Trends in Pediatric Audiology

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Points for Lecture

- Four Part Lecture that involves audience participation
- Cover select areas of Pediatric Audiology that specifically focus on Re/habilitation:
  - Early Audiologic Intervention
  - Considerations in Pediatric Device Fitting
  - Considerations in Verification and Validation
  - Pediatric population and Cochlear Implants
  - Some research results included throughout
Audiology/Policy/Technology

Question: What do you consider to be major advances in the field of pediatric audiology?
Early Intervention and Audiology

- The Joint Committee on Infant Hearing (JCIH) Position Statement, 2007
- Goal: Early Hearing Detection and Intervention (EHDI) to maximize linguistic competence and literacy development for children who are deaf or hard of hearing
- Guidelines: 1, 3, 6 rule
1-3-6 Rule

- Screened no later than 1 month of age
- Comprehensive diagnostic audiological evaluation by 3 months of age
- Receive Early Intervention by 6 months of age
Question

- What are the barriers to early Audiological Intervention? Are the factors simple? Are some more important than others?
Some factors

- Infants in neonatal intensive care unit (NICU) and health related issues
- Diagnosis of mild and moderate hearing loss and Unilateral Hearing loss
- Socioeconomic (SES) level and maternal factors (poverty, educational level, age, insurance status, race)
- Follow-up center proximity and availability

Sources: (Durieux-Smith et al., 2008; Folsom et al., 2000; Liu et al., 2008; Oghalai, Chen, Brennan, Tonini, & Manolidis, 2002; Prieve et al., 2000; Prince, Miyashiro, Weirather, & Heu, 2003; Uus & Bamford, 2006)
Spivak et al., 2009- examined factors related to fitting HA by 6 months
Examined records from 114,121 screened infants over a six year period at six different hospitals
Used 3 categories to describe time at HA fitting: 1) Fit on time, 2) Fit late, or 3) Lost to follow-up
107/192 received HAs; 39% fit on time and 61% fit late or lost to follow-up
Cont....... 

- Found that late ID was related to late fitting AND lost to follow-up
- Unilateral hearing loss was related to late fitting and lost to follow-up
- Coverage by Medicaid and diagnosis of conductive hearing loss were also related to lost to follow-up
Holte et al., 2012 examined factors that influence follow-up after NBHS in children (N=193)

Examined age at diagnosis/confirmation, age at fitting and age at entry into EI and compared to recommended benchmarks (1,3,6)

Gender, test site, SES (measured by maternal education level), and degree of HL examined as potential factors

Eighty-three percent had ABR by 3 months and 61% confirmed HL, 66% had HA within 1 month of confirmation, 75% enrolled in EI by 6 months

SES associated with early diagnosis of HL and fitting of HA
What about device use?
Some Recent Data

- *Moeller et al., 2009*- examined consistency of Hearing Aid (HA) use in 7 infants/families with mild to moderately/severe hearing loss.
- Administered HA use questionnaire and open ended questions at 4 months intervals from ~10 months-28 months.
- Examined 3 categories related to consistent device use: 1) Setting specific, 2) Temperament/State, 3) Activity Related.
Cont....

- Found that consistent device use was variable across situations
- Consistent device use variable at younger ages, but consistent for most settings by ~28 months
Cont..

- **Walker et al., 2013** Examined HA use in children (N=272) with mild-severe loss and possible factors related to use time
- Compared parent report to data logging results
- Also asked open ended questions about situations challenging for HA use
- HA use time related to degree of HL and maternal education
- Parent’s overestimate use time compared to data logging
What about barriers to early CIs?

- The minimum age at CI has decreased over the years and FDA guidelines for minimum age at CI is at 1 year (although many places may be younger).
- Early CI is associated with better in speech and language outcomes (Svirsky et al., 2004; Geers et al., 2009; Nicholas & Geers, 2008; Geers & Nicholas, In press, Nicholas & Geers, In press).
Some Recent Data

- *Chang et al., 2010* examined SES and on access to CIs and related outcomes (N=133 at area Medical Center)
- Compared insurance type [Medicaid (N=64) vs. Private (N=69)]
- No difference in odds of CI or age at CI between the two groups
- Odds of post-operative complications, and missed follow up appointments greater in Medicaid group and odds of bilateral sequential CIs less
Lester et al., 2011 examined barriers to early CI (N=59) in state medical center.

Main outcome measure was age at CI (≤ age 2 years or > 2 years).

Presence of NBHS, insurance type were associated with age at CI.

Other factors related to risk of delayed CI were type of primary and secondary care providers.
Considerations in Pediatric Amplification/Devices
Pediatric Amplification Guidelines

Position Statement of the American Academy of Audiology

March/April 2004
Goal of Hearing Aid Fitting/CI

“To provide a signal that makes low, moderate, and high intensity sounds audible but not uncomfortable and provides excellent sound quality in a variety of listening environments”

AAA Pediatric Amplification Guidelines
2004
What are the Issues in pediatric amplification/devices

- ?
- ?
Critical to Fitting Goal

The wide variability of speech levels and spectra that occur in different listening environments and with different speakers (Pearsons et al., 1977; Stelmachowicz et al., 1993).
Summarizing the Issues

- The level of the signal is dynamic
- Different speakers
- Varied distances
- Speech signal characteristics
Adult vs. Child speech spectrum at various levels
Are the Amplification Needs of Children the same as Adults?

- Children are developing speech and language skills.

- *Stelmachowicz et al., 2001* found differences in the effects of frequency bandwidth in adults vs. children and for male vs. female speakers.

- *Gilkerson & Richards, 2009* examined distribution of words spoken by adult females and males to children (2 to 30 mos):
  - 12,800 words spoken daily
  - 75% of words were spoken by adult females
  - Adult Females: 9,600 words vs. Adult Males: 3,200 words
The adverse effects of noise on speech recognition are greater for children than adults (Blandy and Lutman, 2005; Elliot, 1979; McCreery et al., 2010)

The use of contextual cues (i.e linguistic, semantic and syntactic cues) for speech recognition may differ for adults vs. children (Elliot, 1979; Nittrouer & Boothroyd 1990)
Overhearing and Learning Words

Typically developing children with normal hearing sensitivity will have vocabularies of 3-5 thousand words by age 4-5 years while many children with significant hearing loss will have a vocabulary level of fewer than 500 words (Conrad, 1979).
Relevance of Soft Speech

- Children’s Everyday Listening Environment
- Incidental Language Learning
- Self-monitoring of Speech
- Ease of Listening/Communication
- Speech Spectra/Level of Peers
Hearing Aid Technology

- Digital Signal Processing (DSP)
- Amplitude processing including Wide Dynamic Range Compression (WDRC)
- Noise Reduction
- Feedback Control
- Multi-Memories
- Frequency Transposition and Compression
- Directional Microphones
- FM Technology
Empirical Evidence and Technology for School-Aged Children

- Amplitude Compression- (WDRC vs. Linear) Moderate level of evidence for improved audibility and speech recognition (McCreery et al., 2012)
- Frequency Lowering- Positive results but more research needed (McCreery et al., 2012)
- Noise Reduction- Moderate level of evidence supports that NR does not improve nor does it degrade speech recognition (McCreery et al., 2012)
- Directional Microphones- Moderate level of evidence supports improved perception in controlled conditions BUT more research is needed
Some “MUST READ” articles!


