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Audiologists' preferences in programming cochlear implants

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Audiologists’ Preferences in Programming Cochlear Implants

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Abstract

Cochlear implants have become a viable option for those with severe to profound sensorineural hearing loss who gain little benefit from hearing aids and have poor word recognition ability. However, the techniques audiologists use to program these devices are not standardized (Sorkin, 2013). There is little data available which analyzes how audiologists handle clinical cochlear implant programming between the top manufacturers. These companies supply default settings in their products but is it unknown how often audiologists use these in practice in the United States.

In the present study, a questionnaire based on previous European data from Vaerenberg et al. (2014) was designed to address which settings professionals are using with their patients, how they approach bimodal fitting with a cochlear implant and a hearing aid, and which tests they use to evaluate patient and device performance. This questionnaire was distributed through the platform, Qualtrics, to cochlear implant audiologists throughout the United States by email. 47 responses were recorded with a response rate of 70%.

Results indicate a preference for the default value for some parameters, like default pulse width, but not others. Additionally, there are differences between manufacturers, including in the use of default strategy. Relative to Cochlear, there is a trend toward less use of default strategy for MED-EL and especially Advanced Bionics. Preferences for bimodal fitting techniques trend toward using a partner company's hearing aid, like Cochlear and ReSound. There is no significant correlation between number of implants activated and preference for default.

New and experienced audiologists may benefit from this research in that they may better understand the state of the art of cochlear implant programming. It is clear that there is much variability among audiologists' cochlear implant programming practices, and documenting these differences is important for the betterment of the field.

Introduction

Despite being approved by the Food and Drug Administration since 1988, cochlear implant follow-up guidelines or standards of care remain absent in the literature. Though national organizations like the American Speech-Language-Hearing Association and the American Academy of Audiology have attempted to provide suggestions, there is a lack of specific, verified best practice procedures (Sorkin, 2013).

Vaerenberg et al. (2014) collected data concerning the current practice procedures of audiologists internationally but had few participants who practice in the United States (Vaerenberg et al., 2014). Additionally, this research included the Neurelec device, which is not available for use in the U.S. However, this study did find that among its majority European centers, MAP parameters other than the minimum and maximum stimulation levels are rarely modified. Furthermore, Vaerenberg et al. (2014) found that while 100% of the centers involved in the survey used electrode impedance for MAP settings, only 39% of centers used eSRT, and 59% used eCAP. This is because most centers relied on subject feedback from the patient to guide the programming process. It is important to note that trends in European programming methods may not necessarily be applicable to American programming centers as default values for cochlear implant brands can vary by country. These researchers suggest that their findings may be helpful to new clinicians entering the field, and that creating measurable targets could improve the fitting and programming process. They were clear that their findings did not represent new standards of care.

In a survey of audiologists' techniques for programming cochlear implants with older adults, Rossi-Katz and Arehart (2011) found that ten percent of respondents use eCAP when setting MAP levels. They were also asked about the rehabilitation options presented to patients, and many reported that they suggested listening to audiobooks or other self-directed auditory training such as that offered by some device manufacturers. Overall, most respondents indicated that they did not make additional accommodations when seeing older adult cochlear implant patients except to communicate realistic expectations during patient counseling. Data regarding pediatric programming preferences is vague or not clinical in nature, and largely absent.

Other studies have examined bimodal fitting techniques, with findings that show there is little consensus among audiologists about how to best handle hearing aid programming with unilateral cochlear implant users. Both Yehudai et al. (2013) and Messersmith et al. (2015) suggest that placing more emphasis on low frequency gain in the hearing aid may improve the performance of bimodal patients. Despite these findings, Siburt and Holmes (2015) surveyed 93 centers and found that the most popular hearing aid formula the respondents used was a National Acoustics Laboratory formula, which generally assigns more gain to higher frequencies. Ching et al. (2004) found that bimodal listening can improve both localization abilities and speech perception, so it is important to understand how to best fit these patients to maximize benefit. A survey of the clinical techniques of audiologists in the U.S. is perhaps a fitting first step in identifying a plan of best practice and may even help to increase the 6% of those who could benefit from cochlear implantation that actually use the device (Sorkin, 2013).

The present study seeks to improve understanding of cochlear implant fitting practices in the United States through a survey of audiologists. This work will focus on four areas of interest, including: preference for default settings, objective measurements, subjective measurements, bimodal fitting, and habilitation/rehabilitation strategies. Evaluating audiologists' preference for default settings will aid in understanding if manufacturer defaults match with clinicians' programming strategies. Insight into clinical decision-making can be gained through an assessment of the objective and subjective measurements that audiologists use. Bimodal fitting introduces more complexity into the programming process, so it is important to understand the fitting formulas used for the hearing aid contralateral to the cochlear implants, and the timing audiologists follow in introducing bimodal listening. Finally, habilitation and rehabilitation programs can greatly enhance the auditory performance of new cochlear implant recipients, and we are interested in clarifying which methods audiologists are recommending for both pediatric and adult patients. In gathering data from audiologists in the U.S., we will not seek to create best practice recommendations, but instead understand clinicians' preferences so that they be compared to the evidence for the range of clinical techniques.

Methods

Participants

47 cochlear implant audiologists working mostly in medical centers and universities across the United States participated in the present study. Potential survey participants were identified through mutual contacts, membership in audiology-based social media groups and national organizations, and manufacturer contact lists. After the participant supplied their email address and acknowledged their willingness to participate, the survey link was sent via email along with instructions and an Institutional

Review Board web consent form for their review. To avoid introducing bias, survey participants remained anonymous and were not asked to supply the name of the facility at which they practice. The Institutional Review Board at James Madison University approved the protocol for this research with human participants. Informed consent was provided to all participants and each participant selected "yes" when asked if they agreed to participate.

Questionnaire

Prior to data collection, a questionnaire (appendix I) was created to assess the cochlear implant programming, objective and subjective measurements, bimodal fitting, and rehabilitation preferences of audiologists who work with cochlear implants. The questionnaire went through twelve versions before it was made available for participants and was reviewed by manufacturer representatives and practicing audiologists for confirmation of the latest default parameters as well as question relevancy. Each question was additionally evaluated for clarity and built in Qualtrics to make participation in the survey as easy as possible. Once participants began the questionnaire, they were given one month and unlimited sittings to finish it before the link expired and their responses were recorded.

Participants first answered questions regarding their clinical experience in terms of the setting in which they work, how many pediatric and adult cochlear implants they have activated, and what additional services are performed at their place of work (i.e. vestibular assessment, surgical, or hearing aid fitting). Using the work of Vaerenberg et al., 2014 as a guide, questions were written regarding the use of default values for each parameter of Cochlear, Advanced Bionics, and MED-EL products. Additionally, questions regarding objective and subjective measures used during the programming process, like electrode impedance, were included. Participants were prompted to select how often they used a particular default value or measurement from the categories "always, almost always, half of the time, sometimes, and never." These categories were selected for their presumed familiarity among audiologists, as they are also used in the Abbreviated Profile of Hearing Aid Benefit (APHAB) questionnaire.

Data Analysis

Some data were analyzed using IBM SPSS version 25 and Spearman's Rho and Pearson's r correlations. Other data were analyzed in a qualitative manner.

