Session ID: S1-2  
Session Title: Surgical Technologies  
Abstract ID: 74  
Title: "Silent" Electrode Insertion: Developing a Time-Based Guideline from Intracochlear Pressure Measurements  
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Abstract: "Silent" Electrode Insertion: Developing a Time-Based Guideline from Intracochlear Pressure Measurements  
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Abstract (2,179/3,000 characters):  
Introduction: With increasing focus on hearing preservation during cochlear implant surgery, atraumatic electrode insertion is of the utmost importance. It has been established previously that large pressure spikes can be generated in the cochlea during the insertion of implant electrodes1-3. Estimates of equivalent ear canal pressure suggest these peak pressures may be of sufficient intensity to cause trauma similar to that of an acoustic blast injury1 and may be one source for postoperative loss of residual hearing. Here, we attempt to develop a standard recommendation based on insertion time for a “Silent” electrode insertion in which no spikes in intracochlear pressure are noted.  
Objective: To develop a guideline for cochlear implant electrode insertions based on timing of recordings that generate the fewest transient intracochlear pressure spikes equivalent to high intensity acoustic stimuli.  
Methods: Human cadaveric heads were surgically prepared with an extended facial recess and implanted sequentially with seven different cochlear implant electrodes from three manufacturers via a round window approach. Fiber-optic sensors measured intracochlear pressures in scala vestibuli and tympani near the oval and round windows during timed insertions of 10, 30, and 60 seconds for each electrode.  
Results: CI electrode insertion produced a range of pressure transients in the cochlea (134-155 dB SPL), consistent with results from previous studies. The smallest number of spikes was seen with the longest insertions (60 seconds). High intensity pressure spikes were noted with all electrodes styles tested.  
Conclusion: Our results confirm previous data that suggests cochlear implant electrode insertion can cause pressure transients with intensities similar to those elicited by high-level sounds. Results affirm the importance of atraumatic surgical techniques and suggest that longer insertion times are associated with fewer pressure transients. Based on these data, we propose a recommendation of electrode insertion times of at least 60 seconds to achieve a “Silent” insertion and minimize likelihood of generation of transient intracochlear pressure spikes.  

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Disclosure: S.P.C. is a consultant to Cochlear Americas.
Keywords: Electrode insertion, Hearing preservation, Intracochlear pressures

Session ID: S1-2
Session Title: Surgical Technologies
Abstract ID: 146
Title: Effects of Steroid Application with a Cochlear Catheter on Impedances and Electrically Evoked Compound Action Potentials after Cochlear Implantation

Authors: Lutz Gaertner, PhD, Nils Prenzler, MD, Melanie Leifholz, B.Eng., Athanasia Warnecke, MD, Andreas Büchner, PhD, Thomas Lenarz, MD;
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Abstract: Introduction: It is known that systemic and local administered steroids can reduce the insertion trauma and growth of fibrous tissue after cochlea implantation and thus increase the chance for hearing preservation and lower impedances. Several ways of administration have been described, e.g. systemic, diffusion via middle ear or drug releasing surface coatings. The motivation for the development of a cochlear catheter was to bring the drug to more apical regions without structural harm of the cochlear microstructure.

Methods: A 20 mm silicone catheter was developed for fluid delivery into the inner ear. The cochlear catheter consists of a 20 mm long electrode dummy with a hollow lumen and an opening at the tip to deliver fluids into apical regions of the cochlea. N = 5 patients without relevant residual hearing (> 80 dB hearing loss at 250 Hz) received a cochlear flushing with diluted triamcinolone (4 mg/ml) via cochlear catheter before cochlear implantation. 5 further patients treated with the same electrode and same hearing loss receiving no catheter or steroid, were analyzed as control group. Impedances and the slope of the electrically evoked compound action potential (ECAP) amplitude growth function (AGF) were measured directly after implantation in the OR, on days 3, 10, 17, 24 and at first fitting.

Results: Our findings indicate that impedances in the steroid group are stable until day 10 post-OP and rise between day 10 and day 24 post-OP. Impedances in the control group rise directly after implantation and stay stable until first fitting. At first fitting both groups show the same level of impedance. The effect can be seen on all electrodes. First results of the 3 month measurements and of ECAP AGF slopes will be presented.

Conclusion: Steroid treatment with the cochlear catheter before implant insertion seems to have an impact on the behavior of electrode impedances, affecting all regions of the Cochlea.

Session ID: S1-2
Session Title: Surgical Technologies
Abstract ID: 514
Title: Real Time Intraoperative Monitoring Using the Cochlear Implant Electrode for Hearing Preservation

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Abstract: **Introduction:** Preservation of residual hearing during cochlear implantation has well recognized primary benefits. Several factors are recognized to influence the success of hearing preservation cochlear implantation surgery. Monitoring of residual hearing may offer a surrogate for the preservation of delicate intracochlear structure and function during electrode insertion. Several electrophysiological measures and electrocochleography techniques have been investigated for this purpose, each with their own challenges in providing a reliable and real-time measure of residual cochlear electrophysiological function. We present a novel technique using the implant electrode array to monitor intracochlear electrophysiological potentials during cochlear implantation and correlate this with preservation of residual hearing function.

**Methods:** A prospective pilot study being carried out at a tertiary referral centre enrolling both adult and paediatric patients. Surgery is carried out by a standardized team, utilizing a standardized set up and hearing preservation technique. Intraoperative electrophysiological monitoring (intracochlear microphonic, ICM) is carried out during insertion of the implant electrode, at the culmination of the procedure and at specified intervals postoperatively. The intraoperative and postoperative findings are correlated with preoperative and postoperative residual hearing thresholds and degree of hearing preservation.

**Results:** Intraoperative electrophysiological responses (ICM) were identified in 60% of cases and this was preserved at the end of the procedure in 78% of cases. A better preoperative average hearing threshold was associated with a greater likelihood of detecting an ICM, however the ICM could still be identified in some cases with minimal preoperative residual hearing. The relationship between preoperative and postoperative hearing thresholds, and age and hearing preservation, was statistically significant (p<0.05). Complete preservation of hearing, as defined by the HEARRING hearing preservation classification system, was achieved in 100% of patients that met criteria for EAS cochlear implantation. All patients who received preoperative transtympanic injection of glucocorticoids had complete hearing preservation.

**Conclusion:** The cochlear implant electrode array can be used to perform direct intraoperative monitoring of intracochlear electrophysiological responses that in turn reflect residual hearing function during cochlear implantation and correlates with postoperative residual hearing thresholds and degree of hearing preservation. Further experience and refinement of the stimulation / detection system may provide more sensitive, more accurate and more real-time feedback to the surgeon to facilitate and improve hearing preservation in cochlear implantation.

Session **ID:** S1-2

Session **Title:** Surgical Technologies

**Abstract ID:** 121

**Title:** Reducing Trauma and Optimizing Intracochlear Position with a Shape Memory Polymer Cochlear Implant Array

**Authors:** Kenneth H. Lee, M.D., Ph.D1, Walter Voit, Ph.D.2, Hans Ajieren, B.S. pending3, Eric Eisner, B.S.3, Mark Sonderman, B.S.4, Dongmei Shao, M.D.1; 1Otolaryngology, UT Southwestern Med. Ctr., Dallas, TX, 2Mechanical Engineering, Material Science and Engineering, UT Dallas, Dallas, TX, 3Material Science and Engineering, UT Dallas, Dallas, TX, 4UT Southwestern Med. Sch., Dallas, TX.

**Abstract: Introduction:** Shape memory polymers (SMP) belong to a class of smart materials that can change shape in response to a stimulus. With these polymers, we have developed a cochlear implant electrode array that is straight at room temperature, but changes its shape to self navigate the turns of the cochlea once inserted and warmed to body temperature. Use of an SMP based self-coiling cochlear implant electrode array can reduce insertion trauma and optimize intracochlear array position to improve cochlear implant function and outcomes.
Methods: Self-coiling cochlear implant arrays were generated by laser cutting probes from sheets of SMP. Self-coiling SMP based cochlear implant electrode arrays as well as standard silicon arrays were inserted into a cochlear model and insertion videos were captured. SMP and straight silicon arrays were also inserted into rat cochleae and histological analyses of paraffin embedded sections were performed to determine degree of trauma to the lateral wall of the cochlea and the intracochlear position of the arrays.

Results: Review of videos revealed that the self-coiling arrays inserted into cochlear models at body temperature (37°C) demonstrated that full insertion was achieved with minimal contact with the walls of the cochlea. In contrast, the standard straight arrays had continuous contact with the lateral wall following initial contact at the basal turn. Histological analysis showed less tissue trauma resulting with insertion of the self-coiling arrays compared to that of standard straight cochlear implant arrays. In addition, review of the histological sections revealed that the self-coiling arrays maintained a more medial position within the scala of the middle turn of the cochlea.

Conclusion: We have demonstrated that shape memory polymers can be used to develop a self-coiling cochlear implant array that can be inserted with reduced tissue trauma and more consistent mid-scalar positioning within the cochlea once fully inserted.

Session ID: S1-2
Session Title: Surgical Technologies
Abstract ID: 476
Title: Can Intracochlear Electrocochleography be Used to Estimate Residual Acoustic Hearing Following Cochlear Implantation?
Authors: Jourdan T. Holder, AuD1, Brendan P. O’Connell, MD2, Robert T. Dwyer, AuD1, Kanthaiah Koka, PhD3, René H. Gifford, PhD1, Robert F. Labadie, MD, PhD2;
Abstract: Introduction: The cochlear implant (CI) electrode can be used to record close-proximity electrocochleography (ECochG) responses, which can lend information about physiologic changes occurring in the cochlea. When utilized during cochlear implant insertion, this technique allows for the recording of real-time changes within the cochlea that may be correlated with surgical trauma. The objective of the current study was to determine if ECochG recorded from the CI completed either intra-operatively or post-operatively at activation is correlated with pre-operative and/or post-operative audiometric thresholds.
Methods: Patients with 250-Hz thresholds ≤80 dB HL undergoing CI with a mid-scala device were studied. Using an in-the-canal foam insert, tone bursts (500 Hz, 110 dB) were presented to the operative ear during electrode insertion. ECochG responses were recorded using the implant and a custom signal recording unit. This process was repeated at CI activation. ECochG amplitude collected intra-operatively during CI insertion and at activation were compared with air-conduction audiometric thresholds at both the pre-operative and activation time points.
Results: Sixteen patients (8 female) with residual hearing have been enrolled to date. Mean pre-operative low-frequency PTA (pure tone average of 125, 250, and 500 Hz) at the pre-operative and activation time points was 53 dB HL and 84 dB HL, respectively. Nine patients maintained 250 Hz thresholds ≤80 dB HL at activation with an average threshold shift of 31 dB. Intra-operative ECochG amplitudes were significantly correlated with both the pre-operative low-frequency PTA (r=0.61, p<0.001) and the activation low-frequency PTA (r=0.51, p<0.001). Activation ECochG amplitudes were also significantly correlated with the activation low-frequency PTA (r=0.86, p<0.001).
**Conclusion:** ECochG amplitudes collected intra-operatively and post-operatively from the CI electrode may be used to estimate pre-operative and post-operative behavioral audiograms. As such, this measure may serve as a real-time measure of insertion trauma and cochlear structural preservation and could potentially help guide future surgical insertion.

**Session ID:** S1-2  
**Session Title:** Surgical Technologies  
**Abstract ID:** 466  
**Title:** Use of an Integrated System to Measure Electrical Stapedial Reflexes in Children with Cochlear Implants  
**Authors:** Lizette Carranco Hernandez, M.D.1, Lisette Cristerna Sánchez, M.D.1, Miriam Camacho Olivares, M.D.1, Aniket A. Saoji, Ph.D.2, Leonid M. Litvak, Ph.D.2, Carina Rodríguez, M.S.2;  
1Instituto de Enfermedades Respiratorias, Mexico City, Mexico, 2Advanced Bionics, Valencia, CA.  
**Abstract:** **Introduction:** Electrical stapedial reflex threshold (ESRT) is used to determine the upper limit of electrical stimulation in cochlear implants. While performing routine ESRT measurement, the cochlear implant fitting software and the middle ear impedance measurement system are independently maneuvered to deliver electrical stimulation and measure stapedial reflexes, respectively. In the present study, an integrated system was used to measure ESRT. In this system, the pure tone from the contralateral output of the middle ear analyzer is routed to the auxiliary port of the cochlear implant speech processor and the level of the pure tone is used to send appropriate current level to the implant.  
**Methods:** Prior to ESRT measurement, the electrical stimulus is calibrated to a 2000 Hz pure tone presented at 80 dB SPL which is presented through the contralateral port of the middle ear analyzer. While measuring ESRT the pure tone level is varied in 1 dB steps which corresponds to a change of 10 clinical units in the electrical stimulation. Using the integrated system, ESRTs were measured in the ipsilateral and contralateral un-implanted ear using three probe frequencies of (226, 678, and 1000 Hz) in 19 children (mean age = 8.6 years, SD = 2.29) with Advanced Bionics HiRes 90k implants.  
**Results:** ESRT measured with the integrated middle ear analyzer showed good test/re-test reliability. ESRTs could be measured in 3, 4, and 7 cochlear implant subjects (out of 19) in the ipsilateral (implanted) ear using probe frequencies of 226, 678, and 1000 Hz, respectively. In the contralateral ear, ESRTs were measured in 11, 13, and 13 out of 19 subjects using probe frequencies of 226, 678, and 1000 Hz.  
**Conclusion:** The integrated system allowed the clinician to use the middle ear system to control electrical stimulation and therefore simplified the ESRT measurement in cochlear implants. As compared to the routinely used 226 Hz, a higher probe frequency of 1000 Hz elicits more measurable ESRTs in children with cochlear implants.

**Session ID:** S1-2  
**Session Title:** Surgical Technologies  
**Abstract ID:** 439  
**Title:** Intra-operative Trauma Detection with Help of Electrocochleography and Fluoroscopy Video  
**Authors:** Ralf Greisiger, PhD1, Torquil Sørensen, PhD1, Hilde Korslund, Radiograph2, Marie Bunne, PhD1, Per Kristian Hol, PhD2, Greg Eigner Jablonski, PhD1;  
1Department of Otolaryngology, Univ. Hosp. Oslo, Oslo, Norway, 2Intervention Centre, Univ. Hosp. Oslo, Oslo, Norway.  
**Abstract:** Intra-operative Trauma Detection with help of Electrocochleography and Fluoroscopy video Ralf Greisiger1, Torquil Sørensen1, Hilde Korslund2, Marie Bunne1, Per Kristian Hol2,3, Greg Eigner Jablonski1,3
Introduction
There is rising interest in Electrocochleography (ECoG) measurements during cochlear implant (CI) surgery. These measurements might give the surgeon feedback about CI electrode array insertion. ECoG alone does not allow movements of the electrode to be observed, while these may be causing trauma to the inner ear structures. This has been investigated in our study using per-operative fluoroscopy to monitor the intra-cochlear electrode array movements while simultaneously recording ECoG.

Objectives
The aim of this study is to investigate whether simultaneous ECoG and fluoroscopy imaging can teach us to minimize risk factors during electrode array insertion, with regard to intra-cochlear trauma.

Patients
For this study we investigate at least 10 patients. It is an ongoing study, and all patients investigated until the conference will be included in the presentation.

Methods
During insertion of an Advanced Bionics electrode array, per-operative fluoroscopy video was conducted to monitor the insertion dynamics visually while performing ECoG. The connection between electrode movements and ECoG response was investigated. The surgery itself was carried out using a standard procedure.

Results
Preliminary data measured in our first patients have shown that simultaneous ECoG measurements and fluoroscopy video can be obtained. Together they gave interesting insights about intra-cochlear trauma while the electrode was moving inside the cochlea.

Conclusion
We conclude from our preliminary data that ECoG is a valuable tool to investigate cochlear trauma during electrode insertion. Fluoroscopic imaging helps to identify critical moments during insertion, and to interpret the ECoG results obtained during insertion.

Session ID: S1-3
Session Title: Predicting and Improving Outcomes
Abstract ID: 217

Title: Long-term Results of Auditory Abilities after Cochlear Implantation in Subjects with Unilateral Deafness

Authors: Rolf Battmer, PhD1, Ingo Todt, MD1, Frederike Wagner, MD2, Arne Ernst, MD1, Julia Weber, Audiologist2;
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Abstract: Introduction: Recent treatments for single sided deaf subjects (SSD) are very limited. If treated at all, acoustic signals are only picked up from the deaf side and routed to the hearing side either as an electrical signal (CROS) or through bone conduction (BAHA). Both methods use for the transmission of auditory signals only the contra lateral hearing cochlea and do not utilize the peripheral auditory pathways on both sides. However, through electrical stimulation via a cochlear implant the deaf side can be activated. The aim of our present study was to demonstrate that in such a case speech reception in noise and localization can be improved.

Methods: Nine adult participants with short-term unilateral deafness (<5 yr) participated. All had sudden onset of severe-to-profound hearing loss in 1 ear, which then received a CI, and normal or near
normal hearing in the other ear. Speech recognition in quiet and noise with an adaptive sentence test was tested after 3 months, 6 months and 12 months. Three binaural effects were calculated: summation effect (S0N0), squelch effect (S0NC1) and combined head shadow effect (SCIN0). For localization, a 7 loudspeaker setup (± 90°, 30° distance) was used. Discrimination was tested preoperatively (normal hearing (NH) ear alone) and after 12 months bilaterally (CI and NH).

**Results:** One subject quit the study after 3 months due to subjectively limited benefit. All other participants had open-set speech recognition and excellent audibility with the CI. Sentence recognition in the various noise conditions show significant bilateral improvement over time, i.e. in the condition S0N0 from -3.1 dB preoperatively to -5.7 dB after 12 months. Localization improved bilaterally compared with the NH ear alone up to 10° RMS. The 8 participants wore the CI full time, and subjective reports were positive.

**Conclusion:** Overall, the CI recipients with unilateral deafness obtained open-set speech recognition in quiet and in noise and improved localization. However, careful patient selection is a decisive factor for a successful treatment of this patient group. Under these conditions, CI implantation is a viable treatment of single sided deaf subjects.

**Session ID:** S1-3
**Session Title:** Predicting and Improving Outcomes
**Abstract ID:** 311
**Title:** Predicting Outcomes of Children with Cochlear Implants - Findings from the LOCHI Study
**Authors:** Teresa Y. C. Ching, PhD, Harvey Dillon, PhD, Laura Button, BA Speech pathology, Mark Seeto, MAud, Vicky Zhang, PhD, Patricia Van Buynnder, MAud, MAudSA(ccp); Natl. Acoustic Lab, Australia, Sydney, Australia.
**Abstract:** **Introduction:** To identify factors that influence 5-year language and speech outcomes of children with congenital hearing loss who received cochlear implants between 6 and 36 months of age.

**Methods:** Participants were enrolled in the Longitudinal Outcomes of Children with Hearing Impairment (LOCHI) study, a population-based study that investigated the outcomes of children with congenital hearing loss in a prospective manner. One hundred and fourteen children with cochlear implants were evaluated at 5 years of age, using a battery of standardised tests and custom-designed tests. About half of the children received a cochlear implant before 12 months of age. Parent reports on functional and psychosocial outcomes were solicited. Using regression analyses, this study examined the influence of a range of child-, family- and intervention-related factors on the language and speech outcomes of children at 5 years of age.

**Results:** Age at implantation and nonverbal cognitive ability accounted for 58% variance in language performance. In addition, the absence of additional disabilities and the use of oral communication were significant factors influencing outcomes. The effect of delays in age at implantation on language outcomes was also quantified.

**Conclusion:** The findings highlight the effectiveness of early treatment for improving child outcomes, and the necessity to monitor early outcomes to ensure that children who require cochlear implantation receive the treatment early, before 12 months of age.

**Session ID:** S1-3
**Session Title:** Predicting and Improving Outcomes
**Abstract ID:** 441
**Title:** Development Trajectories of Speech Production between 4 and 8 Years Post-implant
**Authors:** Andrea Warner-Czyz, Ph.D.1, Ann Geers, Ph.D.1, Nae-Yuh Wang, Ph.D.2, Christine Mitchell, ScM3, Laurie Eisenberg, Ph.D.4;
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Abstract: Introduction: This study sought to determine whether phoneme production skills in early-implanted children improved significantly as a function of device experience after 4 years post-implant. Additionally, we aimed to evaluate which variables coincided with fewer phoneme production errors.

Methods: Participants include 160 children with cochlear implants enrolled in a longitudinal, multi-center project, the Childhood Development after Cochlear Implantation study. Participants had a mean age at implantation of 2.4 years. Children completed the Goldman-Fristoe Test of Articulation (GFTA) between 4 and 8 years post-implant. Error scores were computed for each child. Data were analyzed using a mixed-effects linear model utilizing all available GFTA data between 4 and 8 years post-implant.

Results: Model-based mean error score on the GFTA at 4-years post-implant was 51.0. Relative to the 4-year post-implant evaluation, error scores decreased by 5.1, 9.6, 10.9, and 10.6 at 5-, 6-, 7-, and 8-years post-implant, respectively. Older age at implant activation was significantly associated with higher GFTA error scores over follow-up post implant (4.6 points/year older, p<0.0001). Better speech perception scores at baseline and at 3-years post-implant were independently associated with lower GFTA error scores over the 4-8 year follow-up period (both p<0.001).

Conclusion: Phoneme production accuracy continues to improve after 4 years of implant experience, with performance appearing to level off around 6 years of use. Children with a younger age at implant activation and faster development of speech perception skills have a significant advantage for production accuracy.

Session ID: S1-3
Session Title: Predicting and Improving Outcomes
Abstract ID: 250
Title: Factors Affecting Development of Babble in Prelingually Deaf Children Who Use Cochlear Implants
Authors: Liz Hamilton, Principal Speech and Language Therapist1, Helen Peebles, Principal Speech & Language Therapist1, Edward C. Killan, PhD2;
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Abstract: Introduction: The emergence of babble is considered a key landmark in vocal development and is a precursor to the development of first words. Late onset of babble exhibited by children can be a strong predictor of speech and language disorders. An understanding of babble development, and potential factors affecting it, in cochlear-implanted children, would be useful in terms of setting expectations and planning speech and language rehabilitative support. To this end, clinical data for cochlear-implanted children were analysed to provide a descriptive account of babble development at various stages post implant, as well as to investigate potential factors that affect babble development.

Methods: A longitudinal study of 39 cochlear-implanted children was completed over a 4 year period. All children included were pre-verbal with a diagnosis of congenital profound sensori-neural hearing loss. Mean age at implantation was 26 months. Data regarding vocal development was collected at the pre-implant assessment and at 6, 12 and 24 months post implant. Data included parental interviews, observations and the Profile of Actual Speech Skills (PASS), which allows hierarchical categorisation of vocalisations. The influence of hearing aid use prior to implant, age at implant, time taken for optimal programming and home language on speech and language development will be explored using logistic regression. Whilst it is hypothesised that hearing aid use and home language will not be significant
effects, it is predicted that the time taken to achieve an optimal map will have a significant effect on babble development.

**Results:** Initial data analysis indicates that 100% of the children who developed complex canonical babble by 6 months post implant were not found to have any additional speech, language and communication needs. However, 67% of the children with canonical babble and 80% of those with no babble at this stage presented with a diagnosed or suspected additional communication, speech or language need. These categories of babble development will be used by regression analysis to test the above hypotheses.

**Conclusion:** The initial findings from this study indicate that a range of babble development stages has been observed in children at 6 months post implant confirming the outcomes of previous research. In this study the babble hierarchy appears to be a predictor of additional speech, language and communication needs. Further results will be gained from the regression analysis in relation to the hypothesised effects.

**Session ID:** S1-3  
**Session Title:** Predicting and Improving Outcomes  
**Abstract ID:** 327  
**Title:** Category Indicators for Monitoring Long-term Communication Outcomes in a Large Cohort of Children Using Cochlear Implants  
**Authors:** Shani Dettman, PhD1, Dawn Choo, Master of Speech Pathology1, Jaime Leigh, PhD2, Richard Dowell, PhD1;  
1Audiology and Speech Pathology, The Univ. of Melbourne, Melbourne, Victoria, Australia, 2Cochlear Implant Clinic, Royal Victorian Eye and Ear Hosp., Melbourne, Victoria, Australia.  
**Abstract:** Introduction: Formal testing has been used to monitor the rate of language development and progress of listening skills in children using cochlear implants (CI). Evaluating communication outcomes in large, heterogeneous cohorts is challenging, due to the wide range of language assessments and auditory performance measures used at different ages, and the presence of individual differences (child, device and family characteristics).  
Methods: Demographic information and outcome data for over 900 children were collected at routine assessment intervals according to a CI clinic’s protocol. The children's language abilities assessed on a range of commonly used measures and described using the newly developed Categories of Linguistic Performance (CLIP). Speech perception results were classified and analysed using Archbold et al’s (1995) Categories of Auditory Performance (CAP) and Black et al’s (2014)’s adapted scale, Categories of Auditory Performance Index. Speech production skills and phonological processes were examined using Computer Aided Speech and Language Analysis (CASALA). Communication gains and degree of progress over time were documented for a subset of children. Multiple regression analysis was conducted to explore factors contributing to the variability in the children’s communication outcomes during school-entry and school years.  
Results: The influence of variables including, age at implant, age at hearing aid fitting, type of early intervention program, presence of additional diagnoses and socio-demographic indicators, are reflected in the long-term speech and language outcomes for paediatric cochlear implant recipients.  
Conclusion: The benefits of cochlear implantation may be captured by monitoring communication performance for children with sensorineural hearing loss. It is, however, also observed that individual, educational and family characteristics are associated with post-implant outcomes. In addition to providing device support, it is also important for early intervention professionals and CI clinicians to provide evidence-based guidance to families for children with profound hearing loss.
Title: Attention to Speech in Deaf Infants with Cochlear Implants

Authors: Yuanyuan Wang, Ph.D.1, Carissa Shafto, Ph.D.2, Derek Houston, Ph.D.1; 1Otolaryngology, The Ohio State Univ., Columbus, OH, 2Galen Coll. of Nursing, New York, NY.

Abstract: There has been a growing body of evidence suggesting that early auditory deprivation affects the development of the auditory neural pathway as well as other higher-level cortical areas, which may lead to poor processing even after cochlear implantation (CI) (Geers et al., 2011; Holt et al., 2012; Pisoni et al., 2000). For example, infants with CIs often lag behind their normal hearing (NH) peers in a range of speech and spoken language tests (Fagan, 2015; Niparko et al., 2010). In this study, we would like to examine one of the cognitive skills that is critical to the acquisition of spoken language, namely, the ability to “listen” - i.e., sustained attention to speech (ATS) (Columbo & Bundy, 1981; Glenn et al., 1981; Houston, 2003, 2013; Vouloumanos & Werker, 2004, 2007). Specifically, we examined the effects of early auditory deprivation and subsequent CI on the development of ATS in deaf infants with CIs. In addition, we also investigated the extent to which ATS may predict later language outcomes in children with CIs.

Methods: Using the visual habituation procedure, we tested deaf infants who received CIs before 2 years of age and their chronological age-matched NH peers on their ATS. There were total 104 CI-NH paired sessions grouped into 3 post-CI intervals: < 1 month (41 pairs), 3-6 months (35 pairs), and > 8 months (28 pairs) after implantation. Infants received one of four repeating speech sounds paired with a checkerboard pattern on half of the trials while received no sound with the checkerboard pattern on the other half of the trials. ATS was measured as the proportion of time that infants looked at the speech trials relative to the total looking time either at the speech or silent trials. Receptive, expressive language, and word recognition tests were administered to the CI infants 2 and 4 years after implantation.

Results: The results demonstrated that with < 1 month’s CI experience, deaf infants’ mean proportion of fixation to speech trials was significantly lower than that of NH infants, p < .001; with 3-6 months CI experience, CI infants showed a trend in the same direction as their NH peers (looked longer to the speech than to the silent trials) and showed similar mean proportion of speech fixation compared to their NH peers, p = .91; during > 8 months post-CI interval, neither CI or NH infants showed any preference and the fixation behavior did not differ between the two groups, p = .30, see Figure 1. In addition, CI infants’ different looking time to speech vs. silent trials during 3-6 months post-CI interval was significantly positively correlated with the Lexical Neighborhood Test (LNT), p = .021, administered four years after implantation.

Conclusion: These findings suggest 1) auditory deprivation prior to CI may affect deaf infants’ ATS; 2) early implantation may facilitate the development of ATS in infants with CIs; and 3) the ability to attend to speech after implantation may underlie the development of speech perception skills. These results may inform language acquisition theories and bring some insights into our understanding of the role of early auditory experience on cognitive processes. In addition, these findings have significant clinical implications of early intervention on hearing loss and emphasize the importance of developing strong listening skills.
Authors: Eva L. Karltop, MD, PhD, Martin Eklöf, PhD student; ENT, Karolinska Univ. Hosp., Stockholm, Sweden.

Abstract: Introduction: The main objective of this study was to investigate whether prelingually deaf children who received a cochlear implant (CI) before nine months of age developed age-equivalent spoken language abilities to a greater extent than children who were operated on at a later stage. The study also examined the medical risk of intervention with CIs in very young children.

Methods: The spoken language abilities of 137 prelingually deaf children, who received CI, were analysed. The children were divided into five groups depending on their age at the time of the implantation. Language understanding, vocabulary, speech production and speech perception were assessed with language and hearing tests. The levels of the skills were tested at six month intervals after the CI operation. The children were followed-up for up to 14 years.

Results: Children implanted before 9 months of age had no language delay and reached age equivalence results on all language measures. Children implanted at 9-11 months of age had an initial language delay in language understanding and in speech intelligibility, but caught up after 2-3 years. The children implanted between 12-17 months did not close the gap on language understanding during pre-school age, but caught up on vocabulary at early school age. Children operated from 18 months and onwards did not close the gap compared to children in the youngest age group, in any language measures except for speech intelligibility. No increase in complications was recorded when the youngest children who received implants were compared with those who were older when they received their implants.

Conclusion: Cochlear implantation before nine months of age reduce the spoken language delay, compared to children implanted at higher ages, and gives the majority of prelingually deaf children spoken language acquisition similar to that of their normal hearing peers.

Session ID: S2-1
Session Title: Music Perception
Abstract ID: 263
Title: Music Processing Reveals Double Dissociation Effects between Discrimination, Association and Appreciation: Evidence from Adult Pre- and Postlingual CI Users
Authors: Anja Hahne, Dr., Lisa Bruns, Dr., Dirk Mürbe, Prof., Niki Vavatzanidis, M.Sc. Medical Neuroscience; Saxonian Cochlear Implant Center, Technische Univ. Dresden, Dresden, Germany.

Abstract: Introduction: Whereas many adult CI users are capable of understanding oral language, the processing of music is often described as being problematic. Hearing and understanding music comprises very different dimensions which rely on different mechanisms. We aimed to refine the view on music perception with CI by comparing three dimensions of music processing within and across two CI groups: (1) musical discrimination abilities, (2) access to meaning in music, and (3) subjective appreciation.

Methods: Two CI user groups participated in the study. All of them were implanted as adults. Participants’ hearing impression in childhood was either normal (N=38, postlingual) or profoundly impaired (N=15, prelingual). Additionally, a matched normal hearing control group was tested. Discrimination abilities were studied using the MuSiC test developed by Brockmeyer et al. (2011). Semantic meaning was objectively measured by event-related brain potentials (ERPs) on visually presented words. These were presented subsequent to a musical excerpt of about 10 seconds. The words were either semantically related or unrelated to the music as defined in pretests with normal hearing participants. Studies on normal hearing participants had shown that the music influences the
processing of the visual word with unrelated words eliciting a larger negativity than related words (N400 effect; cf. Koelsch et al, 2004). Appreciation of music was assessed via questionnaires.

**Results:** The behaviorally assessed discrimination abilities were reduced in both CI groups compared with the normal hearing group. There were hardly any significant differences across the two CI groups. By contrast, ERP results differed clearly for the two CI groups: the postlingual group showed a similar N400 effect as the normal hearing group whereas there was no N400 effect observable in the prelingual group. The evaluation of musical appreciation was comparable between the prelingual group and the normal hearing group whereas it was significantly lower for the postlingual group.

**Conclusion:** Despite impaired discrimination abilities of both groups, appreciation was reduced only in postlingual CI users. Remarkably, musical meaning processing was restorable in postlingual CI users as shown by a N400 effect, but the ability to activate semantic associations does not imply any benefit in the appreciation of music. Rather, postlingual CI users seem to compare their impression with the situation prior to hearing loss and suffer from the modified input. By contrast, data of prelingual CI users indicate previous dysfunctional concept building. Taken together, our results did not exhibit a simple, one-dimensional picture of understanding music with a cochlear implant. Instead, we demonstrated that the discrimination of musical stimuli, the processing of musical meaning and the appreciation of music are different entities of an overall music impression, influencing each other only marginally. Any inferences on music processing in CI users have to include the musical dimension as well as the hearing history of the CI users.

**Session ID:** S2-1
**Session Title:** Music Perception
**Abstract ID:** 448
**Title:** Beyond Technology: The Interaction of Perceptual Accuracy and Experiential Factors in Pediatric Music Engagement
**Authors:** Kate E. Gfeller, Ph.D., Virginia Driscoll, MA, Adam T. Schwalje, MD; Otolaryngology_Head and Neck Surgery, Univ. of Iowa Hosp. and Clinics, Iowa City, IA.
**Abstract:** Introduction: Prior studies of pediatric CI users, typically enrolling small to moderate sample sizes, have tended to focus on either perceptual accuracy or experiential factors as they influence music enjoyment and participation. Perceptual studies indicate that pediatric CI users as a group are significantly less accurate than normal hearing peers in tasks such as pitch or melody perception, though there is considerable variability among users. Despite the degraded representation of pitch and timbre conveyed by the CI, studies focusing on music engagement and enjoyment indicate that many CI recipients enjoy some aspects of music and engage in music instruction; patterns of enjoyment and engagement are highly variable. This presentation investigates the relations among perceptual and experiential variables, with the intent to better understand their impact on music engagement (participation) of pediatric CI recipients.

**Methods:** We examined the following variables for 77 pediatric CI users of age 12 or older: pitch perception, ratings of personal importance of music, familial involvement in music, and extent of involvement in music instruction. The dataset was limited to pediatric CI users who had reached middle school or higher, because at that stage of development, music ensembles and lessons are generally elective (suggesting personal choice of participation) and also require higher levels of musical accuracy and precision. Regression analyses were conducted to examine the relations among the target variables. The dataset was then broken into tertiles of high, middle, and low pitch perception based upon a range of 1 to 24 semitones thresholds (lower score=higher performance). Musical instruments played were documented. Case examples were identified that illustrate interesting profiles of high to low perceptual accuracy in relation to high to low music involvement.
Results: Analyses revealed that of the 77 participants, 39 fit in the high tertile (M of 4.79 semitones), 16 in the middle tertile (M of 11.83 semitones) and 22 in the low tertile (M of 23.36 semitones) for pitch perception accuracy. Extent of music engagement ranged from 0 to 25 units of music instruction, with means of 6.18, 4.31, and 2.64 units of music instruction for the high, middle, and low pitch perception tertiles. Although CI users in the low pitch perception group were significantly less accurate (p>.0001) than the middle and high perception groups, pitch accuracy did not predict attitudes toward music or extent of engagement in music instruction. CI recipients with middle and high perceptual accuracy demonstrated similar levels of music engagement and positive attitudes toward music. Case study analyses revealed interesting profiles of perceptual accuracy and music engagement. For example, some users with low perceptual accuracy have high engagement in music, which may be due in part to playing instruments requiring lesser pitch perception accuracy (e.g., percussion). In some cases, familial support is associated with persistence in music.

Conclusion: Perceptual accuracy does not predict music enjoyment and engagement among pediatric CI recipients. Other factors such as familial support and judicious selection of music experiences may contribute to active engagement over time. These data suggest that music engagement can be enjoyed by pediatric CI users with appropriate participation options and support, despite atypical music perception.

Session ID: S2-1
Session Title: Music Perception
Abstract ID: 173
Title: A Follow-up Study on Music Timbre and Lexical Tone Perception in Adult Mandarin-Speaking Cochlear Implant Users
Authors: Bo Liu, Master1, Xin Gu, Master1, Ziye Liu, Master2, Beier Qi, Master1, Ruijuan Dong, Master1; 1Beijing Tongren Hosp., Beijing, China, 2Civil Aviation Gen. Hosp., Beijing, China.
Abstract: Introduction: As cochlear implant (CI) has proved to be a successful and effective treatment for severely and profoundly deafened individuals, it enhances speech perception in adults and improves hearing in all respects. The outcome of cochlear implantation has been reported in many studies using different measurements and different languages, however few studies have been conducted on the long-term effects of cochlear implantation on music perception and tone perception. Based on the notion that music appreciation and tone recognition both involve pitch cues, these two aspects of pitch perception may correlate with each other. The objective of this prospective follow-up study was to determine music timbre and tone perception outcomes in Chinese Mandarin-speaking adults with a CI device over the course of 1-year after implantation. We hypothesized that the continuous use and acclimatization of a CI device would benefit timbre and tone perception of postlingually deafened Mandarin patients.

Methods: Twenty-five adult CI users, 16 males and 9 females, with ages ranging from 19 to 75 years old, participated in a year-long follow-up evaluation. There were also 40 normal-hearing adult subjects who participated as a control group in order to provide the normal value range. Musical Sounds in Cochlear Implants (Mu.S.I.C) test battery was undertaken to assess music perception ability. Instrument identification subtest was intended to evaluate the ability of subjects to perceive timbre by identifying the instrument. Mandarin Tone Identification in Noise Test (M-TINT) was used to assess lexical tone recognition. The tests for CI users were completed at 1, 3, 6, and 12 months after the CI switch-on.

Results: The performance of music timbre perception and tone recognition both demonstrated an overall improvement in outcomes during the entire 1-year follow-up process. The increasing trends were obvious in the early period especially in the first 6 months after switch-on and the performance achieved a relatively stable state after 6 months. There was a significant improvement during the 1-year
period in the timbre identification (P<0.001), tone recognition in quiet (P<0.0001) and in noise (P<0.0001) listening environment. The tone perception performance of CI subjects was positively correlated with instrument perception performance in the 1, 3, and 6 months after switch-on (P<0.05).