Hearing Aid Selection

- Determine HA that optimizes all levels of speech regardless of degree, configuration and type of hearing loss
- Task becomes more difficult as degree of loss increases
- Task becomes more difficult with certain configurations
Selection And Verification

- Frequency specific threshold
- Loudness comfort/discomfort measures
- Individual or age appropriate acoustics - Real-ear-to-coupler differences (Moodie, Seewald & Sinclair, 1994)
- Individual needs of the child
Selection and Verification

- Prescriptive formula- audibility based for ALL levels, takes into account non-linear processing (e.g., NAL-NL2 Keidser et al., 2011; DSL [i/o], Cornelisse, et al., 1994; Scollie et al., 2005)
Connect coupler and instrument to coupler microphone. Select one of Test 1 through Test 4.
Desired Sensation Level (DSL)  
Version 5.0 (Scollie et al., 2005)

- Age dependent RECD’s by age in 1 month intervals
- Compatibility with ABR data
- Prescriptions for conductive loss
- Multi-stage Input/Output Algorithm
DSL V5 Cont....

- Multichannel Targets
- Targets for an increased variety of speech input levels and shapes
- Prescriptions for noisy environments
Verification

- Real ear aided response determines output in SPL at the eardrum
- Coupler measures using (RECD) - measure gain and output in 2cc coupler using RECD, pre-set and adjust hearing aids
Verification/validation?

- Aided soundfield threshold measures to assess audibility of SOFT SOUND
- May use warbletone, or recorded speech stimuli (note-Scollie et al., working on developing Ling 6 sounds for aided testing-see Scollie et al., 2012)
- Allows observation of behavioral response to soft sounds
- Used in verification of audibility for CI map/programming-more later
Aided Thresholds are NOT!

- Used to assess functional gain
- Used to assess audibility of higher level speech input (conversation levels or higher)
- Used as a means to verify output of the hearing aid
Predicting Perception of Soft Speech using Aided PTA for Hearing Aid Users

From Davidson & Skinner, 2006

(r = -.65; p < .0002)
Validating Devices for Children
Validation Measures

- Speech perception outcomes
- **Functional Outcomes** - Teacher/parent surveys, checklists
- Language outcomes
- Speech production outcomes
Speech Perception Testing historically considered “gold standard”

Purpose

- Determine need for amplification
- Compare performance with/without
- Determine device benefit
- Compare devices
- Assess performance over time
- Determine need for auditory training
- Determine placement in AT curriculum
Some Examples for Children from easiest to most difficult

- Infant Toddler Meaningful Integration Scale (IT-MAIS)
- Low Verbal and Standard Early Speech Perception (ESP) Test
- Word Intelligibility by Picture Identification (WIPI)
- Lexical Neighborhood Test (LNT)
- Kindergarten Phonetically Balanced (PBK) Wordlist
- CNC word lists (PB used adults and children)
- Bamford Kowal Bench (BKB) Sentence Test and BKB SIN
- HINT sentences
Some Functional Measures

- Early Listening Function (ELF)
  - Assesses detection at various distances
  - For infants and toddlers
  - Karen Anderson provided free
  - Oticon website

- Client Oriented Scale of Improvement – Children (COSI-C)
  - COSI-Dillon et al., 1997
  - National Acoustics Laboratory – NAL website
  - Infants/toddlers/young children
  - Set goals and plan strategies for HA use/benefit
Infant-Toddler Meaningful Auditory Integration Scale (IT-MAIS)

- IT-MAIS - Zimmerman-Phillips, Robbins & Osberger, 2000
- Parent report on vocalizations, sound awareness and meaning
- Often used CI evaluation
- Bionicear.com
Littleears Auditory Questionnaire

- Newborn -24 months
- Standardized on 218 NH children age 0-24 months
- Evaluated for using pediatric CI recipients
- 35 questions
- ~10 minutes to complete
- Med-El website ~$25
PEACH (Parents' Evaluation of Aural/Oral Performance of Children)

- diary kept by parents
- Questions/forms on line-NAL.Gov.au
- Parents report how children are using listening
- Questions relate to how children listening in quiet or noise,
- Hear sounds around them and on the phone

Example Q- “1. I would like to know how often your child is wearing his/her hearing aids and/or cochlear implant. Can you tell me about your child’s routine for wearing his/her hearing aids/cochlear implant in the last week?”
Screening Instrument for Targeting Educational Risk-SIFTER

- Anderson & Matkin, 1996
- Pre-school version and school age version
- Teacher questionnaire
- Assess areas such as attention, participation and behavior risk
Listening Inventory for Education (LIFE)

- Anderson & Smaldino, 1998
- School age children
- Student and teacher
- Teacher evaluates technology student assesses issues pre-post

- 10 questions used with rating scale
- Optional 6 questions for additional environments (gym school assembly etc.
- Sample SQ- “Teacher talking in front of room” 5 point scale-always easy to always difficult
Children’s Home Inventory of Listening Difficulties-CHILD

- Anderson and Smaldino, 2000
- Parent and child can complete
- 15 questions
- Rating scale 1-8 from HUH? 1 to 8 Great!
- Available Phonak
Speech Spatial Qualities Questionnaire

- Gatehouse & Noble, 2004

- 3 domains: **Speech understanding** (mainly in challenging, real-life environments), **Spatial Perception** (assessing perception of localization, distance, movement, etc.) and **Sound Qualities**

- **Rate skills 1-10**

- **SSQ modified for children - 42 items**
Survey of Practice in Pediatric Audiology

- Knowledge and Implementation in Pediatric Audiology
Outcomes/measures to consider

- Different talkers - Why does this matter?
- Emotion of talker? Why does this matter?
- Localizing sounds - should this be part of audiology test battery? Diagnostic value?
- Perception of music
- Can we use “dynamic” measures of language learning?
Emotion Identification and Talker Discrimination

- **Speech**: Complex-pitch corresponds to talker’s Fundamental Freq (F0)
  - Talker gender, age, identity
  - Talker emotion, sarcasm
  - Semantic emphasis (word-stress)
  - For ‘tone’ languages: word meaning (semantics)
  - Sentence prosody, interrogative vs. declarative
  - Separation of sound sources (e.g., a talker’s voice in a background of noise or of other talkers)

- **Music**: Complex-pitch corresponds to melody
For CI users: Complex-Pitch-related Perceptual Problems

- Know what problems exist ➔ more knowledgeable counseling & expectations. Example problems:
  - Music perception
  - Talker discrimination & Emotion Perception
- Understand why problems occur ➔ develop new CI strategies that might improve perception of complex-pitch-related stimuli.