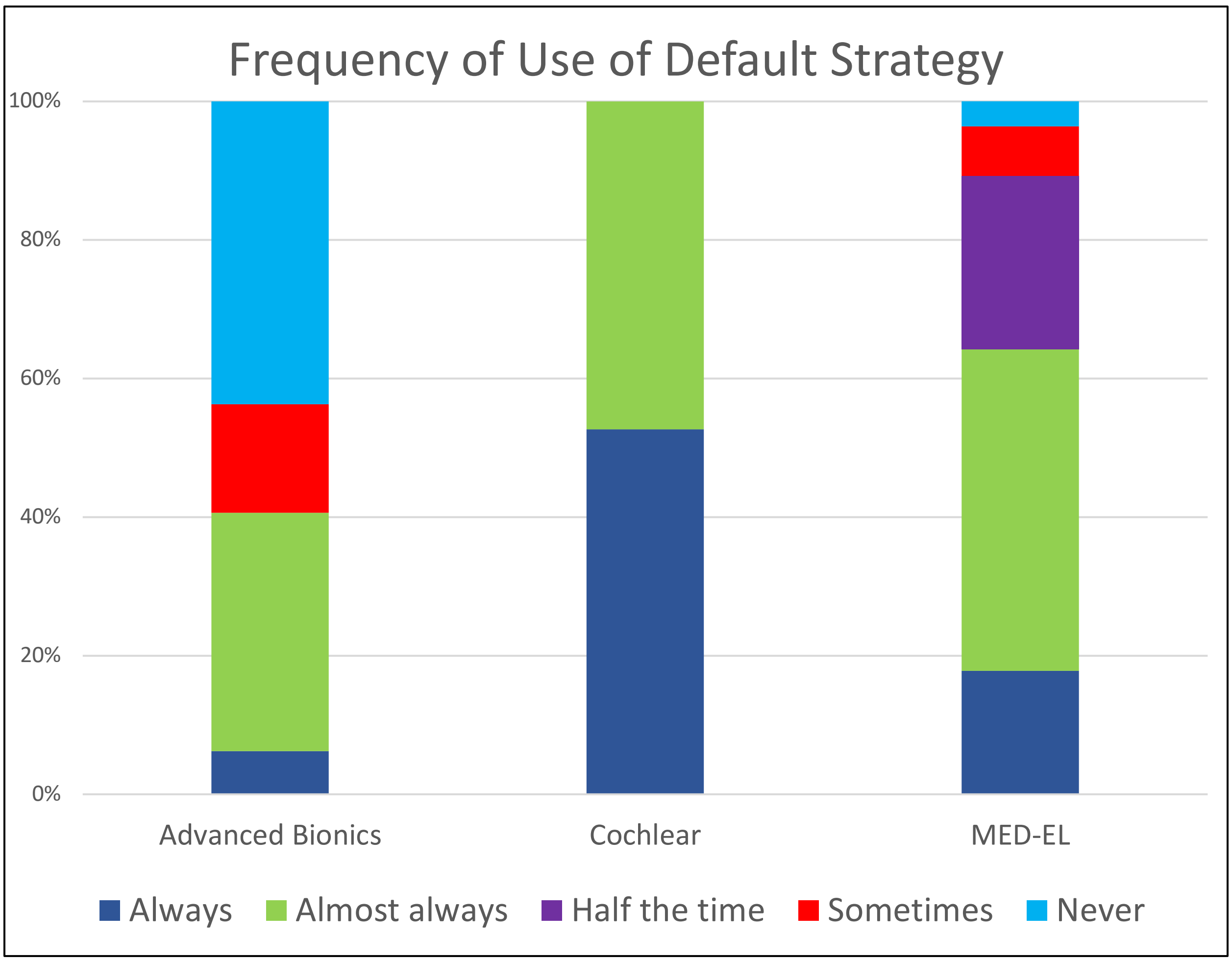
Results

Preference for Default Strategy

Overall, there was no significant correlation between total number of cochlear implants activated (experience) and preference for manufacturer default settings ($p>0.05$). However, findings support the presence of differences between usage of default settings between manufacturers. Figure 1 illustrates a stronger preference for default strategy when using Cochlear products as compared to MED-EL and Advanced Bionics. Specifically, 100% of participants report that they always or almost always use the default strategy (ACE) for Cochlear, while slightly more than 60% of respondents always or almost always use the default strategy for MED-EL (FS-4). Approximately 40% of participants reported that they always or almost always use the default strategy

(HiRes-P) for Advanced Bionics products. Advanced Bionics' newest strategies, HiRes Optima-P and HiRes Optima-S are not listed as the default. When asked specifically about their use of these strategies, there was a slight trend toward more use of HiRes Optima-P.

