Introduction: The development of speech production accuracy is a consistent long-term goal of cochlear implantation. Previous research has focused on speech intelligibility to naive listeners, the development of a phonemic repertoire, and overall accuracy, but there is little to no research that examines the accuracy of various components of speech production. The goal of this study was to examine the rate accuracy of consonants and consonant place of articulation, manner of articulation, and voicing features over time following cochlear implantation and the impact of age of implant on this rate.

Methods: Sixty-three prelingually deafened children with CIs implanted between the ages of 10 and 170 months participated in the study. Data utilized in the study included speech samples obtained prior to implantation up to 11 years post-implant. The connected speech samples were obtained on a yearly basis. Samples were transcribed and entered into a computer-based phonetics program. This program allowed for accuracy of production to be calculated based on the child’s production compared to a target production. The data were analyzed using a multi-level growth model to determine the initial status, initial rate of growth, and deceleration rate of consonants, consonant place of articulation, manner of articulation, and voicing features as a function of age at CI activation.

Results: Age of implantation was a significant predictor of pre-implant accuracy for consonants overall, place of articulation, manner of articulation, and consonant voicing (p = 0.000 for all variables). For the initial linear growth rate, age of implantation was also a significant predictor of this rate for all variables in this study. However, age of implantation was not a significant predictor for quadratic deceleration rate (p = 0.178) for consonants overall, place of articulation (p = 0.065), manner of articulation (p = 0.181), and consonant voicing (p = 0.102). Children who were older performed better on speech measures prior to implantation. Children implanted earlier had steeper rates of growth over time. The deceleration rate was not significantly influenced by age of implantation suggesting children were not approaching mastery of consonants and consonant features. Although, pediatric CI users typically master consonant voicing perception, this feature was difficult to acquire in the production domain. Children implanted below 3 years of age had nearly indistinguishable growth trajectories which suggests that speech acquisition is a very complex behavior dependent on the development and maturation of many systems, not just hearing.

Conclusion: Pre-implant accuracy and initial rates of growth of consonants and consonant features of place, manner, and voicing was significantly impacted by age of implant. Deceleration rate was not significant suggesting that consonant production is not mastered overtime, even after many years of implant use.
Eye Tracking Studies of Spoken Word Recognition and Production in Children with Cochlear Implants

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Topic: Rehabilitation/Educational Aspects

Keywords: Speech and Language Development with CI, Children and Recommended Rehabilitation, Cognitive and Social Development of Implanted Children

Introduction: The majority of CI outcome studies have relied on standardized, omnibus tests of language. These instruments are designed to identify children with language impairments using endpoint measures (e.g., pointing, naming or describing pictures). Although they provide important information, they reveal nothing about the language processes that lead to those responses. We used eye tracking to obtain continuous measures of activation during lexical access. Our previous preliminary findings suggest processing differences between children with CIs and NH peers. In this presentation we continue this exploration with a full complement of participants and with more sophisticated statistical analyses.

Methods: Two parallel experiments examined cohort effects: one production and one recognition. The children saw four pictures: the target, a cohort (onset-match, offset-match—half from high density and half from low density neighborhoods) and two unrelated foils. In recognition, they saw the pictures and a target word. They had to use the mouse to click on the correct picture. In production, the child saw the pictures and then a target border appeared—the child names that picture. Gaze data were collected through the response. In recognition, the child mouse-clicked on the target. Twenty-five children with CIs and 73 children with NH participated. Two additional studies used a picture array with a target, an unrelated foil, and two cohort pictures (one onset match and one offset match); one was a production experiment and one was a recognition experiment. These experiments revealed the time course of lexical access from initial cohort activation to offset cohort activation.

Results: Preliminary analyses indicate that children with CIs exhibit different time courses of lexical access and activation/deactivation from their NH peers. Children with CIs seem typical in the effect of neighborhood density but seem to suffer from greater interference from non-target relatives affecting comprehension. Children with CIs attended to non-target pictures longer than their NH peers, suggesting slower lexical access, and greater and lingering interference from competing words. Mixed model analyses and growth curve analysis will also be used to examine subject-based effects of age of implantation and standardized language and speech perception scores.

Conclusion: The findings suggest that children with CIs differ in their lexical access for production and recognition from their normal hearing peers. Such differences affect their real-time understanding and production of words in sentences and in conversation. Language intervention needs to further emphasize lexical representation and organization for access.
Optimizing Language and Listening Outcomes: Incorporating Lessons from Neurodevelopment to Inform Clinical Practice

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Topic: Rehabilitation/Educational Aspects

Keywords: Speech and Language Development with CI , Children and Recommended Rehabilitation , Cognitive and Social Development of Implanted Children

Introduction: Cochlear implantation has successfully granted auditory access to large numbers of deaf children. Many children are well able to benefit from CIs, showing outcomes on par with expectations for hearing peers. Yet, scores of children with cochlear implants, despite good auditory access, are not developing appropriate, functional language skills. While some discrete auditory skills are needed for audiological assessment and mapping, these are not necessarily the skills that children require for understanding meaning. For many children, there exists a gap between their stronger abilities to access sound and their reduced skills in making sense of what they hear. This begs the question of how professionals might better use current science to inform practice and enhance outcomes for children. Contributions from the fields of speech-language pathology, psychology, audiology, deaf education, language acquisition and neurodevelopment can improve our understanding of how the brain makes sense of sound, leading to comprehension. This has direct implications for intervention, service provision, parental guidance, and overall programming for children with cochlear implants.

Objective: To examine current practices in listening and language training in light of known factors associated with neurodevelopment. Methods This study employs a comprehensive literature review. Interpretation of findings is further informed by clinical practice. The authors of this study comprise an interdisciplinary team, offering insights from speech-language pathology, audiology, psychology and medicine.

Results: Some of the methods currently employed to facilitate language development in children with hearing loss are not adequately optimizing outcomes. In light of better understanding of language, cognitive and neurodevelopmental processes, additional suggestions are offered for closing the gap between what is heard and what is understood.

Conclusion: Advances in technology and medicine have provided deaf children with auditory access through cochlear implantation. For some children there is a gap between auditory access and their ability to attach meaning to sound. Continually evolving and expanding research on brain development describes how the brain analyzes input to extract patterns and integrate linguistic information within the context of social interaction to discover meaning. Based on our review of the literature, clinical practice can be changed by expanding from the focus on discrete auditory skills to a focus on integrating language and listening within responsive, meaningful social language environments in order to bridge the gap between access and understanding. The goal is to maximize the benefit children receive from cochlear implantation - access to sound - to support development of appropriate, functional skills in all areas of language development: phonological, lexical, syntactic, and pragmatic – access to meaning.
Language Environment Analysis (LENA) as a tool to enhance intervention
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Topic: Rehabilitation/Educational Aspects

Keywords: Children and Recommended Rehabilitation, Speech and Language Development with CI, Speech Production of Early Implanted Children

Introduction: LENA technology offers the family and early intervention provider information about the auditory learning environment in the child's typical day. This day can include home with parents and other family members, daycare or school, individual intervention/therapy, communication in the car, at the grocery store, or during any other typical daily activity. The technology provides the family and interventionists with information about the child's auditory and spoken language daily diet (the child's daily spoken language nutrition for the brain). Objective: To present case studies that demonstrate how LENA can be effective in enhancing early intervention services for 1) children who do not speak English in the home, 2) Fathers, 3) Children from homes whose parents have lower levels of education, 4) Children who are deaf or hard of hearing with additional disabilities, 5) children with autism, 6) differential diagnosis of children with additional disabilities, 7) all families who have children (birth through 48 months) who are deaf or hard of hearing.