Questions:

- What is the interaction between CI strategies + pitch mechanisms (of normal ears)
- Should explicit F0-based strategies be used? (again!)
- Are neural pitch mechanisms ‘plastic’?
- Can ‘simulated’ CI listeners be used to explore & assess perception and new strategies?
- How do ‘bimodal’ device-use and bilateral CIs compare for perception of complex-pitch-related stimuli?
Emotion Perception

Emotion Speech Materials:
- 3 simple-vocabulary, semantically-neutral sentences
  - It’s time to go.
  - Give me your hand.
  - Take what you want.
- 1 female talker
- 4 intended emotions (angry, happy, sad, scared)
- Level-normalized (rms)

Presented in soundfield at 65 dB SPL
Emotion Identification

- **Stimulus:** 1 sentence presented in each trial
- **Response:** Identify the emotion, choose one,
  - Angry (A)
  - Scared [Fearful (F)]
  - Happy (H)
  - Sad (S)
Emotion Discrimination

Stimulus: 2 sentences presented in each trial

- Response: were two sentences spoken
  - “same feeling”, or with
  - “different feelings”
Talker Discrimination

Speech Materials:

- Indiana Multi-talker Speech Database (Pisoni and Indiana U)
  - Selected 8 female & 8 male talkers (out of 10 each)
  - 100 IEEE/Harvard sentences spoken by each talker

All were level-normalized (rms)
All presented in soundfield at 65 dB SPL
Methods

Talker Discrimination

- **Stimulus:** 2 sentences presented in each trial
- **Response:** were two sentences spoken by
  - the “same person”, or by
  - “different people”

- **Two conditions:**
  - **Across Gender (♀ vs ♂)**
  - **Within Female (♀ vs ♀)**
Acknowledgments

APEX (Application for Psycho-Electrical eXperiments) ORL Experimental Laboratory, Kuleuven, Belgium (Laneau et al., 2005)

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Consideration of Cognitive Processing Tasks

- Why are some children scoring within the average range (of their hearing age mates) while some show substantial delays?
- Understanding individual differences may help develop screening methods to identify high risk children and novel approaches for targeting intervention.
- Importance of “process” measures: encoding, phonological storage, verbal rehearsal, retrieval strategies, learning, memory.
Audibility, Sensory Aids, Speech Perception and Cognition as Factors in Children’s Vocabulary
Project Outline

Goal
Specify how perceptual and cognitive abilities interact to determine relative benefits of sensory devices for children with moderate to profound sensorineural hearing loss.

Methods
Measures of audibility, speech perception, working memory, novel word learning and processing speed will be examined in relation to vocabulary for HI and NH children.
Acknowledgement

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Mentors/Collaborators:

Washington University
Mitchell Sommers, Ph.D.
Sandra Hale, Ph.D.
Chris Brenner, M.S.
Brent Spehar, Ph.D.

University of Texas at Dallas
Ann Geers, Ph.D.
Subjects

- **Hearing-Impaired:**
  - 51 Subjects
  - Gender: 22 Female, 29 Male
  - Age at Test: 6;9 (range 5;10 – 8;0)

- **Normal Hearing:**
  - 17 Subjects
  - Gender: 10 Female, 7 Male
  - Age at Test: 7;0 (range 6;0 – 8;0)
Hearing Impaired Subjects: Sensory Aids

- **Device Configuration:**
  - Two Hearing Aids: 11 subjects
  - One Cochlear Implant: 4 subjects
  - Two Cochlear Implants: 24 subjects
  - Bimodal Fitting: 12 subjects
Test Measures

Vocabulary
- Peabody Picture Vocabulary Test (PPVT-Dunn & Dunn, 1997)

Speech Perception
- Signal to Noise Ratio (SNR) for Spondees
- Lexical Neighborhood Test (LNT-Kirk et al.,) @ 50 & 70 dB SPL
PPVT

Peabody Picture Vocabulary Test

HI (51)
NH (17)
Speech Perception

<table>
<thead>
<tr>
<th>LNT 50</th>
<th>LNT 70</th>
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<tbody>
<tr>
<td>HI (51)</td>
<td>64</td>
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<tr>
<td>NH (17)</td>
<td>97</td>
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</table>
Cognitive Measures

- Working memory/Simple Word Span
- Working memory/Complex Word Span
- Verbal learning portion of Children’s Memory Scale (CMS)
- Reaction time using Pediatric Speech Intelligibility Stimuli (PSI-Jerger & Jerger, 1984)
- Novel Word Learning
Novel Word Learning Test

- Ability to learn the meaning of a novel word in a related context within the first few exposures and without direct instruction referred to as “fast mapping” (Carey and Bartlett, 1978) or “quick incidental learning” (Rice, 1990).

- Researchers have used novel word learning paradigms to demonstrate that normal-hearing children (as young as 15-18 months of age) are able to acquire new vocabulary incidentally (Oetting, Rice, & Swank, 1995; Rice, Buhr, & Oetting, 1992; Rice & Woodsmall, 1988; Carey, 1978).