**Conclusion:** Adult Mandarin-speaking CI users show an increasingly improved performance on musical timbre perception and tone identification during the 1-year follow-up evaluation after implantation. The improvement of the performance was the most prominent in the first 6 months of CI use. Thus, it is essential to strengthen the rehabilitation training within the first 6 months after implantation. The present study observed a significant correlation between tone perception performance and timbre recognition at some time points for CI users, supporting the hypothesis that music perception and lexical tone for CI users should share similar mechanisms in electrical hearing.

**Session ID:** S2-1
**Session Title:** Music Perception
**Abstract ID:** 248
**Title:** Links Between Audio Features, Aspects of Music, and Happy/Sad Emotions Expressed by Music in Cochlear Implant Users and Normally Hearing Adults
**Authors:** Georgios Papadelis, Associate Professor
MUSIC STUDIES, ARISTOTLE UNIV. OF THESSALONIKI, THESSALONIKI, Greece.
**Abstract:** Introduction: While music listening abilities in Cochlear Implant (CI) users and their appreciation of music have received much attention over the last three decades or so, the effects of degraded peripheral encoding of musical sound through a CI on recipients’ aesthetic/emotional reactions to music are still poorly understood. The main scope of this study was thus to see if perception of happy vs. sad emotions expressed by music is systematically different between CI users and Normally Hearing (NH) individuals, and further, to explore patterns of associations between audio features, aspects of music, and perceived emotional categories, within each group separately.

**Methods:** Judgements of happy vs. sad emotions expressed by fifteen short musical pieces of instrumental Western art music were obtained by a group of CI users (N = 53), and a group of NH adults (N = 44) through the use of a 10-point rating scale ranged from 1 (very sad) to 10 (very happy). These pieces were either solo, or multi-instrument arrangements, specially composed with the intention to produce a range of emotions along the happy/sad continuum (Fitzgerald et al., 2006), as judged by normal hearers. Mapping of those stimuli into a “psychological space” of perceived happiness/sadness was derived for each group separately through the use of multidimensional scaling models (PROXSCAL). A large set of audio and musical features were subsequently extracted for all musical pieces by the use of the MIR Toolbox (Lartillot et al., 2008), and bi-variate correlations between the extracted features and participants’ judgments were calculated.

**Results:** The maps resulted from the two groups were quite comparable (r = .84, p < .001), but not exactly the same, both demonstrating a similar clustering of the musical pieces into discrete emotional categories of (happy, neutral, and sad) in a two-dimensional space. Besides, analysis of correlations showed that the sets of audio and musical features which mostly influenced perceived happiness/sadness were quite similar in both groups including features that related to dynamics (low energy rate), timbre (spectral flux), rhythm and articulation (attack time, tempo, rhythmic fluctuation, pulse clarity, event density), and harmony (mode, harmonic change). Nevertheless, in contrast to NH listeners, CI users’ judgements displayed stronger associations with features related to the dynamics and temporal aspects of music (tempo, rhythm, articulation), while correlations with spectral and tonal features were more suppressed in this group.

**Conclusion:** Although, sub-optimal encoding of timbral and tonal aspects of music through a CI may negatively influence perception of discrete emotional categories, our results suggest that effective
processing of cues related to the dynamics and temporal aspects of music may underlie CI users’ ability to distinguish among levels of happy vs. sad emotions expressed by music in a similar way to that of NH listeners.

**Session ID:** S2-1  
**Session Title:** Music Perception  
**Abstract ID:** 298  
**Title:** Hybrid Music Perception Outcomes: Implications for Melody and Timbre Recognition in Cochlear Implant Users  
**Authors:** Jay T. Rubinstein, MD, PhD, Aaron J. Parkinson, PhD, Ward Drennan, PhD, Christa Dodson, AuD, Kaibao Nie, PhD; VM Bloedel Hearing Research Center, Univ. of Washington, Seattle, WA.  
**Abstract:**  
**Introduction:** Individuals able to use electric-acoustic (EA) stimulation maintain music perception abilities superior to those observed by typical cochlear implant (CI) recipients, making use of electric stimulation alone (e.g., Gfeller et al., 2006; Golub et al., 2012). The assumption is that EA stimulation confers advantages related to the availability of low-frequency (LF) acoustic hearing. The objective of this study was to further examine whether EA-related outcomes for music perception are related to the availability of acoustic cues not present in the electric domain. EA hearing was simulated in a group of normally hearing adult subjects so that the relative contributions of acoustic and electric hearing could be manipulated. Results were compared with the outcomes from a recent Hybrid clinical trial.  
**Methods:** Nine normally hearing individuals listened to stimuli that simulated EA hearing. To simulate electric hearing (E), an eight-band noise vocoder was used to process the stimuli from the melody and timbre subtests of the University of Washington’s Clinical Assessment of Music Perception (CAMP). The vocoder processed input over the frequency range of 813 through 7938 Hz, typical for Hybrid implant subjects in the clinical trial. To simulate residual LF acoustic hearing (A), the stimuli were filtered using a steep low-pass filter at 500 Hz. The shape of the filter was matched to simulate average audiometric thresholds at 125, 250, and 500 Hz based on the Hybrid clinical trial subjects. Input above 500 Hz was further attenuated by at least 80 dB. For conditions simulating EA hearing, the acoustic and electric components were combined unilaterally.  
**Results:** Preoperatively, with just acoustic information, the mean melody recognition score for Hybrid trial participants was 68.8% (SD±26.5%). Postoperatively, the mean score in the EA condition was 65.6% (SD±29.4%). Comparable scores for timbre recognition were 52.7% (SD±19.2%) and 59.4% (SD±22.1%), respectively. For both melody and timbre, pre-to-post differences were not significant. Mean melody recognition scores were 73.5% (SD±15.5%) for the acoustic condition, 39.20% (SD±18.1%) for electric, and 67.9% (STD±21.2%) for EA. The EA and acoustic-only conditions were significantly better (p<0.01) than the electric condition, whereas the EA and acoustic conditions scores were not significantly different (p>0.05). Mean timbre scores were 38% (SD±20.4%) for the acoustic, 36.1% (SD±17.7%) for the electric, and 40.7% (SD±19.7%), for EA. None of these were statistically different (p>0.05).  
**Conclusion:** Data from the Hybrid clinical trial indicate that the presence of LF acoustic hearing permits EA users to maintain good melody perception abilities relative to CI users. Results of the simulation study are consistent with the clinical trial in that LF acoustic hearing appears to be important for melody perception. Melody recognition was better in conditions that included acoustic LF information, but this was not the case for timbre.

**Session ID:** S2-1
Title: Wrap it in Rap - Music Making with Adolescent CI Users

Authors: Bjørn Petersen, Ph.D.1, Stine Deredau Sørensen, MA Linguistics1, Ellen Raben Pedersen, Ph.D.2, Christine Parsons, Ph.D.3, Peter Vuust, Ph.D. Professor1; 1Ctr. for Music in the Brain, Aarhus, Denmark/Royal Academy of Music, Aarhus, Aarhus C, Denmark, 2The Maersk Mc-Kinney Moller Inst., Univ. of Southern Denmark, Odense M, Denmark, Odense, Denmark, 3Dept. of Psychiatry, Univ. of Oxford, Oxford, United Kingdom, Oxford, United Kingdom.

Abstract: Introduction: Whereas implant outcome in adult and pediatric CI users has been studied intensely, information concerning the new generation of prelingually hearing impaired adolescents, who have grown up with the assistance of CIs has so far been sparse. Recent studies, however, indicate that to keep pace with their normal hearing peers, supplementary measures of auditory rehabilitation are in demand throughout adolescence. Music training may provide a strong, motivational and beneficial method of strengthening not only music perception, but also linguistic skills, particularly the prosodic properties of speech. Since adolescence is an age when self-identify is forming and social relations, including music listening and preferences, are particularly important it is fair to assume that also young CI users will engage in musical activities - despite challenging preconditions. The purpose of this study was to examine 1) the potential effects of an intensive musical ear training program on the perception of music and speech in prelingually hearing impaired adolescent cochlear implant (CI) users and 2) these adolescents’ music listening habits and music enjoyment.

Methods: Eleven adolescent CI users participated in a short intensive training program (two weeks) involving group-based music making activities (e.g. rapping and singing) and self-administered computer based listening exercises. Testing of music and speech discrimination was carried out before and after the program for the CI users and in two sessions equally separated in time for a group of normal-hearing (NH) controls. In addition, the participants reported on their music listening habits and enjoyment.

Results: On average, the adolescents CI users improved their discrimination skills within all musical domains after training, which was reflected in a significant overall progress. In particular, they improved their discrimination of rhythm and melodic contour. The NH participants outperformed the CI users in all music and speech discrimination tests except melodic contour. Despite poor music discrimination abilities, the CI users reported levels of music engagement and enjoyment that were comparable to those of the NH group. The CI participants showed high levels of engagement with the music making group, as demonstrated by lack of attrition, and exhibited a marked improvement in their performative skills. By contrast, the participants found the computer based training only moderately useful and on average spent much less time on training than requested.

Conclusion: The findings of this study are an indication of the potential usefulness of targeted music training as an effective and motivating activity for young CI users. In particular, rapping and creation of rap lyrics may form an appealing and relevant element in future training programs; the CI facilitates it well, it has a strong and repetitive focus on language, articulation, rhythm and rhyme and might even represent a possible form of artistic expression for some of the young CI users. Maybe the world will one day see its first profoundly hearing impaired rapper? Indeed, that would mark the ultimate success of the cochlear implant.

Session ID: S2-1
Session Title: Music Perception
Abstract ID: 454
Title: Stability and Predictors of Music Perception and Engagement Over Time in Pediatric Cochlear Implantees
Authors: Adam T. Schwalje, MD, DMA1, Virginia D. Driscoll, MA1, Kate E. Gfeller, Ph.D.2; 1Department of Otolaryngology, Univ. of Iowa Hosp. and Clinics, Iowa City, IA, 2Department of Otolaryngology, Univ. of Iowa, Iowa City, IA.

Abstract: Introduction: Cochlear implantation has been approved for pediatric patients since 1990. Many patients enrolled in our center who were implanted in childhood have now reached adolescence or young adulthood. Long term enrollment provides the opportunity to examine patterns of music perception and engagement as a function of long-term cochlear implant (CI) use, maturation, and participation in music activities.

Methods: This retrospective cohort study tracked the stability of music perception and engagement outcomes in 36 pediatric cochlear implantees gathered longitudinally, before and after the age of 15. Average age of implantation was 8.7 years; 26 were prelingual at implantation. Because availability for music testing was dependent upon completion of protocols for speech and language testing at annual visits, music testing was completed intermittently. We therefore report on available data points gathered before and after the age of 15. A Complexity Pitch Test (CPT), which determines ability to distinguish pitches between 1-24 semitones, was administered to 21 subjects. The first test score, which was administered at least one year after implantation, and the final test score, which was completed after age 15, were compared for each subject. The stability of this score from the first to last administration was analyzed using a paired t-test. Music engagement was quantified as the extent of participation in music instruction as collected from a music background questionnaire for children (CMBQ), which was administered to 27 subjects an average of 3.5 times each. The relationship between cumulative music engagement and pitch perception was analyzed with a Spearman rank correlation.

Results: The first and last results of CPT testing (before and after the age of 15) were not significantly different (paired t-test = 0.70). Repeated measures analysis showed that semitone thresholds were not predicted by a model of pre- versus postlingual implantation, time post implantation, time elapsed between tests, or average speech (CNC and HINT) scores. The cumulative units of musical engagement, as quantified by the CMBQ, were inversely correlated with the most recent measurement of CPT threshold (Spearman’s rho -0.50, p=0.0175). Regression analyses indicated that the music engagement measure was not predicted by a model including language status at implantation, time post implantation, time elapsed between tests, and average speech scores.

Conclusion: These outcomes indicate that pitch perception did not improve significantly as a function of time with the CI for pediatric implantees tested into adolescence. Music engagement, defined as the cumulative number of units of music instruction, was inversely correlated with the recipients’ pitch perception after age 15. Demographic measures related to hearing history (age at implantation, length of CI use), and speech perception scores did not predict music engagement and pitch perception.

Session ID: S2-3
Session Title: Language Development
Abstract ID: 47
Title: Expanding Access through Strengths Based Coaching
Authors: Hannah E. Eskridge, MSP, Lillian Henderson, MSP;
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Abstract: Introduction: For the past twenty years, our center has provided a two week, on-site professional development opportunity to speech-language pathologists, educators, and audiologists working with children in a Listening and Spoken Language approach. Our desire for this program is to train professionals throughout the country and around the world in habilitation skills and strategies to
improve outcomes for children who are deaf or hard of hearing receiving cochlear implants. Although the two-week experience has been highly effective for those who have attended, many professionals who live outside of our area are unable to commit significant time and resources to participate in an on-site experience. Over time, it became clear a different approach was needed in order to extend professional learning to more individuals particularly those serving patients who live in rural areas where access to quality services is often limited (O’Callaghan, et.al). This presentation will demonstrate the need for more professionals trained in working with children receiving cochlear implants as well as tools and strategies to effectively increase capacity of professionals and therefore outcomes for children who are deaf or hard of hearing.

**Methods:** With the use of web-based, flipped classrooms (McLaughlin, et.al), video conferencing, and digital recordings, we have an increased capacity to coach and instruct professionals serving patients throughout the world. We are using 21st century technology along with strengths-based coaching practices based on the principles of adult learning theory, positive psychology, appreciative inquiry, and Non-Violent Communication to increase accessibility to professional learning leading to increased access to Listening and Spoken Language Specialists.

**Results:** In this session, the presenter will discuss how to improve patient care and outcomes via coaching using current technologies and the strategies and techniques of a strengths-based coaching model designed to advance adult learning in order to improve outcomes for children who are deaf or hard of hearing and their families. Learners will explore an on-line web-based, flipped classroom, view videos of recorded coaching conversations using strength based coaching strategies and be able to list next steps to increase professional learning opportunities using virtual platforms at their own centers. They will examine the impact of our changes in coaching delivery and strategies on our patient population.

**Conclusion:** Strengths based coaching using virtual platforms is changing our ability to impact outcomes for children with cochlear implants around the world.

**Session ID:** S2-3
**Session Title:** Language Development
**Abstract ID:** 51
**Title:** Introducing the Open- and Closed-set Task: A Criterion-reference Tool for Assessing Spoken Language Development in Toddlers who are Deaf or Hard of Hearing
**Authors:** David J. Ertmer, Ph. D.
Speech Language and Hearing Sciences, Purdue Univ., West Lafayette, IN.

**Abstract:** There is a pressing need for objective and age-appropriate measures of spoken language acquisition in children who receive cochlear implants (CI) or hearing aids (HA) as infants and toddlers. Such assessment tools are needed to document improvements during the early phases of auditory-guided speech and language development, and to identify children who are at risk for delays in these areas.

**Methods:** This presentation will (1) examine the special challenges in assessing spoken language development in toddlers who are deaf or hard of hearing (D/HH), and (2) introduce The Open- & Closed-set Task (O&C; Ertmer, 2016) as an objective, research-based means of measuring spoken language outcomes following CI or HA fitting at a young age. The O&C is a within-child, criterion-reference task that consists of three lists with 10 stimulus words in each list. The 30 O&C stimulus words were selected because they are typically produced by at least 75% of two-year-old children who have normal hearing (Dale & Fenson,1996). The three word lists are balanced so that they can be given in any order during the first 2 years of CI or HA use. When participating in the O&C, children first listen to and imitate adult models of stimulus words. Their transcribed productions yield scores in Phoneme Accuracy (i.e.,
accuracy of vowel and consonant productions) and Word Acceptability (i.e., an estimate of single word intelligibility). Next, children are asked to select a photograph representing the stimulus word from a set of three photos so that a Word Comprehension score can be calculated.

**Results:** The O&C was found to be sensitive to changes in spoken language abilities across the first 2 years of CI use. By giving the O&C at 6-, 12-, and then 18-months post CI or HA fitting, early interventionists can determine whether toddlers are making gains in phonological development and spoken vocabulary, and - by inference—improvements in auditory perception abilities. This presentation will include a video demonstration of the O&C, research findings related to the development of the O&C, and data regarding reliability and validity.

**Conclusion:** The O&C provides early interventionists with an assessment tool for monitoring progress in auditory-guided speech development and spoken language in very young children who are D/HH—a population for which objective measures are currently in short supply.

**Session ID:** S2-3  
**Session Title:** Language Development  
**Abstract ID:** 187  
**Title:** Parent-Child Interaction Therapy: Outcomes of a Family-Based Behavior and Language Intervention for Children with Cochlear Implants  
**Authors:** Elizabeth Adams Costa, Ph.D.1, Lori Day, Ph.D.2, Colleen Caverly, M.A.1, Nancy Mellon, M.S.1, Meredith Ouellette, M.A.1, Sharlene W. Ottley, Ph.D.1; 1Department of Psychology, The River Sch./RiverREACH Clinic, Washington, DC, 2Department of Psychology, Gallaudet Univ., Washington, DC.  
**Abstract:** **Introduction:** Primary caregivers are critical in facilitating children’s normal development of early interaction patterns, language, and social-emotional development. One way to nurture parent’s skills is through Parent-Child Interaction Therapy (PCIT), an empirically supported treatment that coaches parents and children together to promote child development and positive parent-child relationships. Parents serve as primary language models for their children; supporting parents in providing enriching language environments enhances children’s development. While therapeutic interventions often strive for parent participation, most early intervention settings use traditional child-centered services (Peterson et al., 2007). Quittner et al. (2013) suggest that cochlear implant programs can likely improve child outcomes by incorporating maternal sensitivity training into intervention programs. Several parent interaction-training programs incorporate didactic and/or hands-on experiential coaching to guide parents in effective interaction with their children. One such program is PCIT, a behavioral treatment in which a therapist works with parent-child dyads to promote child development. Parents are taught skills they can apply at home to promote child language, establish a nurturing and secure relationship, increase their child’s prosocial behavior, and decrease negative behavior. PCIT treatment is structured in two parts: Child Directed Interaction (CDI), which is similar to play therapy and engages parents and children in play situations; and Parent Directed Interaction (PDI), which teaches parents consistent and effective behavior management techniques as they play with their child. The therapist is a “coach” for the parent, providing live, real-time feedback using an earpiece as play is observed and directed through a one-way mirror. The goals of the current study were twofold: to evaluate the effectiveness of Parent-Child Interaction Therapy as a psychosocial and behavioral intervention for families of children with hearing loss, and to examine its applicability as a language intervention.  
**Methods:** The effectiveness of PCIT was evaluated for parent participants who had children with hearing loss (N=17), examining both parent’s indirect language stimulation, and changes in child behavior as a
result of treatment. For a subset of the treatment group (N=6), pre- and post-treatment child language samples were compared to matched controls that did not receive PCIT.

**Results**: The change in parents’ language stimulation skills from pre-treatment to post-treatment was analyzed. The frequency of optimal parental language input (as measured by parents use of specific verbalizations) was significantly higher post-treatment (Mdn= 34) than pre-treatment (Mdn = 5), T = 171.0, p < .01, r = .62. Parent report of problematic behavior on a standardized measure was significantly lower post-treatment (Mdn = 85) than pre-treatment (Mdn = 121), T = 5.00, p = .01, r = -.42. The change in Mean Length of Utterance in Words, MLU-W from pre- to post-treatment for the PCIT group (Mdn = .96) was significantly different than the change in MLU-W for the matched control group (Mdn = .26), U = 30.50, p < .05, r = .58.

**Conclusion**: This study suggests that PCIT is a promising intervention that empowers parents to engage in optimal indirect language stimulation, improves parent-child interactions, and ultimately promotes spoken language skills for children.

Session ID: S2-3
Session Title: Language Development
Abstract ID: 309
**Title**: Cochlear Implant Candidacy Considerations and Outcomes for Children with Auditory Neuropathy
**Authors**: Jaime Leigh, PhD1, Evelyn Do, MAud2, Richard Dowell, PhD2, Dawn Choo, MSpPath2, Shani Dettman, PhD2;
1Cochlear Implant Clinic, Royal Victorian Eye and Ear Hosp., East Melbourne, Australia, 2Audiology and Speech Pathology, Univ. of Melbourne, Carlton, Australia.

**Abstract**: Cochlear implantation is currently the intervention option of choice for many children with auditory neuropathy (AN) who are unable to obtain benefit from conventional amplification. Children with AN findings are, however, a heterogeneous group with a wide variety of impairments. Their potential to develop auditory skills with a cochlear implant (CI) can be affected by site of lesion, co-morbidity and the status of the auditory nerve. The aim of this study was to provide an up-to-date report of patient demographics, audiological profile, surgical outcome and post-operative performance for children with AN who have undergone CI at a major tertiary medical facility.

**Methods**: Retrospective review of case notes for 76 children with AN findings referred for CI evaluation at a tertiary medical facility was undertaken. For the 43 children with AN findings who proceeded with CI, speech perception and language assessments were completed pre-operatively and on multiple occasions post-operatively. The rate of progress over time was evaluated and compared to peers normal hearing and those with sensorineural (SN) hearing loss who have also received a CI.

**Results**: Of the 43 children who received CIs, 40% were born prematurely, 33% required treatment for jaundice, and 23% required oxygen at birth. A significant co-morbidity was present for 33% of the group. Six children were identified pre-operatively with cochlear nerve deficiency (CND) on magnetic resonance imaging. All children received hearing aids prior to CI. Mean age at implantation was 3 years 1 month (range 6 months to 16 years). ECAP and/or eABR was conducted at the time of CI surgery in all cases. Post-operative auditory skills were assessed for all children and ranged from no awareness of environmental sounds to ability to follow a conversation audition alone. Twenty-four of the children were at a development stage and/or age appropriate to administer open-set speech perception testing and mean monosyllabic phoneme score, audition alone, was 84%. A measure of post-operative language skills was available for 27 children. Early post-operative language measures suggested all children had delayed language development compared to peers with normal hearing. Some children, however, demonstrated a rate of language development similar to normal, albeit at a delayed age. Limited or no benefit from the CI was associated with older age at CI, presence of a significant co-morbidity, inability
to measure ECAP or eABR, and/or CND. Three of the six the children identified with CND obtained no useful auditory percepts from the CI and became non-users.

**Conclusion:** The majority of children with AN findings using CIs developed speech and language skills comparable to their peers using CIs with SN-type hearing loss who received a CI at a similar age. Children with CND should be given conservative expectations for CI outcome with a high risk of limited outcome or non-use of CI. Inability to record ECAP and/or eABR may suggest that electrical stimulation is insufficient in overcoming the effects of AN and limited benefit from the CI is a possible outcome. This paper highlights the need for careful counselling regarding the potential for less than optimal outcomes for some children with AN. Close monitoring of development in the early post-operative years is required to ensure the child is meeting expectations for oral language development and an alternate communication mode should be introduced when indicated.

**Session ID:** S2-3
**Session Title:** Language Development
**Abstract ID:** 329
**Title:** Trajectories of Performance in Children Implanted Under 18 Months of Age - What is Normal?
**Authors:** Colleen Psarros, Masters of Audiology, Mandy Hill, Masters of Audiology, Kylie Chisholm, Bachelor of Applied Science Speech Pathology; SCIC, Gladesville, Australia.

**Abstract:** **Introduction:** Approximately 30% of children who have received their cochlear implants aged 18 months or younger have needs in addition to their deafness. Since 2006, simultaneous bilateral cochlear implantation is routine for children identified with a bilateral severe to profound sensorineural hearing loss at SCIC. This paper will define the trajectory of auditory function and language performance at the 3 intervals (1, 2 and 5 years) following CI for children who have no considerations in addition to their deafness. Children who have been identified with CMV and CHARGE, or who have other comorbidities, and have received cochlear implants under the age of 18 months will be compared according to this trajectory to assist in the counselling of families for developing realistic expectations of their child’s potential post CI journey and outcomes.

**Methods:** A retrospective analysis was performed on 100 children who received their CI’s between the period of 2006-2016 at the age of 18 months or younger was performed. Variables reviewed included aetiology, presence of comorbidities, ears implanted, electrophysiological findings pre and post operatively, functional questionnaires (PEACH), device programming and usage issues and language outcomes (Rossetti/PLS). The listening and spoken language performance for the children with CMV and CHARGE was plotted on a trajectory along with children with no additional disabilities to compare outcomes achieved and duration of deafness.

**Results:** The profiles of children with CHARGE and with CMV differed according to the number of ears implanted and the interval at which they were implanted. For example, a high prevalence of auditory nerve abnormalities with the CHARGE group led to more unilateral or sequential bilateral CI’s. Often these children were implanted a little later than the cohort without comorbidities due to the need for other medical interventions. The impact on their overall auditory function reflected the delay in management.

**Conclusion:** The trajectories developed can provide essential information for counselling families and setting realistic expectations of what can be achieved, and protocols and procedures for reaching these outcomes. Given the variability in the group of children with CHARGE and CMV the ability to provide a possible spectrum of outcomes is vital for maximising the supports and intervention that are required for maximising the potential of these infants with their families.
Session ID: S2-3
Session Title: Language Development
Abstract ID: 504
Title: The Effect of Multi-Session Training Protocols on Recognition of Sentences in Noise in Prelingual Young-Implanted Long-Term Users of Cochlear Implants
Authors: Liat Kishon-Rabin, PhD, Yossi Buganim, BA, Doreen Zechoval, BA, Daphne Ari-Even Roth, PhD; Communication Disorders, Tel-Aviv Univ., Tel-Aviv, Israel.
Abstract: Introduction: The ability to perceive speech perception in noise has remained a major complaint of the hearing impaired. Despite major advances in technology, performance of cochlear implant (CI) users in adverse listening conditions has shown to be quite limited compared to hearing, putting the CI users at a significant disadvantage in many real-life listening situations. For many years auditory training has been incorporated in clinical practice but with limited empirical support. To our knowledge, only a few studies showed that speech perception in noise can be improved by auditory training in postlingual deafened CI users and none have looked at the influence of training protocols. The purpose of this study was to investigate the improvement of speech perception in noise following multi-session training in prelingual hearing-impaired young-implanted CI users. A secondary purpose was to test the influence of training protocol on learning.
Methods: Participants included 12 prelingual young adults aged 21-29 years, implanted between 2-16 years of age and who used their CI device between 12-23 years). All were good performers in quiet and had no other health related problems. Testing and training material included the Hebrew version of the sentence-in-noise Matrix test which consists of 50 different words with which a total of 100,000 different 5-word sentences with similar grammatical structure can be constructed. Using the Hebrew Matrix test, the signal-to-noise ratio (SNR) at which 50% of the words in sentences were correctly identified was determined in an adaptive procedure before and after training. For each threshold assessment, 20 different sentences were used. Ten training sessions were conducted, 2-3 days apart. Six of the CI users were trained at easier SNR (70% on the psychometric function) and six of the CI users trained at more difficult SNR (50% on the psychometric function). Six speech reception thresholds (SRT) in noise were determined in each training session, totally 60 SRTs. Cognitive tests (working memory, non-verbal intelligence, and visual attention) were conducted as well. Retention of learning was assessed 2-3 months after training was completed. Generalization was assessed using monosyllabic words in 6dB SNR.
Results: (1) For all CI users, training resulted in significant improvements in SRT in noise (2.5-10 dB); (2) Characteristics of the learning functions varied considerably between participants; (3) Large between-subject variability in SRTs in noise was observed at the beginning, but was reduced substantially following training; (5) No significant differences were found between the training protocols; (6) Learning was partially retained; (7) Memory span of nonsense syllables in low-intensity noise best explained performance.
Conclusion: Speech perception in noise can be improved significantly in prelingual CI users following multi-session training. The data support the importance and benefit from auditory training in difficult listening conditions with either training protocol.

Session ID: S2-3
Session Title: Language Development
Abstract ID: 518
Title: Social Determinant of Verbal Language Development after Pediatric Cochlear Implantation: The Childhood Development after Cochlear Implantation Study
Authors: Nae-Yuh Wang, PhD1, Christine Mitchell, ScM1, Laurie Eisenberg, PhD2, Ann Geers, PhD3, John Niparko, MD2; 1Johns Hopkins Univ., Baltimore, MD, 2Keck Sch. of Med., Univ. of Southern California, Los Angeles, CA, 3Univ. of Texas at Dallas, Dallas, TX.

Abstract: Introduction: this study sought to evaluate verbal language development associated with social economic status after pediatric cochlear implantation in the USA.

Methods: Verbal language outcomes from 188 cochlear implant candidates recruited before implantation (mean age 2.2 years), along with 97 concurrently enrolled, age comparable peers with normal hearing, collected through the multicenter Childhood Development after Cochlear Implantation (CDoCI) study were analyzed. Core composite standard scores of Reynell Developmental Language Scale and Comprehensive Assessment of Spoken Language were used to track longitudinal trajectories of overall development of verbal language over 8-years post implantation. Mixed-effects regression models were used to estimate growth rates of verbal language skills by levels of family income and other predictors of language development.

Results: Higher family income was associated in a dose-response manner with accelerated verbal language growth in children with cochlear implant over 8-years of implant experience, similar to the patterns of longitudinal language trajectories by family income levels seen in children with normal hearing. Speech perception, 4-frequency pure tone average, cognitive function screening score, and maternal sensitivity level at baseline pre-implant, and age at implant activation were significant predictors of verbal language development over 8-years post CI, and partially attenuated the association between growth rates of verbal language development and family income.

Conclusion: Lower family income is associated with poorer verbal language development in children with cochlear implant. Identifying modifiable risk factors of poorer outcomes associated with lower social economic status enables better understanding of outcome variabilities, and provides potential targets for intervention in order to reduce outcome disparities after pediatric cochlear implantation.

Session ID: S3-1
Session Title: Outcome Assessment
Abstract ID: 307
Title: Evidence-based Guidelines for the Provision and Timing of Cochlear Implantation for Young Children
Authors: Jaime Leigh, PhD1, Shani Dettman, PhD2, Richard Dowell, PhD2; 1Cochlear Implant Clinic, Royal Victorian Eye and Ear Hosp., East Melbourne, Australia, 2Audiology and Speech Pathology, Univ. of Melbourne, Carlton, Australia.

Abstract: Introduction: Cochlear implantation has now become a standard treatment for bilateral severe-to-profound hearing loss in children. In the past decade, evidence has emerged to support the provision of cochlear implants (CIs) for young infants. The availability of neonatal hearing screening programs has facilitated earlier referral, diagnosis, and intervention for infants with hearing loss; this can lead to earlier cochlear implantation and improved outcomes. It does, however, create a problem for clinicians in providing recommendations about cochlear implantation for young children with hearing-impairment. Below six months of age it is only possible to estimate the audiometric thresholds using objective audiological test techniques (e.g. ABR and ASSR). Beyond this age, these estimates can become more reliable by using conditioned response techniques, but this information does not accurately predict the child’s potential to develop speech and language using conventional hearing devices. Thus, it can be difficult to make a recommendation for cochlear implantation until the child is older and their progress can be measured. Determining the likelihood that individual infants will have an improved speech and language outcome if they receive a CI is a challenge. As a result, evidence-based
guidelines for the provision and timing of implantation for clinicians to assist parental decision-making are needed.

**Methods:** Speech perception results for 78 early-implanted children were compared to 62 children using traditional amplification with hearing losses ranging 25-120 dB HL PTA. Equivalent pure-tone average (PTA) hearing loss for CI users was established. Language of 32 children who received a CI before 2.5 years of age was assessed over six years and compared to hearing peers.

**Results:** Speech perception outcomes suggested that children with a PTA greater than 60 dB HL have a 75% chance of benefit with a CI over traditional amplification. More conservative criteria applied to the data suggested that children with PTA greater than 82 dB HL have a 95% chance of benefit. Children implanted under 2.5 years with no significant cognitive deficits made normal language progress but retained a delay approximately equal to their age at implantation.

**Conclusion:** Hearing-impaired children under three years of age may benefit from cochlear implantation if their PTA exceeds 60 dB HL bilaterally. Implantation as young as possible should minimise any language delay resulting from an initial period of auditory deprivation.

**Session ID:** S3-1  
**Session Title:** Outcome Assessment  
**Abstract ID:** 398  
**Title:** Incorporating Ceiling Effect in Analyses of Speech Perception Outcomes of a Pediatric Cochlear Implant Cohort  
**Authors:** Vedat Topsakal, MD PhD1, Hanneke Bruijnzeel, MD2, Guido Cattani, MsAud2; 1Universitair Ziekenhuis Antwerpen, antwerp, Belgium, 2Universitair Medisch Centrum Utrecht, Utrecht, Netherlands.

**Abstract:** Introduction: Several factors may influence why the optimal age for cochlear implantation is not explicitly defined. The absence of objective pediatric speech and language outcome measures without the occurrence of ceiling effects is known to be one of these underlying factors. Our objective is to compare speech perception data between children with a different age at cochlear implantation incorporating ceiling effects.

**Methods:** Design: We evaluated speech perception by comparing Consonant-Vowel-Consonant (CVC(A)) scores at 5-year follow-up of children implanted between 1997 and 2010. The proportion of children from each age group reaching the 95%CI of CVC(A) ceiling scores ( > 95 %) was calculated to identify performance differences between groups masked by ceiling effects. Study Sample: 54 children implanted between 8 and 36 months.

**Results:** Although ceiling effects occurred, a CVC(A) score difference between age-at-implantation groups was confirmed (H (4) = 30.36; p < .001). Outperformance of early (< 18 months) compared to later implanted children was demonstrated (p < .001). A larger proportion of children implanted before 12 months compared to children implanted between 13 and 18 months reached ceiling scores. Logistic regression confirmed that age at implantation was the only significant value to predict whether a child reached a ceiling score.

**Conclusion:** Although CVC(A) ceiling effects tend to mask thorough delineation of speech perception, speech performance differences existed between children implanted before and after 18 months when including ceiling effects and also when not accounting for these effects during analysis. Development of long-term assessment tools not affected by ceiling effects is essential to maintain adequate assessment of young implanted infants.
Abstract ID: 496
Title: The Effect of Development on Cortical Auditory Evoked Potentials in Normal Hearing Listeners and Cochlear Implant Users
Authors: Eun Kyung Jeon, Ph.D, Au.D.1, Carolyn Brown, Ph.D.2, Paul Abbas, Ph.D.2;
1Communication Sciences and Disorders, Univ. of Utah, Salt Lake City, UT, 2Communication Sciences and Disorders, Univ. of Iowa, Iowa City, IA.
Abstract: Introduction: Can a CI facilitate the development of the auditory brain in children who were born deaf but implanted at a young age? Will the development of the central auditory system in these CI children be like that of NH children? The current study attempts to answer these questions in part by studying developmental effects on two auditory evoked potentials measured at the cortical level: the onset P1-N1-P2 and the ACC. The P1-N1-P2 complex occurs within 50 to 250 ms after a stimulus onset. It is also called an onset response and is related to sound detection. Another is the acoustic change complex (ACC), elicited by any acoustic change in ongoing sounds. It is also called a change response and is related to sound discrimination.
Methods: For NH listeners, ninety-one children aged 3-19 years and eleven young adults participated. A total of fifty-nine CI users participated: forty-eight pre-lingually deafened children aged 3-19 years and young adults, and eleven post-lingually deafened adults. All pre-lingually deafened subjects were implanted with their CI(s) before 3.5 years of age. Speech-like stimuli (/u/-/i/ and /i/-/u/) were presented via a speaker once in quiet and once in noise (+10 dB SNR) conditions to elicit both the onset and change responses.
Results: Results show that both onset and ACC responses were successfully obtained from NH listeners and early-implanted, pre-lingually deafened CI users, from 3 year olds to adults, in both quiet and noise listening conditions. While the morphology, latency, and amplitude of both onset and ACC responses showed similar developmental effects, the ACC matured later than the onset response in both quiet and noise conditions. With background noise, the ACC was affected by noise more than the onset response, which led to a longer developmental trajectory for the ACC. These findings were similar in both NH and CI groups, suggesting that a CI facilitates typical development of the two cortical responses. However, the effect of background noise was prominent in the ACC of CI users. This may indicate the perceptual difficulties of discriminating sounds in noise.
Conclusion: The results suggest that the ACC can be used as a measurement for estimating perceptual performance of individuals in various age and listening groups.

Abstract ID: 285
Title: EEG Alpha Rhythms as a Biomarker for Listening Effort for Speech in Noise Perception in Cochlear Implant Users
Authors: Andrew Dimitrijevic, PhD, Joseph M. Chen, MD;
Otolaryngology, Sunnybrook Hlth. Sci., Toronto, Canada.
Abstract: Introduction: Cochlear implant (CI) users often struggle while listening to a conversation in adverse listening environments such as a noisy room and often report that they feel exhausted after a day of listening. In order to follow conversations, especially in the presence of noise, attention and effort must be exerted and may be related to listening effort (LE). The physiological mechanisms of LE are not well understood. This study relates LE rating to physiological processes as measured by the electroencephalogram (EEG) in CI users while performing a speech perception in noise task. We have previously shown that EEG alpha power is related to speech perception in noise in normal hearing adults.
and children. We therefore hypothesized that alpha power would show a similar relationship in CI users and would additionally be related to LE.

Methods: Ten adult CI users were tested in free field using their everyday CI setting while performing the Digit Triplet Test (DTT). The DTT presents trials of three digits in speech-shaped noise. In an initial behavioral task, the signal to noise ratio (SNR) was varied adaptively until 50% of digits were identified correctly, the Speech Reception Threshold (SRT). Afterwards, 64 channel EEG recordings were made during DTT listening at individualized suprathreshold levels. After each recording block, participants were asked to rank the difficulty of performing the DTT task (i.e, LE).

Results: Listening to speech in noise was associated with increased alpha power, in both normal hearing individuals and CI users. CI users had greater alpha power compared to normal hearing individuals. Significant correlations were observed between left frontal alpha power and LE in CI users using brain source analysis.

Conclusion: CI users and normal hearing have similar cortical oscillation patterns while listening to speech in noise. Given that alpha power was significantly correlated to LE and that CI users had greater alpha power compared to normal hearing individuals, alpha may represent an objective measure of LE in CI users.