Methods: Participants will be provided with an overview of the literature on the use of LENA with children who are deaf or hard of hearing, as well as information about LENA and other populations, such as typically developing children, children with autism and children with language disorders. Information about how LENA has been used as a research tool, as well as an intervention tool will be provided.

Results: Research results about children who are deaf or hard of hearing and the utility of LENA as a tool for detecting autism, flagging risk for additional speech disorders, as well as comparisons of different environments, such as school versus home will be presented. In addition, information about the typical spoken language learning environment of children who participate in specialized early intervention services both in English speaking and Spanish speaking homes, as compared to their typically hearing peers will be presented and discussed.

Conclusion: LENA technology provides valuable information that can compare different environments. Additional information about noise, TV/radio, and silence is automatically available. The amount of meaningful and distant language, an automatic vocalization analysis (the AVA score), estimates of the frequency of the amount of adult words, the child’s vocalizations and conversational turns provide the family and provider with valuable information that is not currently provided through any other assessment or intervention tool.

COI: LENA Foundation
The Impact of Language Underperformance on Social and Communication Functioning in Children with Cochlear Implants


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Keywords: Cognitive and Social Development of Implanted Children, Speech and Language Development with CI

Introduction: Despite the remarkable impact early identification and amplification/implant technology has on language development for children who are Deaf/Hard of Hearing, social and pragmatic communication delays persist. In some children, these social communication delays are related to the underperformance of language levels when considering the child’s cognitive capacity for learning. Objective: To understand the impact language under-performance has on social and communication functioning in young children with cochlear implants (CI).

Methods: Forty-one children age 3-6 years with CI were enrolled in a prospective study of language and functional outcomes. All subjects received: Preschool Language Scales-5, Leiter International Performance Scale-R (providing a nonverbal IQ, NVIQ), Behavioral Rating Inventory of Executive Function. Daily social and communication functioning was measured using the Pediatric Evaluation of Disability Inventory (PEDI) [mean 50+10] and Vineland Adaptive Behavior Scales (VABS) [mean 100+15]. Language relative to cognitive abilities was evaluated to assess cognitively-appropriate language performance, defined as a ratio of language score to NVIQ (“gap” defined as ratio<0.80; low language relative to cognitive abilities).

Results: The mean (SD) duration with CI was 29.5 (16) months. Mean receptive language was significantly lower than NVIQ (73 [17] vs 92 [19], p<.0001). Children with CI scored significantly lower than the population regarding mean PEDI social function scores (37.5, p<.0001) and VABS communication domain score (84, p<0.001). 44% of children had either social or communication function scores >2SD below the mean. In multiple linear regression, NVIQ and language relative to NVIQ (ratio) accounted for 40% of the variance in social functioning and ~60% in communication scores. After controlling for working memory and SES status, compared to children with commensurate language, children with a language gap had significantly lower mean PEDI social function scores (44.5 vs 33, p=0.009). This difference was largest among children with NVIQ >85 (41.5 vs 34.5). Results were consistent with communication function scores. Children with normal/above normal NVIQ and a language gap had similar functional standard scores as children with NVIQ<85 who had language commensurate with cognitive abilities. Age of implant, CI duration, or having a bilateral CI were not significant in models.

Conclusion: The terms functional performance is commonly used to describe functional hearing abilities, limiting our focus to hearing or “ear-related” outcomes. Cognitively appropriate language is vital to achieve appropriate social functioning in all children. Because the ability to function socially in society is a major factor for independence, our data speak to the need for greater understanding of a child’s potential. Proactive language interventions are needed even when language scores are in the average range.
**ACI2014**  
**Persistent Language Delay vs Late Language Emergence in Early-Implanted Children**  
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Topic: Rehabilitation/Educational Aspects

Keywords: Speech and Language Development with CI , Speech Production of Early Implanted Children , Children and Recommended Rehabilitation

**Introduction:** Spoken language levels achieved by many children who receive cochlear implants (CI) during the first three years of life reach age-appropriate limits by the time they enter first grade. For many others, language that is on par with typical-hearing peers is not realized despite early identification, early implantation, and good parental and educational support. These children present different language-learning profiles in the years after implantation.

**Objective:** This study develops a model to differentiate early-implanted children with preschool language delays that persist into the elementary grades from children who achieve normal language as they gain auditory, linguistic, and academic experience.

**Methods:** A group of 60 early-implanted children were classified with: Normal Language Emergence (NLE: N=19), Late Language Emergence (LLE: N=22), or Persistent Language Delay (PLD: N=19) based on their standardized language test scores on the Preschool Language Scale at a mean age of 4.5 years and the Clinical Evaluation of Language Fundamentals at a mean age of 10.5 years. Analyses of Variance and Logistic Regression analyses were used to compare background characteristics and mean performance on speech/language measures during preschool as well as auditory, speech, language and literacy measures at age 10.5.

**Results:** Children with PLD did not differ from children with LLE on a number of variables that have previously been associated with post-implant outcome, including pre-implant hearing, age at first CI, gender, maternal education, nonverbal intelligence or expressive language skills in preschool. Logistic regression analysis identified 7 variables that classified children into language progress groups with 76% accuracy. During the preschool years, children with PLD exhibited significantly less mature speech production skills and greater receptive language delay than children with LLE. They were more likely to have received their first CI in the left ear than children with LLE. At age 10.5, children with PLD used significantly older speech processor technology, had significantly higher aided threshold averages and were less accurate at reproducing recorded speech stimuli. PLD and LLE groups scored similarly in Basic Reading skills, but children with PLD were significantly delayed in Reading Comprehension and exhibited a wider gap between nonverbal and verbal intelligence quotient scores.

**Conclusion:** Results suggest right-ear placement of the first CI should probably be the default option, especially for young children. In addition, encouraging upgraded speech processor technology and insuring the lowest possible thresholds when programming the device may positively influence future language development. Finally, immaturity of speech sound production during preschool years may reflect lack of access to a robust auditory signal at an early age and foreshadow later language difficulties.
Factors Associated with “Language Gaps” Among Children with Cochlear Implants

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Topic: Rehabilitation/Educational Aspects

Keywords: Speech and Language Development with CI, Cognitive and Social Development of Implanted Children

Introduction: In two decades, cochlear implant (CI) technology has positively impacted language development for children who are Deaf/Hard of Hearing (DHH). However, at best, language levels often hover in the average to low average range. A subset of children continue to have language that is significantly lower than their cognitive abilities (i.e. “language gap”) should support. Objective: To determine factors associated with an under-performance of language among children with CI.

Methods: Forty-one children, 3-6 years of age with CIs were enrolled in a broader prospective study on language and cognition in children who were DHH. All children received a battery of standardized assessments including the Preschool Language Scales-5, the Leiter International Performance Scale-R, (providing a nonverbal IQ (NVIQ)) and the Behavioral Rating Inventory of Executive Function. Language relative to cognitive abilities was determined using the ratio of receptive language score to NVIQ. A ratio<0.80 indicated low language relative to cognitive abilities or language gap (underperformance). Multivariable regression was conducted to determine independent factors associated with the language ratio and risk factors for having a language gap.

Results: The mean study age was 58.5 (SD 13.2) months and mean NVIQ was 92 (19.2). Median ages of HL identification and duration with CI were 5.5 and 29.6 months respectively. 24 participants had bilateral CIs (BICI). Mean receptive and expressive standard scores were 73.4 (17.7) and 72.8 (17.5) respectively, with 66% of participants scoring <80 on receptive language testing. Receptive language scores were significantly (p<.0001) lower than NVIQ; over half were underperforming in language (ratio<0.80). Although only 27% of children with NVIQ>100 had language standard scores <80 (threshold for mild language delay in general population), 73% of this subgroup displayed a significant gap in language relative to their cognitive abilities. In multiple linear regression, factors significantly (p<0.05) associated with larger language gaps (lower ratios) included higher NVIQ, better working memory, lower SES, and having unilateral vs. BICI. Age and duration of implant were not associated with the ratio. Children with BICIs had significantly higher ratios (smaller language gaps) compared to children with unilateral CIs (UNICI) (0.88 vs 0.67, p=0.0006). The language ratio was highest among children with BICI and NVIQ<85 (ratio=0.94), indicating language commensurate with cognitive abilities. Children with UNICI had lowest ratios (signifying largest gaps) regardless of NVIQ and actual language standard scores.