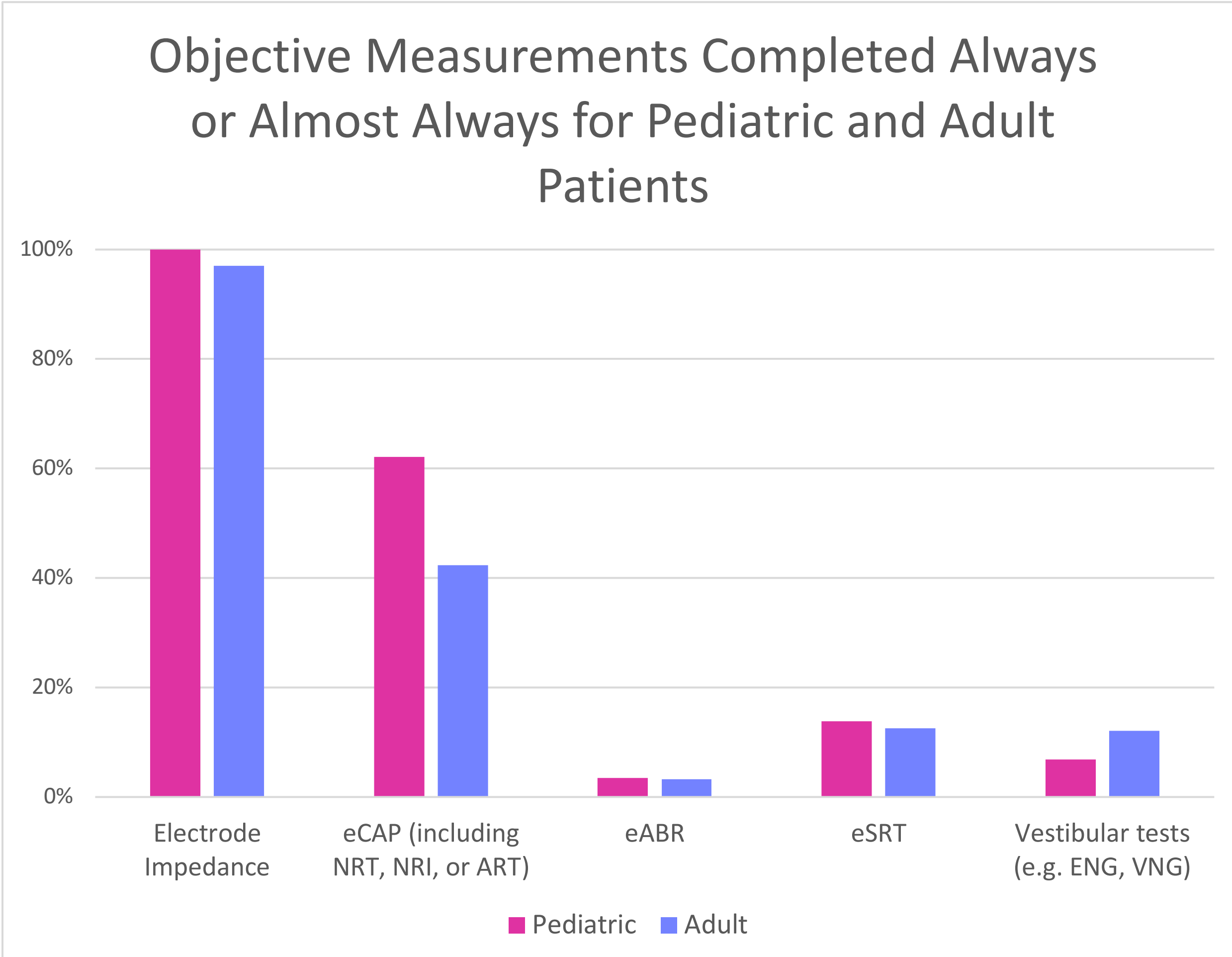
Figure 1



Use of Objective Measurements

When asked about the objective measurements they use (regardless of device manufacturer for pediatric and adult patients) (Figure 2), the trend for adult and pediatric responses is similar. All survey participants reported that they always complete electrode impedance measures for pediatric patients, while one participant said they never measure electrode impedance for adult patients. 62% of participants always or almost always measure electrically-evoked compound action potentials (eCAP) for pediatric patients while 42% indicated they do this for adult patients. When participants are using eCAP, they explain that they use it to verify the overall shape of the MAP, or track device function over time. Less than 20% of participants reported always or almost always measuring electrically-evoked auditory brainstem response (eABR), electrically-evoked stapedial reflex threshold (eSRT), or vestibular assessment for either adult or pediatric patients. Two participants wrote that they only use eABR for difficult to test patients or if they feel behavioral responses are inaccurate or unreliable. Others indicate that they may use eSRT to validate C/M/MCL levels, while some report little success with measuring it. When considering vestibular assessment, one participant explained that vestibular assessment is only completed upon physician referral, while another wrote that they always obtain a baseline prior to surgery.

Figure 2

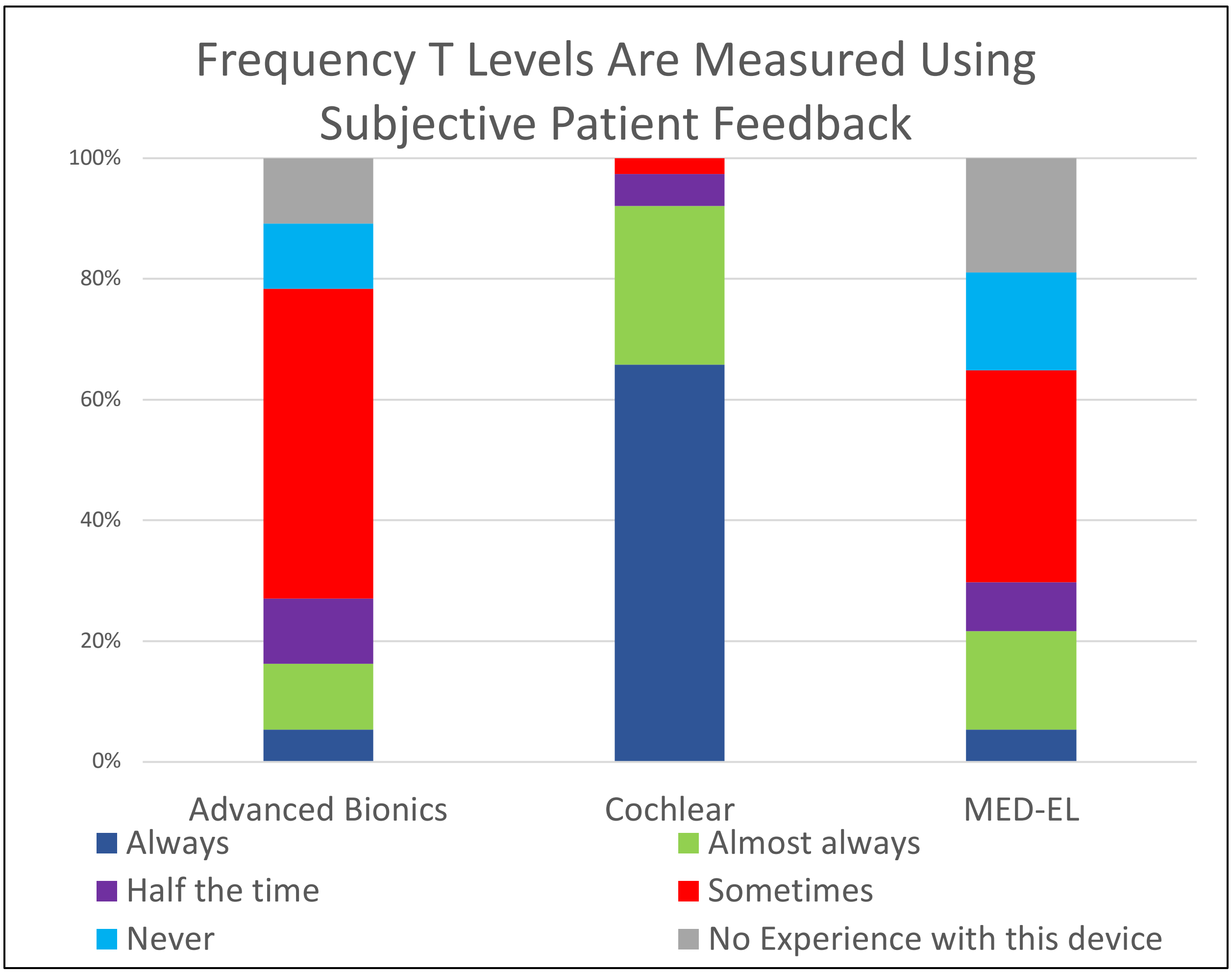


Use of Subjective Measurements

In the subjective measures section of the questionnaire, participants were asked how often they measured T-levels using subjective patient feedback. Figure 3 shows that for Cochlear devices, over 90% of participants either always or almost always complete this measurement. Both Advanced Bionics and MED-EL devices predict the T-level based on other measures, but more than 20% of participants report measuring T-levels at least half of the time.

Further, participants were asked how often they measured loudness balancing regardless of device manufacturer. Fifty-six percent of participants reported that they always or almost always measure loudness balancing. When asked how frequently they measure pitch ranking between electrodes, only 16% of participants responded always or almost always, with most reporting that they measure pitch ranking less than half of the time.