Session ID: S3-1
Session Title: Outcome Assessment
Abstract ID: 299
Title: Programming Characteristics of Cochlear Implants in Young Children- Findings from a Population-based Prospective Study
Authors: Paola V. Incerti, MAud, MAudSA(ccp)1, Teresa Y. C. Ching, PhD1, Robert Cowan, PhD2, Sanna Hou, MAud, MAudSA(ccp)3, Patricia Van Buynder, MAud, MAudSA(ccp)1;
1Macquarie University, Natl. Acoustic Lab., Sydney, Australia, 2The HEARing Cooperative Res. Ctr. (CRC), Melbourne, Australia, 3Natl. Acoustic Lab., Macquarie University, Australia.
Abstract: Introduction: Expansion of cochlear implant (CI) candidacy criteria to include increasingly younger children and more complex cases, has led to new programming challenges for clinicians. The Longitudinal Outcomes of Children with Hearing Impairment (LOCHI) is a prospective, population based study that presents a unique opportunity to comprehensively examine clinical programming parameters used in a young paediatric population over time. This paper aims to 1) describe the CI programming parameters currently used of children in the LOCHI study; 2) examine changes over the first 5 years of life; and 3) examine how these relate to the age of implantation and aetiology.
Methods: This paper reports on 161 of the 450 children in the study born between 2002 and 2006, in three states of Australia (NSW, VIC, and QLD), and who accessed Australian Hearing before 3 years of age, and who received a CI between 6 and 36 months of age. Information was collected at 6 months after initial implantation, and at chronological ages of 3 years -and 5 years of age. Electrical thresholds (T-levels) and Comfort levels (C-levels) were converted from clinical map units to charge-per-phase in nanocoulombs (nC) units for comparison.
Results: Children with auditory nerve deficiency and cochlear lesion were more likely to be using programs with parameters settings that deviated from the default. There was a significant difference in minimum thresholds (T-levels) and maximum comfortable current levels (C-levels) and how these levels varied across time for children with these aetiologies as compared to the general group.
Conclusion: The characteristics of CI as fitted to children reflect the extent to which manufacturer’s recommendations on default settings may be varied to meet clinical needs.
Session ID: S3-2
Session Title: Expanded Indications
Abstract ID: 80
Title: Outcomes of Pediatric Cochlear Implantation in Single-Sided Deafness or very Asymmetrical Hearing Loss
Authors: Karyn L. Galvin, PhD1, Michelle Todorov, MAud1, Rebecca Farrell, MAud2, Robert Briggs, FRACS2, Markus Dahm, FRACS2, Jaime Leigh, PhD2;
1Audiology and Speech Pathology, Univ. of Melbourne, Melbourne, Australia, 2Cochlear Implant Clinic, Royal Victorian Eye and Ear Hosp., Melbourne, Australia.
Abstract: Introduction: Cochlear implantation can provide access to bilateral sound for children with single-sided deafness (SSD) or very Asymmetrical Hearing Loss (AHL). In order to adequately assess the benefits of such treatment, it is important to assess children using a broad assessment protocol and also to document the real-world experiences of children and their families. The objective of this study was to evaluate benefit and functional outcomes for children with SSD/AHL who were implanted in the profound ear.
Methods: Depending on the child’s age, objective tests of spatial hearing and speech perception in noise and subjective questionnaires were administered preoperatively and at 6 and 12 months postoperatively. Spatial hearing testing involved locating the presenting loudspeaker in a 180-degree array or lateralizing sound presented from the left or right. Speech perception in noise testing involved closed-set spondee recognition or sentence recognition in coincident and separated speech/noise conditions. Subjective reports were gathered regarding use of, and adaptation to, the new implant and a number of questionnaires were administered, including the versions of the Speech, Spatial, and Qualities of Hearing Scale for Parents (SSQ-P) and for Children (SSQ-Ch), and the Hearing Environments and Reflection on Quality of Life (HEAR-QL) questionnaire.
Results: Four participants are now more than 6 months postoperative. The first child had a mild-moderate loss contralaterally, was aged 10 years and is 12 months post-implantation. Adaptation to the combination of implant and hearing aid was straightforward, and clear benefit was evident on tests of localization and speech in noise, and on the SSQ-P and SSQ-Ch. The second child had a mild loss contralaterally, was aged 6 years, and is 12 months post-implantation. Data-logging and anecdotal reports indicate limited implant use, and objective and subjective assessments, including the SSQ-P, indicate no benefit over the hearing aid alone. The third child suffered meningitis, was implanted aged 3.5 months due to indications of cochlear ossification, and is 6 months post-implantation. The implant is worn consistently with a hearing aid, and reported functional outcomes have been very positive. The fourth child had normal hearing contralaterally, was aged 10 years, and is 12 months post-implantation. The device is used full time, although there is no evidence of benefit on objective or subjective assessments, including the SSQ-P. More recently, an additional three children with SSD aged 5, 11 and 15 years have been implanted. Their functional outcomes in the first few months postoperative will be reported.
Conclusion: Infants and children with SSD/AHL may easily combine the electric signal with the good acoustic signal and quickly gain significant benefits from the cochlear implant. Other children struggle to adapt to the use of the implant and/or do not show evidence of benefit in the early post-operative period; in these cases, encouragement and monitoring of implant use are crucial aspects of clinical management. Predicting outcomes is very difficult given the limited experience worldwide. Given this, careful preoperative counselling is required to help families in their decision making and to prepare the child and family for the challenges of the postoperative period.
Session Title: Expanded Indications
Abstract ID: 53
Title: Expanding Indications for Cochlear Implantation: Single-Sided Deafness
Authors: Harold Pillsbury, MD1, Margaret Dillon, AuD1, Emily Buss, PhD1, Meredith Anderson, AuD1, English King, AuD2, Ellen Deres, AuD2, Kevin Brown, MD, PhD1; 1Otolaryngology/Head and Neck Surgery, Univ. of North Carolina at Chapel Hill, Chapel Hill, NC, 2Audiology, UNC HealthCare, Chapel Hill, NC.
Abstract: Introduction: Patients with substantial unilateral hearing loss or Single-Sided Deafness (SSD) experience poor speech perception in noise as compared to normal-hearers. Approved treatment options for SSD do not offer improve speech perception in challenging listening environments. These treatments route the signal from the affected ear to the normal hearing ear, which limits access to binaural cues. It is of interest whether cochlear implantation of the affected ear would improve recipients’ speech perception in noise due to stimulation of the auditory pathway on the affected side. The objective of this study was to assess the speech perception and quality of life outcomes with a cochlear implant plus a normal hearing ear during the first 12 months of listening experience.
Methods: Twenty (20) subjects with SSD underwent cochlear implantation as part of a clinical trial. Subjects completed a speech perception in spatially-separated noise task preoperatively, and at 1, 3, 6, 9 and 12 months postoperatively. Test measures included AzBio sentences in a 10-talker babble and the BKB-SIN test. The noise was presented at the same location as the stimulus, to the affected ear, and to the normal-hearing ear. Listening conditions included the normal hearing ear alone (NH alone) and with a bone-conduction device (BCHA+NH) preoperatively, and with the cochlear implant plus the normal hearing ear (CI+NH) postoperatively. Subjects completed the Speech, Spatial and Qualities of hearing (SSQ) scale and Tinnitus Handicap Inventory (THI) at all intervals.
Results: Speech perception performance was either similar or poorer in the BCHA+CI condition as compared to the NH alone condition at the preoperative interval. Postoperatively, subjects experienced a significant improvement in speech perception when listening with the CI+NH. Performance continued to improve through the 12-month interval. Similarly, subjects reported a significant improvement in quality of life with the CI in the early weeks of listening experience. Subjects also reported a reduction in their tinnitus with device use.
Conclusion: Subjects with SSD experienced a significant improvement in speech perception in noise and reported a significant improvement in quality of life when listening with the CI+NH. These results are promising as candidacy criteria expand to consider pediatric recipients. Patient and device variables including age at implantation, duration of hearing loss, electrode array insertion depth and duration of listening experience will be explored.

Session ID: S3-2
Session Title: Expanded Indications
Abstract ID: 459
Title: Indications and Outcomes of Cochlear Implant Revision Surgery for Legacy Internal Devices
Authors: Meredith A. Holcomb, AuD, Jane A. Burton, BA, Elizabeth L. Camposeo, AuD, Ted A. Meyer, MD, PhD, Ted R. McRackan, MD; OTO-HNS, Med. Univ. of South Carolina, Charleston, SC.
Abstract: Introduction: Device failure and surgical or medical complications are the primary reasons for cochlear implant reimplantation (CIR). Historically, well-functioning internal devices have not been considered for revision surgery. Many cochlear implant users are unable to upgrade to the most up-to-date external processors due to incompatibility with their legacy internal device. Subsequently, they cannot take advantage of recent technological advances in sound processing and noise suppression,
which may have the ability to improve their communication ability. The current study investigates the indications for CIR of legacy internal devices and auditory outcomes following cochlear implant revision surgery, including those revised as a means of technology upgrade.

**Methods:** Retrospective review was completed of patients who were initially implanted as a child with a legacy internal device and underwent revision surgery as a young adult. Data were collected regarding age at the time of implantation, the duration of implant use before revision, reason for revision, and pre- and post- CIR speech perception scores.

**Results:** Of the 7 ears (7 patients) with legacy internal devices that required CIR, technology upgrade was found to be the most common reason for revision surgery (5/7). “Soft failure” accounted for the remainder (2/7). The mean age of initial implantation was 3.8 years, and the mean duration of implant use before CIR was 15 years. All subjects were prelingually deafened and all were reimplanted with the same company as their initial device. All subjects were programmed with a new speech processing strategy and were fit with the most recently released external processor following CIR. At last follow up, mean CNC word increased by 18%, CNC phoneme increased by 16%, and AzBio Quiet improved by 37% compared to pre-CIR scores. Due to the small sample size no significant difference was found (all p>0.05).

**Conclusion:** The findings of this study reveal post-CIR audiological benefit was unchanged or improved compared to the pre-CIR results in all reimplanted patients. Given our results, patients who are unable to use the most current external processors due to incompatibility with their legacy internal device should be considered for revision surgery to optimize their overall performance with a cochlear implant.

**Session ID:** S3-2  
**Session Title:** Expanded Indications  
**Abstract ID:** 432  
**Title:** Hearing Preservation and Speech Outcomes in Pediatric Recipients of Cochlear Implants  
**Authors:** Kevin D. Brown, MD, PhD, Holly Teagle, AuD, Lisa Park, AuD, Jennifer Woodard, AuD, Erika Gagnon, AuD, Lauren Kilpatrick, MD; Otolaryngology - Head and Neck Surgery, Univ. of North Carolina Sch. of Med., Chapel Hill, NC.  
**Abstract:** **Introduction:** The benefits of electric and acoustic stimulation of the cochlea in adult recipients of cochlear implants have been well demonstrated. Limited data is available in pediatric patients. We wished to determine the rates of low frequency hearing preservation in pediatric patients and the benefit of combined electric and acoustic processing for speech outcomes. We also wished to determine if differences in intraoperative ECOG testing correlated with different electrode designs and rates of preservation.  
**Methods:** Thirty-three consecutive pediatric subjects underwent cochlear implantation with either a 20mm 22-electrode array or a 24 mm 12-electrode array. All patients had preoperative hearing at of at least 80dB at 250 Hz. A subset of patients underwent intraoperative ECOG testing using either an extra-cochlear promontory electrode or by intra-cochlear testing through the implant electrode itself. Change in ECOG dB sensitivity as the electrode was inserted was recorded. Hearing preservation was strictly defined postoperatively as maintenance of less than 80dB thresholds at 250 Hz. Patients were evaluated at 1 month, 3 months, and 6 months after implantation to determine rates of preservation using pure tone audiometry. Patients were also tested for word recognition post-operatively in CI and CI + acoustic conditions to determine the degree of acoustic benefit.  
**Results:** Low frequency hearing preservation was seen in 90% of patients at 1 month, 88% at 3 months and 80% at 6 months. Higher rates of preservation were seen in patients without EVA in comparison to those with EVA. Different electrodes demonstrated different patterns of ECOG sensitivity as they were inserted and this correlated with hearing preservation. There was a substantial benefit of hearing
preservation with average CNC scores at 3 months in CI alone of 41% vs 74% in EAS/Hybrid with this large difference persisting out to 6 months.

**Conclusion:** Low frequency hearing preservation is possible in a majority of pediatric implant recipients. Benefits of electric and acoustic hearing are similar to benefits seen in adult patients for speech understanding. Intraoperative ECOG permits prediction of hearing preservation and demonstrates important differences between electrode designs.

**Session ID:** S3-2  
**Session Title:** Expanded Indications  
**Abstract ID:** 342  
**Title:** Partial Insertion of Long Flexible Electrodes in Children with High Frequency Hearing Loss  
**Authors:** Thomas Lenarz, MD, PhD, Rolf Salcher, MD, Melanie Leifholz, MD, Anke Lesinski-Schiedat, MD, Andreas Büchner, PhD; Department of Otorhinolaryngology, Hannover Med. Sch., Hannover, Germany.

**Abstract:**  
**Introduction:** High-frequency hearing loss can be observed in children as well as in adults. These patients show in particular an insufficient speech understanding in noise and a not satisfying benefit from hearing aids. One group of these patients shows a stable low-frequency hearing over many years. At the Medical School Hannover, those patients are typically treated with shorter FLEX electrodes of 16 mm and 20 mm lengths and EAS. Another group of patients are those with progressive or fluctuating hearing loss in low-frequencies. These patients have a higher risk to lose their residual hearing directly after implantation or in the next years afterwards. However, their current residual hearing is often too good to already aim for an electric-only stimulation with a longer electrode. For this patient group a new approach was used. FLEX electrodes of 24 mm and 28 mm lengths were partially inserted 16 mm or 20 mm into the cochlea thus giving the opportunity to insert the electrode further if hearing is lost over time.

**Methods:** To analyze if less than 12 contacts inserted are sufficient for speech understanding with EAS, N=4 patients with a fully inserted FLEX16 electrode were investigated. In an acute testing, every second contact was turned-off resulting in 6 active channels, compared to 12 contacts in the normal setting. Patients were tested in speech understanding with EAS. By now, partial insertion of a FLEX28 or FLEX24 electrode was performed in n=4 patients with a high-frequency hearing loss. FLEX28 electrode inserted 20 mm has been used in n=1 case. N=1 child and N=3 adults were treated with FLEX24, partially inserted 16 mm. In all patients treated at least 8 electrode contacts are active. Differences between the pre- and postoperative unaided air-conducted pure tone thresholds in low frequencies (125Hz⋯1.5 kHz) were analyzed. Freiburg monosyllables (FBM) at 65 dB and HSM sentence test in noise (10 dB SNR) were performed.

**Results:** N=4 FLEX16 patients with fully implanted electrodes achieved the same auditory performance in EAS with a smaller number of electrode contacts compared to all electrodes active. Preliminary results for partial insertion (N=2) show an average hearing loss of 15 dB at first activation. Those N=2 patients could use their residual hearing for EAS and achieved 50% in FBM and 58% in HSM at first fitting.

**Conclusion:** First results show good hearing preservation rates with partially inserted FLEX28 and FLEX24 electrodes. Using electric-acoustic stimulation, patients achieved very good performance results. This is in line with the experiments done with FLEX16 patients and reduced active electrode contacts. Especially for children with a progressive hearing loss, this new approach offers the advantages of an EAS treatment. If the hearing loss is progressive the electrode can be further or fully inserted so that the patients can then benefit from larger electrode insertion depths with electric stimulation.

**Session ID:** PH-1
**Session Title:** Poster Highlights  
**Abstract ID:** 426  
**Title:** Estimation of Residual Hearing Using Electrocochleography in Children with Cochlear Implants  
**Authors:** Sarah Coulthurst, MS1, Alison Nachman, Aud1, Michael Murray, MD1, Aniket Saoji, PhD2, Leonid M. Litvak, PhD2, Kanthaiah Koka, PhD2; 1UCSF Benioff Children's Hosp. Oakland, Oakland, CA, 2Research and Technology, Advanced Bionics LLC, Valencia, CA.  
**Abstract:**  
**Introduction:** In cochlear implant patients with preserved residual hearing, intra-cochlear electrode/s from the implant array can be used to measure electro-cochleography (ECoG) threshold in response to an acoustic pure tone stimulus. The cochlear microphonic (CM) portion of the ECoG response is known to correlate with pure tone audiometric thresholds in adult cochlear implant patients with residual hearing. The goal of the present study was to determine if thresholds estimated based on CM (“CM thresholds”) can be used to predict pure tone audiometric thresholds in pediatric cochlear implant patients with preserved residual hearing.  
**Methods:** Seven (mean age = 7.4 years, SD = 4.7) Advanced Bionics patients with HiRes90k cochlear implant and a HiFocus mid-scala electrode array participated in this study. Behavioral pure-tone thresholds for warble tones were measured using insert ear phones over the frequency range from 125 to 2000 Hz in nine cochlear implant ears from seven subjects. ECoG waveforms were recorded on the most apical electrode of the implant array in response to calibrated pure tones and were used to estimate the CM thresholds.  
**Results:** CM thresholds and behavioral audiometric thresholds could be measured for 35 (6 subjects missing 125 Hz behavioral, 4 test frequencies shown No Response at highest stimulus level) frequencies from the nine cochlear implant ears. A strong correlation (r² = 0.72, p < 0.01) was obtained between CM thresholds and the behavioral audiometric thresholds. The mean difference between the ECoG responses and audiometric thresholds was -2.6 (±13.0) dB.  
**Conclusion:** CM thresholds can be used to routinely measure and monitor residual hearing in pediatric cochlear implant patients.

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**Session ID:** PH-1  
**Session Title:** Poster Highlights  
**Abstract ID:** 54  
**Title:** Improving Device Use and Exposure to Different Listening Environments: Use of Datalogging in Pediatric Advanced Bionics Recipients  
**Authors:** Ivette Cejas, PhD1, Annie P. Rodriguez, AuD; 1Univ. of Miami Dept. of Otolaryngology Ear Inst., Miami, FL.  
**Abstract:** Improving Device Use and Exposure to Different Listening Environments: Use of Datalogging in Pediatric Advanced Bionics Recipients

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**Introduction:** Datalogging provides useful information regarding the child’s everyday environment and use time, which can impact overall speech and language development. It can be used to objectively measure and counsel families regarding their child’s hearing aid use (Munoz et al., 2014; Laplante-Levesque et al., 2014). Since this feature is relatively new in cochlear implants (CIs), little is known about its utility in pediatric CI users.
The present study investigates the correlation between parent reports and the information obtained from the datalogging feature in the Naida CI Q series sound processors. This feature provides information regarding a child’s daily usage, program usage, battery type and life, loss of lock, time spent in different listening environments, as well as amount of usage of different features (i.e., directional microphones, audio-streaming devices, etc). The study will report on two phases of data collection.

**Methods:** Device usage in children between 18 months and 6 years of age is being evaluated over a 7 week period. Families enrolled complete a daily online survey to capture their perspective of their child’s CI usage, wearing configuration, and frequency and duration of different listening environments (noise, quiet, music). Data logs are downloaded each week and compared to the data obtained from the online survey for that week. This information is used to counsel the family on wear time optimization and listening environment experiences and to determine if any changes in wear time and/or listening environments changed following counseling sessions.

**Results:** Data so far (Phase 1, n=3) show that children (M= 3 years), on average, spent no time in quiet, 5% in noise, 73% speech in quiet, 9% speech in noise, and 14% in music. Following counseling sessions, overall improvements were noted in daily usage and number of unlocked events. Battery type and slot usage features correlated with parental reports on the survey. Phase two of the study will report data on five additional participants. Data pre to post counseling will be compared to determine whether counseling using data log information changes patterns in device use and listening environments. Differences in listening environments and device use based on age and/or school settings will be reported. **Conclusion:** Counselling positively influenced daily usage. Parents were surprised to find that children spent the majority of their time in environments with speech in quiet instead of mostly noise environments. The most common topics discussed during counseling sessions were daily schedule, commute time, routine family activities, and school environment. Phase II will follow families for an additional week with a more detailed survey regarding their listening environments. Results will provide more detailed information regarding datalogging and parent reports of their child’s listening environments and device use.

Learning Objective:

- Describe phase one and two results of datalog use in pediatric Advanced Bionics Naida CI Q series recipients
- Learn about potential changes in device use and listening environments following counseling utilizing datalogging information

Disclosure of Financial Requirements: This study was sponsored by Advanced Bionics, LLC.

**Session ID:** PH-1  
**Session Title:** Poster Highlights  
**Abstract ID:** 114  
**Title:** Perception of Interaural Time Differences with Cochlear Implants with a Focus on the Ongoing Fine Structure  
**Authors:** Tobias Rottmann, Dipl.-Ing., Thomas Lenarz, Prof. Prof. Dr., Andreas Büchner, Prof. Dr.; Department of Otolaryngology, Med. Univ. of Hannover, Hannover, Germany.
Abstract: Introduction: Coding strategies for cochlear implants (CI) which transfer in addition to the envelope of the incoming signal also the ongoing fine structure were introduced into the market some time ago. However, the possibility of bilaterally implanted CI users to perceive interaural differences in the signal fine structure has not been investigated in detail so far. In principle, a fine structure coding strategy reproduce the fine temporal information of the acoustic input signal on the electrical side, so that an ITD (interaural time difference) perception on basis of the fine structure could be possible. The aim of this study is to evaluate the ITD coding effectiveness with a standard CIS coding strategy and a fine structure coding strategy, as well as making a comparison between the two.

Methods: For this purpose, two binaural stimuli with interaural time differences were presented in a lateralization experiment to the bilaterally implanted subjects. Both processors are connected via the direct-in to a soundcard of a computer which generates the signals. The method of constant stimuli is used, so that seven fixed ITDs in the range of 50 to 600µs are repeatedly presented. Different electrode configurations with one, four and ten active apical electrode pairs were measured to investigate the effect crosstalk the intra-cochlear electrode contacts.

Results: Eleven subjects were included in the study. Seven of these subjects were sensitive to ITDs. They showed good results with the fine structure strategy in the sinusoids condition. With the CIS strategy however, they only reached ITDs in the range of chance level. With the much broader pink noise signal even with the CIS strategy a moderate ITD perception was observed, probably caused by ITD cues in the envelope of the processed signal. However the performance with the fine structure strategy was better than with CIS in most of the cases. We also observed that in general the ITD sensitivity decreased with an increasing number of active electrodes.

Conclusion: In those patients, who were able to perceive ITD cues (<600µs) results with the fine structure strategy were superior compared to the CIS strategy. However, our preliminary results also suggest that channel interaction between intra cochlear electrodes might hamper ITD perception in CI subjects.

Session ID: PH-1
Session Title: Poster Highlights
Abstract ID: 252
Title: Factors Influencing Sound-Source Localization in Children with Bilateral Cochlear Implants
Authors: Catherine Killan, MSc1, Andrew Scally, MSc2, Catherine L. Totten, MSc1, Christopher H. Raine, Ch.M.1;
1Yorkshire Auditory Implant Service, Bradford Teaching Hosp. Fndn. Trust, Bradford, United Kingdom, 2School of Allied Health Professions and Sport, Univ. of Bradford, Bradford, United Kingdom.
Abstract: Introduction: The ability to hear where sounds come from is an important skill for children in social, recreational and educational settings as well as for their personal safety. Clinical assessments find that localization accuracy for children with bilateral cochlear implants varies from near-normal to an inability to localize above chance level. The reasons for this variation are not yet fully understood. This study therefore aimed to statistically model the effects of inter-implant interval and onset of profound deafness on sound localization in children with bilateral cochlear implants.

Methods: The authors conducted a retrospective, observational cohort study using routinely collected clinical data. Participants were 142 bilaterally implanted children aged 4 years or older that completed at least one of three tests 12 months or more post-second implant. Stimuli were pre-recorded voices randomly roved from 65 to 75 dBA in 1 dB steps. Left/right lateralization was assessed via two loudspeakers at ±60° azimuth. Percent-correct scores were calculated and the simultaneous and sequential groups were compared via Fisher’s Exact Test. Sound-source localization accuracy was assessed using two forced-choice procedures; a 3-choice test with loudspeakers at -60°, 0° and +60°
azimuth and a 5-choice test with loudspeakers at -60°, -30°, 0°, +30° and +60° azimuth. Root-mean-square (RMS) errors were calculated. Children were categorized by inter-implant interval: Simultaneous (N=75), 0 to 23 months (N=12); 24 to 47 months (N=18); 48 to 71 months (N=16) and ≥72 months (N=21). They were classified as “Congenitally Deaf” (thresholds of ≥90 dB(HL) at 2 and 4 kHz in at least one ear from birth) or “Acquired/Progressive” (thresholds initially ≤90 dB(HL) at 2 or 4 kHz bilaterally, later falling below this level). Data were analyzed via multiple linear regression modelling, controlling for time since second implant, age, manufacturer and concentration.

**Results:** Lateralization data showed ceiling effects and no effect of simultaneous or sequential implantation was seen. Sound-source localization models for both the 3-choice and 5-choice tests found no significant difference between the simultaneous group and children with 0 to 2 years inter-implant interval (p=0.323; p=0.819 respectively). Inter-implant interval of >2 years led to greater RMS error, from 6.3 degrees (5-choice test; inter-implant interval 48 to 71 months; p=0.08) to 25.1 degrees (3-choice test; inter-implant interval >72 months; p<0.001). Acquired/progressive hearing loss led to better accuracy than congenital deafness by 10.4 degrees (3-choice test; p=0.001) and 5.7 degrees (5-choice test; p=0.013) RMS error. Manufacturer was significant in both models (p<0.001).

**Conclusion:** Unilateral and bilateral auditory deprivation should be minimized for children with profound hearing loss to maximize their future ability to localize sounds via cochlear implants.
progressive hearing loss. The remaining 33.3% of the children presented with other factors that influenced decision making such as speech-language development concerns.

Conclusions: In this population-based study, 11.2% of children implanted presented with hearing levels outside typical audiologic criteria for implantation. Primary reasons for proceeding with later cochlear implantation for the majority of these children were related to the presence of auditory neuropathy and progressive hearing loss.

Session ID: PH-1
Session Title: Poster Highlights
Abstract ID: 338
Title: Critical Review of Suprameatal Approach for Cochlear Implantation
Authors: Vedat Topsakal, MD PhD
Universitair Ziekenhuis Antwerpen, Antwerp, Belgium.

Abstract: Introduction: Mastoidectomy with Facial Recess Approach (MFRA) is considered the reference standard for cochlear implantation. The SupraMeatal Approach (SMA) was developed more recently and does not require mastoidectomy. We aim to identify the optimal operative approach for cochlear implantation based on postoperative complications and hearing preservation in children and adults with a systematic literature review and a retrospective cohort study for paediatric cochlear implantation.

Methods: Studies comparing MFRA and SMA in children and adults were eligible for inclusion for the review. Original reports with moderate relevance and validity were included. Relevance and validity were assessed using a self-modified Critical Appraisal Tool. This review concords with PRISMA guidelines. Secondly we assessed cochlear implant complications in children implanted between 1996 and 2014 before the age of 5 years in the UMC Utrecht. The severity of complications (minor or major) was documented using Hoffman and Cohen criteria. Complications were reported to occur intraoperative, early postoperative or late postoperatively. Intraoperative surgical challenges were correlated to complication occurrence.

Results: Only retrospective, non-randomized studies were identified (Level-III evidence) and 294 citations were retrieved. Six articles were selected for full-text inclusion and 4 articles were selected for data extraction. No article found a significant difference between MFRA and SMA with respect to postoperative complications in children and adults. One study found a significantly (p < .023) higher pediatric MFRA mastoiditis rate, however, meta-analysis did not indicate an overall effect. Analyses of our own data showed an average age-at-implantation of 2.13 years (SD: 1.14). SMA patients were significantly (p <.001) younger (1.04 years (0.55 - 4.2)). Most complications were minor (MFRA: 64.0%; SMA: 73.1%) and occurred early postoperatively (MFRA: 61.5%; SMA: 76.9%). More complications occurred in SMA compared to MFRA patients (61.5% vs. 20.6%; p <.001) and often in young SMA cohorts (6-12 and 18-24 months; p <.008 and p =.016). Especially more infectious complications occurred in SMA patients (p<.05). Logistic regression showed that the surgical technique and not the age-at-implantation caused infectious complication occurrence.

Conclusion: No evidence was identified in existing literature for lower complication rates between the MFRA or SMA for cochlear implantation in children and adults. Pediatric data were only available for children implanted above the age of 24 months. There is a need for Level I evidence to resolve the around postoperative outcomes of SMA. Significantly more (infectious) complications occurred in young cochlear implant patients when own data were analysed. Because young children are prone to develop acute and serous otitis media mastoidectomy (MFRA) could have a protective effect in this population.

Session ID: PH-1
Session Title: Poster Highlights
Abstract ID: 508
Title: Electrically-evoked ABR (EABR) for Potential ABI Candidates via Endoscopically-guided, Direct Round Window Stimulation
Authors: John Germiller, M.D., Ph.D.1, Luv R. Javia, M.D.1, Daniel J. Lee, M.D.2; 1Otolaryngology, Children's Hosp. of Philadelphia, Philadelphia, PA, 2Otolaryngology, Massachusetts Eye and Ear Infirmary, Boston, MA.
Abstract: Introduction: Electrically-evoked ABR (EABR) testing can evaluate cochlear nerve responses to electrical stimulation, and can be used in children with cochlear nerve deficiency to assess nerve status prior to CI or ABI. Historically, electrical stimulation has been delivered by a transtympanic needle electrode placed on the cochlear promontory. However, precise positioning can be somewhat uncertain, since it is not done under direct view of the middle ear. Also in principle, such stimulation might be attenuated by variations in cochlear anatomy and bone thickness. In an effort to more closely simulate the direct stimulation of cochlear fluids provided by an actual CI, we have begun performing EABR via direct stimulation of the round window (RW) membrane under endoscopic guidance. We report results from our first 10 patients.
Methods: EABR was performed unilaterally in 4 children and bilaterally in 6 (total 16 ears; median age 24 mo). All had apparent cochlear nerve aplasia based on parasagittal magnetic resonance imaging (MRI) views of the internal auditory canal. The middle ear was accessed by transcanal tympanotomy. Under endoscopic visualization, a 1-mm ball-tip probe was placed directly on the RW membrane to stimulate fluids of the scala tympani. Nerve responses were measured by wave V on EABR. For comparison, EABRs were generated under traditional stimulation of the bony cochlear promontory, with either needle or blunt tip probes.
Results: Stimulation and EABR measurement was successful using both methods in all 16 ears, and there were no complications. In 14 ears, no responses were detectable by either method, consistent with cochlear nerve aplasia. One of these patients subsequently underwent ABI, during which nerve aplasia was confirmed. The remaining 2 ears had measurable responses by both methods. In both cases, responses were detectable at lower thresholds via RW stimulation than via promontory stimulation (450-700 vs. 700-900 microamperes).
Conclusion: Direct, endoscopic-guided electrical stimulation via the RW membrane is safe and effective for eliciting EABR responses, and may result in improved detection of small responses in patients with severe cochlear nerve hypoplasia. As ABI surgery is invasive with variable outcomes, improving the sensitivity of EABR testing is crucial to determine the presence of a functional cochlear nerve in the setting of equivocal anatomy on MRI.

Session ID: PH-1
Session Title: Poster Highlights
Abstract ID: 326
Title: Hearing Performance with Different Generations of Fine Structure Strategies
Authors: Tobias Rottmann, Dipl.-Ing., Manfred Schwebs, B.Sc., Thomas Lenarz, Prof. Prof. Dr., Andreas Büchner, Prof. Dr.; Department of Otolaryngology, Med. Univ. of Hannover, Hannover, Germany.
Abstract: Introduction: Coding strategies of cochlear implant systems concerning their performance in speech understanding could be constantly improved over the last decade. The classic CIS (Continuous Interleaved Sampler) strategy still forms the basis for many CI coding strategies. Based on this basic principle, MED-EL has been developed different generations of fine structure coding strategies. Therewith better low-frequency is coded by dynamically adapting the stimulation rate on the most
apical channels depending on the incoming acoustic signal. The first generation of the fine structure strategies is called FSP (Fine Structure Processing) which theoretically offered rate pitch information on three but on average only on two fine structure channels. To be able to guarantee fine structure processing on four apical channels regardless of mapping parameters, a more advanced version, FS4, has been developed. Further optimization procedures lead to the newest iteration of fine structure processing, the so-called FS4 HR strategy. HR stands for High Rate and offers an increased stimulation rate in the non-fine structure CIS-type channels in contrast to FS4 LR (Low Rate).

The aim of the two studies presented here was to compare speech perception outcomes of the three fine structure implementations mentioned above (FSP, FS4 LR and FS4 HR).

**Methods:** 15 subjects (1st study) and 20 subjects (2nd study) with a minimum age of 18 years and a minimum hearing experience of 6 months with the FS4 LR (1st study) and with the FSP (2nd study) strategy have been recruited. All subjects were required to yield a minimum score of 20% in the HSM sentence test in noise to be able to participate in the studies.

Within both studies speech tests were conducted right before and after switching the subjects from FS4 LR to FS4 HR (1st study) and from FSP to FS4 HR (2nd study), respectively.

In the 2nd study a control group was included keeping the FSP strategy for three months. Testing material consisted of the Oldenburg sentence test in noise, the HSM sentence test in noise and the Freiburg monosyllabic word test. The complete test battery was repeated three months after the switch-over again for both strategies in both studies.

**Results:** The final data of the FS4 LR and FS4 HR comparison shows significantly better results for the FS4 HR strategy in the Freiburg monosyllables and in the Oldenburg sentence test. Preliminary results of the FSP and FS4 HR comparison show no significant differences.

**Conclusion:** The final data of the FS4 LR and FS4 HR comparison shows significantly better results for the FS4 HR strategy in the Freiburg monosyllables and in the Oldenburg sentence test. Preliminary results of the FSP and FS4 HR comparison show no significant differences.

On the basis of the current study results, it seems viable to give a recommendation for the use of both FS4 HR and FSP in the daily clinical routine. Further study results may show if one of these strategies would be generally preferable.

**Session ID:** PH-1

**Session Title:** Poster Highlights

**Abstract ID:** 199

**Title:** Development of a Parenting Stress Module for Caregivers of School-Age Children with Cochlear Implants

**Authors:** Alexandra L. Quitter, PhD1, Michael F. Hoffman, MS2, Ivette Cejas, PhD3;
1Behavioral Hlth. Systems Res., Miami Beach, FL, 2Psychology, Univ. of Miami, Coral Gables, FL, 3Miller School of Medicine, Univ. of Miami, Miami, FL.

**Abstract:**

**Introduction:** Several studies have shown that parents raising children with severe to profound hearing losses report higher levels of stress in their parenting role than parents of hearing children (Quitter et al., 2010). A condition-specific family stress scale was developed in the early 1990s, prior to the availability of cochlear implants (CIs) (Family Stress Scale, FSS; Quitter et al., 1990), which indicated that communication, discipline, safety and educational placement were among the most stressful parenting tasks. Higher parenting stress was also significantly related to language delays and behavior problems. During the development of the first CI-specific, health-related quality of life measures, focus group participants (e.g., teachers, speech pathologists, surgeons) and individual parent interviews indicated that parents experience frequent and challenging stressors unique to their child’s hearing loss.
and use of a CI. Thus, our objective was to develop a module that reliably measures this type of contextual parenting stress.

**Methods:** Focus groups consisting of health care providers (e.g., audiologists, otolaryngologists) at two cochlear implant centers and professionals at one university-based school were asked about stressors related to parenting a child with a CI. Twenty parents raising a child with a CI, ages 6 to 12 years (M child age = 9.2 years, SD = 1.87), completed a semi-structured interview lasting 45-50 minutes, which was audiotaped and transcribed for content analysis using NVivo. Nine items were generated from this first qualitative phase, with follow-up cognitive testing. During this phase, parents rated the nine items on a 4-point Likert rating scale (extent of stress or concern), with scores standardized on a 0-100 scale; lower scores indicated higher levels of parenting stress.

**Results:** Parents in the cognitive testing group were mostly mothers (90%), with 50% having completed a college degree, 85% caring for another child in the home. We recruited participants with a range of races and ethnicities (65% White, non-Hispanic; 15% African-American, 15% Hispanic, and 5% Asian). Importantly, 10% of families reported that Spanish was the primary language spoken at home. Standardized scores on the Parenting Stress Module ranged from 20.83 (high stress) to 85.19 (low stress), with an average score of 58.33. Parents’ highest rated stressors included: 1) CI/s breaking; 2) CI/s getting lost; 3) child hurt during sports.

**Discussion:** Qualitative data from healthcare professionals working with school-age children with CIs, and parents who were raising them, reported a number of specific stressors affecting the parenting role. Nine items were generated and rated by caregivers in 20 families at two cochlear implant centers, yielding a wide range of parenting stress scores. Themes included decisions about educational placement, CIs breaking or getting lost, and the reactions of others to the child’s CI/s. Next steps include psychometric evaluation of its reliability and validity. A well-validated parenting stress measure, which takes less than 5-minutes to complete, could be both a key outcome measure to assess family adaptation to school-age children’s use of CIs and a clinically useful measure to guide and evaluate parent-child interventions in this population.

**Session ID:** PH-1
**Session Title:** Poster Highlights
**Abstract ID:** 119
**Title:** Aetiology and Outcomes in Paediatric Reimplantation
**Authors:** Christopher Raine, MB.BS.,FRCS.,ChM., Jane Martin, MED, Catherine Totten, MSc., Iqbal Khan, FRCS, David Strachan, FRCS;
Dept Otolaryngology, Yorkshire Auditory Implant Service, Bradford, United Kingdom.
**Abstract: Introduction:** Cochlear implants are one of the most sophisticated and reliable devices inserted into the human body. Despite being constructed to very high specifications the human body is a ‘hostile’ environment for electronic components. Various reasons for implant failure have been recognized. It is essential that such failures are rigorously reported and there needs to be close co-operation with manufacturers in order to continue to improve design.