Conclusion: Even with advances of early identification of hearing loss and CIs, many children continue to show a substantial underperformance of language abilities based on their cognitive capacity. It is critical to understand a child’s capabilities in order to attempt to reach a child’s full language capacity.
Session 2: Cognitive Considerations for Pediatric CI

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Children with Cochlear Implants: Cognitive and Language Factors Towards Speech Understanding in Noise
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Topic: Basic Research

Keywords: Sound Processing

Introduction: Previous work has demonstrated that children with cochlear implants and children with normal hearing benefit from clear slow speaking style, and semantic cues when listening to speech in noise (Smiljanic & Sladen, 2013). Still, children with cochlear implants vary considerably in their ability to understand speech in noise. Variance in performance is likely due to factors such as age of hearing loss identification, severity of pre-operative hearing loss, and age of implantation. Cognitive factors such as attention and memory, and language factors such as phonological processor, may also contribute to the variable speech processing abilities observed in this population.

Objective: The aim of the current study was to examine the benefit of clear speaking style and semantic cues towards speech understanding in noise. In addition, we examined which cognitive and language factors served as predictors of speech understanding in noise performance.

Methods: A total of 12 children with cochlear implants and 14 children with normal hearing participated. The ages ranged from 6;0 years to 12;10 years. They were tested on speech in noise understanding using high and low predictability sentences produced in conversational and clear speaking styles. Cognitive and language measures included receptive and expressive language, phonological ability, memory, attention, and non-verbal IQ.

Results: Preliminary results show that both groups of children benefited from clear speaking style and semantic cues. Children in both age groups performed similarly. Phonological abilities significantly correlated to speech understanding in noise.

Conclusions: Speech understanding in noise among children with cochlear implants is influenced by many factors. Among the factors examined here, phonological processing appears to influence speech in noise understanding the most. Implications of the findings will be discussed.
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Correlation of Neurocognitive Processing Subtypes with Language Performance in Young Children with Cochlear Implants

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Topic: Rehabilitation/Educational Aspects

Keywords: Children and Recommended Rehabilitation, Cognitive and Social Development of Implanted Children, Integrated/Inclusive Education

Introduction: Test data was used to explore the neurocognitive processing of a group of children with cochlear implants (CIs) whose language development is below expectations.

Methods: This cross-sectional study examines the relationship between neurocognitive processing, as assessed by the Kaufman Assessment Battery for Children-Second Edition, and verbal language standard scores, assessed using either the Comprehensive Assessment of Spoken Language or the Clinical Evaluation of Language Fundamentals in 22 school-age children with CIs. Processing scores of CI recipients with language scores below expectations were compared to those of children meeting or exceeding language expectations. Multiple linear regression estimated the associations of simultaneous and sequential processing with language scores.

Results: Though Simultaneous Processing scores between the two groups were similar, the mean Sequential Processing score (91.2) in the below expectations group (n=13) was significantly lower (p=0.002) than that of children (n=9) meeting expectations (110.8). After adjusting for age at implantation, a 10-point higher Sequential Processing score was associated with a 7.4 higher language score (p=0.027).

Conclusion: Simultaneous Processing capacity was at least within the Average range of cognitive performance, and was not associated with language performance in children with CIs. Conversely, reduced Sequential Processing capacity was significantly associated with lower language scores. Neurocognitive skills, specifically cognitive sequencing, serial ordering, and auditory-verbal memory may be targets for therapeutic intervention. Intensive cognitive and educational habilitation and in-milieu intervention may improve language learning in children with CIs.
Early Speech and Language Predictors of Long-term Neurocognitive Outcomes

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Topic: Rehabilitation/Educational Aspects

Keywords: Cognitive and Social Development of Implanted Children, Speech and Language Development with CI

Introduction: Cochlear implants (CIs) provide profoundly deaf children access to speech necessary for the development of spoken language skills. However, CIs do not work equally well for all children and enormous variability in outcomes exist among individual children. Additionally, there is mounting evidence that some children with CIs are at an increased risk for neurocognitive deficits. Our understanding of the mechanisms that underlie increased neurocognitive risk is unclear and represents a significant gap in our knowledge, and is a barrier to the development of novel targeted interventions to help low-functioning children with CIs.

Objective: To identify early speech and language measures following cochlear implantation that predict neurocognitive risk in long-term CI users. We present preliminary analyses using very early measures of closed-set speech perception (Pediatric Speech Intelligibility Test - PSI and Grammatical Analysis of Elicited Language - GAEL-P), expressive language (MacArthur-Bates Communicative Development Inventory- MCDI), receptive language (Reynell Developmental Language Scales - RDLS), and spoken language comprehension (Mr. Potato Head Task) to predict long-term language and neurocognitive functioning.

Methods: Long-term outcome data were obtained from research visits conducted as a part of an outcome study of prelingually deaf, early-implanted CI users. We accessed early speech and language data on a subset of these CI users. The earliest data points within the first 2 years after implantation were selected. On average, our sample was fit with a CI prior to 34-months of age. Depending upon the early measure, participants ranged in age from 3.2 to 4.2 years old on average and used their CI between 7 and 12 months on average at the time these early tests were carried out. At long-term testing, participants ranged in age from 14 to 15 years on average and used their CI between 11 and 12 years.

Results: Early measures of expressive language (MCDI) predicted language, verbal working memory capacity, and fluency-speed up to 16 years later. Early measures of speech perception (PSI and GAEL-P), receptive language (RDLS), and spoken language comprehension (Mr. Potato Head Task) were correlated with language, fluency-speed, and verbal working memory capacity, respectively, up to 14 years later.

Conclusion: These new findings suggest that speech and language development during the toddler and preschool years is an important predictor of long-term language and neurocognitive functioning in early-implanted, prelingually deaf children. Children’s early expressive language skills as reported by parents on the MCDI was the strongest and most consistent predictor of long-term language and neurocognitive functioning. Measures of speech and language obtained as early as toddlerhood can be used to identify very young CI users who may be at risk for later delays in language and executive functioning outcomes.
Auditory-Cognitive Training Improves Language Performance in Prelingually Deafened Cochlear
Implant Recipients

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Topic: Rehabilitation/Educational Aspects

Keywords: Cognitive and Social Development of Implanted Children , Speech and Language Development with CI , Rehabilitation for Children

Introduction: Effective spoken language learning requires more than the ability to hear. Phonological awareness (PA) and working memory (WM) are two skills shown to support spoken language learning.(Gillam & van Kleeck, 1996). Typical PA and WM performance predict typical spoken language development, whereas spoken language delays have been linked to PA and WM deficits (Bowey, 1996; Gathercole, 1999). CI-using children have weaknesses in both skill sets (Peterson et al., 2010), which may partially account for their deficits in spoken language (Geers, 2002). We hypothesized that training CI-using children’s PA and WM will result in improved spoken language performance.

