

**TOWSON UNIVERSITY
OFFICE OF GRADUATE STUDIES**

**RE-EVALUATING CANDIDATES FOR COCHLEAR IMPLANTATION:
TRADITIONAL COCHLEAR IMPLANTATION VS. HYBRID**

by

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**A thesis
Presented to the faculty of**

Towson University

in partial fulfillment

of the requirements for the degree

Doctor of Audiology

Department of Audiology, Speech-Language Pathology, and Deaf Studies

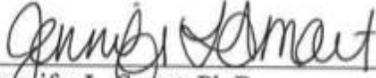
**Towson University
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May, 2016

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AUDIOLOGY DOCTORAL THESIS APPROVAL PAGE

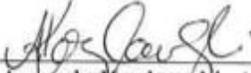
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entitled: Re-Evaluating Candidates for Cochlear Implantation: Traditional Cochlear
Implantation VS. Hybrid has been approved by the thesis committee as satisfactorily
completing the thesis requirements for the degree Doctor of Audiology (Au.D.)



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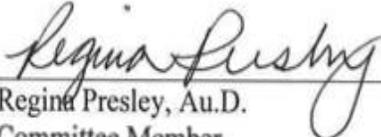
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ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my thesis chair, Jennifer Smart, Ph.D. for the continuous support of my Au.D. thesis research, for her patience, motivation, and immense knowledge. Her guidance helped me in all the time of research and writing of this thesis. Words cannot describe how truly thankful I am for her mentorship throughout my studies at Towson University. I would also like to thank the rest of my thesis committee: Amanda Kozlowski, Au.D, Regina Presley, Au.D., and Brian Kaplan, M.D, for their insightful comments and encouragement. Lastly, I would like to thank my family, my fiancé, and my cohort for supporting me throughout this process. Thank you all for making this one of the most rewarding and memorable experiences of my life.

ABSTRACT

Re-Evaluating Candidates for Cochlear Implantation: Traditional Cochlear Implantation vs. Hybrid

Alexandra Fickey

Cochlear implant (CI) candidacy criteria have expanded due to the advancements in technology (e.g., Hybrid CI), speech coding strategies, and surgical techniques. Now, people with some residual hearing that do not benefit from their best-fit hearing aids can be considered for CI candidacy. Research has shown that improved speech recognition and quality of life can be achieved post implantation for both traditional CI candidates and Hybrid CI recipients (Fitzpatrick & Leblanc, 2010; Hallberg & Ringdahl, 2004; Yeagle, Ceh, & Francis, 2010; Roland et al., 2016).

This study identified patients at the Towson University-Hearing and Balance Center (TU-HBC) that are CI candidates by evaluating their charts using both the traditional and newly expanded CI candidacy criteria. This was achieved through a retrospective chart review. A survey was mailed to TU-HBC patients that were identified as CI candidates. The survey asked questions about their satisfaction with their hearing aid(s) as well as interest in learning more about CIs. The findings from this study found that just over 6% of the TU-HBC patients were CI candidates audiometrically. Of the potential candidates identified (n=156), there were 10 people that returned a completed survey. Their results indicated that they currently perceive minimal benefit from their hearing aids and are interested in learning more about CIs. Interested patients were

invited to attend a CI information session at the TU-HBC as the first step informing them about cochlear implants.

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Chapter 1

Introduction

Hearing loss affects one in every six Americans (Ikeda, Murray, & Salomon, 2009). Hearing loss can be due to genetics (50%), environmental factors (25%) or in some cases the cause may be unknown (25%). One of the most common causes of hearing loss in adults is known as presbycusis, or hearing loss due to aging (Gates, 2012). There are a range of rehabilitation options for people with hearing loss.

There are many factors that determine the rehabilitation plan for a person with hearing loss and how successful they will be with it. These factors include: type, degree, configuration, duration, and onset of hearing loss, as well as their auditory recognition skills (Lasak, Allen, McVay, & Lewis, 2014; Di Nardo, Anzivino, Schinaia, & Paludetti, 2014; Dowell, Hollow, & Winton, 2004). Hearing loss is commonly rehabilitated with traditional amplification (e.g., hearing aids). Hearing aids amplify the acoustic signals in the environment. When hearing aids don't benefit a person their complaint is often that the sound is unclear. Hearing aids can make sounds louder but they cannot provide clarity of the signal. Loss of clarity in hearing may be due to degeneration of sensory hair cells (Hodges & Balkany, 2002). When hearing aids do not provide enough benefit, cochlear implant (CI) candidacy may be explored.