- Researchers examining word learning skills of children with hearing loss (Gilbertson & Kamhi, 1995; Stelmachowicz et al., 2004; Houston et al., 2005; Pittman et al., 2005; Lederberg & Spencer, 2009)
Novel Word Test

- Based on the procedure used by Stelmachowicz et al., 2004
- Six novel words (nouns only) introduced in the context of a picture story presented via a computer program
- Children view six 2-3 minute segments of a story with all six words introduced once during each segment
- Recognition of 6 novel words assessed at the end of each story segment using 6 item closed set test
- Total score possible at each segment is 6 and across all of the segments is 36
Novel Word Learning

All trials:
$F(1,66)=4.96, p<.03$

Last 3 trials:
$F(1,66)=8.06, p<.01$
Novel Word Scores

![Graph showing novel word scores for different categories with comparison to chance level.](image)
Trial Scores

Trial 6:
$F(1,66)=9.44, p<0.01$
Simple Working Memory

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<tr>
<th>Condition</th>
<th>HI (33)</th>
<th>NH (16)</th>
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<tbody>
<tr>
<td>V</td>
<td>44</td>
<td>50</td>
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<tr>
<td>A</td>
<td>47</td>
<td>66</td>
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<tr>
<td>AV</td>
<td>52</td>
<td>66</td>
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</table>
Reaction Time using PSI stimuli

- Speech stimuli, picture cards and competing sentence stimuli from the PSI
- Child asked to decide if auditory stimuli match picture stimuli
- Reaction time measured for Yes/No task
- 6 sentences presented four times each for a total of 24 trials
- 24 trials each in quiet, +10 and +5 dB SNR
- Median Reaction Time calculated for all correct trials
Reaction Time using PSI stimuli

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Reaction Time

Reaction Time (seconds)

<table>
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<th>Condition</th>
<th>HI (50)</th>
<th>NH (17)</th>
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<tbody>
<tr>
<td>Quiet</td>
<td>2.5</td>
<td>1.9</td>
</tr>
<tr>
<td>10 dB SNR</td>
<td>2.5</td>
<td>1.9</td>
</tr>
<tr>
<td>5 dB SNR</td>
<td>2.8</td>
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* * *
Summary

- On going analyses will examine unique contribution of variables to word learning and vocabulary size
- Examine outcomes in speech and language with underlying cognitive processes in mind
Cochlear Implants

- Changing Pediatric Guidelines
- Device Configurations
- Bilateral CIs
- Bimodal Devices
- Bimodal Fittings
- Research Results
Current Trends in Pediatric CI Candidacy

- Decreased age at implantation (12 months)
- Consideration of children with more residual hearing at both ears (≥ 2 years old)
- Consideration of children with asymmetric hearing loss (≥ 2 years old)
- Poor audibility in high frequency range
Clinical Referrals for CI Evaluation

- Bilateral severe to profound loss
- Progressive SNHL
- Aided sound-field thresholds worse than 30 dB HL (at 2000 Hz and higher)
- Missing Ling Sounds at average or soft input
- Plateau in auditory progress
- Auditory Neuropathy/Dysynchrony
Speech Recognition Criteria:

**Adults:**
- \(\leq 50\%\) Sentences aided in ear to be implanted
- \(\leq 60\%\) Sentences best-aided

**Children 2+:**
- \(\leq 30\%\) LNT or MLNT best-aided
- Children < 2 years profound range for thresholds
Audiogram For CI Candidate (Age 2 and up)
Device Configurations

Bilateral Cochlear Implants- Cochlear implants at each ear

Bimodal- Cochlear implant at one ear and hearing aid at the contra-lateral ear

Electro-acoustic Stimulation/EAS- Cochlear implant and hearing aid at the same ear
Bilateral CIs

- Demographics from a world-wide survey of experienced (CI) centers revealed 70% of all bilateral CI (BCI) surgeries by the end of 2007 occurred in children (Peters et al., 2010)

- Research suggests consideration of early BCI and a critical period for benefit (Bauer et al., 2006; Sharma et al., 2007; Gordon et al., 2011)

- Benefits include improved localization, listening in noise, ease of listening, sound quality (For a discussion and related literature see Peters et al., 2010)
Changing CI Guidelines and Bimodal Fittings

- Change in FDA guidelines - greater level of residual hearing/speech recognition in non-implanted ear
- Availability of digital power hearing aids
- Improved cochlear implant speech processing strategies
- Preservation of residual hearing in CIs
Benefits of Binaural Hearing

The ability to localize sound, as well as the ability to detect and understand speech in complex acoustical environments is achieved by the central auditory system’s ability to calculate minute differences in the characteristics of sound arriving at each ear.
Head Shadow Effect

Listening using the ear with the better SNR to improve performance
Binaural Squelch

The advantage of adding the ear with the poorer SNR compared to listening with the better SNR ear alone.
Binaural Redundancy

Benefits:

1) Simply means two ears are better than one when speech or speech in noise are from same location

2) Auditory system’s ability to use redundant information when same signal arrives at both ears

3) Central phenomena
Research Literature on Benefits of Bimodal Devices

In general, adult and pediatric studies have demonstrated benefits of using a hearing aid in the non-implanted ear.

(e.g. Shallop et al., 1992; Chmiel et al., 1995; Armstrong et al., 1997; Blamey et al., 1997; Ching et al., 2001; Kong et al., 2005; Ching, 2007)
Benefits of Bimodal Fittings

- Improved localization
- Improved speech recognition in quiet and noise
- Improved sound/speech quality
- Music appreciation/ melody recognition
- Ease of listening
- Reports of improved voice quality

(Ching, 2007; Simons-McCandless & Shelton, 2000; Kong et al., 2005; Shallop et al., 1992; Chmiel et al., 1995; Armstrong et al., 1997; Blamey et al., 1997; Ching et al., 2001)

Benefits vary across these conditions
Combining Acoustic and Electric Hearing

- Hearing Aid
- Voice pitch/voice quality
- Music appreciation
- Perception in noise

- Cochlear Implant
- Speech recognition ~ consonant and vowel recognition
- Speech intelligibility
Candidacy for Bimodal Fitting

- All CI children should be considered as candidates

- CI users with very limited residual hearing [minimal aided thresholds and speech perception-note (Kong et al., 2005) and (Chang et al., 2006) may still benefit from bimodal stimulation

- Most cases demonstrating no measurable benefit appear to do no worse

- HA use may contribute to more successful CI use

- Literature suggests that period of HA use facilitates spoken language and localization skills in children with CIs (Nittrouer & Chapman, 2009; Grieco-Calub & Litovsky, 2010)
Case Studies
Case 1 “It’s never too late for a bimodal fit!”

- Identified @ 2 Years with **profound** bilateral hearing loss (ABR-behavioral)
- Etiology unknown
- Received CI at Age 3
- Entered CID Age 8
- Used CI at Right Ear
- No Aid at Left Ear
Note that these results are obtained several years after the CI-results at CI evaluation showed profound
Fit with HA @ Left Ear
Speech Perception Results

- HA Only
- CI Only
- HA+CI
- HA+CI
- HA+CI

Conditions:
- Quiet @ 60 dB SPL
- Quiet @ 60 dB SPL
- Quiet @ 60 dB SPL
- Quiet @ 50 dB SPL
- 10 dB SNR (60 dB SPL)
Anecdotal Reports

- Child initially reported that sound quality of hearing aid “very different”, however was very willing to wear aid
- Within three weeks of initiating hearing aid use, demonstrated open set word recognition (36% on LNT @ 60 dB SPL)
- Child reported benefits for listening to quiet speech/speech at a distance and speech in noise
Anecdotal reports cont....