Method: Twenty-one children were recruited from a nearby oral school. All participants were prelingually deafened, aged between 4 and 7 years at test, and had been using their implants for at least one year. Two children were eliminated from further participation because they had performance IQs lower than 70 (Geers et al., 2009; Wechsler, 1995). Of the remaining 19 children, 10 were randomly assigned to the training group and 9 to the control group. Pre- and post-test measures of vocabulary were done using the Expressive/Receptive One Word Picture Vocabulary Test (EOWPVT/ROWPVT Martin & Brownell, 2011). Sentence-level language was assessed using the Oral Written Language Scales (OWLS, Carrow-Woolfolk, 2008). The OWLS asks children to comprehend and produce sentence-level materials. It also yields a composite score, representative of overall oral language. The training program allowed children to practice PA and auditory WM. All skills were presented in the context of colorful computer games (Earobics, Houghton-Mifflin, Evanston, IL) and children received feedback on each trial. Training algorithms built into the software adjusted difficulty according to each child’s ability. Loudness settings were determined by staff members. Training was administered for four weeks. Training was given for 75 minutes per week; no training session was longer than 25 minutes. Control children continued normal classroom activities for four weeks.

Results: We found the expected interaction of group x session on the expressive OWLS, F(1,17) = 7.54, p = 0.01. Children in the training group showed a significant improvement on expressive language scores at posttest (t(9) = 5.31, p < 0.001) whereas there was no change for the control group (t(8) = 1.59, p = .15). There was also a significant interaction for the OWLS composite score, F(1,17) = 5.00, p = .04. No other results were significant. We repeated the analyses entering age of implantation and duration of CI use as covariates. The group x session interactions remained significant, and none of the covariates were found to be significant.

Conclusion: Our hypothesis was confirmed, and children who received combined PA-WM training showed significant improvements on expressive language and a language composite score over untrained children.
How can Psychical Factors Affect Language Development?

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Keywords: Patterns of Early Social-emotional Development in Young Children with Cochlear Implants, Speech and Language Development with CI, Cognitive and Social Development of Implanted Children

Introduction: From the psychoanalytical perspective of language acquisition, the condition to speak a language is the path of psychical constitution. In that theoretical and practical point of view, there are a few subjective operations that the baby must go through, so that he can acquire a language and speak for himself. When brought to the pediatric cochlear implant scenario, the psychoanalytical theory can contribute a lot to the detection of early psychical issues that, later on, could affect the ability to develop oral communication. Even though the cochlear implant is a unique technology, which gives its user the possibility to hear speech sounds, the psychical aspects of language must be taken into consideration to guarantee that the psychical functions of listening and speaking can be developed.

Methods: The Clinical Risk Indicators for Child Development are 31 factors defined from the psychoanalytical theory of psychical constitution. These indicators are derived from four main subjective processes: subject assumption, establishment of demand, presence/absence and paternal function. The theory behind each aspect will be explained. These factors must be taken into account when evaluating a child for a cochlear implant surgery, and the indicators must preferably be explored in an interview with the child's parents and an observation of the child's productions. These clinical indicators can be applied with newborn babies until 18 months, considering there are specific factors according to time of growth (0-4 months; 4-8 months; 8-12 months; 12-18 months). In our service the children are usually older than two, so we explore the factors retroactively. There are factors that indicate higher chance for developmental issues, and others that indicate risk for psychical constitution.

Results: The use of the clinical factors help professionals point out where to intervene. The psychoanalytical theory is brought to understand language acquisition from the subjective perspective: if there are issues in the constitution process, the child will face difficulties to develop a formal communication (be it oral or signaled). The difference between developmental and structural issues is vital to establish a prognosis and to define the type of treatment.

Conclusion: From the psychoanalytical perspective, there are many factors contributing to child development: neurological, genetic, psychical and environmental. However, psychical aspects must be taken into account because if there are issues in that area, the child will face many difficulties in the process of language acquisition and, as we often see in our experience, will not be able to communicate, even if having a cochlear implant at the earliest age and in good environmental conditions.
Introduction: Working memory (WM) is a dynamic system used to temporarily maintain a limited amount of information for current or future processing. WM also acts as an interface between incoming sensory information and long-term memory; consequently, performance on WM tasks can be impaired either by corrupting sensory encoding or preventing access to long-term memory. In normal hearing (NH) children and adults, utilizing long-term linguistic knowledge through covert verbal rehearsal and semantic organizational processes are especially robust mnemonic strategies which support real-time performance during WM tasks (e.g. Cowan et al., 2012; Gathercole & Adams, 1994). Deaf children who use cochlear implants (CI) have been shown to perform more poorly than their NH peers in a variety of WM tasks (Nitterour 2013; Pisoni et al., 2011). These differences are often attributed to disruptions in the way CI users implement covert processes, such as phonological recoding, covert verbal rehearsal, and recovery of phonological traces. However, previous studies of WM performance in CI users have presented memory items auditorily—leading to potentially corrupted sensory traces—and required spoken verbal responses which may be more difficult for CI users. Objective: Determine if CI users show WM delays when overt linguistic processes related to audibility and verbal responding are eliminated. Additionally, we investigated whether WM delays in CI users are specific to linguistic materials or exhibit as generalized deficits within the WM system.

Methods: 40 CI users and 40 NH controls each completed six memory span tasks consisting of 2- to 10-item lists. The tasks differed in presentation modality (auditory or visual), response modality (spoken recall or manual pointing), and stimulus materials (digits, pictures of concrete nouns, abstract symbols, or visual-spatial locations). Span was measured as the longest list length at which all of the items were reproduced in the correct order.

Results: For easily labeled verbal materials, the NH controls displayed larger memory spans than the CI users, even with visual presentation and manual responses. For visual-spatial materials, CI users performed equally as well as the NH controls. Moreover, in both groups, performance on the abstract symbol task correlated with Rapid Digit Naming, a task thought to tap phonological recoding skills (Christopher et al., 2012; Wolf et al., 2000).

Conclusion: The present findings confirm earlier reports that WM delays in CI users are not due to greater demands in overt processes such as speech perception or speech-motor planning. They also indicate that CI users are comparable to their NH peers in utilizing covert processes for spatial information. Finally, the findings suggest that even small individual differences in a basic linguistic processing ability, such as phonological recoding, can result in measurable differences in higher level abilities such as WM span.
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Neurocognitive Correlates of Spectrally-Degraded Speech Recognition in Normal-Hearing Children
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Topic: Basic Research

Keywords: Maturation and Plasticity of The Auditory System

\textbf{Introduction:} Hearing impairments delay and in some cases disrupt the normal time course of the development of speech perception. Without prenatal and early exposure to sound, deaf and hard-of-hearing children begin life already developmentally delayed relative to their normal-hearing (NH) peers. One approach to understanding how the processing of speech through a cochlear implant affects speech recognition has been through the use of spectrally-degraded or “vocoded” speech with normal-hearing listeners. Vocoded speech refers to speech signals that have been processed to preserve gross temporal and amplitude information in the signal but have degraded spectral information. One fundamental gap in our knowledge regarding the perception of spectrally-degraded speech is understanding how NH children perceive vocoded speech. Very little research has used vocoded speech with children and what little research there is has focused on the amount of spectral information needed for intelligibility. This research investigated the perception of vocoded speech by NH children and identified several neurocognitive factors that are related to the perception of spectrally-degraded words and sentences. Objective: (1.) To explain the role of specific neurocognitive factors in vocoded speech perception in children. (2.) Discuss the need for future research looking into the neurocognitive factors underlying speech perception when underspecified acoustic representations of speech are available to the listener.

\textbf{Methods:} Thirty-one children between 5 and 13 years in age participated in the study. Children were tested on recognition of lexically controlled vocoded words in isolation and in sentences from Eisenberg et al.’s (2002) study for measures of vocoded speech perception. Children were also tested on two measures of auditory attention, two measures of short-term memory, and measures of verbal learning and memory.