**Methods:** All patients’ demographics and outcomes are prospectively entered into our departmental database. This allows for retrospective evaluation of outcomes. Between 1991 and 2016 - 559 children have been implanted with bilateral implantation being the routine since 2009 (a total of 747 implants). The data collected included age of initial implantation and subsequent failure, surgical details, pre and postoperative assessments and, where appropriate, Categories of Auditory Performance (CAP) & Meaningful Auditory Integration Scale (MAIS), with a minimum of 6 months postoperative follow up after re-implantation. Reasons for implant failure, once official reports had been received from the companies, were classified according to the European Consensus Statement
Results: Of 747 implants 55 episodes were identified (7.36%) - 13 with bilateral CI; 42 unilateral. Data was available for all bilateral and in 39 of the unilateral cases. 1 child was not reimplanted; 7 children had insufficient data or had moved away from our service. There were no surgical complications. Statistically the 13 bilaterally implanted children showed continued improvement with a positive correlation (0.89). 3 patients regressed on CAP score for a short period however the majority (36) remained static or improved with a positive (correlation 0.88). MAIS school scores showed positive improvement. With regard to the overall cause of re-implantation; 5.5% related to infection and / or extrusion; 9% related to implant performance; 9% with decrement loss of performance related to trauma; 76.5% related to device failure. Of the latter group there was a clear history of trauma in 20%; Younger implantees with a history of trauma were more prone to failure (p=0.023), similarly the age at failure was related to trauma (p=0.035).

Conclusion: Whilst sudden failure is usually quickly diagnosed a gradual decremental decline can be very difficult to identify in younger children. If implanted children are failing to progress then implant integrity should be tested. Surgical reimplantation is safe and if performed as soon as possible produces little loss in function. Single sided implantees do remain stable or continue to progress and all bilateral implantees progressed (as they retained one functioning implant). Trauma in young children is a significant contributory factor despite the robust engineering of implants.

Session ID: PH-2
Session Title: Poster Highlights
Abstract ID: 368
Title: Language Sampling Practices with Children who are Deaf and Hard of Hearing
Authors: Megan Shannahan, B.S., Kristina Blaiser, PhD, CCC-SLP; Communication Sciences & Disorders, Idaho State Univ., Meridian, ID.
Abstract: Introduction: Language sampling can be an invaluable tool for speech-language pathologists to assess the communicative outcomes of children who are Deaf/Hard-of-Hearing. This is particularly important as, in isolation, norm referenced assessments are not sensitive to identify error patterns in the use or omission of high frequency noun and verb morphology, errors that are common in children with hearing aids and cochlear implants. However, a recent study reports that professionals who work with children with cochlear implants do not frequently use language sampling and most often use standardized assessments and checklists to evaluate and monitor progress of children with cochlear implants (Neuss et al., 2013). The purposes of this study is to 1) identify common language sample practices of professionals who work with children who are DHH, 2) identify how professionals are using information gained from language samples and 3) outline common practices and propose a clinical protocol for language sample use
Methods: An electronic questionnaire was disseminated to audiologists, SLPs and Educators of the Deaf in the United States. Participant responses were coded in an Excel file and checked for completeness. Descriptive statistics were used to analyze trends
Results: A total of 168 participants participated in the survey (16.8% response rate). Approximately 77.3% (n=129) of participants reported that over 75% of their caseload was children who are DHH. Additionally, 75% (n=123) of the participants reported that they had worked with children who are DHH for over 10 years. Most participants (n=153; 91.6%) reported that they use language sampling as a part of their intervention when working with children who are DHH. Despite this, approximately half (n=63; 51.2%) of participants reported using norm-referenced testing most often when evaluating language of children who are DHH. When asked how they use information obtained from language samples, participants reported most often to monitor progress of clients (n=79; 62.7%), and to set goals for clients (n=75; 60.0%). Participants overwhelmingly agreed that they found language samples useful with
the populations they serve (n=130; 94.9%) and that they could offer information that norm-referenced assessments could not provide (n=133; 97.1%), despite them being most popularly used for evaluation of children who are DHH. However, despite these advantages, they were least likely to use information obtain from language samples to determine eligibility of services (n=27; 23.0%).

**Conclusion:** Results from the current study reflect that most respondents believe language samples offer a unique look into a child’s language development that norm-referenced assessments are not sensitive enough to detect. Despite professionals’ frequent use of language samples to evaluate language abilities and monitor progress, the lack of standardization may contribute to the increased use of norm-referenced testing to determine eligibility for children who are DHH. It is proposed that the results of this study may help establish a standardized language sample protocol that would guide practices in the use of language samples with children who are DHH.

**Session ID:** PH-2  
**Session Title:** Poster Highlights  
**Abstract ID:** 487  
**Title:** Intraoperative Electrocochleography (ECochG) in Response to Acoustic Stimulus Using the Cochlear Implant Electrode Array and Post-activation Speech Outcomes  
**Authors:** Robert T. Dwyer, AuD1, Jourdan Holder, AuD1, Brendan P. O’Connell, MD2, George B. Wanna, MD2, Marc L. Bennett, MD2, Alejandro Rivas, MD2, David S. Haynes, MD1, René H Gifford, PhD1, Robert F. Labadie, MD2; 1Hearing and Speech, Vanderbilt, Nashville, TN, 2Vanderbilt, Nashville, TN.

**Abstract:**  
**Introduction:** Even with improvements in cochlear implant (CI) technology, large variability in speech understanding outcomes exists. Duration of deafness has consistently been most shown to be the primary variable affecting outcomes in CI listeners—primarily driven by the extreme ends of the function. Fitzpatrick et al. (2014) recently showed high predictive value of electrocochleography (ECoG) on CNC word recognition in adult CI users. The primary purpose of this study was to determine the feasibility of measuring intraoperative ECoG in response to acoustic stimulus using the electrode array and secondly, to correlate this with post-activation outcomes.

**Methods:** 28 adult patients with normal cochlear anatomy undergoing cochlear implantation with an Advanced Bionics Mid-Scala device were studied. Acoustic tone bursts (125 Hz, 250 Hz, 500 Hz, 1000 Hz, and 2000 Hz) were presented to the operative ear via foam insert earphone after electrode insertion. ECoG responses were recorded using the implant electrode array.

**Results:** ECoG responses were successfully measured in 27/29 (93%) ears using the electrode array. The range of the total response (TR) measured was 55 dB. No significant correlation between the magnitude of the TR and post-operative CNC was observed for 11 ears reaching the 3-month time point at the time of abstract preparation (p > 0.05). Further we found no correlation with CNC word score and duration of hearing loss, age at implantation, pre-CI sentence recognition, nor cognitive status (MMSE).

**Conclusion:** ECoG can reliably be measured in most CI patients. Responses to acoustic stimuli were successfully measured in 27/29 (93%) of device insertions. Loss of lock on one device and a kinked stimulus delivery tube resulted in lost data for the remaining 2 cases. Preliminary findings suggest that ECoG magnitude obtained intraoperatively following electrode insertion is not correlated with word recognition; however, the 11 patients had not yet reached expected performance asymptote at the time of abstract preparation. We will continue longitudinal assessment with additional analyses.
Title: Attention to Infant-directed Speech in Deaf Infants with Cochlear Implants
Authors: Yuanyuan Wang, Ph.D.1, Tonya Bergeson, Ph.D.2, Shana Lucius, MA3, Derek Houston, Ph.D.1; 1Otolaryngology, The Ohio State Univ., Columbus, OH, 2The Urban Chalkboard, Carmel, IN, 3Nationwide Children’s Hosp., Columbus, OH.
Abstract: Introduction: Very young normal-hearing (NH) infants prefer and learn better from infant-directed speech (IDS) over adult-directed speech (ADS) (e.g., Cooper & Aslin, 1990; Fernald, 1985; Ma et al., 2011; Singh et al. 2009), because IDS tends to exhibit exaggerated acoustic-prosodic properties, such as slower speaking rate, higher pitch, wider pitch range, and longer pauses, relative to ADS (Fernald and Simon, 1984; Fernald et al., 1989; Werker et al., 1994). Infants who receive cochlear implantations (CIs) may show different sensitivity to IDS versus ADS due to early auditory deprivation and degraded auditory input afterwards (Geers et al., 2011; Holt et al., 2012; Pisoni et al., 2000). For example, in one study we found that CI infants’ sustained attention to speech differed from that of NH infants (Yang et al., in preparation). Therefore, the purpose of the present study was to determine whether infants with CIs, like their NH peers, prefer listening to IDS over ADS.
Methods: Using the central fixation procedure, we tested 46 infants -12 prelingually deaf infants who received CIs before 2 years of age (mean chronological age = 27.24 months; mean hearing age = 11.88 months; CI group), 22 NH infants with matched hearing experience (mean = 11.68 months; NH-HEM group), and 12 NH infants with matched chronological age (mean = 27.55 months; NH-CAM group) - on their listening preference in three blocks: IDS vs. ADS, IDS vs. Silence, and ADS vs. Silence block (the last two served as baseline). We calculated the average looking times to different types of stimuli (IDS, ADS, or Silence) within each block for each infant. To assess CI infants’ developmental language skills, we administered the Preschool Language Scale (PLS; Zimmerman, Steiner, & Pond, 2002) approximately 18 months after implantation.
Results: In the IDS vs. ADS block, both the CI and NH-HEM groups preferred IDS relative to ADS, p = .010 and p = .003, respectively; however, the NH-CAM group looked equally long to IDS and ADS; in the IDS vs. Silence block, all the three groups, in general, looked significantly longer to IDS than to silence, p < .001. In the ADS vs. Silence block, both the NH-HEM and NH-CAM groups looked significantly longer to ADS relative to silence, p = .001 and p = .019, respectively; however, the CI group did not show any preference, see Figure 1. The regression analyses demonstrated that CI infants’ IDS preference quotient (calculated by dividing the average looking time differences to IDS and ADS by the total amount of looking time to both IDS and ADS for each CI infant) in the IDS vs. ADS condition was the single best predictor of PLS Auditory Comprehension, p < .001, and PLS Expressive Communication, p = .052.
Conclusion: The results showed that 1) similar to NH-HEM controls, CI infants prefer IDS over ADS; and 2) the degree of IDS preference predicts language development in CI infants. These findings suggest that infants with CIs may have access to the information provide by IDS for the purpose of language acquisition. They may also inform intervention strategies by indicating what kind of input is most effective for deaf infants to attain age-appropriate language skills.

Session ID: PH-2
Session Title: Poster Highlights
Abstract ID: 148

Title: Evaluation of an Automatic System to Record and Analyze Electrically Evoked Compound Action Potentials
Authors: Lutz Gaertner, PhD1, Andreas Buechner, PhD1, Thomas Lenarz, MD1, Konrad E. Schwarz, PhD2, Stefan B. Strahl, PhD2, Angelika Dierker, PhD2, Philipp Spitzer, PhD2;
Abstract: Introduction: The measurement of electrically evoked compound action potentials (ECAP) provides a basis for programming the speech processor of a cochlear implant (CI) especially in very young children who cannot give sufficient feedback about their hearing impressions. A novel automatic ECAP recording system which is based on a combination of information that was unused so far in standard clinical software was evaluated against human experts.

Methods: In 21 cochlear implants 234 measurements of the amplitude growth function (AGF) have been taken using a new recording paradigm where the current amplitude was increased in quasi-continuous steps and different recording electrodes have been used. Five experienced audiologists determined the ECAP threshold in these measurements. The results were compared to a new automatic analysis making use of a physiological based ECAP classifier based on firing probability of the auditory nerve. Peak picking of the N- and P- peaks of the ECAP response were improved by surface analysis of the AGF. Threshold estimation was supported by fitting a sigmoidal model to the AGF.

Results: Pearson’s correlation coefficient r between the thresholds estimated by the human experts and the automatic system was in the range of 0.78 to 0.91 with a median of 0.83. The correlation coefficient R between the thresholds estimated by different human experts was in the range of 0.84 to 0.92 with a median of 0.88.

Conclusion: The novel automatic ECAP recording system leads to thresholds within those estimated by human experts.

Session ID: PH-2
Session Title: Poster Highlights
Abstract ID: 376
Title: Influences of Working Memory on Hearing Abilities in Cochlear Implant Users
Authors: Hanna Boenitz, M.Sc.1, Bjoern Lyxell, Professor2, Thomas Lunner, Professor3, Andreas Buechner, Professor1, Bruno Kopp, Professor4, Mareike Finke, PhD1;
1Department of Otolaryngology, Hannover Med. Sch., Hannover, Germany, 2R&D, MED-EL GmbH, Innsbruck, Austria.
Abstract: Introduction: Working memory appears to be an important contributor to speech understanding. The “Ease of language understanding” model by Rönnberg and colleagues (2013) states that in difficult listening situations (e.g. with a cochlear implant (CI)) the working memory is needed to compensate the mismatch between the heard word and the stored word pattern. In our study we aimed to investigate the influence of auditory distraction on the working memory capacity, while being engaged in a visual working memory/n-back task. We investigated adult cochlear implant (CI) users by means of electroencephalography (EEG).

Methods:
Thirteen adult CI users were tested in this study. The EEG was recorded while the participants performed a visual n-back task. Participants were presented with a sequence of numbers. In the easiest condition, the participants had to decide if the number was odd or even. In the more complex conditions, participants had to compare the present number either to the previous or the previous to last number, depending on the load condition of working memory. By means of a button press, they had to indicate whether the two numbers were identical. During the visual task, additional auditory distractor stimuli were presented. Participants were instructed to ignore those stimuli. Auditory stimuli included standard and novel sounds (25%). The novel sounds consisted of different environmental
sounds. Due to the experimental setting we could analyze auditory event-related potentials (ERPs; N1aud, Novelty-P3), visual ERPs (N1vis, Target-P3) and visual ERPs following a novel or a standard tone. The analysis of the latter ERPs offers the opportunity to investigate the influence of auditory distraction on the task performance.

Results
Behavioral results indicate slower and less accurate responses in the higher load conditions. Additionally, the responses following a novel tone were significantly faster compared to the standard tones. The sensory auditory ERPs (N1aud) suggest reduced amplitudes for the more difficult condition and additionally showed reduced amplitudes in response of a standard tone compared to a novel tone. The early visual ERPs (N1vis) also showed a relation to working memory capacity: as the task demands increase, the amplitude decreases. The post-perceptual visual ERPs (Target-P3) showed a u-shaped relation in regard to latency. Preliminary results regarding the effects of distraction displayed an influence of working memory as well as type of stimulation. Visual responses following the novel stimuli were increased to standard tones.

Conclusion
Behavioral and also visual results indicate that CI users show a working memory manipulation. The reduced amplitudes of the auditory ERPs suggest an influence of working memory on hearing - not only for speech, but also for tonal stimuli. Behavioral, but also electrophysiological results indicate a facilitation effect rather than a distraction effect of the novel sounds. The novel tone may cause an unspecific state of readiness which might lead to a modulated ERPs response. All in all these results underline the role of cognition in hearing with CIs. Further investigations will be conducted including attempts to also expand these results to CI implanted children.

Session ID: PH-2
Session Title: Poster Highlights
Abstract ID: 35
Title: Auditory Neuropathy Spectrum Disorder: Proposed Profiles for Improved Audiologic Management
Authors: Alison J. Nachman, AuD
AUDIOLOGY, UCSF BENIOFF CHILDREN'S HOSPITAL OAKLAND, OAKLAND, CA.
Abstract: Alison Nachman, AuD
Abstract - TITLE
Auditory Neuropathy Spectrum Disorder: Proposed Profiles for Improved Audiologic Management
OBJECTIVES:
This proposal calls for a categorization of auditory neuropathy spectrum disorder (ANSD) into subtypes or profiles based on etiology in order to assist with audiologic care and management. Children with ANSD represent not one type, but a spectrum of disorders or profiles. Research supports the management and audiologic outcomes differ based on the proposed subtypes. With further clarification on guidelines for management of children with ANSD with more specific categories, audiologists can provide improved care. With a deeper understanding of ANSD subtypes, improved care can include faster referrals to cochlear implant programs when appropriate to avoid unnecessary delays in speech and language development.

METHODS:
Literature review of ANSD description and management. In addition, current hospital database of children with ANSD with retrospective analysis of care and management.

RESULTS:
Utilizing ANSD profiles, coupled with current Guidelines for the management of children with ANSD, clinicians can follow a more precise methodology to determine next steps in management and care. When children with ANSD are profiled by their medical history or lack thereof, more specific protocols can be used in addition to the current Guidelines for Identification and Management of Infants and Young Children with Auditory Neuropathy Spectrum Disorder (2008). Previous subtypes have been proposed based on auditory responses, however, with more specific information regarding the ANSD profile, one would not have to wait until behavioral testing can be obtained to provide the family with projected pathway for auditory management and care. Proposed subtypes include a.) Genetic etiology, b.) Genetic Syndromes (Charcot Marie Tooth, Friedrich’s Ataxia, etc.) c.) Prematurity, d.) Hyperbilirubinemia e.) Unknown etiology (not premature, no genetic component identified, no other peripheral neuropathies, no intra-craniial anomalies, and normal neural anatomy,) and lastly f.) Anatomic etiology (cochlear nerve hypoplasia or aplasia). Specific guidelines for management are provided based on the ANSD profiles. By providing a Guideline for typical outcomes based on the suggested profiles, audiologists will in turn be able to provide improved management and care of these patients and their families.

CONCLUSIONS:
By describing children with ANSD into subtypes or categories, audiologists can provide families and the rest of the medical team with a more confident pathway for the care and management of these often complicated cases. With compounding years of experience of working with this population, professionals can better help to serve and guide families along this journey. By offering families with a projected pathway of care based on ANSD profiles that is more definitive than what is usually offered to families, delays may be avoided.

Session ID: PH-2
Session Title: Poster Highlights
Abstract ID: 328
Title: First Experience With A New Thin Lateral Electrode Array
Authors: Thomas Lenarz, M.D. Ph.D., Nils Prenzler, M.D., Rolf Salcher, M.D., Andreas Buechner, Ph.D.; Department of Otorhinolaryngology, Hannover Med. Sch., Hannover, Germany.
Abstract: Introduction: To be viable, a new cochlear implant (CI) electrode array design must combine: improved surgical ease of use, structure preservation, particularly important for paediatric application, resist backing out of the cochlea and balance hearing preservation against addressing sufficient cochlear tissue to support electrical-only hearing.
Methods: The new electrode array was designed taking account of the detailed 3-dimensional variability analysed from 20 microCT scans of human cochleae. It builds on positive experience with a mid-scala array but has only a slight curvature, being designed to take a lateral scala tympani position. Through four major design iterations, manual and automated insertion experiments on a 3-dimensional force measurement system allowed differential stiffness to be tuned such that insertion forces of under 60 mN were achieved. The final design tested here is 23 mm long, varying from 0.25 x 0.55 mm at the most apical contact to 0.6 x 0.8 mm at the proximal marker contact. To confirm the above design objectives, 10 arrays were implanted in freshly frozen human temporal bones. The insertions were made using a combination of pure and extended round window approaches. Surgical access was realistic, including the facial recess. To stabilize the array, a channel was carefully drilled in the facial recess to accommodate the electrode lead. Each implanted bone was vibrated to assess resistance against extrusion. Both microCT and histological analysis were conducted.
Results: For each bone it was possible to insert all 16 stimulating electrode contacts, with insertion being straightforward in all cases. In two cases the round window was deliberately extended to improve
access. No translocations were found. A mean insertion depth of 405 degrees was achieved. There was no difference in either, ease of insertion, or insertion depth, for extended or pure round window approaches. No backing out was observed during the brief agitation and vibration of each implanted bone.

**Conclusion:** The new array appears well suited to clinical application, particularly where a simple one-handed insertion technique is desired. Its small dimensions allow flexibility for cochleostomy, as well as extended or pure round window approaches. The insertion depth achieved is sufficient to support electrical only hearing, with a slightly deeper insertion likely in clinical practice. With minimal trauma observed in this series, our intention is next to study hearing preservation with this array.

**Session ID:** PH-2
**Session Title:** Poster Highlights
**Abstract ID:** 52
**Title:** Optimizing CI Programming using Clinical Methods of Electrode Deactivation
**Authors:** Sarah W. Kennett, Au.D., Ph.D. Candidate1, Samuel R. Atcherson, Ph.D.1, Charles Finley, Ph.D.2;
1Univ. of Arkansas for Med. Sci., Little Rock, AR, 2Advanced Bionics, LLC, Valencia, CA.
**Abstract:** **Introduction:** While cochlear implants (CIs) are considered a highly successful medical device for restoring speech understanding to hard-of-hearing individuals, high individual variability of outcomes remains a significant concern in the field. An important factor in CI performance variability is the effect of the electrode-neural interface. Significant within-user and between-user variability exists in both neural survival and physical location of the electrode in the cochlea. Because the electrode-neural interface is not well understood in the clinical domain, it is not uncommon for clinicians to assume homogeneity and program devices without consideration for individual variation. Several methods exist for identifying electrodes with poor neural interface, and deactivating those electrodes result in improved outcomes. While these methods are effective, they are not feasible for direct implementation in the clinic. Despite positive trends in outcomes when deactivating pitch-confused pairs using a variety of methods, this recommendation is not a part of common clinical practice.

**Methods:** This project is designed to compare clinical outcomes of conventional CI programming to a research program where electrodes have been deactivated identified by inability to discriminate adjacent electrodes. All measures used in this study are standard procedures using common clinical equipment and assessments as to eliminate the barrier to clinical practice. A total of 28 adults with cochlear implants from Cochlear Corporation, Advanced Bionics, and Med-El will be included in the full protocol. Prior to any programming, the Minimum Speech Test Battery and subjective questionnaires will be presented to each participant. After baseline measures are collected, a psychometric task will be presented to determine electrode pairs with pitch confusion. Those who do not indicate any pitch confused electrodes will conclude their participation in the study. Those in the full protocol will have immediate retesting, exclusively use the new program for an acclimation period, and return for repeat testing of baseline measures. At the end of the study, participants indicate their preferred program.

**Results:** To date, we have collected data on 15 participants and 8 had pitch confused pairs which resulted in inclusion in our full criteria. Prior to data collection it was hypothesized that a majority of participants will have at least one pitch-confused electrode pair, and thus far 8/15 participants fit this criterion. We also hypothesized that individuals will perform better with the research program than with the baseline program. This has also been the case, however we do not have enough participants to indicate statistical significance at this point. In addition, it is hypothesized that participants will prefer the research program to the baseline program. This has been true of 6/8 participants who have completed the entire protocol at the time of this abstract submission.
Conclusion: We do not have enough data to state statistical conclusions on any of our research questions at this point, however preliminary data support acceptance of all our research hypotheses. We anticipate conclusions by the conference in July 2017.

Session ID: PH-2
Session Title: Poster Highlights
Abstract ID: 92
Title: Evolution of Mapping and Vestibular Function During Acute Labyrinthitis in a Pediatric Patient with Bilateral Cochlear Implants
Authors: Susan Gibbons, Au.D., Margaret Kenna, MD, MPH, Dennis Poe, MD, Ph.D., Guang Wei Zhou, Sc.D., Amanda Griffin, Au.D., Ph.D., Jacob Brodsky, MD; Boston Children's Hosp., Waltham, MA.
Abstract: Introduction: Vestibular dysfunction can affect pediatric cochlear implant (CI) patients. Vestibular symptoms such as vertigo and imbalance are known to occur in some CI patients during the immediate post-operative period. However, acute vertigo attack in implanted children occurring remotely from the postoperative period has not been previously well described.
Methods: Case report of a 3-year-old patient. Retrospective review of audiological, vestibular and medical chart notes.
Results: A three-year-old girl with bilateral CIs experienced a sudden onset of vertigo and imbalance, accompanied by a change in hearing performance. She had previously undergone right cochlear implantation at 12 months of age and left cochlear implantation at 16 months of age. Cause of the patient’s hearing loss is unknown, with normal pre-operative MRI results. Cochlear implant programming four days after the onset indicated a significant increase in right-sided electrode impedances, resulting in non-compliance across four out of 22 electrode channels. Left-sided impedances and stimulation levels were stable. Tympanometric measurements were within normal limits bilaterally. Vestibular testing eight days after the onset showed evidence of a severe peripheral vestibular loss on the right side. A prednisone taper was prescribed. Her symptoms resolved entirely 10 days later. Cochlear implant testing following steroid treatment indicated right electrode impedances and stimulation levels had returned to baseline levels. Audiological performance testing at this time also indicated stable right CI detection thresholds and word recognition scores, in comparison to measurements obtained prior to the episode. No residual balance deficits were evident at the four-week follow-up visit.
Conclusion: We present a previously implanted child with symptoms and evidences of unilateral acute labyrinthitis that occurred remotely from the perioperative period, resulting in both deterioration in implant function and ipsilateral peripheral vestibular loss. Children with CIs may be at an increased risk for developing labyrinthitis due to the electrode creating a sustained conduit between the middle and the inner ears. Implant programming status should be assessed in a timely fashion for pediatric CI recipients who experience acute onset of vestibular symptoms.

Session ID: PH-2
Session Title: Poster Highlights
Abstract ID: 115
Title: Remote Support for First- & Follow-Up-Fittings of Cochlear Implants in Children
Authors: Kelly Schepers, BH1, Karin Bauer, BSc1, Stefano Morettini, PhD2, Alexander Möltner, Dip. Ing. (FH)3, Rudolf Hagen, Prof. Dr. med. Dr. h. c.4; 1Stiftung Hör- Sprachförderung, CICSüd, Würzburg, Germany, 2MED-EL Elektromedizinische Geräte GmbH, Innsbruck, Austria, 3MED-EL Elektromedizinische Geräte Deutschland GmbH, Starnberg,
Germany, 4Klinik und Poliklinik für Hals-, Nasen- und Ohrenkrankheiten der Julius-Maximilians- Univ., Würzburg, Germany.

**Abstract: Introduction:** Tele-health is a broad term for the application of information and telecommunication technologies in the delivery of health services in cases where users are separated from healthcare providers by some distance. Cochlear implant audiology is fairly specialized, and is therefore often only available in larger cities or via ‘outreach’ services, which involve a specialist audiologist travelling to different sites. This can place a real burden (in terms of time and expense) on subjects who live in remote or rural locations, and their families. Hughes et al. (2012) noted that most clinical CI programs require 8-10 visits to the CI center within the first year of device use, and annual or semi-annual visits thereafter. Often, a subject’s visits involve travelling considerable distance, with the result that they often arrive tired at the CI clinic. Remote delivery of CI fitting services via tele-health is therefore an attractive option and has the potential to improve access to services and to reduce the burden on families.

**Methods:** While prior studies on subjective preference for remote or face-to-face fitting sessions have been performed, this study is the first of its kind to provide a prospective and controlled assessment of the safety and performance of a remote programming option for CI fitting in children. Accordingly, in this study Children who are bilaterally deaf or bordering on deafness, receiving or using a cochlear implant were recruited. This study aimed to compare the outcomes of electrophysiological testing, fitting parameters, pure tone audiometry and speech intelligibility measures within subjects who received a cochlear implant and underwent the implant fitting procedures. Specifically, subjects were fit via 2 procedures (remote and face-to-face) and electrophysiological parameters, pure tone audiometry and speech intelligibility outcomes were assessed acutely after each session in a standard audiological test setup at the study centers. In addition each fitting session was appraised by the remote expert, local host, and the subject via an ad hoc designed questionnaire and the total time in minutes needed to perform each type of session was recorded.

**Results:** Initial data gathered on subjects receiving a follow-up fitting, show a general good acceptance and a positive appraisal of the remote setting by the subjects themselves and the professionals involved. Likewise, fitting maps generated with either setting did not differ significantly and initial data on the outcomes of the two set-ups on speech intelligibility show similar performances for what concern subjects receiving follow-up fittings. In addition, both the remote and the local fitting could be performed in a similar amount of time without experiencing major delays or interruptions.

**Conclusion:** Remote CI fitting was generally well-received by CI-users and medical professionals. Subjects’ performance on audiological tests after remote fitting was not significantly different than after standard face-to-face fitting. Additionally, remote fitting did not take longer to perform that face-to-face fitting.

**Session ID:** PH-3
**Session Title:** Poster Highlights
**Abstract ID:** 513
**Title:** Bimodal Ear to Ear Audio Streaming: Speech Understanding Advantages in Complex Listening Situations
**Authors:** Sarah Downing, M.S., CCC-A, Emily Cardenas, Au.D., CCC-A, Smita Agrawal, Ph.D.; Advanced Bionics, LLC, Valencia, CA.

**Abstract: Introduction:** The ability to stream full-band audio signals between two ear level devices (e.g., between two Hearing Aids (HA) or two Cochlear Implant (CI) sound processors or between a CI sound processor and an HA) in real time offers opportunities for signal enhancement in several interesting ways. One application (StereoZoom) allows creation of a four-microphone array via two-way
communication between the dual-microphone systems on each of the two hearing devices. The resulting third-order directional system creates a narrower fixed target beam as compared to dual-microphone systems. This could allow users to focus on a single speaker directly in front of them in very noisy environments. In a second application (ZoomControl), audio input at one ear is streamed simultaneously to both ears, thus reducing the signal deficit at the contralateral ear due to headshadow. The direct microphone input at the contralateral ear is attenuated to further enhance the SNR. This could improve speech understanding in noise in situations where the speaker is not in front of the listener, such as when talking on the phone or driving a car. The objective of this study was to assess the benefit of the above two applications of ear-to-ear audio streaming (StereoZoom and ZoomControl) in adult bimodal listeners (cochlear implant in one ear and a hearing aid in the contralateral ear). At the time of the study, these were experimental applications. They are now available for clinical use.

**Methods:** 19 adult bimodal participants (13 males, 6 females, mean age 61 years) with a Naida CI Q90 processor in one ear and a Naida Link hearing aid in the contralateral ear participated in the study. Speech understanding was evaluated using AzBio sentences (60 dBC) in cafeteria noise. SNR was based on the noise level for each participant where their bimodal score in noise was approximately half their score in quiet. An S0N±60,±90,180 speaker configuration was used for assessing the effectiveness of StereoZoom. ZoomControl was assessed with speech on the HA side and noise from the CI side (SHANCI). Bimodal benefit was also measured in both study set-ups by switching off the HA. Ease of listening ratings were obtained in each condition on a 5-point scale ranging from very difficult to very easy.

**Results:** Activation of StereoZoom led to a mean 21% improvement in speech scores in noise (p<0.0001). ZoomControl use improved speech scores by 28% (p<0.0001). Additionally, significant bimodal benefit was measured in both test set-ups (21% and 33% respectively, p<0.0001). Ease of listening ratings were commensurate with the sentence scores.

**Conclusion:** Ear-to-ear audio streaming can allow bimodal listeners to take advantage of enhanced directional capability and focused listening, thereby improving speech understanding and ease of listening in challenging listening situations.
blood spot, cord blood, urine or saliva culture or polymerase chain reaction) 4) hearing loss documented by 2 separate audiological assessments. Exclusion criteria were: 1) case reports or non-original research, 2) language other than English.

**Results:** Thirty-six articles were reviewed. Studies that reported on universal screening identified cCMV in 0.2 – 1% of newborns and of those newborns 8-22% had hearing loss. Sensorineural hearing loss was more prevalent in children with symptomatic cCMV (growth retardation, prematurity, microcephaly, chorioretinitis, seizures, and/or other neurological abnormalities) compared to asymptomatic cases. Post-natal development of hearing loss was 9 – 68% of cases of cCMV and age of onset ranged from 3 months to 16 years. Cochlear implantation in children with cCMV significantly improves expressive and receptive outcomes; however, symptomatic children and those with cognitive impairments have poorer outcomes than non-cCMV CI recipients. This is limited literature comparing rehabilitation outcomes in cCMV and non-cCMV CI recipients.

**Conclusion:** Late onset and progressive hearing loss is seen in children who develop hearing loss from cCMV. Frequent audiologic follow-up is necessary considering the natural history of cCMV hearing loss. Universal screening should be pursued due to the number of asymptomatic children, at birth, who develop late onset/delayed hearing loss. Cochlear implantation is an effective means of improving speech and language skills in this population.

**Session ID:** PH-3  
**Session Title:** Poster Highlights  
**Abstract ID:** 163  
**Title:** Hearing Preservation in Children Following Cochlear Implantation  
**Authors:** Neil S. Patel, MD, Nicole M. Tombers, RN, Melissa D. DeJong, AuD, Alyce I. Breneman, AuD, Brian A. Neff, MD, Colin L. W. Driscoll, MD, Matthew L. Carlson, MD; Otorhinolaryngology, Mayo Clinic, Rochester, MN.

**Abstract: Introduction:**
Presently, there are few studies evaluating the rate of hearing preservation after cochlear implantation in children, as only recently has implantation of children with greater degrees of residual hearing become more widely accepted. As a result of improvements in technology, programming strategies, and surgical technique, the number of children with low frequency residual hearing who undergo cochlear implantation has steadily increased. At the same time, the value of electroacoustic stimulation has been demonstrated, reinforcing the value of atraumatic surgical techniques to preserve cochlear function. The objective of the current study is to report pediatric hearing preservation results following cochlear implantation with conventional full-length electrodes.

**Methods:**
A retrospective review (2000-2016) at a tertiary referral center was performed of all pediatric patients with a ≤75 dB preoperative low-frequency pure tone average (LFPTA; 250-500Hz average), who underwent cochlear implantation with a conventional length electrode. The degree of hearing preservation was determined according to the 2013 HEARRING group guidelines.

**Results:**
A total of 43 ears, in 35 pediatric patients, met inclusion criteria. The mean age at time of implantation was 8.6 years (range 1.4-17.8 yrs), 20 (57.1%) patients were female, and 25 (58.1%) cases were left-sided. The mean preoperative ipsilateral low frequency PTA and standard PTA (500, 1000, 2000, 3000Hz average) were 54.2 dB (range 15 - 75 dB) and 82.2 dB (range 25 - 102.5 dB), respectively. The mean low frequency PTA and standard PTA shifts comparing the pre- and first postoperative audiogram were ∆25.2 dB (range -5 – 92.5 dB) and ∆18.3 dB (range -8.8 – 100 dB), respectively. Overall, 17 (39.5%) ears demonstrated complete hearing preservation, 19 (44.2%) ears partial hearing preservation, and 7
(16.3%) exhibited no measurable acoustic hearing after surgery. In total, 26 (60.4%) ears maintained functional low-frequency hearing (i.e., ≤80 dB LFPTA) based on the initial postoperative audiogram. There was no statistically significant difference in the initial low frequency PTA shift comparing lateral wall and perimodiolar electrodes (Δ22.2 vs Δ28.1; p=0.44), cochleostomy and round window insertions (Δ25.2 vs. Δ24.7; p=0.95), or statistically significant association between age at implantation and low frequency PTA shift (r=0.174; p=0.26).

Conclusion:
Varying levels of hearing preservation with conventional length electrodes can be achieved in over 80% of pediatric subjects. These data may be used to guide preoperative counseling in pediatric patients with residual acoustic hearing. Additionally, the favorable rates of hearing preservation achieved in children provide further evidence for the expansion of pediatric cochlear implant candidacy to include patients with greater degrees of residual hearing.

Session ID: PH-3
Session Title: Poster Highlights
Abstract ID: 484
Title: Effect of Phonological Errors on Speech Intelligibility in Early and Later Implanted Pediatric Cochlear Implant Users
Authors: Olga Peskova, MS1, Nirmal Srinivasan, PhD2, Ann Geers, PhD3, Emily Tobey, PhD3, Peter Assmann, PhD1;
1Behavioral and Brain Sciences, UTDallas, Richardson, TX, 2Audiology, Speech-Language Pathology, and Deaf Studies, Towson Univ., Towson, MD, 3Behavioral and Brain Sciences, The Univ. of Texas at Dallas, Richardson, TX.
Abstract: Introduction: Cochlear implants (CI) allow children with hearing loss (HL) to achieve speech perception and production outcomes to make their speech understandable to normal hearing (NH) adult listeners. This capability is accompanied by a wide variability of scores. In order to understand the factors that contribute to this variability, we investigated the effects of phonological errors, age of implantation and duration of CI use on speech intelligibility of earlier and later implanted CI users.
Methods: Later implanted participants included the group of 107 children implanted between the ages of 2 and 4 tested at 8 years of age. Early implanted participants included the group of 60 children implanted between the ages 1 and 3 (±2 months) tested at 8 years of age. Speech intelligibility performance and number of phonological errors were evaluated using McGarr sentences (McGarr, 1983), which varied in length from 3 to 5 to 7 syllables and were defined as low and high context sentences. Three NH listeners independently heard one sentence from one child and wrote down the words they understood. The average score was calculated for intelligibility. Sentences produced by CI users were transcribed by four speech language pathologists. Broad transcriptions were analyzed using the Computer Aided Speech and Language Analyses (CASALA) software (Serry et al., 1997) to determine the percent correct for each consonant and calculate percent of omissions and substitutions.
Results: Significant negative correlations between speech intelligibility scores and phonological errors for both groups were evident. The earlier implanted group had significantly fewer omission and substitution errors compared to the later implanted group.
Conclusion: The significant reduction in the number of errors for the earlier implanted group indicate advantages of early implantation, longer duration of CI use and newer speech processing strategies relative to later implanted group.
Abstract ID: 147
Title: Cochlear Implantation: Outcomes in Children with Cochlear Nerve Deficiency
Authors: Annie Rodriguez, Au.D., Melissa Auchter, Au.D.; Univ. of Miami Ear Inst., Miami, FL.
Abstract: Introduction: Cochlear implantation in children with cochlear nerve deficiency (CND) is an area that has not been fully explored and remains in debate. CND, which includes both cochlear nerve hypoplasia and aplasia, occurs in approximately 12-18% of ears affected with sensorineural hearing loss (Huang et. al, 2011). In the past, CND has been a contraindication for cochlear implantation; however recent studies have shown some patients with CND achieve open-set word understanding and should be considered prior to pursuing an auditory brainstem implant (ABI) (Buchman et. al 2011). To date, little is known about the outcomes and benefits of pediatric cochlear implant patients with CND.
Methods: Pre-operative imaging (MRI/CT Scan) as well as pre-operative audiometric thresholds and speech perception scores were reviewed and compared to post-operative neural response telemetry data (NRT) and post-operative audiometric thresholds and speech perception scores.
Results: Despite lack of visible nerve tracing on imaging, all three cases presented with NRT measurements, though measurements were found to fluctuate between visits. Post-operative aided thresholds were observed to improve in all patients. Speech perception scores were also found to improve when testing could be completed. Variability in improvement was noted between patients.
Conclusion: Based on the preliminary data found in these case reports, cochlear implantation should not be eliminated as a potential option for patients diagnosed with CND. Results found in these three cases suggest that cochlear implantation may be a viable option for children with CND. Auditory progress was noted in all three cases and despite imaging data, nerve responses were seen through NRT measurements.