- Teachers/parents reported improved voice quality in addition to improved listening skills in challenging listening environment
- Given a choice, child prefers to wear both devices (and does so consistently)
- Child reported that CI “sounds better” when wearing CI+HA
Case 2 (Result of Expanded CI Criteria)

- Child identified with bilateral mild steeply sloping to profound loss at age 18 months
- Fit with digital hearing aids optimized for speech at soft, average and loud levels
- Speech production/intelligibility fair to good (intonation and voice quality good, consonant production only fair)
- Received cochlear implant at age 7
Pre-Implant Audiogram

Hearing Status:
Normal to mild at 250 Hz, steeply sloping to severe at 500 Hz to profound at 1000-4000 Hz at both ears

Aided Speech Recognition
MLNT
Right Hearing Aid 20%
Left Hearing Aid  56%
Binaural 48%
Speech Perception in Quiet

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<th>Left</th>
<th>Binaural</th>
<th>R CI</th>
<th>L HA</th>
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Most recent Results

- CNC words at 60 dB SPL
  - Bimodal 68%
  - CI Only 61%
  - HA only 6%

- BKB-SIN (lower is better)
  - Bimodal 9.8 dB SNR
  - CI ONLY 8.8 dB SNR
  - HA only 23 dB SNR
Hearing Aid Fitting for Bimodal
(Note optimized for maximum audibility)

Connect coupler and instrument to coupler microphone. Select one of REAR 1 through REAR 4.
Audibility for Average Conversational Speech

Connect coupler and instrument to coupler microphone. Select one of REAR 1 through REAR 4.
Post Implant Aided Thresholds

Intensity dB HL vs Frequency Hz
Discussion Points

- Child still strongly prefers HA with CI
- HA Fitting options investigated and child preferred Frequency Compression—more about this later
- Uses FM system at school
- Bimodal benefit may plateau as CI improves
- Other test measures to analyze
- Trade-off across measures may be apparent
Case 3 - Example of Asymmetric Loss

- Meningitis @ 3yr-8mos
- Attended oral pre-school
- Mainstreamed 1st grade
- Loss @ Left Progressed experienced tinnitus (Left)
- Discontinued HA (Left)
- CI @ Left age 10 years

Pre-Implant Aided Right
Speech Perception
- LNT @ 60 dB SPL  32%
- HINT S Quiet 84%
- HINT S +8 SNR  46%
Speech Perception in Quiet

Percent Words Correct

Right HA | Right HA | Left CI | Bimodal CI+HA | Left Cl | Bimodal CI+HA

Pre-Implant | Post Implant 17 Mos | Post Implant 23 Mos
Speech Perception in Noise
+8 dB SNR (S0N0)

Percent Words Correct

<table>
<thead>
<tr>
<th>Left CI</th>
<th>Bimodal CI+HA</th>
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</table>

Post Implant 17 Mos        Post Implant 23 Mos
Most recent Results

- CNC words at 60 dB SPL
  - Bimodal 76%
  - CI Only  86%
  - HA only  6 %

- BKB-SIN (lower is better)
  - Bimodal 7.5 dB SNR
  - CI ONLY 9.3 dB SNR
  - HA only 23 dB SNR
CI and HA Aided Thresholds
Hearing Aid Fitting
Anecdotal Reports

- Child now attends college
- Prefers using hearing aid with CI
- Trials with frequency compression aid conducted—preferred frequency compression
Case 4 Pediatric EAS Fitting

- Female with mild high frequency HL diagnosed at 1 mo, HL progressed, fit with HAs at 3 yrs
- By 8.5 yrs, received standard (31.5 mm) Med-El Pulsar ci100 array at right ear
- BTE HA at left ear and CI and ITE right ear
- Age 9 years, 1 month at beginning of data collection (6 mos post CI activation)
Preservation of Acoustic hearing

Pre-Op Thresholds
- 5 months prior to implantation
- Binaural aided thresholds “B”

Post-Op Thresholds
- Residual hearing preserved from .125 – 1kHz
- Currently 1 yr, 9 mo post CI, and hearing remains stable

Quadrizius, 2008
Results

- Patient performed similarly or slightly better with the bimodal EAS compared to the traditional bimodal fitting.
- Patient has strong preference for use of all 3 devices (bimodal EAS) and continues to do so.
- See Uchanski et al. 2009.
Fitting Questions for the Audiologist

Determining how to best program/fit the cochlear implant and the hearing aid for optimal benefit:

*Do we deliver low frequency to the HA and high frequency to the CI?*

*Do we optimize BOTH devices with the widest frequency range?*

*Or should we restrict gain to regions that have more residual hearing?*

*Should we consider Frequency Lowering (transposition/compression) for HA? Are there differences in bimodal vs. EAS fittings?*

Some studies to review: (Vermiere et al., 2008; Simpson et al., 2009; Mok et al., 2006, 2010)
Evaluation Questions

- How do we best evaluate the effects of bimodal devices using clinically available tests/procedures?
- How do we fit and evaluate very young children?
- Is there a period that HA use is discontinued after receiving the CI?
- When do we consider bilateral implants and is there a degree of hearing associated with this decision?
Outcome Measures for Evaluation

- Indexical properties of speech (emotion and different talkers)
- Music perception
- Subjective reports
- Localization

Very young children may be limited to detection tasks (i.e. Ling Sounds, aided responses) and parent/educator reports and observation will be critical.
Hearing Aid Use

- Consistent hearing aid use should be implemented prior to CI/s
- Hearing aid use after unilateral CI surgery and prior to initial activation is strongly encouraged
- Continued hearing aid use AFTER initial activation is strongly encouraged
Bimodal vs. Bilateral CI’s


Bilateral CI’s or Bimodal?

Issues to consider when reviewing the research

- Fitting of the CI and the HA in bimodal condition and fitting of the CI in bilateral CI condition
- Age at implant for CI (first and second)
- Consistency of hearing aid use
- Type of hearing aid and fitting
Goal of Device Fitting

“To provide a signal that makes low, moderate, and high intensity sounds audible but not uncomfortable and provides excellent sound quality in a variety of listening environments”

- AAA Pediatric Amplification Guidelines 2004
Importance of Bimodal Fitting

Studies have demonstrated that the hearing aid and the cochlear implant should be balanced for loudness for optimal performance and benefit.