\textbf{Results:} Measures of short-term memory, auditory attention, and verbal learning and memory showed several positive relationships with a child’s ability to recognize vocoded words in isolation and in sentences.

\textbf{Conclusion:} This research provides converging support for the role of cognitive factors in perceiving vocoded speech. These findings have direct clinical implications for understanding the enormous variability and individual differences in children and adults with cochlear implants by emphasizing the need for additional research into cognitive factors related to speech perception and spoken language processing.
Session 3: All About Outcomes: Assessing the Whole Child

ACI2014

Verbal Learning and Memory Processes in Early-implanted Long-term Cochlear Implant Users


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Keywords: Cognitive and Social Development of Implanted Children, Speech and Language Development with CI

Introduction: Learning and memory are integral to the development of spoken language. When a child hears a new word, the item must be encoded, stored, and made available for later retrieval. Children with cochlear implants often show delays in the development of receptive and expressive language: they have smaller vocabulary sizes, poorer word recognition skills and lower speech intelligibility scores. However, little is known about the basic processes by which prelingually-deaf children with CIs differ in their ability to learn and recall new words. The California Verbal Learning Test – Children’s Version (CVLT-C) provides measures of verbal learning and memory for lists of spoken words. Measures obtained from this standardized assessment provide insight into verbal learning (e.g., learning strategies and measures of recall and recognition) and can identify disturbances in the core underlying processes. The CVLT is routinely used to diagnose and identify memory impairments in adults and children in many clinical populations and is a commonly used measure in neuropsychological assessments. Objective: The objective of this study was twofold: First, to determine if young, early-implanted, long-term cochlear implant users show disturbances and delays in memory and learning on the CVLT compared with age-matched normal hearing controls. Second, to relate measures of learning and memory obtained from the CVLT to more conventional tests of working memory span (e.g., visual/auditory digit span), as well as routine clinical assessments of speech, language, and spoken word recognition (e.g., PPVT, LNT, HINT-C).

Methods: Two groups of listeners participated in this study: Children with Cochlear Implants (CI) N=24 and Normal Hearing Children (NH) N=21. Both groups were age matched and ranged in age from 9-16 years old (Mean=13 years). The CI group had used their implants for seven years or more (Mean CI Use=10 years). In addition to the CVLT, participants completed a comprehensive battery of neuropsychometric, speech, and language assessments. In the CVLT-C, all subjects were presented with a list of 15 spoken words (List A) and were asked to free recall as many words as they could after a series of repeated learning trials with the same list. An interference trial (List B) and short and long-delay free recall phases were also included.

Results: The normal hearing controls showed better scores on all measures of memory and learning; however, the CI children showed the same overall pattern of learning and memory. CI children produced more recall errors and made less efficient use of learning strategies than their normal hearing peers. Several core measures of learning and memory from the CVLT-C were related to clinical measures of speech perception, language, and demographics.

Conclusion: The CVLT-C provides clinicians and researchers with a high-yield measure of episodic learning and memory processes in CI users that may help identify the locus of delays or disturbances in the elementary verbal learning and memory skills that are important for spoken language processing. The CVLT-C is a useful addition to the clinicians’ toolbox of novel robust outcome measures that provide additional information that may be particularly useful with children who are having difficulties with their CIs.
Electric-Acoustic Stimulation with a Short Electrode Array in a Child with a Precipitously Sloping High-Frequency Hearing Loss: A Single-Subject Case Study

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Topic: Audiology

Keywords: Residual Hearing, Fitting, Outcomes

Introduction: Children who have precipitously sloping severe high-frequency hearing loss typically experience substantial difficulty understanding speech in quite and in noise (Auriemmo et al., 2009; Glista et al., 2009). Some of these children only receive modest improvement in speech recognition with the use of frequency-lowering hearing aids and continue to struggle with communication. Cochlear implantation is often beneficial in restoring access to high-frequency speech sounds and improving performance both in quiet and in noise (Gifford et al., 2008). However, the provision of a traditional cochlear implant typically result in the loss of some or all of the child’s low-frequency residual hearing. The loss of low-frequency hearing in the implanted ear may diminish speech recognition in noise and localization. Hybrid cochlear implants are designed to provide electrical stimulation over the high-frequency range possessing severe to profound hearing loss and acoustic stimulation over the low-frequency portion of the speech range. Hybrid implants typically possess shorter electrode arrays so as to improve the likelihood of preserving the low-frequency residual hearing of recipients who have precipitously sloping hearing loss.

Objective: The objective of this study was to describe the benefits and limitations of a hybrid cochlear implant system for a 10 year-old boy with a mild sloping to profound hearing loss.

Methods: Speech recognition in quiet (PBK-50 words at 60 dBA) and in noise (BKB-SIN) were evaluated in the bilateral acoustic condition, the hybrid condition, the bimodal condition, and the combined condition (i.e., hybrid use of the implanted side and hearing aid use on the opposite ear). The CHILD, LIFE, and SSQ questionnaires were also administered to evaluate subjective benefit of hybrid implant use in everyday life relative to the use of bilateral hearing aids. Additionally, a battery of speech and language measures was administered to evaluate speech and language abilities prior to and after 3 months of hybrid cochlear implant use.

Results: Results indicate significant improvements in speech perception in quiet and in noise with use of the hybrid cochlear implant. Optimal performance was achieved when the child used his hybrid processor on the implanted ear (i.e., electric-acoustic stimulation) and his hearing aid for the opposite ear. The child and his family also reported substantial improvements in subjective performance and satisfaction with use of the hybrid cochlear implant in real world settings. Speech and language assessment also indicated significant improvement in articulation and language after just three months of hybrid cochlear implant use.

Conclusion: Electric-acoustic stimulation, as delivered by a hybrid cochlear implant system, is a viable option and potentially beneficial alternative for children with precipitously sloping severe to profound high-frequency hearing loss.
The Influence of Age at Implantation on Novel Word Learning in Children with Cochlear Implants

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Topic: Rehabilitation/Educational Aspects

Keywords: Speech and Language Development with CI

Introduction: Children with congenital deafness have minimal access to speech. As a result, their ability to acquire spoken language is substantially impaired. The advent of cochlear implants (CIs) make it possible for these children to perceive speech. There is substantial variation in the age at which children receive their CI, and early-implanted children tend to show better language outcomes than late-implanted children. There is some debate about why this relationship between age at implantation and language outcomes exists. One possibility is that an impoverished language input during a ‘sensitive period’ for language development early in life has a detrimental impact on the development of language processing pathways in the brain, and consequently on later language learning ability. Most CI research relies on standardised tests that measure the end product of language learning (e.g., vocabulary tests) making it challenging to determine if early- and late-implanted children differ in language learning efficiency. Dynamic experimental paradigms are useful for assessing language learning efficiency in children with CIs. By using novel words, these experiments control for variations in language experience. Such paradigms have provided evidence for a relationship between better novel word learning ability and earlier implantation in preschool children with CIs. However, it is unclear whether any learning deficit associated with late implantation is specific to language, or whether domain-general cognitive processes are affected. The proposed research addresses these questions.

Methods: Sixteen children with CIs have currently participated; this study is ongoing and data collection is expected to be completed by September, 2014. To date, all children were between the ages of 6 and 11 years (M = 8.41 years; SD = 1.8 years). Average age at implantation was 22.4 months (SD = 18.3). Examiners administered a verbal and non-verbal learning task. Both tasks assessed learning efficiency in children. The verbal learning task involved learning novel names of rare animals, and the non-verbal task involved learning to match sounds with patterns. Forty-five minutes after the verbal and non-verbal training took place, participants were retested on their recall of novel word-object pairs. Examiners also administered measures of receptive vocabulary, working memory, and non-verbal reasoning.