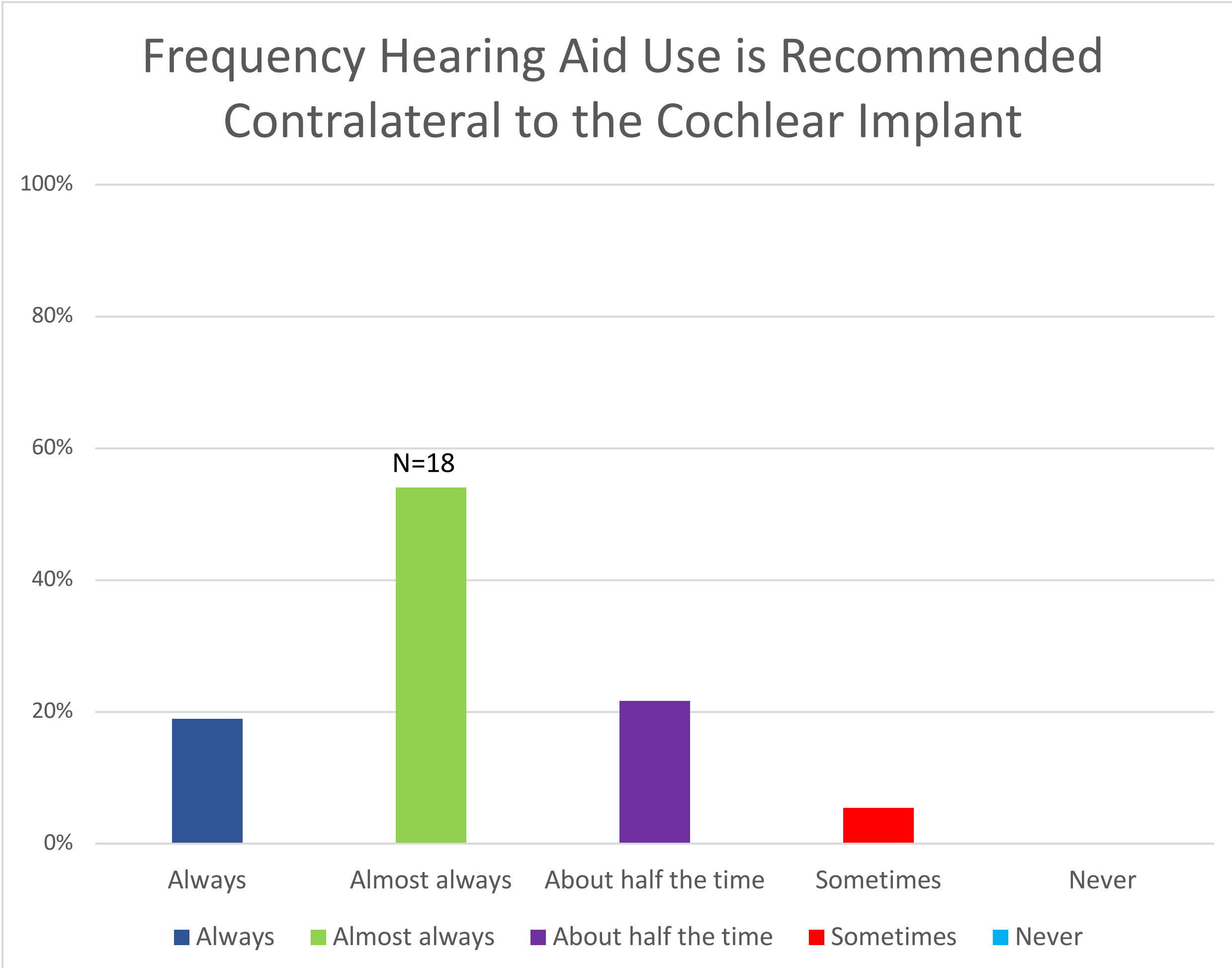
Figure 3



Bimodal Fitting Methods

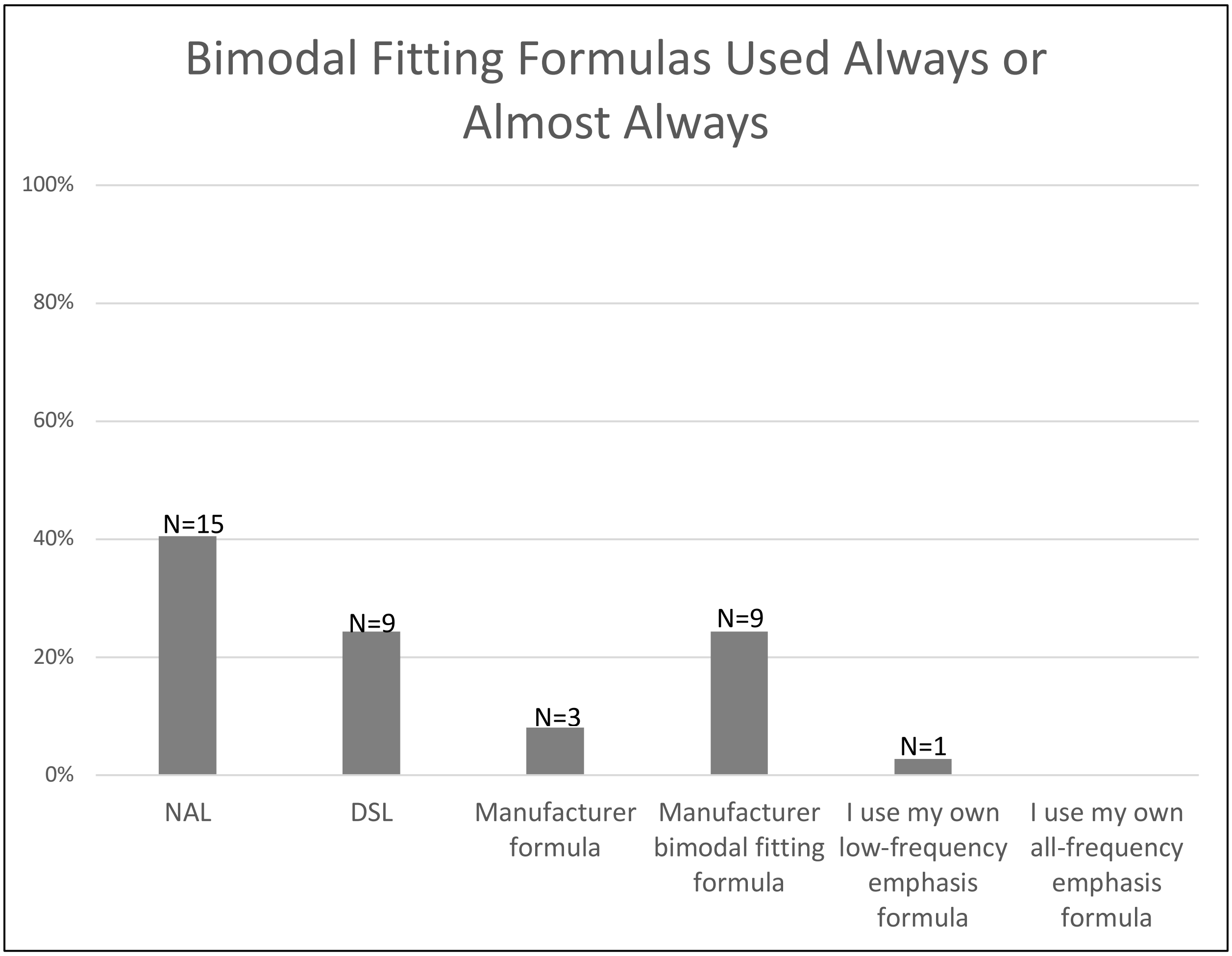
Overall, nearly 75% of participants indicated that they always or almost always recommend a hearing aid contralateral to the cochlear implant (see figure 4). Participants were also asked to indicate the frequency they would recommend bimodal listening for specific time frame after cochlear implantation. There is a general trend toward higher likelihood of a bimodal listening recommendation as more time passes after the implant is activated. This growth in recommendation of a hearing aid contralateral to the cochlear implant was explained by the participants writing that they felt it was important for the patient to have time to adjust to using just the cochlear implant for listening. Some wrote that they believed cortical plasticity on the cochlear implant side to be inhibited by hearing aid use on the non-implanted side. Still others explained that they recommend the patient have at least four to six hours of cochlear implant-only listening time per day to enhance their acclimation, with many stating that they recommend no hearing aid use during auditory training exercises. Situations in which participants indicated they would not recommend a hearing aid contralateral to the cochlear implant include: observed decrement in auditory performance with the hearing aid, if the patient prefers not to use a hearing aid, and if the patient is a candidate for a second cochlear implant.

Figure 4



Participants also indicated their preference for different hearing aid fitting formulas as shown in figure 5. Most participants (40%) indicated that they always or almost always use National Acoustics Laboratories (NAL) fitting formulas, while almost 25% of participants reported using Desired Sensation Level (DSL) or the manufacturer's bimodal fitting formula with the same frequency. Additionally, there is a significant, positive correlation between activation of more pediatric cochlear implants and preference for using the DSL fitting formula ($p<0.01$). In terms of the type of hearing aid selected for bimodal fittings, 81% of respondents reported that they always or almost always recommend the partner manufacturer's hearing aid when available, as is the case with Cochlear and ReSound or Advanced Bionics and Phonak products. Other participants indicate that they recommend either a basic or premium digital hearing aid.