Cochlear implants were previously just for people with severe to profound sensorineural hearing loss but recent advancements in cochlear implant technology has led to expanding candidacy criteria. This expansion in criteria created the opportunity for more people who do not receive optimal benefit from traditional amplification to be considered for a CI. As indicated by Cochlear Americas, a CI candidate is someone who

has a sensorineural hearing loss that ranges from moderate to profound (Weaver, 2015). CIs often provide benefit to people who do not receive optimal benefit with best-fit hearing aids and meet the new criteria. However, people with low frequency residual hearing who do not receive benefit even with best-fit hearing aids and are not traditional CI candidates may qualify for the residual approach or a Hybrid device.

The Hybrid device, which is designed to combine electric and acoustic signals to provide benefit to people who still have low frequency residual hearing but would benefit from cochlear implant technology in the higher frequencies (Incerti, Ching, Cowan, 2013). The acoustic part of the device works like a hearing aid, amplifying the low frequency information. Electric stimulation provides access to mid to high frequency information that a person would otherwise not have access to under best aided conditions. The Cochlear Americas' Hybrid device candidacy criteria indicates that people with normal to moderate hearing loss in the low frequencies precipitously sloping to a moderately-severe to profound hearing loss in the mid to high frequencies are potential candidates.

The residual approach and development of the Hybrid cochlear implant provides an opportunity to restore hearing to individuals who received limited to no benefit from traditional amplification. This evolution of CI candidacy also gives audiologists the opportunity to re-evaluate their current patient population to see who do not benefit from hearing aids to see if they are now CI candidates.

Chapter 2

Literature Review

Hearing Loss

Hearing loss can have an adverse affect on a person's physical, social, and emotional well-being (Ramos et al., 2013). Hearing loss in adults often leads to feelings of isolation, social withdrawal from friends and family, and an overall decrease in quality of life (Hodges & Balkany, 2002). According to the World Health Organization (WHO), hearing loss is one of the most common clinical conditions affecting adults (WHO, 2012). Over 5% of the world has hearing loss, or 360 million people (WHO, 2012). In the United States, one in every six Americans reports difficulty hearing (Ikeda, Murray, & Salomon, 2009). The impact of hearing loss on an individual depends on a variety of factors.

Hearing loss is caused by the disruption of sound transduction to the outer, middle and/or inner ear (Willems, 2011). It is caused by a range of factors including: genetic, environmental, and idiopathic factors (Rehm & Madore, 2008; Willems, 2011). Hearing loss caused by genetics and environmental factors account for 75% of hearing loss cases. The remaining 25% of hearing loss cases are due to idiopathic factors, or unknown causes (Rehm & Madore, 2008). Table 1 provides a summary of the various causes of hearing loss. The cause, type, and degree of loss vary based on a number of factors.

Genetics. Hearing loss caused by genetics account for 50% of hearing loss cases (Rehm & Madore, 2008; Phillips, 2003). When a mutation is present in one gene or multiple mutations are present in multiple genes hearing loss can result (Willems, 2011). Hearing loss caused by genetics are classified by association as non-syndromic or

syndromic. Non-syndromic accounts for 70% of genetic causes of hearing loss and is characterized by hearing loss without association to other anomalies (Willems, 2011). Syndromic accounts for the remaining 30% of genetic causes of hearing loss and may be characterized by hearing loss in conjunction with other anomalies (Willems, 2011). Some of the more common syndromes seen with hearing loss can be found in Table 1. It is important to note that this is not an exhaustive list but represents a sample of the more common syndromes associated with hearing loss. Hearing loss caused by genetic factors only accounts for half of the cases. A quarter of hearing loss cases are caused by environmental factors (Rehm & Madore, 2008).

Environmental factors. Hearing loss due to environmental factors can be divided into two major categories: congenital or acquired. Congenital hearing loss means that the hearing loss is present at birth (Willems, 2011). Acquired hearing loss means it is a hearing loss that was acquired at some point after birth (Kent & La Grow, 2007). Environmental factors refers to pre- and perinatal infections, acoustic trauma, ototoxic drugs, or illnesses (Willems, 2011). Cytomegalovirus (CMV) is the most common cause of congenital infection and is the leading cause of sensorineural hearing loss, which is progressive in nature (Boyer & Boyer, 2004).