Results: Thus far, there is a significant negative correlation between age at implantation and novel word learning even after partialling out performance on the non-verbal control task. The current findings inform our understanding of the impact that language deprivation during sensitive periods has on language learning ability later in life. This in turn will provide useful information for policymakers and healthcare professionals who must make decisions regarding the optimum age at which to implant a child with profound deafness.
Earlier Age at 1st CI – A Starter Engine for Lexical and Semantic Development

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Topic: Rehabilitation/Educational Aspects

Keywords: Speech and Language Development with CI, Cognitive and Social Development of Implanted Children, Children and Recommended Rehabilitation

Introduction: Most severely-profoundly hearing impaired (HI) children are implanted early and with bilateral cochlear implants (CI) in Sweden. Still, the listening and spoken language outcome varies in this small and heterogeneous population.

Method: Data from a prospective study with 34 young school-aged children with CI and 39 age-matched NH controls as well as retrospective group data (n=115) from the Cochlear Implant Clinic (CIC), Karolinska University Hospital, will be presented. Results will be discussed in relation to age at 1st and 2nd CI and other factors that may affect spoken language outcome with CI.

Results: Longitudinal results show that many children reached age-equivalent spoken language outcome over time, especially those who were implanted before 12 months. However, atypical developmental patterns were found in subgroups and some children did not reach expected levels despite an early CI-intervention. In addition, there were children who managed to catch up over time, despite somewhat later age at 1st CI-implantation. Non-verbal cognitive ability and semantic capacity was associated to grammatical sentence understanding (GSU) in school-aged children (CI and NH). Earlier age at 1st CI was associated to lexical-semantic ability, especially receptive vocabulary and environmental factors like bilingual background was associated to expressive vocabulary outcome.

Conclusion: Age at 1st CI is primarily important as a starter engine for linguistic development in children with severe-profoundly HI. However, other factors like non-verbal cognitive ability, spoken language developmental patterns and environmental factors additionally affect spoken language outcome in children with CI.
Deaf Native Signing Children with Cochlear Implants Display Age-Appropriate Spoken English Development

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Introduction: Children with cochlear implants (CCIs) are frequently encouraged to focus on spoken language to the exclusion of sign language. On the other hand, hearing children who are exposed to both a spoken language and a natural sign language from Deaf signing parents (Kodas) can easily become fluent in both[1]. How do CCIs with deaf signing parents, who receive exposure from birth to a full natural sign language (American Sign Language, ASL), perform on spoken English assessments following implantation, in comparison to Kodas and non-signing CCIs?

Methods: We tested 5 CCIs (age 4;00-6;04; implanted before age 3 years) who have deaf signing parents. All children received recommended spoken language therapy following their CI activation, and regular ASL input at home. We also tested 20 Kodas (age 4;09-8;02, mean 6;00). Four spoken English tests were administered: Preschool Language Scales (PLS-4), Expressive Vocabulary Test (EVT), Goldman-Fristoe Test of Articulation (GFTA), and Dynamic Indicators of Basic Early Literacy Skills (DIBELS); in addition, a sample of natural speech was analyzed using the Index of Productive Syntax (IPSyn).

Results: All participants passed the Leiter non-verbal IQ screener. Results on the PLS-4 general assessment of language showed performance above levels predicted for non-signing CCIs[2] and matched typically hearing Koda peers. On measures of expressive vocabulary (EVT), phonology (GFTA), and developing literacy (DIBELS), signing CCIs had standard scores within the normal range for typically hearing monolingual children, matching the Koda comparison group. IPSyn scores were all within the normal range for typically hearing monolingual English children, while previous models based on non-signing CCIs predicted only half would do so well[3].

Introduction: Waardenburg syndrome (WS) is an autosomal dominant disease, characterized by dystopia canthorum, hyperplasia of the eyebrows, heterochromia iridis, white forelock, and congenital sensorineural hearing loss (SNHL). The aim of our study is to evaluate the effectiveness of cochlear implantation in children with Waardenburg syndrome.

Methods: We conducted a retrospective study that included a total of 60 children implanted in our department from 2008 to 2010. Among them we selected 20 children implanted at the same age and the same period. According to the etiology of deafness we divided them into two groups: Waardenburg syndrome and non syndromic deafness. We evaluated and compared clinical, radiological findings, operative course and postoperative performances of both groups. Auditory perception and speech production ability were evaluated using categories of auditory performance (CAP), meaningful auditory integration scales (MAIS), and speech intelligibility rating (SIR) during the follow-up period.

Results: Among the selected cochlear implanted patients we identified: five children with Waardenburg syndrome (4 patients with Waardenburg syndrome type I, and one met the diagnosis of type IV) and 15 with non syndromic deafness. The age at implantation was 18 months. Results of preoperative radiological assessment including temporal bone high-resolution computed tomography (CT) and magnetic resonance imaging (MRI) were available in all patients, and did not reveal any middle ear or inner ear abnormalities. Cochlear implantation surgery went without any particular difficulties. No postoperative complications were observed. All of these patients were active users of their devices. The comparison of auditory perception and speech production with the control group did not reveal any statistical significance.

Conclusion: Cochlear implantation in children with associated disabilities is expected to be less beneficial. However, in our small group of patients, postoperative auditory performances and speech production in Waardenburg Syndrome children were similar to other non syndromic children.
Complications Requiring Cochlear Reimplantation in Children – Changes in the Last 16 Years

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Keywords: Complications, Revision Surgery, Re-Implantation

Introduction: Impacts and implant failures that lead to cochlear implant reimplantation are seldom but will probably one of the main topics in CI surgery in the future. Implant companies claim that implants had become much safer within the last years. Nevertheless reimplantations have to be done from time to time. The aim of this study was investigate the number and kind of complications that lead to pediatric cochlear reimplantation and its changes between 1998 and 2014.

Methods: Operation reports of cases of cochlear implant revision surgery with reimplantation in children (≤18y) between July 1998 and May 2014 had been analyzed retrospectively. It had been reviewed for reason for operation, duration of operation, severe problems during operation, complications and performance after reimplantation.

Results: In the reviewed time 340 pediatric cochlear implantations had been done. 20 of them had been reimplantations. In proportion to all pediatric cochlear implantations the number of reimplantation slightly decreased over the years. In one case a complete reimplantation had been impossible due to intracochlear ossification and scaring. No major complications had been seen after operation. Performance was equal or better then before failure or impact except the case of incomplete reimplantation.

Conclusion: Cochlear reimplantation is a safe procedure. Due to changed operations techniques revision surgery became much faster but is still afflicted with difficulties during replacement of the active electrode. Softer initial surgery will hopefully lead to easier reimplantation. Despite better implants exploding numbers of implantation will lead to higher numbers of reimplantation and will confront surgeons with difficult situations.
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Benefit of Bilateral Hearing on Speech Recognition on the Telephone for Cochlear Implant Recipients

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Topic: Audiology

Keywords: Assistive Listening Devices

Introduction: Understanding speech over the telephone is often difficult for cochlear implant recipients. Innovative bilateral sound-processing algorithms may allow for improvement of performance on the telephone. Objective: This study assessed the ability of 10 implant recipients to understand recorded speech over the telephone in quiet and in the presence of competing noise. The primary objective was to determine whether performance would improve when the recipient received the telephone signal bilaterally as compared to monaural telephone use.