Session ID: PH-3
Session Title: Poster Highlights
Abstract ID: 305
Title: Pediatric Case Report of Performance with Three Different Remote Microphone Systems: Receivers Versus Streamers
Abstract: Introduction: Parents frequently report that their child has difficulty hearing in noise, despite use of new speech coding strategies aimed at conquering this problem. Subjective and objective benefit of noise programs continues to lag behind that realized with remote microphone systems. Schools struggle with the costs associated with providing IEP mandated digital remote microphone systems, and gravitate toward cost-saving single-receiver options coupled to neckloop systems, streamers; or, microphone streamers alone. Historically, signal delivery through non direct connect systems has resulted in poorer performance. Current systems that stream remote microphone signals with or without a single receiver may likewise result in poorer performance compared to direct connect, bilaterally fitted digital receivers. Conversely, wireless streaming of remote microphone signals, with or without a receiver, may be more cosmetically desirable to children, and reduce processor battery drain and power limitations.
Methods: Completed fitting and functional evaluation of three systems: 1) a digital, dynamic remote microphone/2-receiver system, 2) a digital, dynamic remote microphone/1-receiver/streamer system, and 3) a streamer alone using 60 dBA recorded presentation of the W-22 word lists (binaurally) and AZBio sentence lists (monaurally) presented at 0° azimuth in quiet, in noise, and in noise with HAT system. Recorded multitalker babble was presented at -180° azimuth for binaural testing, and at the test
ear for monaural testing in noise conditions, at a SNR needed to reduce performance in quite by ~50%. Optimal receiver gain or streamer volume was identified as that which allowed performance in noise to equal or approximate that in quiet.

**Results:** In quiet, listening with both implants only, RS repeated words with 84% accuracy. In the monaurally aided condition, AZBio sentences were repeated with 95% and 92% accuracy at the right and left ear respectively. In noise (0 SNR), RS’s accuracy declined to 40% for words, and 57% (right), 38% (left) for sentences. With the addition of a digital, dynamic remote microphone/2-receiver system, RS repeated words with 92% accuracy and sentences with 89% (right) and 93% (left) accuracy. With a digital, dynamic remote microphone/1-receiver/streamer system words were repeated with 92% accuracy, and with a streamer alone, words were repeated with 88% accuracy.

**Conclusion:** For this child, essentially equal performance was possible using a 0 SNR in 60 dBA of noise with these three systems. This unexpected finding suggests future hypothesis-based evaluation of these systems is warranted in larger groups of children, and at higher levels of noise.

**Session ID:** PH-3  
**Session Title:** Poster Highlights  
**Abstract ID:** 271  
**Title:** The Immersion 360 System: Bringing the Outside World into the Clinic  
**Authors:** Francois Bergeron, Ph.D.1, Kevin Leung Kam, M.Sc2, Walid Chafiq, M.Sc2, Bastien Bouchard, M.Sc3, Dominique Demers, M.Sc.4;  
1Speech & language pathology, Université Laval, Québec, Canada, 2Neuroprothèses, Université de Montpellier, Montpellier, France, 3Technologies Immersion, Québec, Canada, 4Clinical and biomedical sciences, Université Laval, Québec, Canada.

**Abstract:** Improvement in auditory perception is a major objective of therapeutic interventions for the hearing impaired child. Numerous tests are proposed to guide these interventions and assess their benefits. Optimally, these tests should explore complex abilities such as those encountered by hearing impaired children in daily life. Thus, many contemporary tests were designed on sentence recognition against a speech spectrum noise coming from fixed sources. While sentences appear as a realistic daily stimulus, one can argue that a speech spectrum noise issued from fixed positions with variable or arbitrarily predetermined signal to noise ratios can be far from what children experience in real life. Yet, it is possible to create more realistic test environments. The Immersion 360 system proposes a virtual environment that can reproduce any everyday sound experience and thus, support a more realistic testing condition to assess auditory perception. This project aimed to specify the psychometrics of this system and define norms for speech perception for French speaking normal-hearing people.

**Methods:** Thirty young adults with normal hearing were assessed in Canada and in France with the French adaptation of AzBio in 9 virtual environments (car, garage, cafeteria, restaurant, ball game in a gymnasium, race training in a gymnasium, kindergarten, road traffic, street traffic). Presentation and signal to noise levels were set at the levels measured on the recording sites.

**Results:** Descriptive analysis specify the average, variance and confidence intervals at 95% for each test condition of the Immersion 360 system. Normative data are derived from these metrics.

**Conclusion:** A new test based on virtual environments is now available to assess speech perception in a realistic testing condition. Future work will focus on defining norms with the French pediatric version of AzBio presently in development.
Abstract ID: 583
Title: Learning Molecular Imaging-based Neurologic Predictors of Cochlear Implant Outcome in Prelingually Deaf Children
Authors: Jae-Jin Song, MD, PhD

Abstract: Introduction: There are numerous patient factors affecting the outcome of cochlear implantation (CI). However, preoperative functional status of the cerebral cortex has only been investigated in small numbers of patients. Hence, the current study was performed to reveal functional neuroimaging signatures of speech outcome after CI in prelingually deaf patients using resting-state FDG-PET big-data based machine learning approach and to suggest a outcome prediction model based on cortical predictors of CI outcome. A total of 111 prelingually deaf children underwent pre-CI resting-state FDG-PET. This FDG-PET was used to predict post-CI 3 year speech outcome with regard to open set word and sentence test under auditory-only (A- only) and audiovisual (AV) conditions. FDG-PET data was preprocessed with MarsBaR toolbox for region of interest (ROI) analysis, and 90 cerebral cortical ROIs were used for the analysis. For statistical analysis, LASSO (Least Absolute Shrinkage and Selection Operator) regression analysis using average glucose metabolism of 90 ROIs with regard to post-CI 3 year open set word and sentence scores. In prelingually deaf CI users, activations of the superior temporal gyrus, supramarginal gyrus, and inferior frontal gyrus were predictors of higher post-CI 3 year speech outcome under the A-only condition. Meanwhile, under A-V condition, an additional activation of the anterior cingulate gyrus was necessary to show better speech outcome. In prelingually deaf CI users, activations of the ventral attention network and prefrontal top-down modulator are important to better process language under the A-only condition. Under A-V condition, an additional activation of the salience network is necessary to better understand multimodal information. Taken together, FDG-PET-based machine learning using LASSO could predict CI outcome in prelingually deaf subjects, functional neuroimaging-based outcome prediction may be of help for precision medicine in CI subjects.

Session ID: PH-3
Session Title: Poster Highlights
Abstract ID: 582
Title: Music Enjoyment in SSD Patients: The Synergistic Effect of Electric and Acoustic Stimulation
Authors: David Landsberger

Abstract: Introduction: Although there have been many studies of music perception with a cochlear implant (CI), musical sound quality has been difficult to quantify. For example, ratings of music enjoyment on a scale of 1-100 by deaf CI users are difficult to interpret. The emergence of CI users with normal contralateral hearing presents a unique opportunity to assess music enjoyment quantitatively in CI users by referencing it to that obtained in a normal ear, which provides a known and readily interpretable baseline.

Methods: In the present study, we investigated sound quality of music in Single-Sided Deafened (SSD) subjects with a CI using a modified version of the MUSHRA (MUltiple Stimuli with Hidden Reference and Anchor) method. Listeners rated their enjoyment of brief musical segments of the songs “Ring of Fire” and “Rhapsody in Blue” on a scale of 0-200 relative to a reference stimulus, defined as 100. The reference was the unmodified musical segment presented to the normal hearing ear only. An “anchor” stimulus (defined as 0) was also provided only to the normal hearing ear. The anchor was the same musical segment processed with a 6-channel noise vocoder simulating a 6.5 mm shift. Stimuli consisted of acoustic only, electric only, acoustic and electric, as well as a number of conditions with low pass
filtered acoustic stimuli to simulate varying degrees of hearing loss and bimodal stimulation. Acoustic stimulation was provided by headphone to the normal ear and electric stimulation was provided by a direct connect cable to the subject’s clinical speech processor.

**Results:** Ten out of 11 subjects rated combined electric and acoustic stimulation the best, with a trimmed mean rating “Ring of Fire” as 133 and “Rhapsody in Blue” as 120. The combination of acoustic and electric stimulation was significantly better than unilateral acoustic processing alone. The sound quality of electric stimulation alone was much worse than acoustic stimulation alone. In all tested conditions, adding electric hearing to acoustic hearing provided improvement in sound quality.

**Conclusion:** In summary, music enjoyment from electric stimulation was extremely poor relative to an interpretable normal-hearing baseline. Interestingly, adding the electric stimulation actually enhanced the sound quality of unilateral acoustic stimulation. This effect also happened with low pass filtered, acoustically presented musical segments, suggesting that similar results may be found for bimodal CI users.
significant relationship between the level of interest in music, frequency of listening to music and music genre, and the musical perception total point.

**Conclusion:** Music, one of the indispensable factors in our lives, is also very important to those with hearing loss. As a valid and reliable test that objectively assess all the fields of music in our country, the Turkish Musical Perception Test (T-MPT) is the first and only test both for people with normal hearing and those with hearing loss. An objective assessment of musical perception skills of people will provide benefit in the determination of musical performance for those with normal hearing and, in the development of diagnosis, re/habilitation and amplification systems for those with hearing loss.

**Session ID:** S4-2
**Session Title:** Residual Hearing
**Abstract ID:** 64

**Title:** Evaluation of Long Term Cochlear Implant Use in Patients with Acquired Unilateral Profound Hearing Loss: Focus on Binaural Auditory Outcomes

**Authors:** Griet Mertens, PhD, Paul Van de Heyning, MD, PhD; Univ. Dept. Otorhinolaryngology and Head and Neck Surgery, Antwerp Univ. Hosp., Edegem, Belgium.

**Abstract:**

Background
Cochlear implantation is the only treatment to restore useful hearing to a profoundly deaf ear and, therefore, the only choice in individuals with profound unilateral hearing loss (UHL) that might restore binaural hearing. The study aimed to evaluate the long-term (LT) binaural auditory outcomes in UHL CI, ranging from 3-10 years after CI provision.

**Methods**
LT evaluation was derived from 12 single-sided deaf (SSD) CI recipients and from 11 CI recipients with asymmetric hearing loss (AHL). A structured interview was conducted with each subject. Speech perception in noise and sound localization were assessed in a CIOFF and in a CION condition. Four binaural effects were calculated: summation effect (S0N0), squelch effect (S0NCI), combined head shadow effect (SCIN0), and spatial release from masking. At the LT evaluation, the contribution of a CI and a bone-conduction device (BCD) on speech perception in noise was investigated in two challenging spatial configurations in the same SSD group.

**Results**
All (23/23) subjects wore their CI 7 days a week at LT follow-up evaluation, which ranged from 3-10 years following implantation. In the SSD group a significant combined head shadow effect of 3.17 dB and a spatial release from masking benefit of 4.33 dB were found. In the AHL group, on the other hand, the summation effect (2.00 dB), the squelch effect (2.67 dB), the combined head shadow effect (3.67 dB), and spatial release from masking benefit (2.00 dB) were significant at long-term testing. In both the spatial challenging configurations, the speech in noise results were significantly worse in the condition with the BCD compared to the unaided condition. No negative effect was found for the CION condition. A significant benefit in the CION condition was found for sound localization compared to the CIOFF condition in the SSD group and in the AHL group.

**Conclusion**
All subjects wore their CI 7 days a week at long-term follow-up evaluation. The presence of binaural effects has been demonstrated with speech in noise testing, sound localization, and subjective evaluation.

**Session ID:** S4-2
**Session Title:** Residual Hearing
**Abstract ID:** 86
Title: Chinese Mandarin Tone Recognition in Patients with Bimodal Cochlear Implants

Authors: Yongxin Li, Professor, Xingmei Wei, Master, Yue Gong, Master, Biao Chen, Master, Jingyuan Chen, Master; Otolaryngology, Beijing Tongren Hosp., Beijing, China.

Abstract: Introduction: For deaf individuals with residual low-frequency acoustic hearing, combined use of a cochlear implant (CI) and hearing aid (HA) typically provides better speech understanding than with either device alone. We called it bimodal when a listener has a CI in one ear and a HA in the opposite ear. Because of coarse spectral resolution, CIs do not provide fundamental frequency (F0) information that contributes to understanding of tonal languages such as Mandarin Chinese. Chinese Mandarin is a tonal language with one of four basic tones allotted per syllable. The variation in F0 of the target talker, and the amplitude envelope of the low-pass target speech, are important cues in background noise. The HA can provide good representation of F0 and, depending on the range of aided acoustic hearing, first and second formant (F1 and F2) information. However in many cases cochlear and hearing aid are not in a good fit. Many CI users do not possess enough residual hearing to show a bimodal benefit. So we want to find out how to show maximum benefit with CI and HA together.

Methods: Twelve Mandarin-speaking bimodal patients (8 male and 6 female) participated in this study. Subjects were native speakers of Mandarin Chinese and were between the ages of 8 to 33 years old. All subjects had more than six months of experience with their device at the time of testing. Subjects were recruited from the Department of Otolaryngology, Head and Neck Surgery of Beijing TongRen Hospital (which specifically approved this study). The test material was provided by Mandarin i-CAST software developed by Qian-jie Fu professor. Closedset identification tasks were used to measure Chinese tone recognition (16-alternative, forced-choice). The 16 choices were Ba1, Ba2, Ba3, Ba4, Bi1, Bi2, Bi3, Bi4, Bo1, Bo2, Bo3, Bo4, Bu1, Bu2, Bo3, Bo4. 1, 2, 3, 4 stand for tone 1, 2, 3, 4, respectively. The subjects were tested with CI+HA, with CI-only and with HA. A man spoke the tone in quiet, a woman speaking Ba1 as a background noise with SNR 10dB, 5dB and 0dB, and a man speaking Ba1 as a background noise as the same before. In all, the number of tests is 21[=3 listening (CI, CI+HA, HA)* [quiet+2 background maskers*3 SNR (10dB, 5dB, 0dB)]]. For the CI alone condition, the HA was removed and the HA ear was plugged to prevent eavesdropping. Subjects were seated directly facing a single loudspeaker 1m away. Their basic demographic and audiology information were recorded. The subjects’ pure-tone thresholds at 0.25, 0.5, 1, 2, 4, and 8 kHz were tested with CI+HA, CI alone, HA alone and naked ear of the HA side, respectively. Audiometry was conducted in sound field using warble tones in the first three modes while for the naked ear of the HA side it was conducted using headphone.

Results: No significant bimodal benefits were found in quiet conditions. But Significant bimodal benefits were observed when maskers and targets have different F0 in all SNR conditions. In tone recognition, tone 3 is less affected by the background masker. In vowel recognition, Bo is less affected by background masker, however Ba is relatively more affected by masker.

Conclusion: Bimodal is greatly benefit for recognition of information with different F0. Mandarin tone 3 and vowel o are more stable than the other tones and vowels for bimodal users.
Abstract: Introduction: The use of cochlear implants for the rehabilitation of single-sided deafness (SSD) is an emerging strategy. To date, the majority of the world-literature has focused on the adult population, while outcomes in the pediatric population are sparse. Furthermore, current data has proposed a ‘sensitive period’ during which objective outcomes following cochlear implantation in bilaterally deafened children appear to be optimized, but this question has not been addressed for children and adolescents with SSD.

Methods: The current study is a retrospective review performed at two tertiary academic referral centers. Subjects included all pediatric patients (<18 years of age) who underwent cochlear implantation for rehabilitation of SSD. Demographic data including length of deafness, etiology of deafness, and age at implantation were collected. Outcome measures included speech performance in quiet and noise, subjective reported benefit, and frequency and duration of device usage.

Results: Eight patients (4 females, 4 left ears) were implanted between November 2011 and August 2016. The median age at time of implantation was 9.2 years (range 5-15 years) and the median duration of deafness was 41.5 months (range 10-113 months). All patients had normal hearing in the contralateral ear. Only two patients had residual hearing (45 and 72.5 dB PTA) with poor speech perception (17% and 8% words MLNT). Three patients had congenital unilateral deafness, two had sudden idiopathic sensorineural hearing loss, two had progressive deafness secondary to Connexin 26 mutations, and one due to cholesteatoma. Median preoperative word and sentence recognition scores were 27.5% and 40%, respectively. After a median post-implantation interval of 7 months (range 3-27 months), postoperative word and sentence scores were 74% and 73%, respectively. Only one child did not show improvement in speech perception following CI, and notably she was congenitally deafened and implanted at 9.5 years old. All patients continue to be full time users of their device and report subjective benefit. Other data regarding sound quality, sound localization, tinnitus suppression and performance in noise are variably reported.

Conclusion: Motivated pediatric and adolescent subjects with single-sided deafness can benefit significantly from cochlear implantation. Objective speech outcome measures are improved in both quiet and noise, and the children consistently use their device. Paralleling previously published data for pediatric patients with bilateral deafness, these data suggest that there is most likely a sensitive period after which the efficacy of cochlear implantation for congenital single-sided deafness may be mitigated.
input is an acceptable solution to the listening needs of unilateral CI recipients. Questions remain regarding the hearing handicap in unilateral CI users and how CROS technology may affect reports of handicap. The purpose of this study was to determine if CROS technology provides sustainable benefit in unilateral CI recipients as measured by behavioral studies of hearing performance and subjective report of benefit.

**Methods:** Adults with bilateral profound sensorineural hearing loss using a CI in at least one ear were prospectively enrolled for study. Subjects were fit with an ear level wireless CROS prototype (Advanced Bionic, LLC) designed to wirelessly route the acoustic signal from the non-implanted ear to a Naida CI processor. Subjects wore the CI+CROS configuration exclusively for a minimum of 4 weeks. Speech in noise performance was assessed in the monaural (unilateral CI) and compared to the CI+CROS following a 4 week acclimatization period. Recorded BKBSINTM sentences were used for assessment of speech in noise perception. Subjects were evaluated in the speech front, noise front (0º/0º), speech non-implanted ear, noise implanted ear (90º/270º), speech implanted ear, noise non-implanted ear (90º/270º), and speech front, noise rear (0º/180º) configurations. Benefit and acceptance of the CI+CROS configuration was assessed using subjective questionnaires.

**Results:** Our preliminary data provide strong evidence that benefits gained in traditional monaural listeners through CROS technology are achievable in unilateral cochlear implant (CI) recipients. The addition of the CROS in unilateral CI reduces the variability in performance, allowing for equal performance across all listening conditions regardless of the location of the speaker or noise. Greatest degree of benefit is observed in the monaural to the CI+CROS condition when noise is masking the CI and speech is directed at the non-implanted ear. Subjective reports indicate that unilateral CI recipients perceive benefit from the CI+CROS configuration.

**Conclusion:** Applying CROS technology to unilateral CI recipients provides a novel solution to improving the speech perception in noise deficits associated with monaural listening. Although binaural function cannot be restored with CI+CROS, it may provide an economically favorable solution for those who do not have access to a second CI.
Results
30 children with progressive HL were included. The most common etiologies were related to extended NICU stay, enlarged vestibular aqueduct, family history of HL, and auditory neuropathy. The average diagnosis age for HL was 2.35 ± 1.5 years. 13 (43.3%) children received their implant within 12 months of HL diagnosis, while 17 (56.7%) children were implanted more than 12 month after diagnosis with a mean lag time of 3.11 ± 1.87 years. 92% of children implanted early after diagnosis were identified with severe-profound HL at the time of diagnosis. In contrast, only 25% implanted more than 12 months after diagnosis were found to have severe to profound HL at time of diagnosis. The speech reception thresholds in the early and late implanted groups were comparable at 16.9 ± 2.5dB and 17.9 ± 3.6 dB respectively (p>0.05). Speech discrimination results from the early and late implantation show a trend towards improved results with early implantation. Discrimination for the early and later implanted groups were 87.2 ± 13.0% and 77.4 ± 14.0% (p=0.06).

Conclusion
Children who are identified with progressive hearing loss appear to perform better with their cochlear implants if implanted within 12 months of diagnosis compared to their later implanted counter parts. Speech progress and hearing progression need to be closely monitored to ensure appropriate management.

contralateral ear (CI+NH). Subjects were followed 1, 3, 6, 9 and 12 months post-initial CI activation. Data were analyzed to determine the time-course of improved localization abilities in the CI+NH condition and whether quality of life measures reflected sound field findings. **Results:** Subjects experienced a significant improvement in localization abilities in the CI+NH condition as early as the 1-month interval. Localization abilities continued to improve through the 12-month interval. Subjective questionnaires revealed an early improvement in quality of life in the CI+NH condition as compared to the NH-alone. Initial data from pediatric subjects listening in a CI+NH condition are comparable to results in adults. **Conclusion:** Subjects experienced a significant benefit in spatial hearing abilities after a few weeks of CI use. Achieving a greater understanding of the time-course of improvement and the potential relationship with quality of life is important when counseling patients and their families on treatment options.

**Session ID:** S4-2  
**Session Title:** Residual Hearing  
**Abstract ID:** 213  
**Title:** Masking Release with Changing Fundamental Frequency: Electric Acoustic Stimulation Resembles Normal Hearing Subjects  
**Authors:** Alice B. Auinger, MD, Dominik Riss, MD, Rudolfs Liepins, DI, Wolf-Dieter Baumgartner, MD, Christoph Arnoldner, MD; Department of Otorhinolaryngology, Med. Univ. of Vienna, Vienna, Austria.  
**Abstract:** Introduction: Users of electric acoustic stimulation (EAS) show superiority over cochlear implant users (CI) in challenging listening situations as it can be found in multiple talker environments. The preserved low-frequency region in EAS patients might be one reason for this benefit. We therefore investigated whether users of EAS benefit from increasing the fundamental frequency (F0) difference between a target talker and a masking talker.  
**Methods:** We included 29 patients representing three groups: EAS and CI users and normal hearing listeners (NH). All CI and EAS users were implanted with a MED-EL cochlear implant and had at least 12 months of experience with the implant. The Oldenburger sentence test (OlSa) corpus served as test material, one specific sentence was used as a masker. In this masker sentence the fundamental frequency (F0) was increased by 4, 8 and 12 semitones. All other sentences from the OlSa corpus were presented unchanged at a fixed level. The speech reception threshold (SRT) for all F0 conditions was assessed by adaptively varying the masker level.  
**Results:** EAS users and NH listeners showed a statistically significant improvement in speech perception with increasing the difference in F0 between target and masker sentence. In classic CI or EAS with electrical stimulation only, speech perception was independent from differences in F0. With increasing the difference of F0 between target and masking signal a release from masking was observed only in configurations where the low-frequency region was presented acoustically.  
**Conclusion:** The low-frequency content of a speech signal seems to include important cues for separating multiple sources of speech. By combining acoustic and electric information, EAS listeners can benefit from fine-structure cues in the low-frequency region and segregate audio streams from multiple talkers more effectively. Preserving the low-frequency acoustic region seems to be crucial to provide CI users with the best benefit.
Title: White Matter Anisotropy in the Left Anterior Superior Temporal Region Predicts Speech Perception Improvement in Young Cochlear Implant Recipients

Authors: Zhizhou Deng, PhD1, Patrick C. M. Wong, PhD2, Erin M. Ingvalson, PhD3, Nancy Young, MD4; 1the Chinese Univ. of Hong Kong, Hong Kong, Hong Kong. 2The Chinese Univ. of Hong Kong, Hong Kong, Hong Kong. 3Florida State Univ., Tallahassee, FL. 4Ann & Robert H. Lurie Children’s Hosp. of Chicago, Chicago, IL.

Abstract: Introduction: Previous research has shown that the ventral auditory pathway is associated with sound-to-meaning processing in spoken language learning in adulthood. The goal of the present study is to examine whether this pathway can predict speech perception outcomes in young cochlear implant recipients, as associating the speech signal with word meaning is an important part of early language development. Diffusion tensor imaging (DTI) provides information about white matter neural fiber tracts that interconnect different areas of the brain including those involved in language. We hypothesize that the ability to accurately predict individual outcomes based on preoperative imaging will be enhanced by data from DTI, and that the left ventral auditory pathway would be most predictive of outcomes.

Methods: This is a prospective study of 13 CI recipients implanted before age 4 years (M 19.34 ± 9.42 months) who underwent neuroanatomical MRI and DTI sequences prior to implantation. Standard clinical measures of speech perception (e.g., MAIS, ESP) were obtained pre- and six months post-activation. A diffusion tensor model was used to obtain voxel-wise fractional anisotropy (FA) values. The obtained FA maps were then processed using a modified tract-based spatial statistics (TBSS) analysis. To examine the unique contribution of white matter anisotropy to speech perception improvement after implantation, we conducted partial correlations between the speech perception improvement and FA values while controlling for age. Significant clusters were identified with a threshold of single voxel p < .01 and a cluster size larger than 54 mm3, as determined by a Monte Carlo simulation. To identify which language pathway mediates speech perception improvement, we used the cluster of white matter showing significant correlation with speech perception improvement as the seed voxels in probabilistic tractography.

Results: We found that FA values in one cluster in the left anterior superior temporal region were positively correlated with speech perception improvement after controlling for age. Fiber tracking results showed several tracts to connect to the anterior part of the left superior temporal region. The main white matter pathway started from the left anterior temporal pole (seed region) and went along the inferior temporal area before reaching the left posterior temporal-parietal region.

Conclusion: Prior studies have demonstrated that the ventral auditory cortex is part of the ventral auditory pathway that is important in early language learning. Our DTI study provides preliminary data that may prove useful to enhancing our ability to predict CI outcomes preoperatively based upon brain anatomy and function. At present there is not an accurate way to predict speech perception outcomes, even in early implanted children. A predictive model based upon comprehensive noninvasive neural measures would provide an important means to plan individualized post-implant therapy.
Abstract: **Introduction:** Though cochlear implants (CIs) promote the development of children’s speech and language systems, individual outcomes are highly variable. The most consistently reported predictors of outcomes, such as age of implantation and residual hearing, explain a small portion of the variance. This study uses new techniques to develop an objective pre-surgical neural measure to predict CI outcomes in early deafened children. The ability to accurately predict individual outcomes is a critical first step towards development of precision rehabilitative therapy to maximize language acquisition in children who are at risk for language delay following cochlear implantation.

**Methods:** Prospective study of 36 CI recipients implanted below age 4 years who underwent pre-surgical neuroanatomical MRI. Standard clinical measures of speech perception were done before surgery and six months post-activation. Neuroanatomical comparisons between children receiving CIs and age-matched children with normal hearing (NH) were used to determine which neural networks were either affected or unaffected by auditory deprivation. These data were used to create hypothesis driven machine learning models to classify CI recipients into high versus low improvement groups based upon neuroanatomy alone. The first hypothesis, the neural recycling hypothesis, predicts that brain regions significantly affected by auditory deprivation would be most predictive of post-surgical outcomes. The second hypothesis, the neural preservation hypothesis, postulates that brain areas unaffected by auditory deprivation would most likely contribute to post-implantation language development. The ability of these models to predict improvement in speech perception outcomes was compared.

**Results:** The most obvious morphological differences between the children in the CI and NH groups were in the left auditory cortex, in white and gray matter, and in local density and morphological patterns. Consistent with the neural preservation hypothesis, the machine learning models based upon brain regions unaffected by auditory deprivation had the highest accuracy, sensitivity and specificity in classifying children in the CI group into high versus low improvement. A convergence of data from models that were built using different model parameters further supported this hypothesis. Importantly, these models were more accurate than the use of preoperative behavioral measures such as residual hearing.

**Conclusion:** Machine learning models that relied upon brain regions unaffected by auditory deprivation, mostly in auditory association and cognitive brain regions, produced the highest accuracy, specificity and sensitivity in patient outcome classification. The use of neuroanatomical data allowed us to most objectively predict outcomes without relying on the patients to perform any auditory tasks.

**Session ID:** S4-3
**Session Title:** Basic Research
**Abstract ID:** 159

**Title:** Spectral-Temporal Modulated Ripple Discrimination by Children with Cochlear Implants

**Authors:** David Landsberger, Ph.D.1, Monica Padilla, Ph.D.2, Amy S. Martinez, MA1, Laurie S. Eisenberg, Ph.D.3;
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**Abstract: Introduction:** A post-lingually implanted adult typically develops hearing with an intact auditory system, followed by periods of deafness (or near deafness) and adaptation to the implant. For an early implanted child whose brain is highly plastic, the auditory system matures with consistent input from a cochlear implant. It is likely that the auditory system of early implanted cochlear implant users is
fundamentally different (with different limitations and bottlenecks) than post-lingually implanted adults. The purpose of this study is to compare the basic psychophysical capabilities and limitations of these two populations on a spectral resolution task to determine potential effects of early deprivation and plasticity.

**Methods:** Performance on a spectral resolution task (SMRT) was measured for twenty bilaterally cochlear implanted children (aged between 5 and 13 years) and twenty hearing children within the same age range. Additionally, 10 bilaterally implanted post-lingually deafened cochlear implanted adults and 10 hearing adults were tested on the same task. Cochlear implant users (adult and children) were tested bilaterally, and with each ear alone. Hearing listeners (adult and children) were tested with the unprocessed SMRT and a vocoded version.

**Results:** For children with normal hearing, a positive correlation was found between their age and their SMRT score for both the unprocessed and vocoded versions. Older hearing children performed similarly to hearing adults in both the unprocessed and vocoded test conditions. However, for children with cochlear implants, no relationship was found between SMRT score and chronological age, age at implantation, or years of experience with a cochlear implant. Pediatric performance with a cochlear implant was poorer than the adult performance with a cochlear implant. Additionally, SMRT score was significantly better for the first implant a child received alone than with the second implant alone. However, a significant difference was not observed for the first and second implants for adults.

**Conclusion:** Results suggest that basic psychophysical capabilities of early implanted children and post-lingually implanted adults differ when assessed in the sound field through their implant processors. Because spectral resolution does not improve with age for early implanted cochlear implant users, it seems likely that the sparse representation of the signal provided by a cochlear implant limits spectral resolution development. These results are consistent with the finding that post-lingually implanted adults, who developed their auditory system from normal auditory inputs but now receive the same sparse signal as the implanted children, perform significantly better than children on the spectral resolution test.

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**Session ID:** S4-3  
**Session Title:** Basic Research  
**Abstract ID:** 378  
**Title:** Magnetic Targeting of Stem Cell and Gene Therapy to the Inner Ear  
**Authors:** Trung N. Le, MD PhD FRCSC, Lola Awofala, MSc, Vincent Lin, MD FRCSC, Joseph Chen, MD FRCSC, Alain Dabdoub, PhD; Otolaryngology Head & Neck Surgery, Univ. of Toronto, Toronto, Canada.

**Abstract:**  
**Introduction:** Hearing impairment has a significant negative impact on the quality of life in a society that mainly relies on fast, complex communication. We have previously demonstrated that magnetic targeting delivery of stem cell to cochlea with a magnetized cochlear implant could promote survival benefit and hearing recovery. The objective of this study is to further characterize and optimize magnetic targeting as an effective delivery method of stem cell and gene therapies to treat hearing loss and potentially improve cochlear implant function.

**Methods:** Mesenchymal stem cells (MSCs) are equipped with Adeno-associated virus (AAV) containing brain-derived neurotrophic factor and green fluorescent protein marker. The expression of these transgenes is driven for an early onset and robust expression. The enhanced MSCs-AAV are magnetically targeted to the cochlea using superparamagnetic nanoparticles and a magnetized cochlear implant. Long-term supply of MSCs-AAV can be achieved through multiple systemic injections. Histological
qualitative changes are monitored by examination of MSC localization, number of hair cells, supporting cells, and spiral ganglion neurons. Functional quantitative changes are examined through in vivo neurotrophic factor level and hearing recovery.

**Results:** Expression of transgenes is stable through several passages and does not affect the self-renewal capability and multipotency of MSCs. The enhanced MSCs are found to be magnetically targeted to the cochlea in high number. We are looking to correlate our current findings with elevated neurotrophic factor level, improved survival of hair cell and spiral ganglion neurons, as well as hearing recovery.

**Conclusion:** Our study proposes to use novel and recently proven magnetic targeting delivery methods to concentrate stem-cells and gene therapy factors into the inner ear. Our initial approach is to explore effective ways to provide localized treatment to the damaged cochlea in conjunction with cochlear implant surgery. Our studies will enable the development and testing of new biological delivery strategies to the inner ear that can lead to potential recovery from hearing loss.

**Session ID:** S4-3  
**Session Title:** Basic Research  
**Abstract ID:** 411  
**Title:** Novel Approaches to Microbial Opsin Delivery for an Optogenetic based Cochlear Implant  
**Authors:** Vivek Kanumuri, M.D.1, Maria Duarte, B.S.2, Lukas D. Landegger, M.D.2, Osama Tarabichi, M.D.2, Xiankai Meng, Ph.D.1, Ariel Hight, Ph.D.1, Elliott Kozin, M.D.1, Konstantina M. Stankovic, M.D., Ph.D.2, M. Christian Brown, Ph.D.1, Daniel Lee, M.D.1;  
1Harvard Med. Sch./MEEI, Boson, MA, 2Harvard Med. Sch./MEEI, Boston, MA.  
**Abstract:** **Introduction:** The cochlear implant (CI) provides meaningful sound and speech perception but outcomes are highly variable across similar cohorts of patients. In addition, CI users experience degraded performance in noisy environments and with music appreciation and this may be due to limited spatial specificity from electrical current spread. Optogenetics is a powerful technology that harnesses light-sensitive proteins called opsins to modulate responses of photosensitized neurons with millisecond precision in vitro and in vivo. Unlike electricity, light can be focused to create a greater number of independent channels of auditory information compared to electricity. A fundamental step towards light-based stimulation of the cochlea is robust gene delivery and expression of opsins in spiral ganglion cells (SGCs). Herein, we describe several minimally invasive methods to photosensitize SGCs via local and systemic injection in a murine model.  
**Methods:** Local opsin delivery into the cochlea was achieved by direct injection through the round window of P3 mice using adeno-associated virus (AAV) with Chronos opsin and GFP reporter. Systemic delivery of opsins was achieved using injection into superficial temporal vein of P1 mice with AAV-Chronos-GFP. Transgenic mice expressing opsins were used as positive controls and generated using knock-in mouse models in combination with Cre mouse lines to selectively express Channelrhodopsin2 (ChR2). Subjects were sacrificed and immunohistochemistry of the cochlear sections performed followed by confocal microscopy after a five week incubation period  
**Results:** Opsin expression in SGCs was achieved using local injection, systemic injection, and transgenic approaches. Local viral-mediated transduction achieved higher rates of expression in SGCs compared with systemic viral-mediated transduction. Transgenic lines demonstrated the most robust expression of opsins and this was observed in both type I and type II SGCs  
**Conclusion:** Delivery of light-sensitive opsins to SGCs is achievable through multiple minimally invasive approaches. These findings represent an important step toward the development of a light-based cochlear implant
Session ID: S4-3  
Session Title: Basic Research  
Abstract ID: 499  
Title: Vowel Recognition Scores of Children with Cochlear Implants are Related to Speech-based Spectral Resolution and Time with the Implant  
Authors: Mishaela DiNino, M.A., Matthew B. Winn, Ph.D., Julie G. Arenberg, Ph.D.;  
Department of Speech and Hearing Sciences, Univ. of Washington, Seattle, WA.  
Abstract: Introduction: While cochlear implantation at a young age can result in favorable auditory perception outcomes, considerable variability persists among speech recognition scores of early-implanted children. Spectral resolution, the ability to resolve the frequency components of an auditory signal, is essential for accurate speech identification but is limited in cochlear implant (CI) users of all ages. Children with CIs have been found to vary in their individual spectral resolving capabilities; these individual differences may contribute to the wide range of pediatric CI users’ speech identification scores. Further, normal hearing children’s performance on tests of spectral resolution and identification of spectrally-degraded speech have been found to improve with age, reflecting auditory system development. Thus, maturity of the auditory system may also play a role in pediatric CI users’ speech recognition abilities. The present study examined the relationship between speech-based spectral resolution, auditory system development, and vowel identification scores of children with CIs.  
Methods: Thirteen children with CIs between the ages of 11 to 17 years (m = 14.2 years) performed a vowel identification task and a test of speech-based, functional spectral resolution. All but one participant received their first CI prior to 5 years of age (m = 2.85 years). Eleven participants were bilaterally implanted and performed the tasks with each CI separately, for a total of 24 CIs tested. Stimuli were presented in the sound field. Participants identified vowels in /hVd/ context (naturally-spoken by a female talker) from a closed set of 10 stimuli. For the speech-based spectral perception test, children categorized the speech sounds /ba/ and /da/, which were manipulated on a continuum of formant transitions. Analysis of results from this test yielded a logistic regression coefficient that indicated the listener’s ability to use formant cues. A larger formant cue coefficient indicates greater ability to utilize the spectral cue. Chronological age and “CI age,” or time with the implant, were also analyzed to determine the influence of auditory system development on these two tasks.  
Results: Greater ability to use the formant cue in categorization was significantly correlated with higher vowel recognition scores. Greater “CI age,” or longer time with the implant, was significantly correlated with higher vowel recognition scores and better use of the formant cue for speech categorization. No relationship was found between chronological age and either vowel identification performance or use of the formant cue.  
Conclusion: These results indicate that pediatric CI users’ vowel identification performance can be explained partly by their ability to make categorical judgments about spectral cues in speech sounds. In addition, “CI age,” rather than chronological age, is associated with both spectral resolving capabilities and vowel recognition scores. These findings suggest that cochlear implantation enhances auditory system development and could lead to more rapid maturation of auditory perception. Future studies could determine the timeline of auditory system development in this population by employing a longitudinal study design.

Session ID: S4-3  
Session Title: Basic Research  
Abstract ID: 150  
Title: Automatic Cochlea Segmentation Using Diffusion Snakes
Authors: Ibraheem Al-Dhamari, MSc Computer Science1, Sabine Bauer, PhD2, Dietrich Paulus, Prof. Computer Vision3, Roland Jacob, PD Dr. med.4; 1Computer Science, Koblenz Landau Univ., Koblenz, Germany, 2MTI, Koblenz Landau Univ., Koblenz, Germany, 3AGAS, Koblenz Landau Univ., Koblenz, Germany, 4Ear, Nose and Throat, Military hospital, Koblenz, Germany.

Abstract: Introduction: A prior knowledge of cochlea size is an important factor for an efficient cochlea implant surgery. Medical image segmentation techniques can help to get such measurement by accurate extraction of the cochlea. We propose a fully automatic segmentation method for human cochlea three dimensional images using a Level Set model-based approach. Our dataset and source code will be available for free and can be downloaded from our public server.