Common causes of acquired hearing loss due to environmental factors include: ototoxicity, loud noise exposure, sudden sensorineural hearing loss, and bacterial meningitis (ASHA, 2015). Ototoxicity refers to drugs either over the counter or prescription that are toxic to the inner ear (Cone et al., 2015). Common categories of ototoxic drugs are chemotherapy, loop diuretics, and aminoglycoside antibiotics. There are more than 200 other known ototoxic medications (Cone et al., 2015). Hearing loss

due to ototoxicity presents with a sharply sloping high frequency sensorineural hearing loss (Cone et al., 2015). Hearing loss caused by ototoxicity may go unnoticed until speech understanding is affected due to the progressive nature of the damage (Cone et al., 2015).

Sudden sensorineural hearing loss (SSNHL) is defined as a sensorineural hearing loss of 30 dB HL or poorer at a minimum of three adjacent frequencies occurring within 72 hours (Lionello et al., 2014). The cause of SSNHL is often unknown but it may be due to otologic, autoimmune, neoplastic, vascular or infectious diseases, or trauma (Lionello et al., 2014; Schreiber, Agrup, Haskard, & Luxon, 2010). However, only about 10% of SSNHL cases have an identified cause leaving most cases of SSNHL idiopathic. The incidence rate of SSNHL is between 5-30 cases per 100,000 per year (Schreiber et al., 2010). SSNHL typically presents as a unilateral hearing loss with symptoms of tinnitus and aural fullness in 80% of cases and vertigo in 30% of cases. SSNHL affects a wide age range of people, with an average age of 50-60 years old, and varies in audiometric degree and configuration (Schreiber et al., 2010). In addition to all of the causes of hearing loss listed in Table 1 the process of aging alone can cause hearing loss.

Table 1

Causes of Hearing Loss and Common Examples for Each Category

| Category | Association | Examples |
|---------------------|---------------|-------------------------------------------------------------------------------------------------------------------------------|
| Genetic (50%) | Non-Syndromic | Connexin 26 |
| | Syndromic | Alport Brancio-oto-renal CHARGE Downs Jerville & Lang-Nielson NF2 Pendred Turner Usher Waardenburg |
| Environmental (25%) | Congenital | Infections (e.g., CMV) Birth trauma Outer, middle, or inner ear anomalies |
| | Acquired | Ototoxicity Noise exposure Trauma Infection Disease |
| Idiopathic (25%) | N/A | Unknown |

Note. Modified from Cone et al., 2015, Fagan, Laurent, & Swanepoel, 2015, Rehm & Madore, 2008, and Zahnert, 2011. This list is not exhaustive.

Presbycusis. As a person ages the sensory cells in the cochlea degenerate, this cause of hearing loss is known as presbycusis (Ko, 2010). Presbycusis is the most common type of hearing loss in adults (Gates, 2012). Presbycusis typically affects people in their 60s and progresses as the person ages (Gates, 2012). Hearing loss due to presbycusis affects 25% of adults aged 55 to 64 and 43% of adults aged 65 to 84 (Ramos et al., 2013). The typical audiometric configuration is a sloping sensorineural hearing loss that is worse in the higher frequencies (Stach, Hornsby, Rosenfeld, & DeChicchis, 2009). The most common complaint amongst patients with presbycusis is that they have difficulty understanding speech, likely because the majority of speech sounds are high

frequency (Deng, Ji, & Yang, 2014). One major variable across all causes of hearing loss, including presbycusis, is how it affects the individual. Identification and diagnosis of hearing loss is conducted through an audiologic evaluation.

The Audiologic Evaluation

An audiologic evaluation minimally includes the assessment of the outer, middle and inner ear. A full audiologic examination includes: otoscopy, tympanometry, acoustic reflex thresholds, otoacoustic emissions, pure tone audiometry, and speech audiometry (Gelfand, 2009; Lasak, Allen, McVay, & Lewis, 2014; Medwetsky, 2014). An audiogram is a graphical representation of subjective pure tone testing which helps the audiologist identify the type, degree and configuration of the hearing loss (Manchaiah & Stephens, 2013). The results of the comprehensive audiologic evaluation assist with making appropriate recommendations and rehabilitation options. Hearing loss is described by the type, degree, and configuration seen on the audiogram.