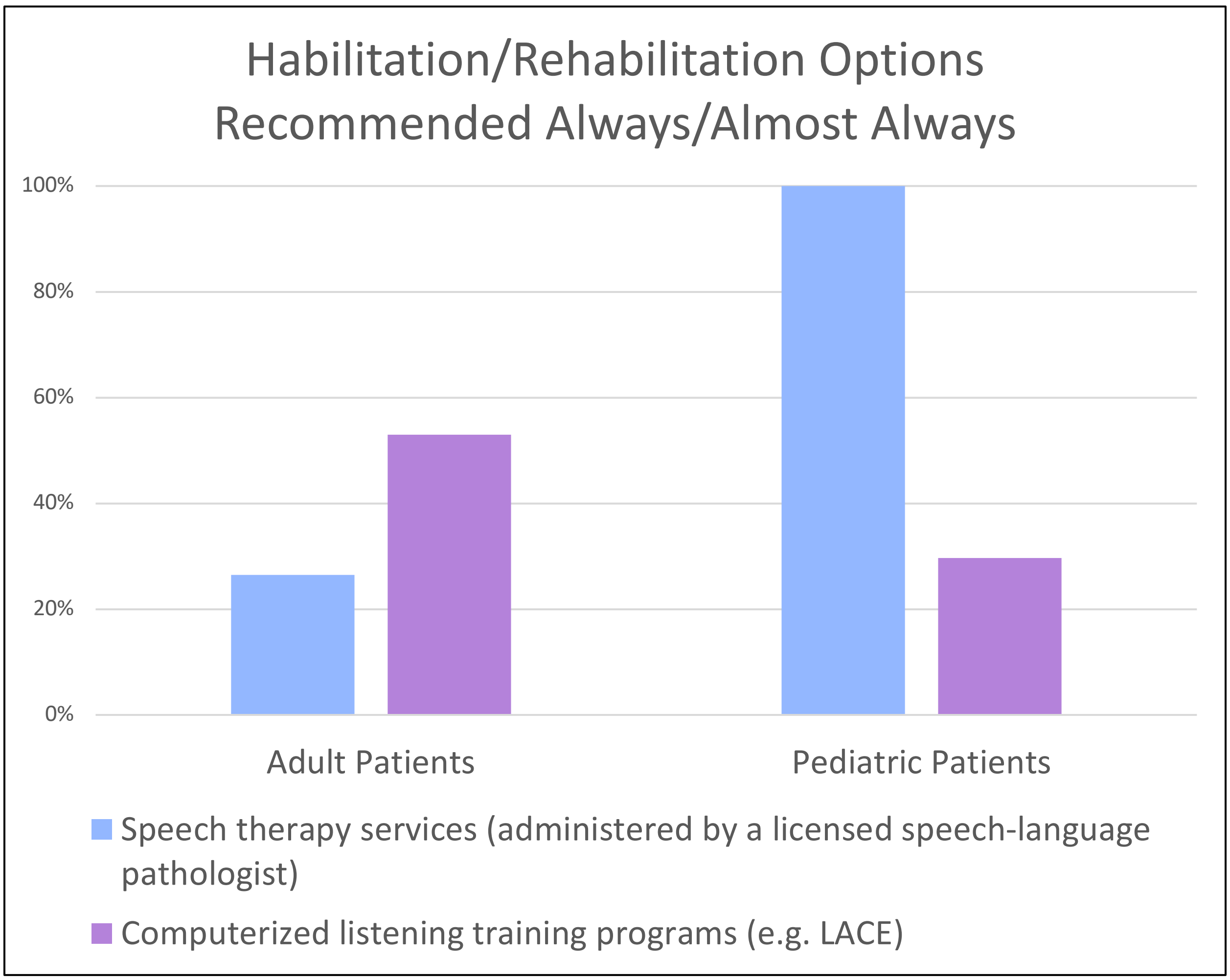
Figure 5



Habilitation/Rehabilitation Strategies

Participants were also asked the question, "Please indicate which habilitation/rehabilitation methods that you recommend for use after device activation for adult and pediatric recipients". Figure 6 details the results separately for pediatric versus adult patients. All participants indicated that they recommend speech therapy for pediatric patients. Almost 30% of participants say they recommend computerized listening training programs for children. However, the opposite is true for adult cochlear implant patients, as about 52% of participants recommend computerized listening programs such as LACE to their patients, while only 26% of say that they recommend speech therapy for adult patients. Computer-based programs that were recommended to patients include Angel Sound, The Listening Room, Listen Up, Auditrain, and LACE.

Figure 6



Discussion

Use of Default Strategy

When considering the use of default strategy among the three manufacturers, there is a clear difference among them. The lower use of default for Advanced Bionics implants can be explained by participants who say they use HiRes-Optima S or P strategy as recommended by the company for improved battery life. This strategy has yet to be approved for use in pediatric populations in the U.S., so it is not listed as the default. Additionally, Advanced Bionics default settings may vary by clinic site as this company does not update their software often to reflect new default values. Instead, a template may be made with newer values that are recommended by the company. This is also evident when considering Advanced Bionics default input dynamic range (IDR) which has a similarly low rate of usage to default strategy. Other reasons cited by participants for not using the default strategy across manufacturer include patient preference or sound quality issues.

Objective Measurements

Despite the prevalence of post-operative dizziness being around 20% by some reports (Bittar, Sato, Ribeiro, & Tsuji, 2017), few audiologists in the present study indicate that they perform vestibular assessment most of the time. There is similarly low use of eSRT measures although respondents write that this is a useful tool for difficult to test patients as well as children. For pediatric patients, less than 20% of participants indicated that they measure eSRT always or almost always, while 75% say they measure it at least sometimes. For adult patients, less than 20% participants measure eSRT always or almost always, while 56% report measuring it at least sometimes. For eCAP, 62% of participants indicate they measure this more than half of the time for pediatric patients, and 42% for adult patients. This is perhaps due to more difficulty in obtaining reliable behavioral responses from children. Though it is difficult to directly compare the two findings, Vaerenberg et al. (2014) found that 39% of centers included in their study used eSRT, while 59% used eCAP for setting MAP profiles. Walkowiak et al. (2011) found that eSRT measurements are better predictors of MCL than eCAP. Additionally, eCAP takes more than four times as long to measure when compared to eSRT (Kosaner, Spitzer, Bayguzina, Gultekin, & Behar, 2018). One participant in the present study did indicate that they hoped to begin using eSRT soon with elderly patients who may have difficulty determining loudness during programming. However, overall results of the present survey indicate that perhaps audiologists as a whole have been slow to adopt new technology and use it regularly.

Subjective Measurements

When asked about measuring T-levels using subjective patient feedback, it is surprising that there is still a group of clinicians who always or almost always do this for Advanced Bionics and MED-EL products despite those software modules predicting these values without requiring that they be measured. One participant indicated that this is because using the T-level default sometimes causes patients to miss low intensity sounds or have inappropriate detection of sounds. Conversely, there were respondents who report that they measure T-levels using subjective patient feedback only sometimes for Cochlear products when this value is integral to programming this brand. Hughes et al. (2001) found that T-levels increase over the first year post-activation for pediatric patients, and C-levels increase in the first year of use for both adult and pediatric patients. This emphasizes the importance of measuring accurate T-levels and C-levels, particularly in the first year of stimulation, to ensure appropriate dynamic range.