Methods: This study included 10 participants who were bilateral CII/HiRes 90K implant recipients. All subjects were fitted with Naida CI Q70 processors with the T-Mic 2 microphone. Sound processor programs were created using their everyday signal coding strategies. Each of these programs was configured with 100% T-Mic2 microphone only input. Sentence perception in quiet and in noise was evaluated using two programs: The participant’s conventional everyday program. The participant’s everyday program with wireless streaming of the telephone signal from the sound processor on the side of the telephone to the sound processor on the opposite ear. Performance was evaluated in four conditions: Conventional monaural telephone use in quiet Bilateral telephone use (via inter-aural wireless streaming) in quiet Conventional monaural telephone use in noise Bilateral telephone use (via inter-aural wireless streaming) in noise. Recorded CNC monosyllabic words (one list per condition) were presented from a telephone which the participant held to his/her preferred ear. In the noise conditions, classroom noise was presented from four loudspeakers located in the corners of the room. The level of the competing noise signal was 65 dBA at the location of the subject.

Results: Repeated measures analysis of variance indicated that use of bilateral wireless streaming of the telephone signal improved the ability to understand speech on the telephone in quiet and in the presence of noise.

Conclusion: An inter-aural wireless streaming technology that delivers the telephone signal from one implant sound processor to the processor on the other ear can improve speech recognition of cochlear implant users both in quiet and in noisy environments.
The Impact of Bilateral Cochlear Implantation on Listening Effort Revealed Through Measurements of Pupil Dilation

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Topic: Audiology

Keywords: Objective Measures, Binaural Hearing, Speech Test Theory

Introduction: For children and adults with cochlear implants (CIs), the decision of whether to undergo a second CI surgery depends on whether the potential benefits are quantifiable and understood in terms that are meaningful to the patient and family. After the activation of a second CI, patients typically report that they experience significant benefits when listening in challenging situations, and that they generally exert less effort when listening to speech. However, clinical speech audiometry and tone thresholds may not improve significantly, leading to the question of how to quantify all the benefits of the second implant. Previous studies have identified benefits in terms of sound localization and speech perception in noise. The current study presents a paradigm shift in the approach used to measure benefits of bilateral CIs, by measuring potential benefits of a second CI as the reduction in listening effort exerted by patients on a speech recognition task. Listening effort has become a topic of great interest regarding its effects on the quality of life for people with hearing impairment. Pupil dilation was used to measure effort, as it is a reliable index of cognitive load, and can be quantified with granularity that is fine enough to identify subtle differences in effort demanded by various listening conditions. In this study, we sought to quantify effort exerted by bilateral CI patients who listened with their better ear, poorer ear or both ears. The goal was to identify differences in listening effort exerted in these three conditions, and to distinguish listening effort from intelligibility performance.

Methods: Ten adult bilateral CI patients heard and repeated simple sentences from the IEEE/Harvard corpus in quiet while their pupil diameter was measured using a distal eye tracker. Luminance was controlled to reduce the pupillary light reflex, and baseline dilation measurements were made before each trial, to obtain small-scale changes on the order of 2-4 seconds for each sentence. Polynomial growth curve analysis was used to model the growth of pupil diameter from the onset of the sentence to the verbal response.

Results: When listening to sentences, patients’ pupil diameter grew largest and at the highest rate for the poorer ear, and was significantly smaller for the better ear. Smallest pupil dilation was measured when patients listened bilaterally. This effect did not emerge clearly for the minority of patients who did not report a strong preference for either ear.

Conclusion: Pupil dilation can be used to demonstrate better and poorer ears in bilateral CI recipients. It also demonstrates that bilateral listening reduces listening effort in ways that are not captured by the use of the “better ear” alone, even when in a simple quiet listening condition. As such, the impact on listening effort should be among the many considerations that go into the decision over whether to implant bilaterally.
The Effect of Inter-Device Interval on Performance Among Bilateral, Pediatric Cochlear Implant Recipients

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Topic: Audiology

Keywords: Outcomes, Binaural Hearing

Introduction: Binaural cochlear implantation in children results in improved sound localization and hearing in noise abilities as well as a trend for improved speech and language acquisition. While these results are clear, the ideal interval between the first and second implants (i.e. inter-device interval) is yet to be determined. In theory, prolongation of the inter-device interval could result in poorer performance and a lack of binaural skills development. Objective: To determine if prolongation of the inter-device interval in children receiving bilateral cochlear implants adversely affects speech perception outcomes.

Methods: Retrospective review of our pediatric cochlear implant database revealed 347 pediatric patients who had undergone bilateral implants. Those who had undergone revision surgery or had less than 6 months of follow-up after the second implant were excluded from analysis. Data was collected pertaining to the age at surgery, the inter-device interval, best PBK-W score greater than 6 months from surgery from each ear and demographic data about each patient. A ratio of PBK-W was generated (PBK-W 2nd side/PBK-W 1st side) to attempt to minimize confounding from other patient factors. This ratio was plotted against inter-device interval. Outliers from the trend in outcome were individually analyzed for the amount of residual hearing in the second ear.

Results: The inter-device interval was found to be important in performance with the second implant, with longer durations having worse outcomes.

Conclusions: Where clinically appropriate, the second implant should be implanted soon after the first to minimize the period of auditory deprivation thereby maximizing integration potential.
Pitch Ranking, Pitch Matching, and Binaural Fusion in Children with Bilateral Cochlear Implants: How to Bring Research Into Clinical Practice

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Introduction: The abilities of a listener to localize and hear in complex acoustic environments rely largely on the capacity of the binaural system to integrate inputs from the two ears. Individuals with bilateral cochlear implants (CIs) have shown larger variability and poorer performance on binaural hearing tasks compared with their normal hearing peers. It is hypothesized that one of the limiting factors is the inability of young CI users to perceptually integrate signals (binaural fusion) from the two CIs. It is also hypothesized that binaural fusion depends on the ability to form unique pitch percepts for sounds presented at different locations along the cochlear arrays. Results will be discussed in the context of applications to clinical bilateral CI programming and patient counseling.

Methods: Thirteen children with bilateral CIs ages 10-15 years participated in three experiments: (1) rank ordering the perceived pitch of stimuli presented from 11 locations along each cochlear array; (2) comparing the perceived pitch across the two ears directly and determining whether sounds were perceived to be the same; (3) reporting whether binaural electrical stimulation produces perceptually fused sounds. All stimuli were presented via research processors that provide tight control over the exact electrodes, their levels, and relative timing. Stimuli were presented at current levels that subjects determined to be loud but comfortable.

Results: All subjects were able to perform the pitch-ranking task. All subjects rank-ordered pitch perception in a manner consistent with high-to-low, base-to-apex mapping of electrodes, with large variability regarding the consistency of the responses. On the direct pitch comparison and binaural fusion tasks, some children were able to perform similarly to adults, such that response patterns demonstrated binaural fusion and integration between the two ears. Other subjects were unable to consistently fuse the auditory images. The results will be discussed in the context of auditory plasticity, effects of early vs. late-onset of deafness, and clinical CI mapping procedures.

Conclusion: Children with bilateral CIs receive inputs on a daily basis from two independent processors. When they are presented with electrical stimulation via research processors, their ability to consistently combine the unique inputs from their two ears into a signal auditory image is highly variable. This limitation could directly impact children’s ability to localize sounds and understand speech in complex acoustic environments. Applications in the clinical programming and counseling of children with CIs may achieve a goal of providing audiologists with tools that improve bilateral mapping procedures. The effects of proper bilateral loudness balance and binaural fusion can have long-term impact for habilitation.
Language and Academic Outcomes for Early-Implanted Children with Bilateral Versus Unilateral Cochlear Implants

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Keyword: Speech and Language Development with CI

Introduction: It has been shown that use of bilateral cochlear implants (CIs) yields significant perceptual benefits, but it is still unclear whether bilateral CI use significantly improves language and/or academic outcomes for children with early CIs. This study provides new evidence regarding language and academic outcomes for children with early bilateral and unilateral CIs. Objective: This study reported on language and academic outcomes for early-implanted children with CIs, determined whether these outcomes were age-appropriate, determined whether there was a significant difference in these for children with unilateral and bilateral CIs, and identified factors that were predictive of these outcomes.