(Armstrong et al., 1997; Dooley et al., 1993; Blamey et al., 2001; Ching et al., 2001, 2004; Keilmann et al., 2009)
Fitting Cochlear Implants and Hearing Aids

- Both devices will require determining the range for sounds from just audible to comfortable

- **Hearing Aid** - the range of acoustic stimuli that is audible and comfortable

- **Cochlear Implant** - the range of electrical stimuli that is audible and comfortable
Cochlear Implant Fitting

- Select speech strategy and relevant parameters for CI map
- Obtain threshold and comfort levels for map
- Use loudness scaling procedures to set “C’s” or “M’s” and to balance loudness across electrodes
- Use sensitivity, volume and input dynamic range settings to make speech clear and comfortably loud within electrical dynamic range (James et al., 2003; Holden et al., 2007; Davidson et al., 2009)
Another view of CI Fitting
Using Loudness Scaling

- Signal used for mapping each electrode/electrode band increased in clinical current units from threshold to comfort/maximum loudness
- Picture stimuli that allows children to rate perceived loudness
- Observe responses to stimuli for very young children
Loudness Growth Task
Response Cards

VERY SMALL  SMALL  PERFECT  BIG
Validate Map for Audibility and Comfort

- Verify that soft sounds are audible by sound field thresholds between 15-30 dB HL (Skinner, 2003)
- Conduct speech perception testing in quiet (50 and 60 dB SPL) and noise
- Determine comfort of high level frequency specific FM tones and speech input in sound field (75-80 dB SPL).
- Determine audibility and comfort of speech in everyday listening environments
Why use aided thresholds for CI/Bimodal fitting?

- Consistently shown to be a predictor of CI outcomes (Davidson et al., 2010; Skinner et al., 2003; Nicholas & Geers, 2007, 2010)
- Aided thresholds serve as common metric for minimal audibility for CIs and HAs
- Essential to CI and Bimodal Fitting
Aided CI Thresholds and Ling Sounds

Warble Tone Thresholds

Frequency (Hz)
-10 0 10 20 30 40 50 60 70 80 90 100 110 120

250 500 1000 2000 4000

Ling Sound "ah"

Ling Sound "s"
Aided CI thresholds - FM tone vs. Narrow-band Noise (Davidson et al., 2009)
Aided Thresholds and Audibility for CIs

- 3G/Freedom AI = 74
- Esprit/Spectra AI = 45
Aided Thresholds and Speech Perception

(Davidson, Geers & Brenner, 2010)

Speech Perception Scores

- LNT at 70 dB SPL
- LNT at 50 dB SPL
- BKB in Quiet
- BKB in Noise

<table>
<thead>
<tr>
<th>Condition</th>
<th>Average Percent Correct</th>
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<tbody>
<tr>
<td>LNT at 70 dB SPL</td>
<td>56.7 ± 10</td>
</tr>
<tr>
<td>LNT at 50 dB SPL</td>
<td>35.1 ± 10</td>
</tr>
<tr>
<td>BKB in Quiet</td>
<td>74.8 ± 10</td>
</tr>
<tr>
<td>BKB in Noise</td>
<td>49.1 ± 10</td>
</tr>
</tbody>
</table>

*Significant difference between conditions
Hearing Aid Fitting

- Select a hearing aid that will provide audibility and comfort for a range of speech levels from very soft to loud
  - It’s not just about power now!
  - Flexible processing and programming capabilities for frequency bands
  - Flexible compression characteristics for gain and output (getting maximum audibility allows us to balance CI and HA)
  - Consider Frequency lowering
  - Feedback control
Fitting/Adjusting for Bimodal Fit

- Balance comfort / loudness of input levels from soft to loud across devices using
  - Live voice presentation
  - Calibrated running speech @ ~65 dB SPL, ~70 dB SPL, ~80 dB SPL
  - Environmental sounds at various levels
  - Adjust Global Map C/M levels or volume, adjust output of hearing aid, evaluate compression characteristics of each device, evaluate frequency specific C levels, output etc..
Fitting/Adjusting for Bimodal Fit (CI+HA)

- Balance comfort /loudness of input levels from soft to loud across devices using
- Live voice presentation
- Calibrated running speech @ ~65 dB SPL, ~70 dB SPL, ~80 dB SPL
- Environmental sounds at various levels
- Adjust Global Map C/M levels or volume, adjust output of hearing aid, evaluate compression characteristics of each device, evaluate frequency specific C levels, output etc.
Validating Fit of CI+HA

- Aided thresholds
- Aided speech testing (binaural and monaural)
  - Speech Perception in quiet (50 and 60 dB SPL)
  - Note that HA only testing may not be possible or a less difficult test may be needed (good to have baseline)
  - Most important to determine that bimodal perception is not degraded compared to CI alone
The Goal of Bimodal Fitting

Loudness Scale 0=nothing, 1=very small, 2=small. 3=perfect, 4=big, 5=too loud
Summary

- All CI patients should be considered for bimodal fitting (CI+HA)
- Both devices must be optimized for comfort and audibility of all speech levels (although questions remain as to “optimal fitting”)
- Second CI considered when bimodal fitting offers limited benefit—likely a “trade off” across outcome measures
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Effects of Hearing Aid Frequency Response Settings in Children with Bimodal Device Fittings

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Support for Research Provided by Cochlear America’s, St. Louis Children’s Hospital Research Foundation and Phonak
Project Outline

- Studies have supported the coordinated fitting of a hearing aid (HA) and cochlear implant (CI) for bimodal use (CI + HA at non-implanted ear) that emphasizes balanced audibility and loudness across the two ears/devices.

- Guidelines for allocating frequency information to the cochlear implant and hearing aid are less well established.

- Become more critical as cochlear implant guidelines expand to include patients with increased amounts of residual hearing.
Study Participants

- 14 children; 6 female, 8 male
- Mean age at test = 12 years (range 7-21 years)
- All unilaterally implanted with a Nucleus CI24RE CA or CI512
- All used a Nucleus Freedom or CP810 speech processor
- Mean age at CI = 7.5 years (range 4-19 yrs)
- Mean duration of CI use = 5 years (range 2.5-9.0 yrs)
- All children were experienced HA users at the non-implant ear
- All children were fit with a Phonak Naida IX UP BTE
- Mean Unaided PTA at HA ear 84 dB HL (range 32-102 dB HL)

Bimodal fit was optimized to balance for loudness between ears when possible, and CI was unchanged throughout the study.
Study Design

- Three HA frequency responses were evaluated

  *Wideband* frequency response-optimized for audibility for all frequencies - traditional fitting

  *Restricted* high frequency response - only amplified low frequencies

  *Frequency compression* response

- 3-4 weeks between each session to allow for acclimatization to new HA setting

- HA frequency response for both restricted and frequency compression were individualized based on hearing
Unaided Thresholds at the HA ear