Additionally, only 16% of participants indicated that they measure pitch ranking more than half of the time despite evidence showing that this may be important for speech understanding among cochlear implant users. Saleh et al. (2013) used a pure-tone pitch ranking task to find and deactivate indescriminable electrodes in unilaterally implanted adult patients. By using a clinically appropriate testing procedure and deactivating those electrodes that do not contribute to a “distinct perceptual experience,” twenty of twenty-five participants reported an improvement in overall sound quality, and sixteen saw significant improvements in speech perception scores. This points to the clinical utility of pitch ranking and should be considered when a patient’s speech perception or sound quality are not optimal.

Bimodal Fitting Methods

While a preference for using NAL fitting formulas was present, this result would presumably change were more pediatric cochlear implant audiologists included in the study as there was a positive correlation between number of pediatric cochlear implants activated and preference for DSL fitting formulas. However, as more companies produce bimodal hearing aid fitting formulas, it is hypothesized that the number of audiologists using them will grow. This specialization of hearing aid fitting formulas is supported by the work of Yehudai et al. (2013) which reports that formulas to increase gain at 250-500

Hz may be beneficial to bimodal users in improving sound quality and music appreciation. Additionally, Veugen et al. (2016) suggests that loudness balancing between the cochlear implant and hearing aid using either a three-band or broadband fitting method can increase speech understanding.

Habilitation/Rehabilitation Methods

There was a clear difference in recommendation of habilitation/rehabilitation options for adult versus pediatric patients. Audiologists participating in this study were far more likely to recommend services by a licensed speech-language pathologist to pediatric patients than their adult counterparts. Conversely, participants were more likely to recommend computer-based listening training programs to adults than to children. These results are not unexpected, but further dividing the questions to address pre- and post-lingually deafened patients may result in different responses. Adding an option for self-directed practice such as listening to audiobooks or music may also help to classify the types of auditory training patients are engaged in, as many participants wrote that they make similar recommendations.

Conclusion

In conclusion, the results of this study suggest that individual audiologists have varying methods for working with patients with cochlear implants. We have shown that audiologists have different preferences for defaults across manufacturers, and that there are small groups of respondents who do not necessarily follow manufacturer recommendations all of the time. Additionally, it seems that most audiologists do not always use all objective measurements in CI programming and follow-up, especially vestibular testing and eSRT which they may not have access to or experience with in their clinic. However, there are clear trends that indicate a consensus among clinicians in the areas of habilitation/rehabilitation methods and recommendation of amplification in bimodal patients. These data support the notion that audiologists adapt their practices for each patient, with patient preference and sound quality being the most often used text responses throughout the questionnaire. Future research should include more focused, detailed surveys to closely examine each of the sections included in this study. Shorter questionnaires may also allow for a greater number of responses. These data are not meant to create a new plan of best practice for audiologists in the U.S., but are instead a way to understand clinical practices to improve future patient outcomes.

Appendix I: Literature Review

Cochlear implants are electronic medical devices designed to allow for direct stimulation of the auditory nerve for those with severe to profound hearing loss (Wolfe & Schafer, 2014). These devices consist of two main components: the implanted receiver and electrode array, and the external microphone and sound processor (Zwolan, 2008). The internal portion of the device is surgically placed into the temporal bone and cochlea by a trained surgeon, while the external portion is programmed and adjusted by an audiologist. Despite the widely recognized success of cochlear implants, with some calling it the “most successful of all neural prostheses to date,” (Wilson & Dorman, 2008) fewer than 6% of Americans who could benefit from cochlear implantation receive the surgery and follow-up (Sorkin, 2013). This may be due to difficulties with insurance coverage or general lack of awareness, but it leads some researchers to believe that it points to the need for standardized care practices, which may prevent some patients from missing out on critical services (Sorkin, 2013). This makes a survey of cochlear implant audiologists in the United States particularly timely.

In the United States, these devices are available from three manufacturers: Cochlear, Advanced Bionics, and MED-EL. Each comes with its own advantages and disadvantages, as well as brand-specific candidacy criteria. Additionally, each brand contains its own default values and parameters, leaving audiologists to handle three completely different device families.

Vaerenberg et al. (2014) attempted to analyze how audiologists worked clinically with different devices through an international survey. Their participants included audiologists at a single conference, with only 3 American cochlear implant centers represented in the data. This makes generalizing the data for the U.S. problematic for a number of reasons, one being that at the time of the article's writing, some companies' default values were different for the United States versus other countries. Additionally, the education requirements for audiologists may widely vary depending on the country. For these reasons, this study may not be especially relevant to audiologic practice in the United States. However, trends were present among the mainly European participants indicating that clinicians rarely change MAP settings except minimum and maximum stimulation levels. Participants in the survey also reported that other than electrode impedance, which was measured by 100% of respondents, no other objective measurement was completed for more than 5% of the individual cases.

Other studies have examined the programming techniques of audiologists working with a patient using a hearing aid on the ear contralateral to the cochlear implant. This is known as bimodal fitting, and Scherf et al. (2014) found that all audiologists who participated in their survey recommend hearing aid use contralateral to the cochlear implant when possible. This paper also reported that there was limited use of a method to balance the sound of the cochlear implant and hearing aid, and that most participants did not refit the hearing aid after cochlear implant activation. Perhaps as a result of this lack of follow-up fitting procedures, Scherf et al. (2014) found that the majority of adult bimodal users stop using their contralateral hearing aid after receiving a cochlear implant. However, there were no American participants in the Scherf et al. (2014) study and these data are found to be in contrast with findings from Siburt and Holmes (2015).

When compared to Scherf et al. (2014), Siburt and Holmes (2015) illustrates the need for United States-specific studies of cochlear implant programming protocols. Siburt and Holmes (2015) found that the large majority of audiologists reprogram the hearing aid of bimodal users after cochlear implantation, but that they wait varying periods of time after implantation to do so. According to their participants from smaller centers, it is most likely that the professional who is responsible for reprogramming the hearing aids is the same person who is handling the cochlear implant programming. However, this is reversed in larger clinics, which are more likely to have different professionals for each device. Additionally, their findings show that 28% of the study participants use National Acoustics Laboratories prescriptive formulas, with others using Desired Sensation Level (16%) or manufacturer-specific formulas (18%). Other respondents wrote-in their methods, including loudness balancing with the cochlear implant. When asked about the frequency they use real-ear measurements for the hearing aid of a bimodal patient, only 25% of participants reported that they always do this.

Yehudai et al. (2013) studied the functional status of hearing aids in bimodal users in Tel-Aviv, Israel and found that 81% of their study participants were using a hearing aid that did not meet prescribed targets. Their work stresses the importance of loudness and pitch balancing between the cochlear implant and the hearing aid, and the potential benefits of providing sufficient low-frequency gain, namely improved sound quality and music appreciation. Additionally, the researchers suggest that while they used the NAL-NL1 fitting formula for hearing aid verification among the participants, formulas designed for use contralateral to a cochlear implant may allow more hearing aids to reach speechmap targets by providing more gain at 250-500 Hz. However, in contrast with

Scherf et al. (2014), Yehudai et al. found that the majority of adult unilateral cochlear implant users continue to wear their hearing aid contralateral to the implant even if improperly fit due to the addition of low frequencies the hearing aid may provide.

Supporting the notion that low frequency information from the hearing aid in bimodal fittings is critical, a pilot study from Messersmith et al. (2015) shows that reduction of gain in frequencies above 2000 Hz may improve performance of bimodal patients who are not performing well with traditional hearing aid fitting formulas. This study included cochlear implant users whose speech understanding performance decreased with the addition of a hearing aid for the contralateral ear. AzBio sentences were presented in quiet, and participants completed the testing in cochlear implant only and cochlear implant plus hearing aid conditions. Results suggest that introducing a fitting formula with a gain roll-off of 12 dB per octave at frequencies higher than 2000 Hz may improve both subjective sound quality and performance on behavioral speech recognition tasks. The authors state that additional investigation is needed to understand the needs of patients whose performance is degraded by the addition of a hearing aid contralateral to the cochlear implant since their study included a small number of participants.