Type of hearing loss. The type of hearing loss refers to where (outer, middle, and/or inner ear) the hearing loss occurs. A conductive hearing loss (CHL) is a problem with the outer and/or middle ear and is identified by air conduction thresholds that are poorer than bone conduction thresholds (Zahnert, 2011). A sensorineural hearing loss (SNHL) is a problem with the inner ear and/or the eighth nerve and is identified by air conduction and bone conduction thresholds that are outside normal limits (Manchaiah & Stephens, 2013; Zahnert, 2011). A mixed hearing loss is due to a combination of conductive and sensorineural problems (Zahnert, 2011). Each type of hearing loss can range in severity or degree.

Degree of hearing loss. The degree of hearing loss refers to severity of the loss. There are two widely used charts that guide professionals on the various categories of degree of hearing loss. ASHA's (2011) categories of degree of hearing loss include a slight loss and are often used in textbooks for training audiologists (e.g., Gelfand, 2009). The degrees of hearing loss as described by ASHA (2011) are shown in Table 2. The WHO (2015) describes degree of hearing loss using a different scale, as seen in Table 3. The scale used by the WHO categorizes degree of hearing loss by the better ear for grade of impairment from 0-4, 0 indicates no impairment and 4 indicates profound impairment (WHO, 2015). Hearing loss is not only described in terms of the type and degree of hearing loss but it is also described based on the configuration of thresholds across frequencies.

Table 2

Degree of Hearing Loss- ASHA 2011

| Degree of Hearing Loss | Threshold |
|------------------------|-------------|
| Normal | < 15 dB HL |
| Slight | 16-25 dB HL |
| Mild | 26-40 dB HL |
| Moderate | 41-55 dB HL |
| Moderately-Severe | 56-70 dB HL |
| Severe | 71-90 dB HL |
| Profound | ≥ 90 dB HL |

Note. Modified from ASHA, 2011. The audiometric values are averages of values at 500, 1000, and 2000 Hz.

Table 3

Grades of Hearing Impairment and Degree of Loss- WHO 2015

| Grade | Degree of Hearing Loss | Threshold |
|-------|------------------------|-----------------|
| 0 | No impairment | ≤ 25 dB HL |
| 1 | Slight impairment | 26-40 dB HL |
| 2 | Moderate impairment | 41-60 dB HL |
| 3 | Severe impairment | 61-80 dB HL |
| 4 | Profound impairment | ≥ 81 dB HL |

Note. Modified from WHO, 2015. The audiometric values are averages of values at 500, 1000, 2000, and 4000 Hz.

Configuration. The configuration of the hearing loss refers to the threshold formation as read across frequencies, often described from low to high frequencies or left to right on the audiogram. A list of commonly used terms and their definitions are seen in Table 4. The configuration of the hearing loss often plays an important role when creating an appropriate hearing loss management plan. Additionally, audiologists also talk to their patients about their speech understanding because difficulty understanding speech is often the reason a patient pursues an audiologic evaluation.

Table 4

Configuration of Hearing Loss

| Term | Description |
|-----------------------|------------------------------------------------------------------------------|
| Flat | < 5 dB rise or fall per octave |
| Gradually falling | 5-12 dB increase per octave |
| Sharply falling | 15-20 dB increase per octave |
| Precipitously falling | ≥ 25 dB increase per octave |
| Rising | > 5 dB decrease per octave |
| Saucer | ≥ 20 dB loss at high and low frequencies but not in the mid frequencies |
| Trough | ≥ 20 dB loss in the mid frequencies as compared to 500 or 4,000 Hz |
| Notched | ≥ 20 dB poorer at one frequency with recovery at adjacent frequencies |

Note. Modified from: Schlauch, R.S. & Nelson, P. (2015).

