

CO CI CONSORTIUM DEMOGRAPHICS
- Approximately 30 members
  - Implant audiologists
  - Educational audiologists
  - University faculty
  - CHIP providers
  - Deaf educators
  - Speech language pathologists
  - Implant manufacturer personnel (Cochlear, Advanced Bionics, and Med-El represented)
  - Parent consultants

RESOURCES – AUDITORY SKILLS AND EXPECTATIONS
- http://coloradociconsortium.wikispaces.com

RESOURCES
Colorado Cochlear Implant Consortium – an avenue to get collaboration from multiple disciplines across the state as well as reach professionals in more rural settings

http://coloradociconsortium.wikispaces.com
RESOURCES – AUDITORY SKILLS AND EXPECTATIONS

<table>
<thead>
<tr>
<th>Table 1: HOW TO RESPONSE TO ONE-BASED TEST PLAN</th>
<th>Table 2: HOW TO RESPONSE TO TWO-BASED TEST PLAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Some issues with spoken language</td>
<td>Some issues with under-standing</td>
</tr>
<tr>
<td>Confirms child versus not hearing</td>
<td>Confirms child versus not hearing</td>
</tr>
<tr>
<td>Contact O/M regarding possible environment issues</td>
<td>Contact O/M regarding possible environment issues</td>
</tr>
<tr>
<td>Assess that environment issues for child</td>
<td>Assess that environment issues for child</td>
</tr>
<tr>
<td>Break down into smaller steps, and teach those</td>
<td>Break down into smaller steps, and teach those</td>
</tr>
<tr>
<td>Is there different materials that the child</td>
<td>Is there different materials that the child</td>
</tr>
<tr>
<td>Increase the intensity of training toward the</td>
<td>Increase the intensity of training toward the</td>
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<tr>
<td>Written plans of understandable sounds months for three months</td>
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RESOURCES - COMMUNICATION

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<th>School Team</th>
<th>Cochlear Implant Center</th>
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<td>Cochlear Implant Center</td>
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<td>5/29/2015</td>
<td><a href="mailto:tina.stoody@unco.edu">tina.stoody@unco.edu</a></td>
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<tr>
<td><strong>RESOURCES</strong></td>
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THANK YOU!!! QUESTIONS????