Methods: Multi-modal cochlea images of patients from different genders and ages are collected. These images contain CBCT, CT and MRI modalities. They were automatically pre-processed (normalization and histogram equalization) and registered, manually segmented and the shapes are manually extracted. These shapes are used in the training phase and as a background truth for the test phase (evaluation). We added a shape prior energy to Chan-vese terms as described in figure 1.

Figure 1: Flowchart of the proposed method

Results: We used the standard Dice Coefficient (DC) and the Hausdorff Distance (HD) for the evaluation purpose. Other standard model-based approaches such as Geodesic Active Contours (GAC) and Di*usion Snakes will be compared to the proposed method. Using the shape prior enhances the quality of the results and produces better segmented cochlea images as figure 2 shows.

Figure 2: A sample of the results, a: a region of coronal view of a CBCT cochlea image, b: segmentation result without using the shape prior (DC=0.91), c: segmentation result with using the shape prior (DC = 0.95)

Conclusion: We have described an automatic segmentation method for human cochlea images. The results will be compared to standard model-based methods such as GAC using standard evaluation metrics such as DC and HD. Results can be enhanced by using a high resolution mCT model which will be a focus in future work.

Session ID: S5-1
Session Title: Imaging / Revisions
Abstract ID: 220
Title: Predictors of Round Window Visibility In Cochlear Implantation with Temporal Bone High Resolution Computed Tomography
Authors: Shuping Sun, MD, PhD, Wei Lu, MD, PhD; The First Affiliated Hosp. of Zhengzhou Univ., Zhengzhou, China.

Abstract: Introduction: To discuss the predictors of round window(RW) visibility in cochlear implantation(CI) with temporal bone high resolution computed tomography(HRCT).

Methods: From January 2013 to January 2017, 130 cases underwent both HRCT and CI in our hospital were analyzed. The distance from facial nerve to posterior canal wall(FWD), the angle between facial nerve and inner margin of round window(FRA), the angle between facial nerve and tympanic anulus to inner margin of round window(FRAA) were detected at the level of round window on axial temporal bone HRCT. A line parallel to the posterior wall of ear canal was drew from the anterior wall of facial nerve at the level of round window on axial temporal bone HRCT and its relationship with round window was detected (facial-round window line, FRL):type0-posterior to the round window, type1-between the
round window, type2-anterior to the round window. Their (FWD, FRA, FRAA, FRL) relationships with intra-operative round window visibility were analyzed.

**Results:** FWD (F=18.76, P=0.00), FRA (F=34.57, P=0.00), FRAA (F=14.24, P=0.00) can affect the intra-operative RW visibility significantly. RW can be exposed completely during CI when preoperative HRCT showing type0 FRL. RW may be partly exposed and not exposed when preoperative HRCT showing type1 and type2 FRL respectively.

**Conclusion:** FWD, FRA, FRAA and FRL of temporal bone HRCT can predict intra-operative round window visibility effectively in CI.

**Session ID:** S5-1  
**Session Title:** Imaging / Revisions  
**Abstract ID:** 68  
**Title:** Outcomes of Revision Cochlear Implantation for Soft Failure  
**Authors:** Kyle S. Kimura, MD1, Brendan O'Connell, MD2, Marc Bennett, MD2, David Haynes, MD, FACS2; 1Vanderbilt Univ. Med. Ctr., Nashville, TN, 2Department of Otolaryngology, Vanderbilt Univ. Med. Ctr., Nashville, TN.  
**Abstract:** Introduction: It is estimated that roughly 3-8% of cochlear implants fail in some capacity. In cases in which in situ device testing suggests normal function, but patients experience either subjective or objective decline in performance, counseling regarding expected outcomes can be challenging. The objectives of this study are therefore as follows: 1) examine the incidence of cochlear implant soft failures at a high volume implant center, and 2) report outcomes of revision cochlear implantation in these cases.  
**Methods:** Medical records of patients undergoing cochlear implantation at a single institution from 2006-2016 were reviewed. Cases in which in situ integrity testing suggested normal device function yet patients experienced one of the following: 1) decrement in performance, 2) non-auditory sensations, or 3) intermittent sound quality issues. Soft failure was confirmed with either abnormal device testing after revision or improvement in symptoms/performance. Speech performance was assessed pre- and post-operatively using CNC word scores tested in a quiet environment in the CI-only condition.  
**Results:** During the ten-year study period, 1,082 patients underwent 1,469 cochlear implantations. Overall, 11 revision cochlear implantations (0.7%) were performed for presumed soft failure. Device analysis after re-implantation revealed device failure in one patient. Four patients were re-implanted due to significant objective performance decrement (mean decrease in CNC score of 24%). After revision implantation, mean CNC score increased 28% in these patients to a level comparable to their best performance pre-operatively, and sound quality was restored. The remaining six patients were re-implanted for subjective symptoms without performance decrement. Of these, one patient endorsed sound quality issues that improved with re-implantation. Six cases were revised due to non-auditory sensations, with symptoms described as a shock (n=5) or localized pain (n=1). All patients noted complete resolution of their symptoms post-operatively.  
**Conclusion:** The incidence of revision cochlear implantation for soft failure at our institution is low (0.7%). Our data suggest that patients re-implanted for localizing non-auditory sensations or an objective decrease in speech performance experience significant improvement, despite testing that may suggest normal device function.
**Title:** Comparison of Skull Radiograph and Computed Tomography Measurements of Cochlear Implant Insertion Angles: A Temporal Bone Study  
**Authors:** Daniel Jethanamest, MD1, David R. Friedmann, MD1, Mari Hagiwara, MD2, J. T. Roland, Jr, MD1, Mario A. Svirsky, PhD1;  
**Abstract:** **Introduction:** Accurate estimates of cochlear implant (CI) electrode position are desirable to facilitate investigations of the association between position and clinical outcomes. Electrode location measurement is frequently done using radiographs but the accuracy of these measurements has not been carefully validated against computed tomography (CT)-based data, which are more precise but require a higher radiation dose. For many CI patients, particularly pediatric users, accurate estimates of electrode position without additional radiation exposure can be useful. This study aims to investigate the feasibility of measuring CI electrode array angular depth of insertion (aDOI) on post-insertion skull radiographs for both lateral wall and perimodiolar arrays, in comparison to CT in a series of cadaveric temporal bones.  
**Methods:** Two different electrode array designs, one lateral wall and the other perimodiolar, were implanted in five cadaveric temporal bones each, for a total of 10 specimens. High-resolution CT of each specimen as well as a skull radiograph were acquired. The aDOI of the arrays was measured independently from CT and from the radiographs.  
**Results:** Post-insertion skull radiographs allowed for reliable aDOI measurements for both lateral wall and perimodiolar arrays. The imaging modalities provided comparable measures, with a mean difference between aDOI measurements between the two modalities of 8.4 degrees (range 1.8 to 16.0 degrees).  
**Conclusion:** Post-insertion radiographs provide reliable measures of angular insertion depth for CI electrode arrays in comparison to CT. This method is suitable for both lateral wall and perimodiolar arrays and can provide meaningful information about electrode position for patients without a postoperative CT.

**Session ID:** S5-1  
**Session Title:** Imaging / Revisions  
**Abstract ID:** 377  
**Title:** Revision Cochlear Implantation  
**Authors:** Noam Yehudai, MD, MHA, Talma Shpak, PhD, Caroline Peleg, MA, Osnat Rot, MA, Dana Egra-Dagan, MA, Chanam Mazzawi, MA, Riad Khnifes, MD, MHA, Michal Luntz, MD; Department of Otolaryngology—Head & Neck Surgery, Bnai Zion Med. Ctr., Haifa, Israel.  
**Abstract:** **Introduction:** Improved documentation of cochlear implantation (CI) outcomes, together with the increase in the number of implantees and the straightforward involvement of many of them in the hearing society, have led to widening candidacy criteria. Yet, a CI may sometimes require replacement, due to device failure or medical reasons. The aims of the study are to define the rates of revision CI and influencing factors.  
**Methods:** A retrospective chart review including 79 CI replacements performed between 1998 and 2016. Parameters evaluated included age at CI, date of CI, type of device, date and indication for revision. Kaplan-Meier survival estimates were calculated for cumulative revision rate versus the number of years post CI for several subgroups. Survival distributions between these subgroups were analyzed and compared and the relative hazard ratios were calculated.  
**Results:** 75 patients (19 adults and 56 children) underwent 79 CI replacements surgeries. The most common indications were 'soft' and 'hard' device failure (36.7% and 45.6% of indications for
replacements, respectively) followed by medical indications (17.7%) which include infection and chronic pain at the receiver stimulator site, and late development of retraction pocket cholesteatoma in children who were implanted as young babies. Overall revision and device failure rates were 7.1% and 5.8%, respectively. Replacement rates between 2003 and 2016 were significantly lower than those between 1998 and 2002 (4.5% vs. 28.8%, OR = 3.37, p<0.001). Replacement rates were significantly higher in children compared to adults (8.6% vs. 4.6%, OR = 1.86, p<0.04).

**Conclusion:** Hard device failure is the main indication for revision cochlear implantation followed by soft device failure. Revision rates have significantly decreased over the years, probably due to improved technologic reliability, but are still significantly higher in children compared to adults.

**Session ID:** S5-1  
**Session Title:** Imaging / Revisions  
**Abstract ID:** 228  
**Title:** Insertion Depth Angle Prediction Accuracy for Cochlear Implant Electrode Array Selection  
**Authors:** Lukas Anschütz, MD1, Stefan Weder, MD1, Georgios Mantokoudis, MD1, Martin Kompis, Prof. MD, PhD1, Marco Cavassaccio, Prof. MD1, Wilhelm Wimmer, PhD2; 1Department of Otolaryngology, Head and Neck Surgery, Univ. Hosp. Bern, Inselspital, Bern, Switzerland, 2ARTORG Center for Biomedical Engineering, Univ. of Bern, Bern, Switzerland.

**Abstract:**  
**Introduction:** It is hypothesized that preoperative planning of a specific angular insertion depth for CI electrode arrays can be achieved by utilizing the correlation between the cochlear diameter and the cochlear duct length. In practice, however, the result can be distorted mainly for two reasons: wrongly measured cochlear diameters (i.e., incorrectly aligned image slices to visualize the cochlea) and an uncontrolled insertion depth of electrode arrays (i.e., difficulty to reproduce the insertion point and depth). The aim of this ex vivo study was to evaluate the accuracy of insertion angle prediction with a logarithmic equation under optimal conditions, i.e. optimally aligned imaging slices to measure the cochlear diameter and a controlled insertion of electrode arrays in human specimen.

**Methods:** Eight human temporal bones (Thiel conservation) were imaged with a cone-beam computed-tomography scanner (0.33 mm3 voxel size). An oblique slice was placed according to anatomical landmarks to ensure a reproducible visualization of the basal turn. In the basal turn plane, the maximum diameter of the cochlea through the round window was measured. Using a logarithmic equation the linear insertion depth required for an insertion angle of 540° degrees was computed. Lateral wall electrode arrays (28 mm length) were marked at the specific insertion depth and inserted through the round window. The insertion was stopped when the marks reached the round window membrane. The electrode arrays were fixed using bone wax to avoid array migration. After the insertion, CBCT images were taken to assess the insertion outcome, i.e., the angular insertion depth, the implanted scala, and the array course.

**Results:** The mean cochlear diameter was 8.9 mm (range, 8.3 mm to 9.4 mm). On average, the estimated linear insertion depth for a 540° insertion was 24.9 mm (range, 23.2 mm to 26.3 mm). An average angular insertion depth of 529° (range, 510° to 555°) was achieved. This corresponds to a mean positioning error of 11° (standard deviation, ±15°). The differences were not statistically significant (p = 0.11, two-tailed Wilcoxon signed rank test). All electrode arrays had a smooth course along the lateral wall and were fully implanted into the scala tympani.

**Conclusion:** The presented results demonstrate the possibilities and limitations of insertion angle prediction using a logarithmic equation. It was possible to place the electrode arrays closely to the aimed target, however, clinical settings will introduce additional error sources such as bending of the array within the cochlea and the difficulty to reproducibly stop at the planned position. Regarding the
latter, computer-assisted planning and controlled insertion devices could help to increase the positioning accuracy of CI electrode arrays.

**Session ID:** S5-1  
**Session Title:** Imaging / Revisions  
**Abstract ID:** 359  
**Title:** Cochlear Implant Device Failures - Indications for Revision and Outcomes  
**Authors:** Noam Yehudai, MD, MHA, Talma Talma, PhD, Caroline Peleg, MA, Osnat Rot, MA, Dana Egrad-Dagan, MA, Chanan Mazzawi, MA, Riad Khnifes, MD, MHA, Michal Luntz, MD;  
Department of Otolaryngology—Head & Neck Surgery, Bnai Zion Med. Ctr., Haifa, Israel.  
**Abstract:**  
**Introduction:** Device failure is the most common cause for revision cochlear implantation (CI). Device failure can be abrupt with immediate deprivation of auditory perception (hard failure), or gradual, with progressive decline in hearing function or non-auditory symptoms, while auditory perception continues (soft failure). The aim of the study is to define characteristics of patients with device failure and describe post revision CI outcomes in these cases.  
**Methods:** A retrospective chart review including 65 cochlear implant device failures (13 in adults and 52 in children), diagnosed and re-operated between 1998 and 2016. Data regarding patient demographics, pre-CI symptoms, findings in the returned device analysis company reports and post revision medical and auditory outcomes were retrospectively analyzed.  
**Results:** There were 29 'soft' device failure and 36 'hard' device failure. In adults, most failures were soft failures (10/13), and in children most failures were hard (31/52). Mean intervals between CI and re-implantation for soft and hard failure were 5.38±3.82 years (range, 0.6-13.2) and 4.51±3.35 years (range, 0.7-14.9), respectively. Median intervals between symptoms and re-implantation for soft and hard failure were 13.2 months (range, 0.1-6.3) and 3.6 months (Range, 0.1-8.5), respectively. Hearing outcomes in all re-implanted patients improved after re-implantation compared to their performance prior to revision CI.  
**Conclusion:** The diagnosis of soft device failure is hard to make and confirmed only by improvement of symptoms after re-implantation. Therefore, re-implantation in these individuals is often postponed. The present study finding showing that patients improve following re-implantation supports a faster soft device failure decision making algorithm.

**Session ID:** S5-1  
**Session Title:** Imaging / Revisions  
**Abstract ID:** 91  
**Title:** Three-dimensional Visualization of Micro-anatomical Structures of the Human Inner Ear  
**Authors:** R. van de Berg, MD1, T. van den Boogert, MD1, N. Guinand, MD2, Jp. Guyot, Prof.2, H. Kingma, Prof.1, A. Perez-Fornos, PhD2, S. Handschuh, PhD3, L.j. Chacko, MSc4, R. Glueckert, Dr. rer. nat.4, M. van Hoof, MD1, A. Schrott-Fischer, Prof.4;  
**Abstract:**  
**Introduction:** Knowledge of the neuro-anatomical architecture of the inner ear contributes to the improvement and development of cochlear and vestibular implants. The present knowledge is mainly based on two-dimensional images (histology) or derived models that simplify the complexity of this architecture. This study investigated the feasibility of visualizing relevant neuro-anatomical
structures of the inner ear in a dynamic three-dimensional reproduction, using a combination of staining, micro-CT and a newly developed image processing algorithm.

**Methods:** Four fresh cadaveric temporal bones were postfixed with osmium tetraoxide (OsO4) to visualize membranes and myelinated nerve fibers and decalcified with EDTA. A micro-CT was used for scanning at a resolution of 10 micrometers (4 scans) and 5 micrometers (1 scan). A new image processing algorithm was developed and applied in Mathematica (version 10.4). The scans were visualized in 3D slicer.

**Results:** OsO4 enhanced the contrast in all scans and the signal-to-noise ratio was substantially improved by the image processing algorithm. The three-dimensional models provided detailed visualization of the whole inner ear. Details were visible up to neurons, nerve crossings and the specific neurosensory structures like the tunnel of Corti and the otolith organs.

**Conclusion:** The combination of OsO4 with micro-CT and the newly developed image processing algorithm provides an accurate and detailed visualization of the three-dimensional micro-anatomy of the human inner ear.

Session ID: S5-3
Session Title: Quality, Access and Policy
Abstract ID: 375
Title: A New U.S. Standard - AAMI CI86 Cochlear Implant Systems: Requirements for Safety, Functional Verification, Labeling and Reliability Reporting
Authors: William Regnault, PhD1, Vasant Dasika, PhD1, Aami Ci Committee, -2;
1US FDA, Silver Spring, MD, 2AAMI, Arlington, VA.

Abstract: **Introduction:** A U.S. standard for cochlear implant systems, AAMI/Ci86 Cochlear Implant Systems: Requirements for Safety, Functional Verification, Labeling and Reliability Reporting has been developed by the American Association for Medical Instrumentation (AAMI). The standard establishes acceptable design and testing requirements as well as statistical and analytical reliability methods for cochlear implant systems. Both implantable and external components are covered including electrodes, stimulators, sound processors, batteries, system accessories and supporting software.

**Methods:** The AAMI Cochlear Implant Committee was formed in 2010. Development was a collaborative 6-year effort between cochlear implant manufacturers, FDA representatives, surgeons, audiologists, academicians, and members from public/professional organizations.

**Results:** AAMI/Ci86 uniquely combines requirements relating to uniform reliability reporting, appropriate bench testing, and regulatory submission content. To our knowledge, these areas have been unaddressed, addressed in less detail, or addressed separately by existing national/international standards for medical devices. Publication of AAMI/Ci86, expected by early 2017, will combine all three elements in a single document specifically for cochlear implants. Following publication, cochlear implant manufacturers may voluntarily choose to comply with AAMI/Ci86 by submitting high-quality, scientifically-supported regulatory marketing applications to regulatory bodies. Also, more uniform and transparent reporting of device reliability information will be provided to the public by manufacturer adherence to the requirements of the standard.

**Conclusion:** Compliance to the clear, uniform, minimum requirements for cochlear implant systems established by AAMI/Ci86 should spur manufacturers to innovate device designs with improved reliability and safety that will reach market sooner.
Title: Delay in Diagnosis and Compliance with 1, 3, 6: An Analysis of National EDHI data
Authors: Maura Cosetti, MD1, Anita Jeyakumar, MD2; 1Otolaryngology, New York Eye and Ear Infirmary of Mount Sinai, New York, NY, 2Pediatric Otolaryngology, Virginia Tech Carilion Sch. of Med., Roanoke, VA.
Abstract: Introduction: National Early Hearing Detection and Intervention (EDHI) programs stress compliance with “1-3-6” in which newborns are screened within 1 month of age, diagnosed within 3 months and referred for early intervention by 6 months. The advent of universal newborn hearing screening (NBS) has led to impressive progress with >96% of newborns nationwide screened within 1 month of birth. However, significant challenges remain in timely confirmatory testing and referral for early intervention for those babies who refer on their initial screening.
Methods: Available national EDHI data (2014) was analyzed for compliance with 1-3-6. Trends in regional and state-specific rates of non-compliance were investigated.
Results: In 2014, 3,877,851 babies were screened for hearing loss in 56 states (including 5 territories and the District of Columbia.) A total of 63,341 babies failed their NBS and of these, 34.4% (n=21,819) were lost to follow-up (LTFU). Range of LTFU was widely variable, ranging from 0% in Vermont to 85.7% in the District of Columbia. While there was a variety of reasons for lost to follow up including the family declining the testing, over 50% (n=12,402) of the lost to follow up babies were for unknown reasons.
Conclusion: Substantial gains in NBS have led to upwards of 96% of newborns being screened within 1 month of life. New focus on confirmatory testing is necessary to reduce those LTFU and reduce delays in timely diagnosis and appropriate interventions.

Session ID: S5-3
Session Title: Quality, Access and Policy
Abstract ID: 249
Title: Application of Kaizen Principles, Methods, and Tools to a Large Cochlear Implant Program; A Quality Improvement Study
Abstract: Introduction: The 2010 Healthy People goal of increasing “the number of people who are deaf or very hard-of-hearing who use cochlear implants” was reiterated in the 2020 goals. US based CI programs struggle to provide adequate access for the growing number of patients who could potentially benefit. Several studies have demonstrated that one of the major factors limiting access to CIs is inadequate reimbursement as well as the long-term requirement for audiology resources. Kaizen (sometimes also referred to as “Lean”) seeks to improve both quality and operational efficiency. Kaizen has been adapted to healthcare and using it, hospitals have for example, reduced inventory, shortened waiting times, increased productivity and improved patient safety and quality of care.
Methods: Apply Kaizen principles, methods and tools to improve metrics of quality, cost and accessibility when applied to a large CI program. Data was collected at several time intervals and will be presented.
Results: Preliminary data show a significant improvement in accessibility for patients seeking implantation, along with decreased patient contact hours without sacrificing quality. Conclusions: Applying Kaizen principles to this CI practice was successful in streamlining the patient experience.

Session ID: S5-3
Session Title: Quality, Access and Policy  
Abstract ID: 145  
Title: The Fundamentals for Developing a National Registry of Auditory Implants  
Authors: Rishi Mandavia, MRCS ENT1, Alec Knight, PhD2, John Phillips, FRCS3, Andy Hall, MRCS ENT1, Elias Mossialos, PhD4, Peter Littlejohns, MD2, Anne Schilder, PhD1; 1Ear Inst., Univ. Coll. London, London, United Kingdom, 2Department of Primary Care and Public Health Sciences, King’s Coll. London, London, United Kingdom, 3Norfolk and Norwich Univ. Hosp., Norwich, United Kingdom, 4Centre for Health Policy, Imperial Coll. London, London, United Kingdom.  
Abstract: Introduction: The regulation of surgical implants is vital to patient safety and there is an international drive to establish registries for all implants. Hearing loss has a major health, social, and financial impact worldwide. Recognising the high unmet need of hearing care, industry is targeting this field with a growing range of surgically-implanted hearing devices including Cochlear Implants and Bone Conduction Hearing Devices. Currently, there is no comprehensive UK registry capturing data on these devices in neither children nor adults; in its absence, it is difficult to reflect on practices, monitor clinical and cost-effectiveness and develop national policy. Recognising that developing and maintaining a national registry of auditory implants faces challenges, we set out to identify the fundamentals for this process from previous and existing UK surgical registries.  
Methods: Systematic literature review and narrative synthesis adhering to PRISMA recommendations (PROSPERO database registration number: CRD42016039793). Inclusion criteria were: publications describing the design, development, critical analysis or current status of a national surgical registry. We used a data extraction table developed by thematic analysis and synthesised extracted data into a structured narrative.  
Results: Sixty-seven publications were included. The fundamentals to successful registry development include: steering committee to lead and oversee the registry; clear registry objectives; planning for initial and long-term funding; strategic national collaborations amongst key stakeholders; dedicated registry management team; consensus meetings to agree registry dataset; established data processing systems; anticipating challenges; implementing strategies to increase data completion. Patient involvement and awareness of legal factors should occur throughout the development process.  
Conclusion: This review identifies the fundamentals for developing a successful national registry of auditory implants including strategies to increase the chance of success. The key strength of our approach is that it provides robust knowledge that can be used to inform the development of any surgical registry. It also provides a methodological framework for international surgical registry development.

Session ID: S5-3  
Session Title: Quality, Access and Policy  
Abstract ID: 355  
Title: Unilateral Cochlear Implant: Impact on Quality of Life Measured With the Glasgow Benefit Inventory  
Authors: David Low, MBBS, Hosam A. Amoodi, MD FRCSC, David Shipp, MA FAAA, George Kurien, MD FRCSC, Trung Le, MD FRCSC, Joseph Chen, MD FRCSC, Vincent Lin, MD FRCSC; Otolaryngology - Head and Neck Surgery, Sunnybrook Hlth. Sci. Ctr., Toronto, Canada.  
Abstract: Title: The Utility of the Glasgow Benefit Inventory in Unilateral Adult Cochlear Implant Recipients
Introduction
Unilateral cochlear implantation in adult patients with bilateral severe to profound hearing loss is now considered the standard of care. Our objective was to use the Glasgow Benefit Inventory (GBI) to quantify the improvement in quality of life in our patients.

Methods
This was a prospective study in a tertiary care center. A total of 500 post-lingually deafened adults were enrolled in the study. Their pre- and post-operative GBI and HINT scores were collected and analysed.

Results
Interim analysis of the first 224 patients shows a significant improvement in the total (+39.77), general health (+53.53) and social (+23.36) scores of the GBI. The improvement in physical scores were not significant. The total and general health scores of the GBI correlated significantly with the postoperative HINT score and the change in HINT score.

Conclusion
The GBI reflects the improvement in quality-of-life (QOL) after unilateral cochlear implantation in adult patients. This finding concurs with other QOL instruments and provides yet another QOL measure in cochlear implant recipients.

Session ID: S5-3
Session Title: Quality, Access and Policy
Abstract ID: 269
Title: Cochlear Implant Access and Medicaid
Authors: Donna Sorkin, 22101, MA
American Cochlear Implant Alliance, American Cochlear Implant Alliance, McLean, VA.

Abstract: Introduction: Medicaid provides healthcare for persons of all ages whose income and resources are insufficient to pay for such services. The program was created in 1965 and has grown to become the third largest domestic program in the Federal budget. Medicaid is a joint program, funded primarily by the Federal government and run at the state level according to state specified criteria. Cochlear implant coverage is determined by each state. Children are covered for CI in all 50 states because of Federal EPSDT rules though the nature of the coverage, candidacy criteria, and reimbursement characteristics are determined state by state. It is estimated that Medicaid covers 15% of all CI surgeries (adults and children) and up to 50% of pediatric surgeries in some states. Though the adult coverage numbers are relatively low, Medicaid is a significant contributor to access to care for children. It is unclear what specific alterations will be made in Medicaid in the future though given the momentous changes that have been discussed for healthcare, there may well be alterations in CI coverage. Having a thorough understanding of policies in an individual state may help clinicians, parents and policy-makers productively discuss and address proposed changes or proactively seek changes to better service children and their families.

Methods: CI programs in 35 states with robust cochlear implant programs were surveyed using a mail survey instrument regarding Medicaid CI coverage characteristics for children in their state. Programs were also queried about the major challenges they faced in providing appropriate support for low- and moderate-income families and specifically those whose children are covered by Medicaid. The information was summarized.

Results: A range of patterns exist relating to Medicaid coverage for children across the states reviewed. The major areas of difference include policies on bilateral cochlear implantation, processor replacement and/or upgrades, coverage of habilitation services, and candidacy criteria. Reimbursement of services by Medicaid varies quite significantly and can impact on access.
Conclusion: Although there are differences by state, in general Medicaid provides a vehicle for providing children from low- and moderate-income families access to CI care. There are strategies that have been utilized to improve coverage and reimbursement under Medicaid and these can be employed by clinicians, parents and advocates to expand access to care for children.

Session ID: S5-3
Session Title: Quality, Access and Policy
Abstract ID: 39
Title: AAMI CI86, A New Standard for Cochlear Implants. What Does it Mean for CI Professionals?
Authors: Teresa Zwolan, PhD1, Julie Verhoff, PhD2;
1Otolaryngology, Univ. of Michigan, Ann Arbor, MI, 2Audiology, Joe DiMaggio Children’s Hosp., Hollywood, FL.
Abstract: Introduction: A new U.S. standard, AAMI CI86 Cochlear Implant Systems - Requirements for Safety, Functional Verification, Labeling, and Reliability Reporting has been developed by a standards committee of the Association for the Advancement of Medical Instrumentation (AAMI).
Methods: A committee comprised of CI surgeons, audiologists, and representatives from device manufacturers and the FDA met regularly to develop a new standard that includes specification of how device reliability information for both internal and external components of cochlear implant systems will be determined. It additionally includes information regarding how such information will be reported to regulatory authorities, to the public, and to the clinical community.
Results: The standard is expected to be approved in January 2017 and to be published by March 2017.
Conclusion: This presentation will describe various components of the standard, with direct discussion of how the standard will impact clinical care.

Session ID: S6-1
Session Title: Electrode Array
Abstract ID: S10
Title: New Lateral Wall Electrode: Evaluation of Surgical Handling, Radiological Placement, and Histological Appraisal of Insertion Trauma
Authors: Alejandro Rivas, MD1, Colin L. W. Driscoll, MD2, Robert D. Cullen, MD3, Stephen J. Rebscher, M.A.4, Ana H. Kim, MD5, Brandon Isaacson, MD6;
Abstract: Introduction: Lateral wall electrodes are generally considered easier to insert and more amenable to a round window approach for cochlear implantation. They are also favored for preservation of residual hearing. The design intent of the new lateral wall electrode is to facilitate an easy round window insertion approach, to cover the main body of spiral ganglion cells and to offer an atraumatic insertion to help preserve residual hearing.
Methods: A group of 5 surgeons participated in the temporal bone study, each using 8 electrodes and 8 fresh temporal bones with intact facial recesses. The choice of surgical approach and insertion method was taken by the surgeon with consideration of the individual bones. Questionnaires were conducted to assess the handling characteristics and insertion properties of the electrodes. Plane film x-rays and micro-CT were taken to determine the angular insertion depth of the electrode and its placement within
the scala tympani. Histology was then conducted to confirm electrode placement and to assign a trauma ranking based on the Eshraghi Trauma Scale for each electrode.

**Results:** Questionnaire data indicates that the electrode was easy to handle in the surgical space and suitable for round window insertion. The shape of the electrode allowed easy visualization of the cochlear opening. X-rays confirmed that it achieved the desired angular insertion depth. Histology showed an extremely low rate of intracochlear damage.

**Conclusion:** The temporal bone study confirms that the design intents of the new lateral wall electrode were met. It promises an electrode that is easy to insert, that offers a standard length electrode to cover electrical hearing and the real potential to preserve residual hearing to allow access to electro-acoustic stimulation.

**Session ID:** S6-1

**Session Title:** Electrode Array

**Abstract ID:** 495

**Title:** Perimodiolar, Slim Straight and Thin Perimodiolar Electrode Arrays: Comparison of Performance Outcomes

**Authors:** J. Eric Lupo, MD, MS, Allison Biever, PhD, David Kelsall, MD; Rocky Mountain Ear Ctr., Englewood, CO.

**Abstract:** **Introduction:** Recent studies of hearing preservation in cochlear implantation (CI) have suggested that round window insertion with a lateral wall electrode is less traumatic than a cochleostomy approach. The lateral wall or thin straight electrode does not approximate the modiolus of the cochlea as does a perimodiolar electrode thereby minimizing trauma to the delicate inner ear structures and may lead to improved performance. Other studies have shown that perimodiolar (curved) electrode arrays lower the neural response telemetry (NRT) threshold and consume less power likely because of the closer proximity to the spiral ganglion cells in the modiolus. Research has demonstrated that perimodiolar electrodes provide excellent hearing performance, a more focused stimulation and greater power efficiency. Despite the difference in the goal to be achieved by the electrode (peri-modiolar vs lateral wall), there is little known of the ultimate effects of the selected electrode on patient performance.

**Methods:** In this retrospective study, we examined the programming parameters, hearing preservation and outcome data for three groups of subjects who received the slim straight electrode array (CI422 or CI522), those who received a perimodiolar electrode array (CI24RE or CI512) and those who received a thin perimodiolar (CI532) device. All cochlear implantation procedures from July 2012 to December 2016 performed at a single CI center were reviewed for study inclusion criteria. The review examined data from 93 slim straight, 78 perimodiolar and 38 thin perimodiolar adult recipients. The programming parameters compared for each recipient group included NRT thresholds as well T and C Levels. CI performance as represented by sentence and word performance at 3, 6, and 12 months post-activation and hearing preservation was compared for the three groups. The paired t-test was utilized to test for statistical significance.

**Results:** Preliminary data from these groups demonstrate a significant difference between NRT thresholds, and T and C Levels exists between the three groups, with the perimodiolar and thin perimodiolar electrode groups having a much lower value. A significantly better preoperative word and sentence score was observed from the slim straight cohort compared to the perimodiolar cohort. No significant difference was seen between the perimodiolar, slim straight and thin perimodiolar electrodes in terms of CI performance for sentences in quiet and words measured at 3, 6 and 12 months post-activation.
Conclusion: The results of the study support the premise that closer proximity to the modiolus afforded by perimodiolar electrodes results in lower NRT and T and C levels as compared to a lateral wall electrode such as the slim straight electrode. The slim straight electrode cohort and thin perimodiolar electrode cohort demonstrated better hearing preservation outcomes compared to the perimodiolar electrode cohort. Despite the differences seen in NRT and T and C levels and hearing preservation, at all time points post-activation, no significant difference was observed in sentence and word scores between the slim straight, perimodiolar and thin perimodiolar electrodes.

Session ID: S6-1
Session Title: Electrode Array
Abstract ID: 239
Title: Effect of Electrode Position on Electrophysiological and Psychoacoustic Parameters in Cochlear Implant Patients with Lateral and Perimodiolar Electrode Arrays
Authors: Chantal Degen, MD, Andreas Büchner, PhD, Thomas Lenarz, MD PhD; Otorhinolaryngology, Hannover Med. Sch., Hannover, Germany.
Abstract: Introduction: The electrode position within the cochlea plays an important role for the interaction between electrode contacts and spiral ganglion cells. It is determined by the form of the electrode carrier. Straight electrode arrays (Nucleus™ 522 “SRA”) are pressed against the lateral wall of the cochlea, while precurved arrays (Nucleus™ 532 “SMA” and 512 “Contour”) curl around the modiolus and ideally have no contact to the lateral wall. Recent improvements in postoperative DVT (digital volume tomography) imaging resolution now allow determination of the distance between each electrode contact and the medial wall of the cochlea and to observe correlations with electrophysiological and psychophysical measurement values in individual patients.
Methods: Postoperative high resolution DVT-images of 30 patients with Cochlear® Nucleus™ 532, 522 and 512 implants were evaluated using the Comet (Cochlea Measurement Tool) program to determine the distance between the 22 electrode contacts and the medial wall as well as to the central axis of the cochlea (modiolus). During the fitting week after the initial activation ECAPs, T- and C-levels and spread of excitation were measured.
Results: Patients with perimodiolar electrode arrays (Nucleus™ 532 and 512) overall have significantly lower ECAP thresholds, T- and C-levels than patients with the straight des Nucleus™ 522 implant. The distance of individual electrode contacts to the medial wall varies among contacts of the same array.
Conclusion: Our results show that the electrode position has a significant effect on both electrophysiological and psychophysical parameters. Low psychophysical thresholds are among other aspects relevant for prolonging battery life. We are currently evaluating the relationship between the spread of excitation and the intracochlear position of electrode contacts as well as the effects on speech perception and will report on those outcomes.

Session ID: S6-1
Session Title: Electrode Array
Abstract ID: 472
Title: Short and Standard Electrodes in Infants with Profound Deafness
Authors: Camille C. Dunn, PhD1, Elizabeth Walker, PhD2, Tanya Van Voorst, AuD1, Stephanie Gogel, AuD1, Marlan Hansen, MD1, Bruce Gantz, MD1; 1Otolaryngology, Univ. of Iowa, Iowa City, IA, 2Communication Disorders, Univ. of Iowa, Iowa City, IA.
Abstract: Introduction: Bilateral cochlear implantation in children with profound sensorineural hearing loss has become a well-accepted approach to aural habilitation. Although the benefits of binaural listening using two cochlear implants are compelling, there is some concern that bilateral implantation...
might limit children from taking advantage of future advances in molecular and/or genetic treatments of the inner ear. Placement of standard length electrode arrays more than 20 mm into the scala tympani usually results in significant damage to the scala media, Organ of Corti and supporting cells. Preservation of the supporting cells in the Organ of Corti might be of particular interest as these cells have been shown to be the progenitors of hair cells in birds and other animals. The purpose of this feasibility study is to evaluate whether the use of a shorter length cochlear implant in one ear and a standard electrode in the contralateral ear is a viable option for children with profound bilateral sensorineural hearing loss. A secondary purpose of this study is to determine if the ear with the shorter length electrode performs similarly to the standard length electrode.

**Methods:** This FDA-approved investigational device exemption study is being conducted as a repeated-measure, single-subject experiment. Nine pediatric subjects between the ages of 12-24 months with profound bilateral sensorineural hearing loss were implanted with a 10 mm electrode in one ear and a 24 mm electrode in the contralateral ear and 8 pediatric subjects between the ages of 12-24 months have been implanted with a 16 mm electrode in one ear and a 24 mm electrode in the contralateral ear. Speech perception was evaluated pre- and post-operatively using the IT-MAIS parent questionnaire. The Early Speech Perception test (ESP), Children’s Vowel, and PB-K words were used to evaluate speech perception and the Minnesota Child Development Inventory and Preschool Language Scales-3 were used to evaluate global language development.

**Results:** Preliminary results for all children have been collected pre- and post-operatively using the IT-MAIS. All children showed incremental improvements in their scores overtime. The ESP and Children’s Vowel results indicated no difference between the individual ears for the children tested. Some differences between ears favoring the longer electrode were indicated using an open set PBK-word test. Performance compared to age-matched children implanted with standard bilateral cochlear implants showed similar results for speech perception and language outcomes.

**Conclusion:** The use of a shorter length cochlear implant in one ear and a standard long electrode in the contralateral ear might provide another option for bilateral cochlear implantation in children with bilateral profound sensorineural hearing loss. Waiting until children can perform an open-set word score post-operatively is necessary to determine similarities or differences between the ears.

**Session ID:** S6-1
**Session Title:** Electrode Array
**Abstract ID:** 473
**Title:** Surgical Outcomes with a New Slim Modiolar Cochlear Implant Electrode Array
**Authors:** Jacques Herzog, MD1, Jonathan Mcjunkin, MD2, Nedim Durakovic, MD3, Craig Buchman, MD4;
1Ctr. for Hearing and Balance Disorders, Chesterfield, MO, 2Otolaryngology, Washington University, St Louis, MO, 3Otolaryngology, Washington Univ., St Louis, MO, 4Washington Univ., St Louis, MO.
**Abstract:** **Introduction:** The objective of this study is to describe the surgical outcomes of patients implanted with a new, slim modiolar cochlear implant array from a tertiary cochlear implant center.
**Methods:** All patients met conventional cochlear implant candidacy criteria. Pre- and postoperative pure tone audiometry and speech perception testing were carried out in a standard fashion. Intraoperative radiographic imaging results, electrode impedances, and NRT were collected.
**Results:** 100 consecutive patients have been implanted to date. Intraoperative electrode tip rollovers were identified using plain film radiographs while still in the operating room. There were no tactile or visual clues, impedance anomalies, or NRT abnormalities that identified tip rollovers during/following insertion. All tip rollovers were resolved with electrode re-insertion at the same setting. Many patients
had preserved auditory function at the 3-month postoperative interval. Consistent, full-length scala tympani insertions were confirmed using postoperative CT imaging in a subset of individuals.