When considering cochlear implant programming and follow-up issues, subjective measurements completed with the patient’s input, when possible, can be very important to clinical decision-making. Saleh et al. (2013) used a pure-tone pitch ranking task to find and deactivate indescriminable electrodes in unilaterally implanted adult patients. Participants faced a two-alternative forced choice test in which the center frequency of each filter was presented to evaluate the perceptual contribution of adjacent electrode pairs. If the participant could not complete the pitch-ranking task with an electrode, it was deactivated, and two new programs were created based on the remaining electrodes. One program used a wider pulse width, and the other a faster stimulation rate. By using a clinically appropriate testing procedure and deactivating those electrodes that do not contribute to a "distinct perceptual experience," twenty of twenty-five participants reported an improvement in overall sound quality, and sixteen saw significant improvements in speech perception scores. This points to the clinical utility of pitch ranking, which should be considered when a patient's speech perception or sound quality are not optimal. However, results from this study were not separated in terms of the program with wider pulse width and program with faster rate, so it is unknown which is most effective for patients.

Furthermore, Shapiro and Bradham (2012) suggest that the success of cochlear implant users is largely dependent on the quality of the programming completed by the audiologist, and that this process can be separated into four stages: preprogramming, operating room, initial stimulation, and follow-up. To achieve the best outcomes for their patients, audiologists must be able to maximally perform in each of these areas. In the pre-programming phase, patients must be prepared for the experience of auditory stimulation. While in the operating room, audiologists should perform intraoperative monitoring tasks like impedance telemetry and electrically-evoked stapedial reflex thresholds (eSRT) to verify auditory nerve stimulation. When completing initial stimulation with the cochlear implant, behavioral measures like electrical thresholds and most comfortable loudness level should be recorded. Additionally, audiologists must choose a strategy for speech processing, though no agreement exists as to the most successful method. Finally, in the follow-up phase, Shapiro and Bradham (2012) emphasize the need for a planned schedule of follow-up appointments to address potential fluctuations in electrical thresholds or changing auditory abilities and needs. However, the authors acknowledge a need for more standardized procedures to improve device programming outcomes, but a concomitant resistance to change among professionals.

Overall, there is a lack of consensus among researchers or clinicians about a standard method for how audiologists should approach cochlear implant programming. Additionally, bimodal fitting with a hearing aid contralateral to the implant presents a unique set of issues that is addressed in different ways depending on the country in which the patient is located. The available literature on the subject of clinical protocols for programming implants, bimodal fitting, and objective and subject measurements is limited, and suggests that U.S.-specific data is needed to improve understanding of the standard of care. While there maybe be trends in how some audiologists handle clinical decision-making, there remains large variability in the ways audiologists manage these decisions with cochlear implant patients. Perhaps a clear understanding of the state of audiologists' preferences in programming cochlear implants will contribute to improving the penetration rate of these devices and improve the outcomes of recipients

Appendix II

Questionnaire Version 12

When considering the following questions, think of your cochlear implant programming practices in general and what testing and programming you usually perform.

Definitions:

Adult: Patients age 18 years and older

Pediatric: Patients age 0 through 17 years

Mapping visits: Mapping visits refer to the visits when at least a new MAP is measured and the sound processor is configured and programmed (with either an old or new MAP).

1.) Total Number of Implants

Since you began programming cochlear implants, about how many cochlear implants have you, personally, activated?

Adult CI______ Pediatric CI_______

2.) Adult/Pediatric Ratio

Estimate the adult/pediatric patient ratio for the patients that you have personally seen. (select one)

- ☐ Only adult patients
- ☐ More adult than pediatric patients
- ☐ Equal numbers of adult and pediatric patients
- ☐ More pediatric than adult patients
- ☐ Only pediatric patients

3.) What type of facility do you work in?

- ☐ Privately-owned clinic
- ☐ Medical Center
- ☐ University clinic

<u>4.) Services Performed at Center</u>

Please indicate which services are provided at the facility in which you work.

A.) Medical/ENT

- ☐ Yes
- ☐ Referred Elsewhere

B.) Surgical (cochlear implantation)

- ☐ Yes
- ☐ Referred Elsewhere

C.) Auditory Rehabilitation

- ☐ Yes
- ☐ Referred Elsewhere

D.) Hearing Aid Fitting

- ☐ Yes
- ☐ Referred Elsewhere

E.) Vestibular Assessment

- ☐ Yes
- ☐ Referred Elsewhere

F.) Other (please explain):

<u>5.) How is the decision made about which manufacturer to use?</u>

- ☐ Surgeon preference
  - Always
  - Almost Always
  - Half the Time
  - Sometimes
  - Never
- ☐ Audiologist recommendation
  - Always
  - Almost Always
  - Half the Time
  - Sometimes
  - Never
- ☐ Patient decision

  - Always
  - Almost Always
  - Half the Time
  - Sometimes
  - Never
- Other (please explain)

6.) Cochlear

If you fit Cochlear, do you use default settings? Please indicate below.

Parameter	Always, Almost Always, Half the Time, Sometimes, Never (select one)	When I do not use default, I set values to:	Why I do not use default
Number of active channels/electrodes			
Gains (default=0)			
Strategy (default is ACE/ACE)			
Stimulation Mode (default is MP1+2)			
Channel Rate (900)			
Maxima (default is 8)			
Pulse Width (25)			
Volume Adjustment (20% of Dynamic Range)			
Analysis C-SPL (65)			
Analysis T-SPL (25)			

Loudness Growth (20)			
Frequency Table			
Power (auto)			
Volume and Sensitivity (Volume is 6, sensitivity is 12)			
Program Settings (default is SCAN)			

Other (please explain):

<u>7.) Advanced Bionics</u>

A.) If you fit Advanced Bionics, do you use default settings? Please indicate below.

Parameter	Always, Almost Always, Half the Time, Sometimes, Never (select one)	When I do not use default, I set values to:	Why I do not use default
Number of active channels/electrodes			
Strategy (default is HiRes-P)			
Clearvoice (default is "Off")			
Pulse Width Algorithm (default is APW I)			
T (default is 10% of M)			
Gains (default is 0 for all channels)			

Volume Max (default is 20%)			
Volume Min (default is 50 %)			
Sensitivity (default is 0 dB)			
IDR (default is 60 dB)			
Audio Mixing (default is 50/50-Mic/Aux)			
Mic Mode (default is "Omni Directional"			
Filter (default is Extended Low)			
AGC (default is 2-Dual Loop)			

Other (please explain):

B.) When fitting Advanced Bionics, what percentage of the time do you use HiRes Optima P versus HiRes Optima S strategies

I use HiRes Optima ____% of the time

I use HiRes Optima S ____% of the time

8.) Med-El

If you use Med-El, do you use default settings? Please indicate below.

Parameter	% of time I use default (select one)	When I do not use default, I set values to:	Why I do not use default
Number of active channels/electrodes (default is 12)			

Pulse duration (default is 7.08 microseconds)			
Strategies (default is FS4)			
Lowest frequency from (For FSP and FS4-p, default is 100 Hz. For HDCIS, default is 250 Hz)			
Frequency bands ((default is logarithmic FS—100-8500 Hz)			
AGC Compression Ratio (default is 3:1)			
AGC sensitivity (default is 75%)			
MapLaw (default is logarithmic with compression=500)			
Lock THR Charge (default is 10% of MCL)			
Volume Mode (default is IBK)			
Microphone Directionality (default is "Natural")			
Wind noise reduction (default is "Mild")			

Other (please explain):

9.) Objective Measurements

Regardless of the cochlear implant manufacturer, indicate the frequency (in the five categories: Always, Almost Always, Half the Time, Sometimes, Never) you use the following objective measurements and imaging for pediatric and adult recipients. Please also indicate how you each item is used for programming?