Speech recognition. Speech audiometry is a common practice when administering a hearing test because it gives information about the person's functional

hearing ability (Van Zyl, 2015). Performance on speech recognition tests has multiple clinical functions (Gelfand, 2009). Specifically, speech recognition test performance allows the clinician to gauge how the person may perform with traditional amplification (Van Zyl, 2015). The most commonly administered speech recognition tests include: speech recognition thresholds (SRT) and word recognition testing (WR) (Van Zyl, 2015). The SRT is the lowest intensity level a person can recognize and repeat back words, commonly from a list of spondee words (Gelfand, 2009). WR testing requires the patient to repeat back words commonly from a list of phonemically balanced monosyllabic words (Gelfand, 2009). WR is reported in percent correct. The SRTs and WR scores provide information on a person's speech recognition ability in a quiet, ideal listening environment. However, people who have hearing loss often report having the most difficulty in more adverse listening situations (e.g., restaurant, social gathering, phone conversations, while watching the television, etc.).

A more realistic everyday listening environment involves speech in background noise. There are speech recognition tests that can be administered to acquire a more realistic picture of a person's functional hearing ability (e.g., AzBio in noise). These additional tests may further assist with counseling, aural rehabilitation, and selection of amplification. Another factor that can affect speech perception performance is the aging central auditory system, which can impact the way auditory signals are processed and interpreted in the brain (Gates, 2012). A common complaint of people with hearing loss is that they can hear a person when they are talking but they do not understand what they are saying (Gelfand, 2009). Traditional rehabilitation options (e.g., hearing aids) make

sound louder but they often do not make things clearer, making complaints related to clarity difficult to address with hearing aids alone.

Rehabilitation

The results from the audiogram, speech performance, and patient complaints contribute to the development of a rehabilitation plan for a person with hearing loss. The two main rehabilitation options for sensorineural hearing loss are hearing aids and cochlear implants (Lasak, Allen, McVay, & Lewis, 2014).

Hearing aids. Hearing aids amplify the sound coming into the ear, as an attempt to compensate for the reduced volume resulting from the damaged outer hair cells (OHCs) within the cochlea. But it is important to note that a sensorineural hearing loss can be due to a loss of OHCs in the cochlea, and/or a loss of inner hair cells (IHCs) in the cochlea. If there is also a loss of IHCs then the clarity of speech is also impaired (Lasak, Allen, McVay, & Lewis, 2014). Unfortunately, hearing aids cannot compensate for a loss of clarity (Hodges & Balkany, 2002). However, cochlear implant technology may provide people with hearing loss a different way to access sound and help to restore the clarity for people that do not receive any (or minimal) benefit with hearing aids (Carpenter, 2009).

Cochlear implants. A CI is a device that provides access to sound to someone that receives minimal benefit from traditional amplification (i.e., hearing aids). CIs electrically stimulate the residual neurons in the auditory nerve, sending the sound directly to the auditory cortex (Peterson, Pisoni, & Miyamoto, 2010). A CI can improve a person's audibility and intelligibility of sound. CIs do this by amplifying sound and increasing the dynamic range that is more similar to that of a healthy cochlea (Dowell,

2005). Current CI devices are multichannel and utilize the tonotopic organization of the cochlea to provide different information to each electrode placed in the cochlea (Zwolan, 2015). As CI technology evolves the option to receive a CI becomes a more viable option for people who do not benefit from hearing aids. As of December 2012, approximately 324,200 CIs have been implanted worldwide (NIDCD, 2014).

Candidacy for Adults

CI candidacy criteria continues to evolve as improvements in technology are made. The advances in technology include: electrode array design, surgical techniques, and signal coding strategies which all helped broaden CI candidacy criteria (Weaver, 2015). Criteria indications are set forth by the Food and Drug Administration (FDA) and vary for each manufacturer and each device. The devices are approved by the FDA through clinical trials and the criteria used during the clinical trials are ultimately what gets approved (or denied) through the FDA.

There are currently three CI manufacturers that are approved by the FDA and used in the United States today: Advanced Bionics, MED-EL, and Cochlear America. Candidacy is based on current CI patient results (e.g., clinical trials), device indicators, and insurance requirements (Stach, Zwolan, & Slager, 2015). Physicians can choose to perform off label surgeries (for the patients that may not fit the FDA criteria but have a need for the CI) (Stach, Zwolan, & Slager, 2015). Initially, CI candidacy criteria were indicated for adults with post-lingual, bilateral profound to total SNHL, and receiving no benefit with best-fit hearing aids (Hodges & Balkany, 2002). CI candidacy criteria has evolved to be more flexible with requirements for audiometric thresholds. The residual approach uses a soft surgical technique and the Hybrid has a shortened electrode array

(Friedland & Runge-Samuelson, 2009). These developments have led to an expanded candidacy criteria. Criteria for the cochlear implant are indicated by an audiometric range of moderate to profound SNHL. Criteria for the Hybrid is indicated by an audiometric range of normal to moderate in low frequencies, sloping to severe to profound hearing loss in the mid to high frequencies.