**Conclusion:** When using the slim modiolar cochlear implant electrode array, intraoperative radiographs are necessary to confirm placement and avoid intraoperative tip rollovers. Techniques will be described to avoid this outcome. The Slim modiolar array has excellent peri-modiolar placement within scala tympani. Hearing preservation is possible with this device.

**Session ID:** S6-2  
**Session Title:** Fitting  
**Abstract ID:** 175

**Title:** MAP Optimisation with Artificial Intelligence  
**Authors:** Paul J. Govaerts, MD, MSc, PhD, Miguel Artaso, MSc, PhD, Geert De Ceulaer, Eng., David Pascoal, M.Aud., Matthias Meeuws, MSc, Martine Coenen, MA, PhD; The Eargroup, Antwerp-Deurne, Belgium.

**Abstract:** Introduction: The fitting of cochlear implants to date is an art in the hands of experts. The steady increase in cochlear implant recipients and the need for evidence based medicine require the optimisation of this process. The authors have introduced the concept of Target driven, computer assisted fitting. Target refers to audiology, spectral discrimination, loudness scaling and speech audiometry. Computer-assisted refers to applications based on Artificial Intelligence (AI).

**Methods:** Concept The concept and working principles of this new approach will be explained. The switch-on is characterized by an incremental series of prebuilt MAPs. Test results are entered into FOX, the software application with AI. After analysis, FOX recommends MAP changes to improve the test results. A typical fitting session takes 30-60' time and a typical first year fitting series consists of 4 sessions for adults and 1-2 additional sessions for children under 6 years. Adults: retrospective study Since the measurable impact of this fitting approach can best be shown in adults, eighty six adult CI recipients with postlingual deafness and who received a CI between 1999 and 2015 underwent annual assessments including speech audiometry with open set monosyllables and phoneme scoring. A weighed average phoneme score at 40, 55, 70 and 85 dBSPL presentation level is plotted as a function of time. Children: case demonstration A girl with congenital deafness due to CMV infection, received a first CI (Cochlear Nucleus) at the age of 8 months and a second CI at 11 months. She received an incremental series of prebuilt MAPs at switch-on. The switch-on took only a few minutes and will be shown on video. Subsequent sessions comprised audiometry and spectral discrimination.

**Results:** This new and systematic approach comprises (1) the repetitive monitoring of the CI recipient’s functional state by well described outcome measures, which come with pre-set targets; (2) an in depth knowledge and modelling of the CI behaviour in the acoustical, electronic and electrical domains; and (3) artificial intelligence to suggest MAP changes to bring the functional state to target. The retrospective study in 86 adults shows an increase in the average speech audiometric scores from 56% phoneme score in 2008 to 76% in 2016. We will argue that this improvement is unlikely to be the result of processor upgrades or learning effects. The case demonstration will show a typical and uneventful switch-on and early follow-up of an early implanted child. It will show how this (semi-)automated switch-on does not require objective measures and is very comfortable for the child.

**Conclusion:** The introduction of Artificial Intelligence in CI fitting is essential in this new approach of target-driven, computer-assisted CI fitting. This approach is systematic and (semi-)automated and helps the audiologist to obtain good psychoacoustic results with small variation.

**Session ID:** S6-2  
**Session Title:** Fitting
Abstract ID: 442
Title: From Activation to Complex Programming: The When, Why and How of Pediatric NRT
Authors: Yetta Abrahams, Masters of Clinical Audiology, Aleisha Davis, Masters of Speech Pathology; The Shepherd Ctr., Newtown, Australia.
Abstract: Introduction: Neural response telemetry (NRT) has been available for clinical use for many years and is well established as a tool that provides an effective basis for the management of pediatric cochlear implant recipients. There is however significant variation in how clinicians apply these tools, and very little pediatric data to described the optimal frequency of measuring NRT thresholds. With recent advances in programming tools, the measurement of NRT thresholds has been further developed and refined resulting in significant improvements in the ease and efficiency of making these measurements. This study aims to gather recent information to support clinical decisions about when and why clinicians should measure these responses and what clinical impact this might have.
Methods: A retrospective review of clinical data was conducted analysing the NRT responses of 180 paediatric ears from a single cochlear implant program. Responses were collected from intraoperative testing, initial activation and any subsequent appointments where NRT responses were measured. The amount of variation in NRT thresholds over time for each individual was reviewed in conjunction with electrical impedance values and measures of their functional listening abilities.
Results: The analysis of individual patterns of variation and stability in NRT thresholds provide the basis for the evolution in clinical programming protocols. As a result of this analysis a range of clinical processes have been appropriately streamlined, improving the overall clinical efficiency within the pediatric cochlear implant service and the experience for children and their families. This is demonstrable in both straightforward and more complex clinical cases. Overall for this cochlear implant program, the number and frequency of programming appointments immediately after activation has been reduced, as has the duration of time taken for children to demonstrate optimal access to sound.
Conclusion: A clear understanding of NRT stability and change over time is extremely useful for clinicians involved in optimising listening outcomes for children and provides the basis for improving children’s outcomes and clinical efficiencies in the short and longer term.

Session ID: S6-2
Session Title: Fitting
Abstract ID: 477
Title: Clinical Trial Results Wireless Programming Pod
Authors: Sara Neumann, AuD, Mila Morais Duke, AuD; Hearts for Hearing, Oklahoma City, OK.
Abstract: Introduction: Cochlear implant technology has continued to develop rapidly in recent years especially with regard to wireless technology. Historically, hardwired programming cables have been a reliable and widely accepted solution for clinical programming sessions. Some clinical limitations to hardwire programming cables may include room set-up (distance from computer to patient chair), active pediatric patients, and occasional programming cable malfunction. As a novel solution to these challenging programming situations, Cochlear has developed a wireless programming interface, named the Cochlear Wireless Programming Pod (WPP). The WPP was recently evaluated as part of a clinical multi-center clinical trial.
Methods: Thirty unilaterally implanted participants across three clinical sites were programmed with the Wireless Programming Pod in the multi-center clinical study. Study participants were seen for two clinical visits approximately one month apart. Subjective feedback was obtained from the audiologist at each programming session. This feedback included reliability of Wireless Pod during the study
programming session, ease of use, clinical considerations and preference of programming interface for future sessions.

**Results:** Subjective audiologist feedback indicated the Wireless Programming Pod was reliable and easy to use in an overwhelming majority of programming sessions. With regard to future programming sessions, clinicians strongly preferred the WPP interface in lieu of standard/hardwire programming methods.

**Conclusion:** In this dataset, the Cochlear Wireless Programming Pod appears to be an effective alternative for cochlear implant programming sessions. This technology development may be a beneficial interface for programming sessions in the future compared to standard/hardwire programming configurations.

**Session ID:** S6-2  
**Session Title:** Fitting  
**Abstract ID:** 478

**Title:** Real World Listening Environments and the Success of Children Using SCAN  
**Authors:** Yetta Abrahams, Masters of Clinical Audiology, Aleisha Davis, Masters of Speech Pathology; The Shepherd Ctr., Newtown, Australia.

**Abstract:** **Introduction:** Since the introduction of datalogging and automated auditory scene analysis sound processing (SCAN) in the Nucleus 6 sound processor, clinicians have been divided about the appropriateness of these applications for the pediatric population. Datalogging has provided details about the variety and nature of listening environments children are in with a level of detail previously unobtainable. Clinicians now have access to significant evidence to drive clinical decisions to ensure listening is optimal for all children, particularly given the amount of background noise children are typically exposed to. This detailed information provided by datalogging can be used to support the use of SCAN for all listeners and by closely monitoring listening and spoken language performance, children’s listening can continue to be optimised for the true breadth of listening environments they are living and learning in on a daily basis.

**Methods:** A retrospective review of clinical programming data from children with cochlear implants from a single pediatric cochlear implant program was conducted. Datalogging and program settings for over 100 children under 10 years of age were reviewed in conjunction with measures of functional listening and language abilities. Detailed analysis was undertaken to review the features of listening environments for different age groups, as well as the impact of the use of SCAN for listening and spoken language development.

**Results:** Children from 6 months through to 10 years of age spend time in a variety of listening environments, and are exposed to a range of background noise far greater than previously expected by clinicians and families. The use of SCAN in this population has not in any way impeded the progress of functional listening or speech and language development and has been well accepted by all recipients.

**Conclusion:** Children, families and clinicians benefit positively from a more realistic understanding of the listening environments children are spending time in outside of a clinical setting. Across a variety of ages, children spend time in extremely varied listening environments, and can therefore in theory benefit significantly from automated optimisation of sound processing such as SCAN. When this is applied in the pediatric context, listening and language performance is in no way hindered, and the learning experience for the recipient is consistently enhanced.

**Session ID:** S6-2  
**Session Title:** Fitting  
**Abstract ID:** 488
Title: Evaluation of the Kanso Sound Processor: Clinical Trial results

Authors: William Shapiro, AuD
New York Univ., New York, NY.

Abstract: Introduction: Results of two clinical trials evaluating the Kanso Sound Processor will be presented. The Kanso Sound Processor is a unique off-the-ear (OTE) configuration of sound processor with integrated coil and magnet for those individuals seeking a discreet off the ear solution. This dual microphone OTE processor allows access to Nucleus 6 technology and wireless connectivity. The objective of these studies was to evaluate the acceptance of the Kanso Sound Processor with emphasis on subjective hearing performance, retention & comfort, reliability and ease of use.

Methods: For the two studies, 50 participants were upgraded to the Kanso Sound Processor. These participants were across three centers in the United States (30 participants) and one in Sydney, Australia (20 participants). Both studies utilized a single-subject, repeated measures design which allowed for each participant to act as their own control. Subjective data was collected via diaries and questionnaires from all 50 participating individuals with regard to retention, comfort, ease of use, subject hearing performance and connectivity. This data will be presented in addition to supporting speech perception data on a subset of participants using the N6 behind-the-ear (BTE) processor and the Kanso (OTE) processor. Test metrics available for the 20 aforementioned participants includes CNC Words in quiet, and Speech Reception Threshold (SRT) with adaptive co-located noise.

Results: Qualitative usability data indicated the Kanso Sound Processor provides a more discreet lifestyle wearing option. Participants rated the OTE processor better with regard to comfort, retention, ease of use when compared to their own BTE processor. Speech perception results did not indicate significant differences between the Kanso OTE and the N6 BTE sound processor on CNC words in quiet or adaptive SRT testing with co-located noise.

Conclusion: Participant self-reported ratings following take home experience indicate that the Kanso OTE sound processor provides benefit particularly for participants seeking a more discrete and easy to use device compared to conventional BTE sound processor offerings. Clinical speech performance also demonstrates the benefits of dual microphone directional processing in the Kanso OTE processor.

Session ID: S7-1
Session Title: Telehealth / Delivery
Abstract ID: 194
Title: Telehealth: Remote Programming of Cochlear Implants
Authors: Allison Biever, Au.D.
Rocky Mountain Ear Ctr., Englewood, CO.

Abstract: Introduction: The remote model of service delivery is gaining traction across medical disciplines and is the next step for the field of cochlear implants. Because cochlear implants require regular follow up visits with an audiologist, remote programming is a logical and valuable option for recipients who have difficulty getting to a clinic. This multi-center investigation explored the safety and efficacy of remote cochlear implant programming for the purpose of establishing practice guidelines and increasing recipients’ access to care.

Methods: Forty cochlear implant recipients (ages 12-88) were recruited at four US sites and completed speech perception testing at their regular clinic. At the second visit, the subjects participated in a remote programming session whereby the subject and the audiologist were in different physical locations. Programming was conducted through a video conferencing platform, allowing the subject and the audiologist to see and hear one another through the computer as the audiologist remotely controlled the programming software. At the third visit, the subject repeated the speech perception
testing, and completed subjective questionnaires about their experience. This visit sequence was completed once with a designated facilitator present, and once with the subject alone.

**Results:** Subjects were successfully programmed remotely, and clinicians documented the techniques they developed for ensuring a satisfactory session. Mean speech perception scores showed no significant difference between programming conditions, indicating performance equivalency of in-office programmed maps and remotely programmed map. Feedback from subjects and clinicians indicated that telehealth is a viable alternative to traditional in-office programming that has benefits for both recipients and clinics.

**Conclusion:** Telehealth is a safe and effective option for cochlear implant users who cannot easily travel to regular audiology visits. Audiologists should be trained in the nuances of using remote programming technology and should use clinical judgment when selecting subjects who are appropriate for telehealth. Further discussion points on this topic include: remote programming in various populations, state licensure requirements, and reimbursement.

**Session ID:** S7-1  
**Session Title:** Telehealth / Delivery  
**Abstract ID:** 521  
**Title:** Remote Programming of Cochlear Implants - Access Opportunities and Challenges  
**Authors:** Tom Walsh, MBA  
Advanced Bionics, Valencia, CA.

**Abstract:** **Introduction:** CI recipients require a lifetime of care and audiologists must find ways to serve established recipients without compromising access to CI by new candidates. Previous presentations at this conference have explored the feasibility and efficacy of CI remote programming. Several challenges exist to widespread adoption of CI remote programming services, and this session will focus on the regulatory/legal hurdles.

**Methods:** This talk will briefly review the literature on CI remote programming feasibility/efficacy to date and discuss the regulatory/legal issues impacting the use of remote programming for cochlear implants.

**Results:** The presentation will identify specific regulatory/legal hurdles to CI remote programming, and will discuss potential actions to address those challenges.

**Conclusion:** Manufacturers, clinicians, and professional societies have the opportunity to collaborate to address regulatory/legal issues impacting access to remote programming, and ultimately, access to CI services for the growing population of CI recipients.

**Session ID:** S7-1  
**Session Title:** Telehealth / Delivery  
**Abstract ID:** 60  
**Title:** Telehealth for Teens: Remote Programming Benefits in the Adolescent Population  
**Authors:** Lisa R. Park, AuD1, Holly Teagle, AuD1, Jennifer Woodard, AuD1, Erika Gagnon, AuD2;  
1Otolaryngology/Head and Neck Surgery, Univ. of North Carolina at Chapel Hill, Durham, NC,  
2Otolaryngology/Head and Neck Surgery, Univ. of North Carolina at Chapel Hill, Raleigh, NC.

**Abstract:** **Introduction:** For quite some time, audiologists at this institution have used telehealth as a way to evaluate device function (impedance and evoked response measures) in the operating room for both children and adults. The successful implementation of this technology along with the noted financial and practical benefits proposes investigation into remote programming of cochlear implants. Other medical disciplines have successfully implemented telehealth programs with patients. Studies investigating remote programming with adults have shown similar performance with remote MAPs.
when compared to programming performed in the office. For patients who have significant travel needs, health concerns, and transportation limitations, remote programming is an attractive option. This study presents a subset of data from a larger multicenter study investigating the efficacy and safety of remote cochlear implant programming. For the technologically savvy teenage population, remote programming can give ownership and autonomy to the mapping process while maintaining the integrity of sound quality.

Methods: Data and video from 10 subjects between the ages of 12 and 17 are included. These individuals were tested in the sound booth with recorded CNC words before and after two remote programming sessions. The first programming session was facilitated in-person with a trained assistant, while the second was not. After each remote session, the subject wore the new program for several weeks before returning to the clinic for sound field testing. These results were compared to those obtained with the subject’s familiar MAP. Subjective data on the efficiency of the session were recorded.

Results: The remote programming process was simple for all of the adolescent subjects and minimal training was required. Speech perception for programs created through telehealth were comparable to those obtained with familiar MAPs created in person. For a few subjects, outcomes were slightly better with the remote programs. Anecdotal observation for these subjects included an increase in subject engagement during remote programming which may account for the increase.

Conclusion: Programming cochlear implants via a telehealth model can be an effective and safe method of delivery for adolescents. Potential use, strategies, and caveats will be reviewed.

Session ID: S7-1
Session Title: Telehealth / Delivery
Abstract ID: 467
Title: Challenges and Outcomes Associated with Providing Teletherapy to Vulnerable Children with Hearing Loss
Authors: Matthew Fitzgerald, Ph.D.1, Meg Farqhar, MSW1, Joy Kearns, M.S.2, Jannine Larky, M.A.1, Kathleen Sussman, M.S.2, Arturo Manriquez, B.S.1, Nikolas Blevins, M.D.1; 1Otolaryngology - Head and Neck Surgery, Stanford Univ., Palo Alto, CA, 2Weingarten Children’s Ctr., Redwood City, CA.
Abstract: Introduction: Language acquisition in children with prelingual hearing loss is often delayed without appropriate early intervention. Unfortunately, many children with hearing loss lack access to necessary therapy. This is particularly true for ‘vulnerable’ populations, having low socioeconomic status, lack of social support, or language/cultural barriers. Working with these populations presents multiple challenges. The Babytalk program has provided listening and spoken-language teletherapy, social work services, and audioligic counseling for vulnerable children throughout California since 2012.

Methods: Our objectives were: (1) To characterize objective markers to identify vulnerable children. (2) To identify specific needs and strategies to deliver teletherapy to vulnerable populations. (3) To quantify auditory and language outcomes in vulnerable populations, and relate those to observed challenges. We retrospectively examined demographic data from participants in the Babytalk program regarding socioeconomic status, geographic isolation, familial education, and other social issues. We correlated these with familial performance in teletherapy, including rates of attendance to teletherapy and clinical appointments, hours of case management needed per hour of therapy delivered, and the Parental Stress Index. We examined our strategies to optimize teletherapy. These were provided by reports from program therapists and social worker. Auditory and language outcomes were quantified by several measures, including the LittleEars Questionnaire (LEQ), the Preschool Language Scales, 5th edition (PLS-5), and the MacArthur Bates Communication Development Index (CDI).
Results: To date, 85 families have been enrolled for teletherapy with BabyTalk, with an additional 42 families receiving counseling services only. Approximately 77% could be classified as vulnerable. Several trends emerged from analysis of data from vulnerable children. First, consistent parental engagement was challenging, resulting in higher rates of missed sessions. As a result, considerably more resources from social work, teletherapists, and support staff were necessary to provide expected services. A second key trend was that improved communication and rapport initiated by providers appeared to improve compliance, and therefore overall outcomes. Empathy and flexibility were key contributors to facilitation of services. Finally, despite the challenges associated with vulnerable children, improvements in auditory and language behaviors were noted. For example, LEQ, PLS-5 and CDI scores generally improved relative to a pre-therapy baseline. In some instances, vulnerable children obtained scores similar to those obtained by children with normal-hearing. However, most still showed significant delays despite improving during teletherapy.

Conclusion: Vulnerable children and families affected by hearing loss are likely to require additional time, effort, and resources when enrolled in a teletherapy program. Such families can be prospectively identified through examination of demographic data. Strategies and resources to increase communication and parental engagement and can mitigate these challenges, thereby enabling improvements in auditory and language development. This information is likely to be useful to establish expectations for resource allocation as teletherapy programs become increasingly commonplace.

Session ID: S7-1
Session Title: Telehealth / Delivery
Abstract ID: 390
Title: Delivering Cochlear Implantation to Underserved Populations: Cost-Effectiveness and Outcomes among the Plain Population
Abstract: Introduction: Providing cochlear implantation to a rural, technologically-limited, and financially impoverished population provides significant challenges. In this paper we review an algorithm for cost-effective evaluation and treatment of fourteen children with profound hearing loss in the Plain population who received cochlear implantation. Models for habilitation, use of telemedicine for mapping, and speech and language outcomes will be discussed.
Methods: The medical records and family questionnaires of fourteen children from the Plain population undergoing cochlear implantation through a specialty medical clinic in rural Pennsylvania were reviewed for expense of work-up, patient demographics, related medical conditions, and speech and language outcomes.
Results: The average age at implantation was 20.9 months (range9-53 mo.) and the average follow-up was 28 months (range9-50 mo.). There were 8 males and 6 females implanted; 10 patients had bilateral implantation and 4 unilateral implantation. Ten patients had an identified genetic disorder, one had congenital CMV, and three had an unknown source of hearing loss. Speech and language outcome measures were assessed with LittleEARS and pre- and post-implant family satisfaction with the child’s speech perception. There were significant cost-savings to families through use of a stream-lined work-up and limitation of travel utilizing telemedicine for mapping and programming, and home listening and spoken language therapy. All children met or exceed their hearing age on testing and there was a high family satisfaction rating with speech perception.
Conclusion: Use of cost-effective measures (focused evaluation, telemedicine, and home therapy) allows for successful habilitation with cochlear implantation of a rural, underserved population of children.

Session ID: S7-2
Session Title: Audiology Assessment and Indications
Abstract ID: 304
Title: Relationship between Objective and Behavioural Audiology for Infants Being Assessed for Cochlear Implantation: Implications for CI Candidacy Assessment
Authors: Jaime Leigh, PhD1, Rebecca Farrell, MAud1, Denise Courtenay, MSpPath1, Richard Dowell, PhD2, Robert Briggs, FRACS1;
1Cochlear Implant Clinic, Royal Victorian Eye and Ear Hosp., East Melbourne, Australia, 2Audiology and Speech Pathology, Univ. of Melbourne, Carlton, Australia.

Abstract: Introduction: The wide spread introduction of universal newborn hearing screening has resulted in a dramatic reduction to the age of diagnosis for children with congenital hearing impairment. Parents of children with hearing impairment can now seek intervention (language intervention and device options) for their child within the first few months of life. The age a child receives a cochlear implant (CI) is well accepted as having a significant impact on the speech perception, speech production and oral language outcomes for children with severe-to-profound hearing loss. Early implantation provides a child with congenital severe-to-profound hearing loss the opportunity to develop oral language skills at a rate comparable to their typically hearing peers. Recent evidence suggests that children with hearing loss in the severe range may now also benefit from a CI. As these findings become more widely accepted, paediatric CI services are under increased pressure to make CI recommendations for infants as early as possible. Providing evidence-based and timely recommendations for implantation is a significant challenge for paediatric CI programs. Clinical practices at most tertiary institutions providing CI services for young children require the establishment of reliable behavioural audiological results prior to recommending a CI. Recent clinical data from a major tertiary medical facility, providing CI services for children for more than 30 years, suggests that the time frame from the initial hearing loss diagnosis (objective audiology) to the establishment of consistent behavioural hearing levels can vary considerably (from four weeks to one year and four months) with several possible influencing factors. The time between hearing loss diagnosis and confirmation of behavioural hearing is a key factor affecting, and potentially delaying, the age a child receives a CI. This study aimed to challenge the need for behavioural audiology and evaluate feasibility of making CI recommendations based on objective audiology, with the goal of reducing the time taken for CI candidacy evaluation.

Methods: Retrospective review of patient files for all children (N=124) referred to the paediatric CI service before three years of age over a three-year period was undertaken. Results for click-ABR, ASSR and behavioural audiology at 500, 1k, 2k and 4k Hz and tympanometry were collected and relationships were investigated for 64 children who met the inclusion criteria. Data were excluded for 59 children due to the presence of AN findings, ME pathology at the time of testing, if no response was obtained on ASSR at 85 dB and testing was discontinued and/or behavioural testing was judged to be unreliable by two experienced clinicians.

Results: Results for objective measures (click-ABR and ASSR) were significantly correlated with behavioural results. The correlations, however, were poorer than expected with limited predictive value. Potential explanation for the weak correlations will be discussed.

Conclusion: Findings of this study do not support making CI recommendations based on the findings of click-ABR and ASSR alone. Reducing the average age children with severe-to-profound hearing loss
receive a CI is a priority for the institution were this study was conducted. An alternate evaluation pathway for infants which incorporates a multifaceted assessment is warranted and will be proposed.

**Session ID:** S7-2  
**Session Title:** Audiology Assessment and Indications  
**Abstract ID:** 188  

**Title:** The Effect of Front-End Processing on Speech Perception of Cochlear Implant Users  
**Authors:** Kristen Rak, Priv.- Doz. Dr med.1, Sebastian Schraven, Priv.- Doz. Dr med.1, Andreas Radeloff, Priv.- Doz. Dr med.2, Alexander Möltner, Audiologist3, Rudolf Hagen, Prof. Dr. Dr. h.c.1;  
1Department of Oto-Rhino-Laryngology, Plastic, Aesthetic and Reconstructive Head and Neck Surgery and, Univ. of Wuerzburg, Wuerzburg, Germany, 2Department of Oto-Rhino-Laryngology, Head and Neck Surgery „Otto Körner“, Univ. of Oldenburg, Oldenburg, Germany, 3MED-EL GmbH, Innsbruck, Austria.  

**Abstract:**  
**Introduction:** Over the past few years, most cochlear implant (CI) developments that aimed at enhancing speech recognition have focused on signal-processing strategies and electrode design. However, considerable improvements may also be reached by employing front-end processing. The SONNET audio processor provides users of a CI with two front-end processing features: Microphone Directionality (MD) and Wind Noise Reduction (WNR). Both features are available in 3 different modes: MD Omnidirectional, MD Natural, MD Adaptive and WNR Off, WNR Mild, WNR Strong, which can be combined in various ways. The aim of the study was to assess speech perception outcomes with different combinations of MD and WNR implemented in the SONNET audio processor compared to the OPUS2 audio processor.  

**Methods:** 31 adult unilateral CI users with a minimum of 6 months experience with their prior audio processor were upgraded to the SONNET. Three test visits were conducted, visit I at upgrade, visit II 3 weeks and visit III 6 weeks after the upgrade. During the study, subjects only used the SONNET. At each visit the subjects were tested with their prior audio processor (OPUS2) and with the SONNET programmed with different combinations of MD (omnidirectional, natural and adaptive) and WNR (off, mild and strong) modes. All tests were conducted in a quiet office-like room with an average reverberation time of 0.55 seconds. At visit 1 subjects were tested using the Oldenburg adaptive sentence test (OLSA) with the speech signal presented from the front and background noise presented continuously from 90°, 180° and 270°. This test was done in the same condition with babble noise. At visit 2 subjects were tested using the OLSA with wind blowing to the audio processor from an angle of 45° at a speed of approximately 7 km/h with no additional background noise. At visit 3 subjects were tested in quiet using the Freiburger monosyllables test.  

**Results:** The results of speech tests in both speech shaped and babble noise with the SONNET in its default setting (MD “natural” and WNR “mild”) showed significant benefit for speech perception in noisy conditions comparing to the OPUS2. Comparing the results of speech test with all 9 combinations of MD and WNR in wind revealed that in windy conditions speech perception is always better with WNR turned on compared to WNR “Off”. The results of the Freiburger monosyllabic test in quiet resulted in better speech perception with the SONNET than with the OPUS 2.  

**Conclusion:** Employing front-end processing in CI audio processors improves speech recognition in difficult hearing conditions. The two new features, microphone directionality and wind noise reduction in the SONNET in its default mode give CI users significant benefit for speech perception in noisy and windy conditions.
Title: Update on the Pediatric Minimum Speech Test Battery for Children with Hearing Loss
Authors: Andrea D. Warner-Czyz, Ph.D.1, Kristin Uhler, Ph.D.2, Rene Gifford, Ph.D.3;
1Communication Sciences and Disorders, The Univ. of Texas at Dallas, Dallas, TX, 2School of Medicine, Univ. of Colorado - Denver, Aurora, CO, 3Vanderbilt Univ., Nashville, TN.
Abstract: Introduction: Assessment of patient outcomes and documentation of treatment efficacy serve as an essential component of (re)habilitative audiology. However, no standardized protocol exists for the assessment of speech perception abilities for children with hearing loss. In fact, individual clinicians, sites, and researchers use a wide variety of practices and protocols to evaluate this population. This presents a significant challenge in tracking performance of children who utilize various hearing technologies for within-subjects assessment, between-subjects assessment, and even across different facilities. The adoption and adherence to a standardized assessment protocol could help facilitate continuity of care, assist in clinical decision-making, allow clinicians and researchers to define benchmarks for an aggregate clinical population and, in time, aid with patient counseling regarding expectations and predictions regarding longitudinal outcomes.
Methods: The Pediatric Minimum Speech Test Battery (PMSTB) working group, comprised of clinicians, scientists, and industry representatives, commenced in 2012 and worked collaboratively to construct the first PMSTB.
Results: This paper will present the PMSTB hierarchical protocol, which includes measures designed to evaluate speech discrimination for infants and word/sentence recognition in quiet and in background noise for children using hearing technology before school entrance at the age of 5 years or a language equivalent of five years.
Conclusion: This consensus statement represents an evidence-based approach to pediatric speech perception, incorporating clinical expertise, research support, and patient/family concerns. Implementation of the data-driven and clinically-relevant PMSTB in clinical practice and dissemination of associated data are both critical for achieving the next level of success for children with hearing loss and for elevating pediatric hearing health care ensuring evidence-based practice for (re)habilitative audiology.

Session ID: S7-2
Session Title: Audiology Assessment and Indications
Abstract ID: 291
Title: Implantation of Non-Traditional Pediatric Cochlear Implant Candidates: An Evaluation of Outcomes and Factors Contributing to Post-Operative Performance
1Department of Hearing and Speech, Vanderbilt Bill Wilkerson Ctr., Nashville, TN, 2Department of Otolaryngology- Head and Neck Surgery, Vanderbilt Bill Wilkerson Ctr., Nashville, TN.
Abstract: Introduction: Current FDA labeling for cochlear implant manufacturers severely limits the number of pediatric patients that could potentially benefit from cochlear implantation. However, many implant centers are currently implanting pediatric patients that do not meet FDA labeled indications for cochlear implantation. The purpose of this study was to further examine the degree of benefit derived by children who have either asymmetric hearing loss or better than criterion hearing and/or speech understanding and further investigate factors that may be useful in predicting outcomes in this non-traditional population.
Methods: Data for 38 subjects were obtained from a retrospective review of medical records for pediatric patients under the age of 18 implanted at a tertiary academic referral center. Inclusion criteria were as follows: 1) pure tone average (PTA) less than 70 dB HL in one or both ears for children between
the ages of 2 and 18 and less than 90 dB HL for children under the age of 2 and/or 2) better than criterion speech understanding for older children. Demographic information, pre- and post-implantation speech perception scores in the cochlear implant (CI) only condition and bimodal condition, scores on auditory questionnaires, parental and patient report of device usage, and datalogging information will be used in subsequent multi-variate analyses.

Results: At the time of abstract preparation, data analysis for 38 subjects revealed that non-traditional pediatric cochlear implant recipients exhibited significant improvement in speech perception scores in both the CI only and bimodal conditions following implantation (p < 0.05). Additionally, age at implantation was inversely correlated with performance in the CI only condition, but there was not a significant correlation between age at time of implantation and post-implantation performance in the bimodal condition, likely due to the prevalence of asymmetric hearing loss in this population. We will continue to add patients to the data set and further analyses will be completed in order to determine whether these findings are consistent for a larger number of patients, various degrees of asymmetric hearing loss, and whether we observe a point of diminishing return.

Conclusion: These data provide further evidence that non-traditional pediatric CI recipients derive significant benefit from cochlear implantation. These results have significant clinical implications for the expansion of pediatric candidacy criteria. Further analysis may reveal clinically relevant factors that can be used to predict postoperative outcomes and should be considered when evaluating this non-traditional population.
**Results:** Immediately post-operatively, hearing was preserved in all ears. Long term follow up suggests mostly stable hearing thresholds. Of greater importance, functional listening and speech clarity improved for all children who were implanted prior to speech patterns becoming established, but this was not the case for some children who were implanted later in childhood.

**Conclusion:** Cochlear implantation early in life is equally important for children with congenital partial hearing as it is for children with congenital severe to profound hearing loss. Being unable to detect and discriminate mid to high frequency speech sounds can result in poor speech clarity that cannot be mediated later in childhood.

**Session ID:** S7-3

**Session Title:** Rehabilitation and Outcomes

**Abstract ID:** 382

**Title:** The Relationship between Factors of Cognition, Speech Perception, and Language in Children with Cochlear Implants

**Authors:** Elizabeth Adams Costa, Ph.D.1, Julie Verhoff, Au.D., Ph.D.2, Sharlene Wilson Ottley, Ph.D.3, Christine Mitchell, ScM4, Nancy Mellon, M.A.5, Meredith Ouellette, M.A.5, Colleen Caverly, M.A.1; 1Department of Psychology, The River Sch./RiverREACH Clinic, Washington, DC, 2Department of Audiology, The River Sch./RiverREACH Clinic, Washington, DC, 3Department of Speech and Language Pathology, The River Sch./RiverREACH Clinic, Washington, DC, 4Epidemiology, Johns Hopkins Bloomberg Sch. of Publ. Health, Baltimore, MD, 5The River Sch./RiverREACH Clinic, Washington, DC.

**Abstract:**

**Introduction:** Outcome data for children with cochlear implants continues to show high variability. Research suggests that age of implantation, degree of residual hearing prior to implantation, maternal sensitivity, socioeconomic status, and nonverbal cognitive abilities influence language outcomes. Studies investigating the cognitive profiles of children with CIs are also variable, but generally report lower scores on measures of verbal abilities and working memory tasks compared to hearing peers. It is hypothesized that working memory is critical to the development of spoken language, and positive correlations have been found between working memory and language development in children with CIs. Nittouer (2016) emphasized the importance of considering how children with CIs function in real world versus controlled laboratory settings. Many children with CIs experience considerable difficulty hearing in noise. There is also a developmental effect associated with speech recognition performance in the presence of background noise: children under the age of five are at an even greater disadvantage than older children in classrooms with poor acoustics. Performance is likely influenced by mediating factors of maturation, cognition, language comprehension, and working memory. The goal of the current study was to investigate the relationship between cognitive factors, language abilities, and speech recognition for children with cochlear implants in a fully inclusive educational model where they have access to typically developing peers.

**Methods:** This cross-sectional study examined data for 22 children between the ages of five and eight to explore the relationship between cognitive flexibility (Fluid Reasoning Index), working memory (Working Memory Index), speech recognition (Articulation Index), listening in noise (Bamford-Kowal-Bench Speech-In-Noise), receptive vocabulary (Peabody Picture Vocabulary Test), and core language (Comprehensive Assessment of Spoken Language).

**Results:** Significant correlations were found between working memory and speech perception (p=0.02), working memory and core language (p=0.01), and receptive vocabulary and core language (p=0.00). A relationship approaching significance was found between receptive vocabulary and speech detection in noise (p=0.06). The relationship between working memory and core language was only found in children with language scores below the mean (p=0.008), but was not present in children with language scores above the mean (p=.86). An older age at activation was associated with a lower language score. None of
the examined variables were significantly associated with speech-in-noise scores, and unlike with the language outcome, there appears to be less of an effect of activation age.

**Conclusion:** The results of the current study suggest that relationships are demonstrated between audiological, cognitive, and language factors. Interindividual variability in neurocognitive processing likely accounts for the demonstrated scatter in outcomes for children with CIs. Studies further examining the neurocognitive profiles of children with high and low language outcomes may help to clarify risk factors, indentify areas for intervention, and predict outcomes.

**Session ID:** S7-3  
**Session Title:** Rehabilitation and Outcomes  
**Abstract ID:** 410  
**Title:** Bilateral Cochlear Implantation in Children with Autism  
**Authors:** Adrien Eshraghi, MD, FACS, Kadri Ila, MD, Fred F. Telischi, MD, Sandra Prentiss, MD, Michael Hoffer, MD, Diane Martinez, MD, Sandra Valendia, MD, Jeenu Mittal, MSc, Ronen Nazarian, MD; Univ. of Miami Miller Sch. of Med., Miami, FL.  
**Abstract:** Introduction: Benefits of bilateral cochlear implantation (CI) in children with severe to profound hearing loss have well been documented; however, outcomes continue to vary. Benefits of cochlear implantation become unclear in those recipients presenting with additional needs such as autism spectrum disorder (ASD). The purpose of this study was to investigate the benefits of bilateral implantation in children with ASD and compare performance to the unilateral implanted kids with ASD and a group of aged matched neurotypical peers implanted.  
**Methods:** A retrospective study of unilaterally and bilaterally implanted children dually diagnosed with deafness Autism Spectrum Disorder (ASD) was conducted. Outcomes of receptive and expressive language scores pre- and post-implantation of five bilaterally implanted ASD, 10 unilaterally implanted ASD children and 15 age matched control neurotypical kids were compared. Additionally, a parental communication survey was administered to assess communication and behavioral scores. Scores were compared across groups.  
**Results:** Receptive language scores were significantly better in the bilaterally implanted group compared to the unilaterally implanted group; however, lower than the neurotypical age-matched peers. Expressive language in the bilaterally implanted group showed improvements over the unilaterally implanted group, but were not statistically significant. In the bilaterally implanted group, parents reported most improvement in music enjoyment, reacting to sounds and vocalization following implantation, while for unilaterally implanted children, parents reported most improvement in name recognition, responding to verbal requests and music enjoyment.  
**Conclusion:** Although outcomes following cochlear implantation of children with ASD lag behind their neuro-typical developing peers, significant benefits in language and behavior were observed in bilaterally implanted children.

**Session ID:** S7-3  
**Session Title:** Rehabilitation and Outcomes  
**Abstract ID:** 89  
**Title:** Development of School-Age and Parent-Proxy Health-Related Quality of Life Measures for Children with Cochlear Implants  
**Authors:** Michael Hoffman, M.S.1, Ivette Cejas, Ph.D.2, Alexandra Quittner, Ph.D.3; 1Psychology, Univ. of Miami, Miami, FL, 2Otolaryngology, Univ. of Miami Miller Sch. of Med., Miami, FL, 3Behavioral Hlth. Systems Res., Miami, FL.
Abstract: **Introduction:** Severe to profound hearing loss is associated with lower health-related quality of life (HRQoL), which reflects the wide-ranging effects of deafness on oral language, cognition, and social/behavioral development. However, there are currently no CI-specific HRQoL measures that were developed using the FDA process. This study presents the first HRQoL instruments (CI-QoL) for children with CIs, ages 6 to 12, and their parents.