Hearing Level (dB) (ANSI - 2004)

Frequency (Hertz)

125  250  500  1000  2000  4000  8000

-10  0   10   20   30   40   50   60   70   80   90   100   110   120
DSL targets for Restricted HA fitting
Aided Thresholds-Wideband HA Fitting
Aided Thresholds: Restricted HA Fitting

Aided HA Thresholds: Restricted

Frequency (Hertz)

Hearing Level (dB) (ANSI-2004)

-10
0
10
20
30
40
50
60
70
80
90
100
110
120
125 250 500 1000 2000 4000 8000
Aided Thresholds: Frequency Compression

Aided HA Thresholds: Freq Comp

Frequency (Hertz)

Hearing Level (dB) (ANSI-2004)
Unaided and HA Thresholds

Hearing Level (dB) (ANSI-2004)

Thresholds
Frequency (Hertz)

125 250 500 1000 2000 4000 8000

-10 0 10 20 30 40 50 60 70 80 90 100 110 120

HA Restricted
HA Wideband
HA Compression
Unaided
Group data using the **BEST** bimodal score for each subject was significantly better than the CI alone ($F(1, 13) = 12.69$, $p = .003$).
Group data using the **BEST** bimodal score for each subject was significantly better than the CI alone \( F(1, 13) = 12.69, p = .003 \).

Which score is best varies by individual.
Perception of Open-Set Words

Group data using the **BEST** bimodal score for each subject was significantly better than the CI alone ($F(1, 13) = 12.69, p= .003$).
Perception of Sentences in Noise

Group data using the BEST bimodal score for each subject was significantly better than the CI alone ($F(1, 13) = 11.54$, $p = .005$).
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Which score is best varies by individual.
Group data using the **BEST** bimodal score for each subject was significantly better than the CI alone \((F(1, 13) = 11.54, p = .005)\).
Localization Testing

Scored as degrees of error (RMS)
10° between each speaker
Analysis of group data revealed significantly better scores in the bimodal conditions compared to CI alone ($F (1, 12) = 13.939, p = .003$). Post-hoc comparisons showed that both wideband and frequency compression HA settings were significantly better than CI alone ($p = .01$ and $.006$ respectively).

The **BEST** bimodal condition was significantly better than CI alone ($F (1,12) = 25.47, p = .000$).
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Which score is best varies by individual.
Localization of Sound

Analysis of group data revealed significantly better scores in the bimodal conditions compared to CI alone \((F(1, 12) = 13.939, p= .003)\). Post-hoc comparisons showed that both wideband and frequency compression HA settings were significantly better than CI alone \((p= .01 \text{ and } .006 \text{ respectively})\).

The **BEST** bimodal condition was significantly better than CI alone \((F(1,12) = 25.47, p=.000)\).
Talker Discrimination

Group data using the **BEST** bimodal score for each subject was significantly better than the CI alone (F (1, 12) = 12.33, p= .004).

Note that a score >65.6% (black horizontal line) is significantly above chance; only 8 children scored above this level and 6 scored ≤ this level.
Talker Discrimination

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Note that a score >65.6% (black horizontal line) is significantly above chance; only 8 children scored above this level and 6 scored ≤ this level.

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Note that a score $>65.6\%$ (black horizontal line) is significantly above chance; only 8 children scored above this level and 6 scored $\leq$ this level.
Reported Preference

- Preference for HA responses in everyday listening environments varied across patients;
- 10 preferred frequency compression,
- 2 restricted and
- 2 reported no preference.
Conclusions

- Scores in the **BEST** bimodal condition were significantly better than the CI alone condition across all outcome measures, although the best bimodal condition varied across individuals and outcome measures.

- Group data revealed that the wideband and frequency compression conditions were significantly better than the CI alone for localization and the majority of children performed best with frequency compression.

- The majority of children preferred frequency compression over wideband or restricted.

- Individual results support consideration of both restricted bandwidth and frequency compression, in addition to the traditional wideband frequency response, for HA settings used in bimodal fittings.
Auditory Neuropathy Spectrum Disorder (ANSD) and CIs
Review of ANSD Literature


- Calls attention to the fact that more research needed to control for co-morbidity of other medical histories and etiologies

- Research that extends beyond auditory outcomes
Objective; Describe pre-implant profiles and outcomes of children with ANSD that receive CIs

N=140 diagnosed with ANSD- 39 used NO assistive device, 44 unilateral or bilateral HAs, 49 use unilateral or bilateral CIs and 8 use HA+CI (bimodal)
Recent Results, continued

- 52 children received CI in ear with ANSD
- Of that group - 42% premature and other medical comorbidities, 38% had abnormal imaging, 81% had thresholds $\geq 70$ dB HL
- Considered amplification trial 3-6 months
Recent Results, continued

- Device options available at UNC no assistive device, unilateral or bilateral HAs, unilateral or bilateral CIs

- All families offered FM (~ 12 months of age)
Measures

- Speech perception tests: IT-MAIS, ESP, PBK and MLNT or LNT
- All live voice at 70 dB SPL
- Results divided into 3 groups
  A) CI use < 6 months (n=11) and not tested
  B) CI use > 6 months and unable to take open set test (n=15)
  C) taking open set test battery and obtained some open set ability (n=26)
- Magnetic Resonance Imaging (MRI) and Electrical-elicited compound action potentials (ECAP) also examined
Method

- Group B had IT-MAIS administered to parents of 13 children
- Pre-implant mean score 26% (SD=21%) vs. 76 post CI score (SD=16%)
- Note that only three of the 15 total children in this group had no other medical diagnosis
Results

- Group C: n=26, note significant variability in performance mean PB K phoneme score 76% (SD=22%) and mean word score 54% (SD=34%)

- 73% achieved score of >30% and 27% ≤ 30% - what is significant about these numbers?
Results

- Note that variables typically noted to be associated with implant benefit were NOT significantly associated with outcomes for this group-i.e. age at test, duration of CI use, duration of HA before CI, pre-implant PTA, etc...