Measurement	At mapping visits I measure this for pediatric patients (select one)	How I use this measurement for programming for pediatric patients	At mapping visits I measure this for adult patients (select one)	How I use this measurement for programming for adult patients
Electrode impedance measurements				
Electrically-evoked Compound Action Potentials (ECAP) (including NRT, NRI, ART)				
Electrical Auditory Brainstem Response (EABR)				
Electrically-evoked Stapedial Reflex Threshold (ESRT)				
Vestibular tests (e.g. ENG, VNG)				

Other (please explain):

<u>10.) Subjective Measurements</u>

Answer these questions regardless of the manufacturer used unless otherwise specified.

A.) Please indicate the frequency you measure C/M/MCL levels using subjective patient feedback.
Always, Almost Always, Half the Time, Sometimes, Never

i. **If measuring M level with Advanced Bionics, what stimulus type do you use?**
- ☐ Speech
  - Always
  - Almost Always
  - Half the Time
  - Sometimes
  - Never
- ☐ Toneburst
  - Always
  - Almost Always
  - Half the Time
  - Sometimes
  - Never
- ☐ Live Speech
  - Always
  - Almost Always
  - Half the Time
  - Sometimes
  - Never
- ☐ Not Applicable/I have not programmed Advanced Bionics devices

B.) For the following questions, consider your measurement of T levels.

i. **Please indicate the frequency you measure T levels using subjective patient feedback overall.**
  - Always
  - Almost Always
  - Half the Time
  - Sometimes
  - Never
  -

ii. **Please indicate the frequency you measure T levels using subjective patient feedback for Advance Bionics devices.**
  - Always
  - Almost Always
  - Half the Time
  - Sometimes

- Never
- Not Applicable/I have not fit Advanced Bionics devices

iii. **If yes, please indicate the frequency you measure T levels using subjective patient feedback for Cochlear devices.**
- Always
- Almost Always
- Half the Time
- Sometimes
- Never
- Not Applicable/I have not fit Cochlear devices

iv. **If yes, please indicate the frequency you measure T levels using subjective patient feedback for Med-El devices.**
- Always
- Almost Always
- Half the Time
- Sometimes
- Not Applicable/I have not fit Med-El devices

C.) Please indicate the frequency you measure loudness balancing.

- Always
- Almost Always
- Half the Time
- Sometimes
- Never

D.) Please indicate the frequency you measure pitch ranking between electrodes.

- Always
- Almost Always
- Half the Time
- Sometimes
- Never

<u>11.) Sound Field Audiological Measurements with cochlear implant (aided condition)</u>

A.) Do you conduct warble-tone or narrow band noise audiometry?

- Always
- Almost Always

- Half the Time
- Sometimes
- Never

B.) Do you conduct speech discrimination in quiet?

- Always
- Almost Always
- Half the Time
- Sometimes
- Never

C.) Do you conduct speech discrimination in noise?

- Always
- Almost Always
- Half the Time
- Sometimes
- Never

When you conduct speech discrimination testing, which word list do you use? Select all that apply.

- **CNC**
- **Az Bio**
- **BKB Sin**
- **Other:**

D.) Do you conduct loudness scaling testing?

- Always
- Almost Always
- Half the Time
- Sometimes
- Never

E.) Do you conduct phoneme discrimination testing?

- Always
- Almost Always
- Half the Time
- Sometimes
- Never

<u>12.) Bimodal fitting</u>

A.) Frequency you recommend/consider a hearing aid on the contralateral side

- Always
- Almost Always
- Half the Time
- Sometimes
- Never

B.) Please answer the following questions about when you recommend or consider hearing aid use on the side contralateral to the cochlear implant.

	Frequency you recommend hearing aid use on the contralateral side immediately following cochlear implant activation	Frequency you recommend hearing aid use on the contralateral side 2-4 weeks after cochlear implant activation	Frequency you recommend hearing aid use on the contralateral side 5 weeks or more after cochlear implant activation	Other bimodal fitting protocol comments
For those who used a hearing aid on the contralateral side prior to surgery	▪ Always ▪ Almost Always ▪ Half the Time ▪ Sometimes ▪ Never	▪ Always ▪ Almost Always ▪ Half the Time ▪ Sometimes ▪ Never	▪ Always ▪ Almost Always ▪ Half the Time ▪ Sometimes ▪ Never	
For those who did not use a hearing on the contralateral side prior to surgery	▪ Always ▪ Almost Always ▪ Half the Time ▪ Sometimes ▪ Never	▪ Always ▪ Almost Always ▪ Half the Time ▪ Sometimes ▪ Never	▪ Always ▪ Almost Always ▪ Half the Time ▪ Sometimes ▪ Never	

C.) When fitting bimodal, what approach do you use for hearing aid fitting?

☐ NAL:
- Always
- Almost Always

- Half the Time
- Sometimes
- Never

☐ DSL:
- Always
- Almost Always
- Half the Time
- Sometimes
- Never

☐ Manufacturer formula:
- Always
- Almost Always
- Half the Time
- Sometimes
- Never

☐ Manufacturer bimodal fitting formula
- Always
- Almost Always
- Half the time
- Sometimes
- Never

☐ I use my own low frequency emphasis formula:
- Always
- Almost Always
- Half the Time
- Sometimes
- Never

☐ I use my own all frequency emphasis formula:
- Always
- Almost Always
- Half the Time
- Sometimes
- Never

D.) Do you and/or the hearing aid audiologist:

☐ Adjust the hearing aid to match cochlear implant settings
- Always
- Almost Always
- Half the Time
- Sometimes
- Never

☐ Adjust the cochlear implant to match hearing aid settings.
- Always
- Almost Always
- Half the Time

- Sometimes
- Never

E.) When you recommend a hearing aid for bimodal use, which type of hearing aid do you recommend?

- ☐ Premium digital hearing aid:
  - Always
  - Almost Always
  - Half the Time
  - Sometimes
  - Never
- ☐ Basic digital hearing aid
  - Always
  - Almost Always
  - Half the Time
  - Sometimes
  - Never
- ☐ Partner manufacturer's hearing aid (ex: Cochlear+ReSound, and Advanced Bionics+Phonak)
  - Always
  - Almost Always
  - Half the Time
  - Sometimes
  - Never

F.) What are your criteria for no hearing aid use on the contralateral side?

- ☐ The hearing aid interferes with perception through cochlear implant
- ☐ There is no proven benefit of hearing aid use on the contralateral side
- ☐ Other (please explain)

<u>13.) Speech Therapy and Auditory Verbal Therapy</u>

Please indicate which habilitation/rehabilitation methods that you recommend for use after device activation for adult and pediatric recipient.

Method	Frequency I recommend this for adult patients	Frequency I recommend this for pediatric patients

Speech therapy services (administered by a licensed speech-language pathologist)	▪ Always ▪ Almost Always ▪ Half the Time ▪ Sometimes ▪ Never	▪ Always ▪ Almost Always ▪ Half the Time ▪ Sometimes ▪ Never
Computerized listening training programs (e.g. LACE)	▪ Always ▪ Almost Always ▪ Half the Time ▪ Sometimes ▪ Never	▪ Always ▪ Almost Always ▪ Half the Time ▪ Sometimes ▪ Never

Other (please explain):

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