**Methods:** These instruments were developed following the FDA Guidance on Patient-Reported Outcomes (2009). Phase I consisted of a literature review to hypothesize a conceptual framework and discussion guides to elicit information from stakeholder focus groups (e.g., physicians, speech pathologists), and open-ended interviews with children and their parents. During Phase II, stakeholders (n = 30) and parent-child dyads (n = 21; M = 9.1 years; M at implantation 4.4) were recruited from CI Clinics in Miami and Philadelphia. Interviews were transcribed and uploaded into Atlas.ti for coding of common themes using content analysis. Based on these results, the conceptual framework was revised and initial instruments were created using the most frequent and impactful concepts. The instruments were designed to be administered on a tablet for automatic scoring. The self-report, child version utilizes a multimodal approach to maximize understanding (i.e., pictorial representations, audio recording of items, written text). Children can simply point and click on the picture or rating. A new set of child-parent dyads (n = 20; Mage = 9.2) were recruited at both sites to complete cognitive testing of the instruments to ensure clarity, ease of use, and comprehensiveness. Based on this feedback, the items were modified, and final draft instruments were created.

**Results:** The initial version of the child measure contained 33 items clustered into 8 domains: Noisy Environments, Academic Functioning, Child Acceptance, Oral Communication, Social Functioning, Fatigue, Emotional Functioning, and Device Management. Based the cognitive interview data, 3 items were removed due to lack of clarity and response variability (e.g., how often does your teacher help you in class?) and 3 items were added (e.g., how often does your child feel uncomfortable?). The initial draft of the parent-proxy included 55 items grouped into 10 scales: those listed above, Behavior Problems, and Parenting Stress. Following cognitive interviews, 5 items were dropped (e.g., how often is your child teased?) and 1 item was added (e.g., how concerned are you about splitting time between your child with a CI and siblings?).

**Conclusion:** CI-specific HRQoL instruments have now been developed for school-age children with CIs and their parents using the FDA protocol. Following a psychometric validation, these CI-specific measures will enable us to track long-term outcomes, identify key targets for intervention, and analyze cost-effectiveness.

**Session ID:** S7-3
**Session Title:** Rehabilitation and Outcomes
**Abstract ID:** 106
**Title:** PEARLS: A Parenting Intervention for Pediatric CI Recipients & Their Families
**Authors:** Ivette Cejas, PhD1, Michael Hoffman, MS2, Domitille Lochet, MS1, Alexandra L. Quittner, PhD3;
1Barton G. Kids Hear Now Center, Univ. of Miami, Miami, FL, 2Psychology, Univ. of Miami, Miami, FL, 3Behavioral Hlth. Systems Res., Miami, FL.

**Abstract:** **Introduction:** Early interventions have the potential to improve language development in deaf children using cochlear implants (CIs); however, few interventions for this population have been developed or evaluated. Recent studies have highlighted the critical role parents play in facilitating language in children with CIs. In particular, the quality of parent-child interactions, specifically maternal sensitivity (MS) and use of facilitative language techniques (FLT), have been shown to positively affect
children's growth in oral language. To date, few parent-focused interventions have been developed to improve parent-child interactions in the context of language learning. The purpose of this study is to develop and evaluate an intervention that focuses on parent sensitivity training and the use of FLTs to improve parent-child interactions and communication in children with CIs (Parent-Child Early Approaches to Raising Language Skills; PEARLS).

**Methods:** A draft manual for the PEARLS intervention was developed and its feasibility was tested in a handful of children. The intervention consisted of 10, 1-hour sessions over 3-months and combined standard auditory-verbal therapy with training in sensitive parenting and higher-level FLTs. Therapists modeled a new parenting or language technique, coaching parents in how to interact in positive, warm ways that encourage child autonomy. Families who agreed to participate completed a baseline assessment, which included: 1) videotaped parent-child interactions coded for both MS and FLTs (Free Play and Art Gallery Task); 2) self-reported parental self-efficacy and involvement (SPISE); 3) parental report of auditory skills (IT-MAIS); and 4) language using the PLS-5. Families also completed a post-assessment following the PEARLS intervention and a 6-month follow-up to evaluate sustainability of skills.

**Results:** Six families with deaf children, ages 12 to 48 months participated in this study. The mean age of the sample was 28.8 months and one parent had less than a high school diploma and 5 had a college degree. Cognitive scores of the children were within the average range (M=113). Post-intervention, parents reported higher self-efficacy and parental involvement. Improvements were also observed in coded maternal sensitivity and auditory skills. Mothers were highly satisfied with the intervention and described the intervention as, “helpful,” “flexible,” “balanced & realistic approach,” and liked that it was “tailored to the family's skill level.” Importantly, parents reported no problems attending the sessions and the AV therapist, who conducted the intervention described PEARLS as helpful and easily integrated into practice.

**Conclusion:** Parent interventions are cost-effective, ecologically valid, and can be translated to “real world” clinical settings. PEARLS is the first evidenced-based intervention designed to improve parent-child interactions and communication in children using CIs. Preliminary results revealed a positive effect on the parent-child relationship, parental involvement and self-efficacy. The plan is to pilot this intervention in a larger group of children. If effective, this intervention has the potential to optimize the benefits of cochlear implantation and guide pediatric cochlear implant programs nationally.

**Session ID:** S9-1  
**Session Title:** Technology and Innovation  
**Abstract ID:** 458  
**Title:** Restoration of the High Frequency Angular Vestibulo-ocular Reflex with Vestibular Implants  
**Authors:** Nils Guinand, MD1, Raymond van de Berg, MD2, Erich Schneider, Prof.3, Maurizio Ranieri, Ing.1, Samuel Cavuscens, Ing.1, Robert Stokroos, Prof.2, Herman Kingma, Prof.2, Jean-Philippe Guyot, Prof.1, Angelica Perez Fornos, PhD1; 1HUG, Geneva, Switzerland, 2MUMC, Maastricht, Netherlands, 3Ludwig-Maximilians-Univ., Munich, Germany.  
**Abstract:** Introduction  
vHIT(video Head Impulse Test) has become a gold standard in vestibular testing. It allows side specific, independent assessment of the 6 semicircular canals in the high frequency range. Therefore vHIT is an optimal test for the evaluation of the performance of vestibular implants, which are devices designed to primarily restore the canal function in patients with a bilateral vestibular loss (BVL). The purpose of this study was to evaluate whether it is possible to restore the high-frequency, angular vestibulo-ocular reflex (aVOR) with a vestibular implant.
Methods
Two patients with a bilateral vestibular loss were fitted with a vestibular implant prototype. The device consists in a modified cochlear implant (MED-EL, Innsbruck, Austria) where 3 electrodes were taken out of the cochlear array and put in separate branches that were implanted in the ampullae of each semicircular canal. The high-frequency, aVOR was assessed using the vHIT(EyeSeeCam system) while motion-modulated electrical stimulation was delivered via one of the implanted vestibular electrodes (S1 – lateral ampullary nerve, S2 – superior ampullary nerve). aVOR gains were compared to control measurements obtained in the patients when the device was not activated.

Results
The aVOR gain in the plane and direction of the implanted ear increased monotonically with increased modulation depths, reaching a maximum gain of 0.48 (S1 - horizontal) and 0.90 (S2 - RALP) at the largest modulation depth tested. The gains away from the implanted ear were much lower (<0.30). There was a significant positive correlation between aVOR gains and modulation depth (Pearson’s linear correlation; S1: R²=0.98, p<0.001; S2: R²=0.94, p<0.01). Both patients presented low aVOR gains (<0.20) when the system was not activated, as expected.

Conclusion
Using the vHIT, these results demonstrate that it is possible to restore the high-frequency aVOR using motion-modulated electrical stimulation of the vestibular afferents, delivered with a chronically implanted, prototype vestibular implant. This result extends previous findings, confirming that our device successfully restores multimodal vestibular function, providing clear evidence that a vestibular implant might become an effective rehabilitation alternative for patients with a BVL in a near future.

Session ID: S9-1
Session Title: Technology and Innovation
Abstract ID: 292
Title: Preliminary Findings of a Parent-focused Intervention Using Mobile and Wearable Technology to Enrich the Everyday Language Environments of Young Children
Authors: Dawn Choo, Master of Speech Pathology1, Shani Dettman, PhD2, Richard Dowell, PhD2, Robert Cowan, PhD3, Jaime Leigh, PhD2; 1The Univ. of Melbourne and The HEARing CRC, Melbourne, Victoria, Australia, 2Audiology and Speech Pathology, The Univ. of Melbourne, Melbourne, Victoria, Australia, 3The HEARing Cooperative Res. Ctr., Melbourne, Victoria, Australia.
Abstract: Introduction: Timely access to audition and engagement in early intervention (EI) are the cornerstones of enhancing communication outcomes for children with sensorineural hearing loss. Children’s language environment and family participation in the early years have also been recognised as influential factors in the development of listening and oral language skills. With the growing number of paediatric cochlear implant (CI) recipients and demands on speech pathology/ EI services, there is an impetus to explore complementary models of care which advocate a participatory approach. Recent advances in technology have provided families of paediatric CI users with the opportunity to be more involved in their own care management outside of clinical appointments through digital and mobile health. This study aims to: (1). explore the use of wearable and mobile technology to promote positive changes in parental language behaviours in daily life and; (2). understand clinician/parents perspectives regarding technology in supporting early language.
Methods: Part 1. Dyads with typical hearing were recruited in Australia for a prospective crossover study. Children were aged between 6 months and 3 years. Mother/child interaction samples were analysed from 8 (16-hour) weekly recordings using the LENA wearable language processor. The use of a mobile app which prompted parents with strategies for creating shared parent-child interaction
opportunities at home was also examined. There were 3 conditions: (A). language recordings only; (B). language recordings and the provision of short feedback sessions based on recorded language counts (frequency of adult words, conversational turns and child vocalisations); (C). feedback and use of the mobile app. Pre- and post- trial child language evaluations were conducted and parent-report questionnaires data (parental knowledge and self-efficacy) were collected. Part 2. Trial participants and clinicians working in EI settings were also invited to complete an online questionnaire exploring their perspectives on wearable and mobile technology.

**Results:** Part 1. Outcomes of the 8-week pilot study supported the use of feedback as a facilitator of enriched language input to the child. Participants had higher average word and conversational turn counts after receiving language feedback and after using the mobile app (Conditions B and C) relative to the control condition (A). Part 2. Preliminary questionnaire responses regarding perspectives on wearable and mobile technology varied considerably; respondents indicated that parental education, cost, and accessibility were key barriers to the integration of technology in EI.

**Conclusion:** Part 1. This study suggested that, with adequate support, technology can promote parental engagement and enrich home language environments. Part 2. User issues, identified in this study, will require consideration in order to shape implementation of participatory health approaches in this population.

**Session ID:** S9-1
**Session Title:** Technology and Innovation
**Abstract ID:** 161
**Title:** Benefit of Adaptive Dual-Microphone Beamformers for Understanding Speech in Noise in Cochlear Implant Recipients and Bimodal Listeners

**Authors:** Lisa Dahlstrom, AuD1, Richard Gurgel, MD1, Smita Agrawal, Ph.D.2; 1Otolaryngology, Univ. of Utah, Salt Lake City, UT, 2Advanced Bionics, Valencia, CA.

**Abstract:** Introduction: The objective of this study was to evaluate the benefit of adaptive dual-microphone beamformers for understanding speech in noise in cochlear implant (CI) recipients. Bimodal listeners (CI in one ear and a hearing aid (HA) in the contralateral ear) were also studied with an HA designed specifically for CI recipients.

**Methods:** Ten adult Advanced Bionics CI recipients (3 unilateral, 7 bilateral; median age 73 years) and nine adult bimodal listeners (Advanced Bionics CI plus contralateral HA; median age 81 years) participated. Sentence perception in multi-talker babble (SONO) was compared between omnidirectional microphones (T-Mics) and adaptive dual-microphone beamformers (UltraZoom) using the Naida CI Q70 speech processor. Bimodal participants were tested with the new Naida Link HA. The Link was programmed with a unique bimodal fitting formula and implemented a beamformer matched to that of the CI sound processor. Each subject was tested at an individually determined signal-to-noise ratio that reduced the speech score to approximately one-half the score in quiet (range: -2 to 11 dB SNR).

**Results:** Both groups demonstrated significant improvement in sentence recognition when listening with adaptive dual-microphone beamformers (bimodal listeners: 27%; CI users: 33.5%, p < .001). Bimodal listeners also reported immediate acceptance and improved sound quality with the new HA. A 13% bimodal benefit was experienced when using just the omnidirectional microphones in the CI and HA.

**Conclusion:** Adaptive beamforming technology can make face-to-face conversations in noisy environments significantly more intelligible and easier for CI users and bimodal listeners.
Title: Legal and Ethical Obligations of the Clinician-Patient-Industry Relationship  
Authors: Michael Page, AuD

Abstract: Introduction: Professional relationships between clinicians, patients and industry are regulated by law and ethical codes. Most clinicians have limited understanding of the laws and codes to which they are bound. Patients are usually completely unaware of the regulations to which their providers are held. Industry partners are only slowly developing training programs which create awareness and obligation to regulations and codes.

Methods: This presentation utilizes a thorough review and provides a very brief and descriptive compilation of federal laws and organizational codes of ethics to which all providers and industry members are bound.

Results: The following statutes and codes will be reviewed and their relevance presented: Safe Harbor, Anti-Kickback Statute, State Unfair and Deceptive Practices Act, AdvaMed, AAA Code of Ethics, US Food and Drug Administration, HIPAA, Physician Payment Sunshine Act, False Claims, and Stark Law.

Conclusion: Awareness creates safe and beneficial relationships between clinicians, patients and members of industry. Adherence builds reliable, independent, protected, lawful and outcomes-focused associations, for the ultimate benefit of patients served.

Session ID: S9-2
Session Title: Audiology / Devices
Abstract ID: 208

Title: The Effectiveness of a Middle Ear Implant in Some Cochlear Implant Candidates
Authors: Joseph Chang, MD1, Anna McCraney, AuD2; 1Otorhinolaryngology, Texas Ear Ctr., Houston, TX, 2Audiology, Ototronix, St. Paul, MN.

Abstract: Introduction: For decades, there have basically been two treatment options for patients with sensorineural hearing loss - hearing aids (HAs) and cochlear implants (CIs). Hearing aids have long been used as the primary treatment method until such time patients are struggling due to limited aided benefit at which point they become cochlear implant candidates. While hearing aids have improved significantly over the years, recent studies have shown that patients with similar cochlear potential for speech understanding (based on maximum word recognition under earphones or PB max) (McRackan, Hoppe) can have significantly different aided outcomes with CNC word recognition scores varying by as much as 60%. This difference between PB max and aided CNC WRS is called the Speech Perception Gap. (Dyer) So, it is possible that a patient may receive limited benefit from hearing aids and qualify for a cochlear implant, yet still have substantial cochlear potential that is simply not able to be realized through hearing aid use. Middle Ear Implant ( MEI) word recognition scores have been shown to have good correlation to word recognition testing under earphones. (Dyer) We sought to evaluate outcomes for our series of patients who received a minimally invasive, electromagnetic middle ear implant and also met the requirements for a cochlear implant based on aided speech recognition scores.

Methods: 11 ears, in 9 adult patients (2 female; average age 62.7 years) underwent implantation of a minimally invasive, electromagnetic middle ear implant system. Of these patients, 9 ears had CNC word recognition scores of 30% or less (range 0%-28%) and would meet cochlear implant candidacy. Of those 9, 7 also met the indications for the electromagnetic middle ear implant (PB max of 60% or greater). Each patient was evaluated for CNC word recognition pre-operatively with appropriately fit hearing aids and post-operatively following implantation with the middle ear implant. Primary outcome measures included CNC word recognition score with the MEI compared with hearing aids, and comparison of the CNC word recognition scores with hearing aids and middle ear implant to PB max.
Results: The average MEI WRS was 67.4% (range, 58%-82%), a 52.6% improvement (range, 44%-66%) over HAs (p < 0.001). The average difference between CNC WRS with the MEI and PB max was 8.7% (range, -6%-24%), a 52.6% improvement (range, 44%-66%) over HAs (p < 0.001).

Conclusion: These data demonstrate that the MEI provides superior WRS than HAs for patients with significant differences between PB max and aided CNC scores in this cohort of patients who also met criteria for cochlear implantation. PB max was a reasonable predictor of CNC WRS outcomes with the MEI. The MEI CNC outcomes compare favorably and were actually better than average cochlear implant CNC outcomes, and the MEI patients had no additional hearing loss due to the implantation procedure. In advising patients who may be candidates for both a CI and the MEI, the PB max will provide useful predictive information to help clinicians counsel patients on their choice of hearing implant technology.

Session ID: S9-2
Session Title: Audiology / Devices
Abstract ID: 125
Title: Bonebridge in Children with Pinna Abnormalities and Canal Atresia
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Abstract: Bonebridge in Children with Pinna Abnormalities and Canal Atresia
Introduction: Children with pinna abnormalities and canal atresia, either bilateral or unilateral, always present with conductive or mixed hearing loss and this is one of the indications of Bonebridge, a new active osseo-integrated transcutaneous bone conduction implant.
Methods: This was a prospective, single-subject repeated measures designed study in which each subject serves as his/her own control. Two tertiary centres were chosen to enroll patients from 2013 to 2016. Six patients who suffered from conductive hearing loss were enrolled into the study. All of them fulfilled the criteria of Bonebridge implantation. A trial of bone conduction hearing aid was the prerequisite before final decision of Bonebridge implantation was made. Their demographic data and medical parameters were documented. The preoperative preparations, surgical techniques and complications were assessed. The subjects’ audiometric thresholds (air conduction, bone conduction and sound field at frequencies 250Hz to 8kHz) were assessed preoperatively, then subsequently at 6 months postoperatively. Subjective satisfaction with the device was evaluated by means of the Hearing Device Satisfaction Scale (HDSS) questionnaire. The results were analysed with IBM SPSS Statistics version 22.
Results: Six patients, four males and two females, were included in the study. Their age ranged from 11 to 18 years old. All patients had conductive hearing loss. Four patients had bilateral microtia and canal atresia. The other two had unilateral microtia and canal atresia. Computed tomography (CT) scans of temporal bone were performed in all the patients preoperatively to assess the suitability of implant placement. The Bone Conduction Floating Mass Transducers (BC-FMT) were placed at sinodural angle in five patients and at presigmoid area in one patient. All the operations were performed under general anesthesia and took between 45 to 60 minutes. There were no major complications. Only one patient reported mild infection of the incision site, which recovered within a week with local and oral antibiotics. Audiometric thresholds for air and bone conduction showed no significant change with respect to time (P>0.05), for any of the tested frequencies until 6 months of follow-up. This confirmed that the patients’ residual unaided hearing did not deteriorate with treatment. Meanwhile, sound field testing with aided thresholds showed significant improvement over time (p<0.05) at all tested frequencies until 6 months of follow up postoperatively. The aided hearing thresholds for frequencies from 500Hz to 4kHz at 6 months of follow-up postoperatively were between 21 to 30 dB. All the patients
were very satisfied with the implant in terms of improvement of the aided hearing thresholds (91% to 98%) and acceptable cosmetic appearance of the sound processor.

**Conclusion:** Bonebridge is a new transcutaneous bone conduction hearing implant that has been demonstrated to be safe and effective in improving patients’ hearing thresholds from the age of 5 years old and above in children with pinna abnormalities and canal atresia. A thorough radiological and surgical planning with CT scan is crucial to locate the site for optimal implant placement to avoid unnecessary surgical complications. It provides another alternative treatment for patients with hearing loss who fail conventional hearing aids.

**Session ID:** S9-2  
**Session Title:** Audiology / Devices  
**Abstract ID:** 167  
**Title:** Cortical Auditory Evoked Potential (CAEP) and Behavioural Measures of Auditory Function in an Child with a Single Sided Deafness  
**Authors:** Oscar M. Cañete, PhD1, Suzanne C. Purdy, PhD1, Michel Neeff, MD2, Colin Brown, MD2, Peter R. Thorne, PhD3;  
1Speech Science, The Univ. of Auckland, Auckland, New Zealand, 2ENT, Starship Children’s Hosp., Auckland, New Zealand, 3Section of Audiology, The Univ. of Auckland, Auckland, New Zealand.  
**Abstract:** Promising evidence for the benefits of Cochlear implant (CI) for adults with single-sided deafness (SSD) has been reported in the literature. Studies showed that a CI could be effective in reducing the perception and disability associated with the tinnitus in people with SSD. Additional positive effects were observed and include improved speech in noise recognition, sound localisation and self-perceived hearing abilities.  
Children with untreated SSD are experiencing auditory deprivation at the same time as neuro-maturation is occurring in central auditory pathways and they are engaged in complex listening tasks such a learning in a noisy classroom. Changes in auditory function over time and the impact of introducing hearing technology are therefore of great interest for this population. This case study examines auditory function over time in a child with SSD who received a CI.  
**Methods:** Cortical auditory evoked potentials (CAEPs) in noise (+5 dB signal to noise ratio) elicited by speech sounds were recorded and auditory skills were assessed using tests of sound localisation, spatial speech perception in noise, and self-ratings of auditory abilities (Listening for inventory education, LIFE and Speech, Spatial and Qualities of Hearing Scale, SSQ parental version). Measures were obtained prior to and after a cochlear implant (CI) fitting, including one, six and 12 months after the CI switch on.  
**Results:** Spatial speech recognition improved over time. At 12 months post-CI, word recognition scores were similar to those of normal hearing children. Signal-to-noise-ratios for sentences decreased (i.e., improved) over time post-CI. Sound localisation markedly improved at 12 months post-CI compared to baseline. Self-perception of difficulty scores decreased over time. Parental ratings of hearing abilities improved compared to baseline for all subscales. It was possible to observe the emergence of the P1-N1-P2 complex at 12 months post-CI, which was clearer frontally across stimuli. N250 response changes over time suggest the presence of a possible ‘binaural interference’ effect and/or a cochlear implant mapping effect.  
**Conclusion:** The CI was associated with improved recognition of speech in noise, better sound localisation sounds and improved perception in different listening environments. CAEP changes indicate some adaptation within the central auditory system to the new “binaural” condition.
Title: Measuring Sound Processor Threshold Levels for Pediatric Cochlear Implant Recipients Using Visual Reinforcement Audiometry via Telepractice

Authors: Joshua D. Sevier, AuD., Sangsook Choi, PhD., Michelle Hughes, PhD.; Cochlear Implant Research, Boys Town Natl. Res. Hosp., Omaha, NE.

Abstract: Introduction: Recently there has been a growing trend for integrating distance services using telepractice in healthcare. Due to a limited number of centers offering cochlear implant (CI) services across the country, using telepractice for programming CIs is an attractive solution, particularly for the pediatric population. Regular visits are required to maintain proper programming levels, but young children have a limited capacity for attention and cooperation. Often this results in additional visits to the clinic, which can increase burdens to families. The goal of this study was to investigate the feasibility of using telepractice to program CIs for very young children, specifically using visual reinforcement audiometry (VRA). This study investigated whether VRA testing using a local play assistant and a remotely located CI audiologist can be used as alternative for traditional, in-person testing. We hypothesized that behavioral thresholds obtained via remote and in-person methods of testing would be similar.

Methods: Data were collected using an AB-BA design (A, in-person; B, remote) over two visits. Participants ranged in age from 1-3 years. Behavioral thresholds were obtained using VRA for one basal, middle, and apical electrode. A test assistant offered a mild distraction for the child in order to identify behavioral responses. Once conditioned to a stimulus presented using clinical software via a standard programming cable, the audiologist used a repeated ascending procedure to obtain behavioral thresholds. The response rate was calculated as the ratio of the number of electrodes attempted versus measured. Test duration was recorded for both conditions. A parent/caregiver questionnaire was used to evaluate perceived quality aspects of remote and traditional CI programming.

Results: Preliminary data from 16 subjects showed no difference in thresholds between in-person and remote conditions. Data from a larger group will be presented (goal is N=20). To date, the response rate was similar between in-person and remote conditions. Regarding test duration, preliminary data suggested similar test time between remote and in-person testing. Results of the questionnaire using a Likert scale indicated that caregivers perceived remote and in-person testing to result in similar efficiency/quality.

Conclusion: At time of current data collection, preliminary data indicate that remote programming utilizing VRA is a feasible alternative to traditional, in-person programming. Given that children in this youngest age group have limited attention spans and unpredictable levels of cooperation that can increase the number of visits to the CI center, remote programming using VRA techniques could relieve the financial and time burden experienced by families in remote locations who have young children with cochlear implants.
Abstract: Introduction: Cochlear implantation commits patients and care teams to relatively resource intensive post implant rehabilitation over several months. This type of specialized care is often only available in certain centres and is reliant on sound-field testing for objective threshold and speech measures. However, tablet audiometers are now able to use the cochlear implant processors themselves, in a calibrated fashion, as the transducer. This new hardware configuration opens up new testing options and may obviate the need for a calibrated sound-field and audiometric booth for functional testing. This innovation could significantly reduce clinic costs, enable remote monitoring, and improve patient access to providers in more locations.

Methods: In collaboration with the three main cochlear implant manufacturers five different speech processors were pilot tested as direct transducers with a tablet audiometer. Both speech perception and functional audiometry were evaluated.

Results: Cochlear implant recipients underwent calibrated tablet audiometry and traditional audiometry. Tablet threshold measures were obtained using a forced alternate choice game that employed a modified Hughson-Westlake bracketing paradigm. No significant differences were detected in pilot data.

Conclusion: It is now possible to use select CI processors as transducers when directly connected to a tablet audiometer. This pilot study suggests that this new hardware setup delivers comparable results to traditional methods. The use of a tablet audiometer may reduce the need for sound-field evaluation in cochlear implant patients, thus enabling mobile and remote testing, improved accessibility, and more complete continued follow-up care.

Session ID: S9-3
Session Title: Auditory Brainstem Implantation
Abstract ID: 48
Title: Oral Communication Assessment and Outcomes in Children with Auditory Brainstem Implants
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1USC-Caruso Family Center for Childhood Communication, Univ. of Southern California, Los Angeles, CA, 2The Children’s Cochlear Implant Center at UNC, Univ. of North Carolina, Chapel Hill, NC, 3Huntington Med. Res. Inst.s, Pasadena, CA.

Abstract: Introduction
The use of auditory brainstem implants (ABIs) in children who are not candidates for cochlear implants (CIs) due to anatomical issues is currently under investigative trials in the United States. Evidence-based research with this population is limited. There are some reports from other countries, but inclusion criteria, assessment, and outcomes are varied. Children with ABIs seem to progress differently than children with CIs in terms of the rate at which various skills develop and the children’s ability to use or generalize auditory information. For children with ABIs, we are just beginning to identify which metrics are sensitive to measuring outcomes at the level of the individual child, with potentially divergent rates of development across the listening, speech, and language hierarchies. Due to more gradual rates of gain, commonly used metrics of speech perception, speech production, or language do not capture subtle gains that children with ABIs make. Measures that have fallen out of use with the achievements of current-day CI users may have renewed utility. In this talk, we discuss challenges of assessment and test selection, emergence of oral communication, and implications of findings for children with ABIs.

Methods
Data are combined for 10 children from two pediatric ABI centers in the United States (5 children from each center) that are conducting FDA-approved safety and feasibility studies of ABIs in children. Both
studies have similar enrollment criteria (e.g., trial with CI prior to ABI unless precluded by anatomy, normal cognition, similar age at ABI—2–5 years vs. 18 months to 5 years) and include a similar range of testing (e.g., speech perception and production, language). Most children have at least two years of ABI use, but range from 1 to 3.5 years.

Results
As a group, despite audiometric data showing evidence of sound awareness, the children’s generalized responses to sound develop slowly. Spoken language growth is slow and challenging to measure based on typical standardized tests. Parent-child interactions and diagnostic therapy are informative to functional performance. Speech growth as measured by Identifying Early Phonological Needs in Children with Hearing Impairment (IEPN; Paden & Brown, 1992) showed some of the earliest gains. At two to three years post ABI, all 10 children continue to need visual language support (Cued Speech, Signed English, or American Sign Language), but supplemental examples of longer-term ABI users show spoken language supported by speech reading can occur. It is not yet clear how outcomes in US children compare to those reported internationally.

Conclusions
Children with ABIs gain sound awareness, but higher-level auditory skills may emerge over an extended period of time. Oral communication develops slowly, necessitating ongoing use of visual communication for most, at least in the first three years. Tests that measure minute increments in skills, such as the IEPN, appear to capture growth better than tests designed for the mainstream population of children with normal hearing or those with CIs. The pattern of auditory, speech, and language growth in children with ABIs appears to be different from that of children with CIs, requiring different habilitation and educational considerations.

Session ID: S9-3
Session Title: Auditory Brainstem Implantation
Abstract ID: 282
Title: Pediatric Auditory Brainstem Implant: Outcome and Early Age at Implantation
Authors: Liliana Colletti, PhD1, Marco Mandalà, MD2, Giacomo Colletti, MD3, Vittorio Colletti, Professor4; 1ENT Department, Univ. of Milano, Milano, Italy, 2ENT Department, Azienda Ospedaliera Universitaria Senese, Siena, Italy, 3Department Of Maxillo-Facial Surgery, Univ. of Milano, Milano, Italy, 4Intl. Ctr. For Performing And Teaching Auditory Brainstem Surgery In Children, Milano, Italy.
Methods: Between 2000 and 2016, 116 children ranging in age from 8 months to 16 years were implanted with ABIs, either Cochlear or Med-El devices, all via the retrosigmoid approach at our institution or elsewhere following our personal protocol for auditory brainstem implants. Patients were excluded from this study if data were incomplete or if surgery was performed at an outside institution, leaving 84 patients who were included in this study. Assessment of auditory perception was performed in all children with the Categories of Auditory Perception test (CAP), an eight-point hierarchical scale of auditory performance. The CAP scale ranges from no awareness of environmental sound (category 0) to conversational use of the telephone with a known speaker (category 7). The CAP was selected because it is simple, easily administered and easily understood by speech therapists and audiologists as well as parents without experience as assessment methods for deaf children. Highly reproducible across independent observers outcome measures covers the extremely wide range of auditory performance
observed in our preliminary studies on ABI surgery in children and can be completed for all children, even the very young, also taking into consideration the different rates of development in these children. 

**Results:** The mean age of the 84 children was 3.81±2.89 years. There were 45 males and 39 females. 

Summary of outcomes: 1) For most children, the CAP score increased after implantation 2) Implantation beyond the age of 4 years hardly ever resulted in normal CAP scores or in integration into the mainstream primary school (20 to 30% of cases) 3) Implantation between the age of 12 and 36 months always resulted in normal CAP scores after 3 years with a 66% probability of integration into the primary 4) Significant improvements were attained in children as a function of age at implantation, with children under 2 years performing significantly better than older ones (p=0.0088). 5) There were no intraoperative or perioperative permanent complications. 6) Success was defined as final CAP scores reached or bypassed level 5. By this definition, 37.31% of patients were treated successfully. 

**Conclusion:** New outcomes with ABIs in children show the power of brain plasticity. All children with congenital deafness who underwent ABI implantation before the age of 2 years appeared to benefit from the implant. These data add evidence to the importance of early implantation (before the age of 2 years). Intervention before the age of 3 years seemed to be critical to avoid irreversible auditory performance losses, and intervention before the age of 2 years seemed to be critical to achieve optimal results 

**Session ID:** S9-3 
**Session Title:** Auditory Brainstem Implantation 
**Abstract ID:** 253 
**Title:** Longitudinal Changes in Electrically Evoked Auditory Event-Related Potentials in Children with Auditory Brainstem Implants 
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**Abstract:** **Introduction:** Neural encoding and processing of electrical stimuli in the central auditory system can be evaluated using electrophysiological measures of auditory event-related potentials (eERPs). In United States, the auditory brainstem implant (ABI) has been used as an investigational device in FDA-approved clinical trials to restore auditory perception in non-tumor children since 2013. The feasibility of using eERPs to evaluate cortical neural encoding of electrical stimuli delivered by the ABI has been established in one of our previous studies (He et al., 2016). This longitudinal study aimed to investigate whether eERPs recorded in children with ABIs showed similar maturational changes in response morphology as those reported in children with cochlear implants. 

**Methods:** Study participants included five children with ABIs (S1-S5) ranging in age between 4.1 and 7.5 years. All subjects were unilaterally implanted with a Cochlear Nucleus 24M ABI due to cochlear nerve deficiency in the test side. The stimulus was a train of biphasic, charge-balanced electrical pulses with a pulse rate of 250 pulses per second. It was presented at the maximum comfortable level measured for each stimulating electrode during each test session in a monopolar-coupled stimulation mode (MP1+2). For each subject, eERPs were recorded for all active electrodes used in their programming maps at multiple time points between one month and 42 months after initial device activation. Intra-class correlation tests were used to evaluate the repeatability of eERPs recorded in different test sessions.
Results: All subjects showed morphological changes in eERPs over time. However, the degree and the pattern of change showed substantial inter-subject variations. Whereas changes in some responses recorded in S2 and S5 suggested auditory maturation, eERPs recorded for a subgroup of ABI electrodes in S1 and S4 supported the possibility of electrode migration. Signs and/or symptoms of non-auditory stimulation were also observed at 41 months in S1 for the same group of ABI electrodes that showed the greatest changes in eERPs.

Conclusions: eERPs in children ABIs change over time. Potential factors accounting for the change include auditory maturation, change in stimulation level, and electrode migration (although imaging confirmation for this hypothesis is lacking). Children with ABIs need to be closely monitored for signs and symptoms of non-auditory stimulation that could emerge over time. Neuroimaging correlates are needed to better understand the emergence of non-auditory stimulation in these children.

Session ID: S9-3
Session Title: Auditory Brainstem Implantation
Abstract ID: 418

Title: Pediatric Auditory Brainstem Implant Outcomes: An Update from one North American Institution's Clinical Trial

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1Otolaryngology, Massachusetts Eye and Ear Infirmary, Boston, MA, 2Otolaryngology, Children's Hosp. of Philadelphia, Philadelphia, PA, 3Audiology, Massachusetts Eye and Ear Infirmary, Boston, MA.

Abstract: Introduction: Auditory brainstem implants (ABI) are neuroprosthetic devices that offer sound perception to patients who may be ineligible for other forms of auditory rehabilitation. Although the first successful auditory brainstem implant occurred nearly four decades ago for an adult woman with neurofibromatosis type (NF2), U.S. studies examining the safety and efficacy of the ABI children who are not cochlear implant (CI) candidates only began in 2012. There are four open studies of pediatric ABI surgery in the U.S. Here we report interim surgical and audiologic data from our ongoing FDA trial examining the safety and efficacy of the ABI in non-NF2 pediatric patients.

Methods: Retrospective chart review. Out of 27 deaf infants with unfavorable cochlear nerve anatomy who were screened, six underwent ABI surgery with implantation of the Cochlear Nucleus 24 ABI or ABI541 between October and December 2016. A seventh subject is enrolled, with future surgery scheduled. Primary outcome measures include perioperative complications, sound perception, and language development.

Results: Eight ABIs were placed (6 primary, 2 revision), with an average age at first surgery of 18.3 months. One subject was born prematurely at 32 weeks. One subject had CHARGE syndrome with normal cognition, and two children had mild cognitive delay. The average hospital stay was 2.9 ± 0.8 days. There were no cerebrospinal fluid leaks, facial nerve deficits, or other surgical and postoperative complications. Average timing of device activation was 7.9 ± 3 weeks postoperatively. One device activation elicited a gag reflex/bradycardia; the remaining six did not elicit any non-auditory stimulation. One subject is pre-activation. Audiometric outcomes demonstrate behavioral thresholds of 22-40 dB HL in four subjects, a fifth subject responding to 75 dB HL at three months post-activation. Two children exhibit environmental awareness and imitate speech sounds. All children utilize sign language for primary communication. Two subjects experienced device failure: one device failed following mild head trauma over the device and the other experienced spontaneous failure one year after surgery.
Conclusion: In this retrospective chart review of our clinical trial investigating the ABI in non-tumor pediatric patients, preliminary data suggest that primary and revision ABI surgery are safe and well tolerated. At this early stage, all subjects with activated ABIs detect sound and two subjects demonstrate pattern perception.

Session ID: S9-3  
Session Title: Auditory Brainstem Implantation  
Abstract ID: 262  
Title: Auditory Brainstem Implantation Is Beneficial For Prelingually Deaf Children  
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Abstract: Introduction: Children born with severe cochlear malformation, cochlear aplasia or hypoplasia/aplasia of the cochlear nerve are no good candidates for cochlear implantation (CI). The only possibility for restoration of hearing in these cases is direct stimulation of the hearing pathways at brainstem level. This work demonstrates the effectiveness of auditory brainstem implantation (ABI) even in very small children with prelingual deafness for restoration of hearing and speech.  
Methods: A 12 channel ABI system (MedEl, Austria), which has proven effectiveness and safety in neurofibromatosis patients since the last 16 years was used for implantation. The pediatric ABI program started in 2009. Meanwhile 25 implantations in 24 children, 10 male and 14 female were performed by the first author. Two children had a successful revision surgery after a fall on the implant side or a spontaneous breakdown of an other ABI system. The mean age was 3.3 years, median 2.8. The youngest was 1.25, the oldest 6.5 yrs. Surgery was performed in supine position using a retrosigmoid approach and multimodal neuromonitoring. In all cases intraoperative E-ERA were recorded.  
Results: The preoperative evaluation with high resolution MRI and CT revealed in 16 children aplasia of the cochlear nerve. The others had cochlear dys-aplasia together with hypoplasia of the 8th nerve or syndromal lesions like Goldenhar Syndrome. In most cases surgery was difficult due to complete or partial occlusion of the lateral recess of the forth ventricle (foramen of Luschkae). In 75% branches of the AICA or the vessel itself were crossing the implant site and had to be dissected. In every case the electrode paddle was small enough to fit properly into the recess. E-ERA recordings could be derived in each case. There were no neurologic complications and only minor surgical complications as subcutaneous CSF leaks in 4 children. All children in whom the device was activated so far regained sound awareness and insisted using the implant all day. The category of auditory performance scores (CAP) showed in 58.8% values better than CAP 3, in 23.5% equal to CAP 3 and in 17.6% below CAP 3.  
Conclusion: ABI is a safe and successful surgical procedure for restoration of hearing and speech in prelingual deaf children. Precious time of plasticity of the auditory pathways should be used as early and intensively as possible. Therefore in doubtful CI candidates ABI should be the primary indication.