- However-ECAP and MRI findings were correlated with outcomes
Considerations

- Robust or present ECAP vs. absent or atypical
- Normal vs. abnormal MRI findings
- Absence vs. presence of other medical issues
- ECAP and MRI findings related
- Presence of CND related to poor outcomes
Auditory Neuropathy/Dys-Synchrony: When to Consider Cochlear Implantation

Ruth Reeder, MA,CCC-A
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Presented at the Wisconsin Speech-Language-Hearing Conference April 2005
Diagnosis

- Abnormal ABR
  - Cochlear microphonic (CM) present, no other measurable waves
  - Reverses in polarity
  - Cancels out with alternating polarity
  - CM seen most clearly at higher stimulation levels

- Otoacoustic Emissions
  - Initially Present OAE’s – transient or distortion product, transient recommended
  - Initially Absent OAE’s
  - OAE’s gradually disappear over time

- Behavioral Testing

- Tympanometry and Acoustic Reflexes
Suggested Protocol

- Audiologic Evaluation
- Speech and Language Evaluation
- Psychological Evaluation
- Other
  - ENT, Genetics, Neurology, OT, PT
- Counseling
Communication

- Constant ongoing communication between service providers is essential for monitoring speech and language progress and the need for further intervention
Rehabilitative Options

- Trial with hearing aids
  - Fit the loss
  - Flexible amplification
  - Possibly FM use in classroom
- Cochlear implant evaluation early on; may be a viable option if limited benefit with traditional amplification
- Monitoring only
When to Consider Cochlear Implantation

- Auditory/oral communication progress is delayed compared to:
  - Communication with signs or cued speech
  - Expectations given rehabilitation and cognitive potential
- Sufficient benefit from hearing aids has been ruled out
- Family supportive of CI option
Case Studies
Case A

- Born at 28 weeks gestational age - remained in the NICU for 10 weeks - Cerebral Palsy
- Parents suspicious of HL at age 5 mos
- Diagnosed with AN/D bilaterally at 10 mos
- Consistent HA use bilaterally at 11 mos
- Mild cognitive delays possible
- Using total communication
Case A

- CP effected speech & sign production
- Was making progress in auditory/oral communication
  - Slower than expected, even with CP
  - Progress was in small increments followed by plateau
- Age at implant – 31 mos
Pre-Implant Audiogram (Case A)

- Closed-Set
  - Detect all Ling 6 but 0% discrim
  - 100% C vs I
  - 0% ESP LVS
  - 0% ESP LVM

- Open-Set
  - 0% GASP

- RE Implanted
3 Months Post-Implant (Case A)

- Discriminates all Ling sounds from a distance
- Many recognizable words and word approximations
- Understands familiar phrases through audition alone
After Device Reprogramming (Case A)

- Detection levels in the optimal range for a cochlear implant
Closed-Set Speech Perception (Case A)
Open-Set Words
Speech Perception (Case A)

![Bar chart showing speech perception for different cases and time points.](chart.png)
Language (Case A)

[Graph showing the relationship between chronological age and language age]
Case A Summary

- Rate of progress in auditory/oral communication increased dramatically after implantation.
- Speech production better than anticipated given the neuromuscular involvement.
- Child continues to progress well – relies on hearing & speech as primary means for communication.
Case B

- Born at 26 weeks gestational age
- Fit with hearing aids at 1 year of age
- Hx chronic middle ear infections and PE tubes at 2 ½ yrs
- Seen for hearing test because hearing aids had been recommended but family didn’t think he needed them
Audiogram (Case B)

- CA = 3y 3m
- SRT
  - RE 45 dB HL
  - LE 45 dB HL
- OAEs
  - Absent bilaterally
- Recommended trial with hearing aids
Case B

- Did not like/wear hearing aids – family reported that his hearing ability seemed to fluctuate
- Parents expressed concern with behavior
- Diagnosed with AN/D bilaterally 4 ½ yrs
Audiogram (Case B)

- **LNT MLV**
  - Quiet – 92%
  - +10 – 64%

- **PBK**
  - 0% at 60 dB SPL
  - 48% at 70 dB SPL

- **HINTC (70 dB SPL)**
  - Quiet – 70%
  - +10 SNR – 53%
Audiogram (Case B)

- Has more difficulty with background noise
- Did significantly better with a louder signal
Case B

- **Language** (CA = 4y 9m)
  - PPVT III: 4y 11m
  - EVT: 4y 6m
  - CELFP: 3y 11m – 5y 5m

- **Speech**
  - Excellent intelligibility w/ distortions of /s/ and n/ng & f/thr substitutions

- **Psychological**
  - Average range of cognitive ability
  - ADHD – Refer to MD for evaluation
Case B Summary

- **Recommended**
  - F/U with physician regarding ADHD
  - Repeat trial w/HAs since improved word understanding at louder levels
  - Consider trial with FM in classroom
Case D

- Born at 35 weeks gestation
- While in utero, had intraventricular hemorrhage on left side
- Dx with AN/D at 1½ yrs of age
- HAs worn consistently bilaterally
- TC – but primarily an oral communicator
Pre-Implant Audiogram (Case D)

- CA = 3y 3m
- Closed-set Words
  - 42% SVM
- Open-set Words
  - 42% GASPW
  - 0% MLNT
  - 0% LNT
  - 0% PBK
Pre-Implant (Case D)

- Cognitive function in the high-average range
- Language (CA = 3y 3m)
  - PPVT & EVT: AE <1y 9m
  - PLS3: AE = 1y 10m
- Speech
  - 60-70% intelligible w/known topic
  - <50% intelligible w/unknown topic
Case D

- Implanted at almost 4 years of age (RE)
- EABR obtained in OR
  - Compared to pre-implant ABR
ABR: pre-I

EABR: via CI at time of surgery
Speech Perception (Case D)
## Language (Case D)

### Pre-Implant
- CA = 3y 3m
- Total Communication
- PPVT < 1y 9m
- EVT < 1y 9m
- PLS3
  - Receptive = 1y 8m
  - Expressive = 1y 11m

### 1 Year Post-Implant
- CA = 4y 11m
- Auditory/Oral Communication
- PPVT 2y 9m
- EVT 4y 5m
- PLS4
  - Receptive = 3y 6m
  - Expressive = 2y 4m
Case D

- Limited progression with oral language
- Wore hearing aids w/o complaint, but wasn’t making good auditory progress
- Rapid improvement in auditory skills post-implant
- Continued good progress in language development
- Speech intelligibility continued to be poor at 1 yr post-implant, improving at 18 mo evaluation (possible oral-motor issues)
AN/D Conclusions

- Audiogram may not correlate with speech perception abilities
- However, children with detection levels in severe-to-profound range function similar to those w/SNHL in that range
- Some children with AN/D will benefit from:
  - Cochlear implantation
  - Hearing aid
  - No amplification
- Monitoring regularly w/ team approach is key
Conclusions

- Some children with AN/D will benefit from:
  - Cochlear implantation
  - Hearing aid
  - No amplification

- Monitoring regularly w/ team approach is key
Thank You

davidsonl@ent.wustl.edu
References

* See Hand Out for references for today’s presentation