Methods: Language outcomes of 91 elementary school-aged children with CIs who were participating in a prospective longitudinal study were measured using standardized tests. Academic outcomes (mathematics, oral language, reading and written language) for 44 8-year-old children were also assessed using a standardized academic assessment tool. Information about factors known to influence language and academic development was also collected. Outcomes were examined, and predictors identified, using linear regression analyses.

Results: Older (8-year-old) children with bilateral CIs achieved significantly better language scores than did children with unilateral CIs. Although group mean scores for the younger (5-year-old) children with bilateral CIs were greater, these differences were not statistically significant. Age at second CI was found to predict the rate of language growth, along with higher levels of parental involvement, higher cognitive ability, female gender, less screen time for children and more time spent by parents reading to children. Between 59-69% of the variance in language outcomes was predicted by the regression models. Children using bilateral CIs also achieved significantly higher scores for oral language, math, and written language on the academic assessment than did children using unilateral CIs. Greatest improvements were predicted for children with younger ages at second CI. High levels of parental involvement, greater time spent by children reading, and hearing aid use after first CI were the main predictive factors for academic success, although other factors were also identified. Between 48-72% of the variance in academic outcomes was predicted by the regression models.

Conclusion: This study provides further new evidence that children with CIs can achieve language and academic outcomes similar to those of their peers with normal hearing. Older children with sufficient bilateral CI experience had significantly better language and academic outcomes than did children with unilateral CIs, when other factors were controlled for. Outcomes were significantly predicted by a number of factors related to parenting and child characteristics, with high levels of parental involvement of crucial importance.
A Review of the Literature on the Cost-Utility of Bilateral Cochlear Implantation

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Topic: Economics and Public Policy

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Introduction: Unilateral cochlear implantation was proven to be cost-effective both in children and adults, but the cost-utility of bilateral implantation is still debated. Objective: To review the studies of the cost-utility of bilateral cochlear implantation published in the scientific literature, trying to understand the origin of the disparate results.

Methods: We registered for each study the goal population (either adults, or children, or both), the instrument used to measure the increase in quality of life (visual analog scales, time trade-off (TTO), health utility indexes …), the informants (cochlear implant users, their parents, health professionals, volunteers…), and the incremental cost-utility ratio (ICUR) returned. The small number of studies and the disparity of the results made it meaningless to conduct a meta-analysis.

Results: 8 studies were identified: [Summerfield et al., 2002], [Summerfield et al., 2003], [Summerfield et al., 2006], [Bond et al., 2009], Cochlear Europe Ltd. [unpublished; submitted to NICE], [L-Pedraza Gómez et al., 2007], [Bichey and Miyamoto, 2008], and [Summerfield et al., 2010]. The ICUR obtained ranged from $2,187/QALY (for a mix population of adults and children) to £40,410/QALY for children and £100.000/QALY for adults. The main cause of the disparity is the difference in the estimates of the increase in quality of life, which ranged from 0.03 to 0.11. These extreme values were obtained when using the HUI-3 index. (Another measurement also based on the HUI-3 but not used in those cost-utility analyses, obtained an “increase” of 0.003.) We also found that the way of framing the questions when using the time trade-off method seems to be biased and may have led to underestimate the benefit of bilateral implantation. In some of those studies the sensitivity analyses returned results that apparently contradict both the conclusion of the base-case analysis and the evidence that has proven the effectiveness of bilateral implantation. On the contrary, the above-mentioned ICUR of $2,187/QALY seems to be an underestimation.

Conclusion: The cost-utility analyses of bilateral cochlear implantation have returned disparate results. Most of them seem to be an overestimation of the ICUR, while one seems to be an underestimation. The main cause for those contradictory results is the use of different estimates for the increase in the quality of life due to the second implant, especially when using the HUI-3, which in our opinion is not an adequate instrument for this problem. There are additional qualitative arguments that cast doubts on the results returned by those studies. For these reasons, it is necessary to design and conduct new studies that can measure more accurately the cost-utility of bilateral implantation.
Efficacy of Bilateral Cochlear Implants in Children: Gaps in the Evidence
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Keywords: Speech and Language Development with CI, Quality of Life, Multiple Handicapped Children

Introduction: There are a considerable number of studies that have demonstrated the benefit of bilateral cochlear implants in children and adolescents. The perceived benefit, however, may be limited to specific outcome measures including speech perception in noise and sound localization based on the quality and level of evidence of published reports. The Implantable Hearing Devices Committee of the American Academy of Otolaryngology-Head and Neck Surgery Foundation is tasked with reviewing medical policies from third-party payers and the Centers for Medicare and Medicaid Services and providing opinion regarding individual state health technology assessments. It is important that members of the hearing health care community understand the perceptions of those entities that place value on a medical intervention and their influence on our mission to provide care to children with significant hearing loss. The foundation of these perceptions is derived from independent review of the available literature. The identification of gaps in the evidence should help to direct future quality clinical research efforts.

Methods: Review and analysis of the quality and level of evidence of the existing published clinical research on bilateral cochlear implants in children and adolescents and identification of gaps in the evidence to support bilateral implantation as it pertains to specific performance parameters and outcomes.

Results: Although existing clinical evidence supports significant benefit as it pertains to specific outcome measures for bilateral cochlear implants in children, the available evidence applies most directly to children who have pre-lingual deafness, who have demonstrated success with their first implant and have adhered to a post-operative auditory and language training schedule, and who have no significant disabilities other than hearing loss. The perceived gaps in the evidence to support bilateral cochlear implants in children include: 1) Attainment of complex language skills, functional hearing, and impact on academic achievement and employment, 2) Disease-specific quality of life and cost effectiveness, and 3) Performance outcomes in those with significant disabilities other than hearing loss.

Conclusion: The availability of health care dollars to support a rehabilitation intervention is closely associated with the available clinical evidence that demonstrates significant value of the intervention. The hearing health care community of physicians, audiologists, speech and language therapists, and implant manufacturers should strive to provide the clinical evidence necessary to influence medical policy coverage determination by third-party payers and others. Further quality clinical research based on the perceived gaps in the evidence should provide a means for justifying the perceived value of bilateral cochlear implants in children and adolescents.
Sequential Bilateral Cochlear Implantation in Children: Contributing Factors on Performance Outcomes

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Introduction: Prior to 2012, only a select number of private insurers provided coverage for pediatric bilateral cochlear implantation in our state. In March 2012, our State Department of Community Health expanded Medicaid coverage to include bilateral cochlear implants for beneficiaries ages 12 months through 20 years, increasing the number of children with access to this important aspect of care. Objective: The purpose of this study is to identify factors that contribute to pediatric cochlear implant users’ outcomes following sequential bilateral implantation.

Methods: Retrospective review of speech perception and speech and language scores obtained by 48 children who underwent sequential bilateral cochlear implant surgery at a large tertiary medical center from 2008 to 2013. The study evaluates and compares data collected with the first device immediately prior to bilateral sequential cochlear implantation and data collected 6 months and 1 year after bilateral cochlear implantation.

Results: Results on speech/language measures will be presented as a function of language growth over time prior to receiving a bilateral and 6 and 12 months post-bilateral. Speech recognition scores obtained with the first CI will be compared to scores obtained with the second CI. Additionally, speech perception will be evaluated as a function of improvement based on bilateral hearing.

Conclusion: Result of this study will provide a greater understanding of factors contributing to performance outcomes in children who undergo sequential bilateral cochlear implantation. Findings from the study could influence preoperative counseling of unilateral CI users and their families considering bilateral implantation.

COI: Cochlear, Med El And Advanced Bionics¹