Evolving criteria allows for people with more residual hearing but poorer hearing aid performance to receive cochlear implants. During the audiologic assessment WR testing is conducted, which is an important part for determining CI candidacy and potential benefit after implantation (Dowell, 2005). The recommended tests to assess performance pre- and post-implantation include: AzBio sentences, Bamford-Kowal-Bench Speech-in-Noise (BKB-SIN) or the Hearing in Noise Test (HINT) sentences in noise, and CNC monosyllabic words administered using recorded speech at an intensity level of 60 dB SPL (Gifford, Dorman, Shallop, & Sydlowski, 2010). Speech recognition testing with and without noise will provide the clinician with a better picture of the patient's speech understanding abilities (Gifford et al., 2010). The results or scores will assist in counseling pre- and post-implantation regarding realistic expectations and achieved improvement.

There are three main areas in audiology that are used to determine candidacy. The three main areas assessed include: audiometric thresholds, speech recognition, and trial with hearing aids (Gifford et al., 2011). Audiometric thresholds refer to the severity of the candidates hearing loss. Advanced Bionics and MED-EL indicates a bilateral severe-to-profound SNHL (≥ 70 dB HL) while Cochlear Americas indicates bilateral moderate-to-profound SNHL (≥ 90 dB HL) hearing loss (Gifford et al., 2011). Speech recognition

criteria refers to the candidate's performance with speech tests administered while wearing their hearing aids. A trial with best-fit hearing aids is also necessary in many cases to evaluate if traditional amplification is beneficial. FDA approved candidacy criteria for each company can be seen in Table 6. In addition to these guidelines candidates are evaluated on a case-to-case basis because hearing loss, speech perception, hearing aid benefit and realistic expectations vary widely between each patient.

Table 5

CI Candidacy Criteria for manufacturer as indicated by the FDA

| | Advanced Bionics | Med-El | Cochlear Americas |
|-----------------------|-------------------------------------------------------------------------------------------------------|-------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|
| Hearing loss | Severe-to-profound SNHL | Severe-to-profound bilateral SNHL | Moderate-to-profound SNHL |
| Onset of hearing loss | Post-lingual | Doesn't specify | Pre-, peri-, post-lingual |
| Speech perception | 50% or less on a test of open-set sentence recognition (e.g., HINT sentences) in best aided condition | 40% or less on HINT sentences in best aided condition | 50% or less on sentences in ear to be implanted and 60% or less in opposite ear on open-set sentence recognition |

Note. Modified from information presented by Stach, Zwolan, & Slager, (2015, March).

An otologic and medical assessment is necessary to deem the implantation surgery safe and successful for the candidate (Niparko, Lingua, & Carpenter, 2009). Establishing the etiology of hearing loss will assist in determination of candidacy and may help to counsel the patient regarding prognosis after implantation. However, it is not always possible to determine the etiology of hearing loss. A computed tomography (CT) scan and/or magnetic resonance imaging (MRI) of the temporal bone and internal auditory canal must be performed to ensure patency and presence of necessary inner ear

structures (Dowell, 2005). Abnormalities of the mastoid, middle ear or labyrinth can have negative implications for implantation. Additional specialized tests, for example, an electrically evoked auditory brainstem response (EABR) test may also be performed as it will give information on the functional integrity of the auditory nerve and the pathways when it is unknown (Zwolan, 2015). Vestibular disturbance is possible after surgery (Dowell, 2005). In most cases, vestibular issues resolve over a few weeks. However, sometimes balance can remain an issue for longer periods of time. For elderly patients who have an increased risk of falls this should be monitored post implantation (Dowell, 2005). General health status is assessed to ensure that the candidate is able to undergo general anesthesia and the rehabilitation process post-implantation (Dowell, 2005; Niparko, Lingua, & Carpenter, 2009). An elderly cognition screening is also important. The psychological state of the person should be assessed because changing the mode of communication is life altering. As inferred, determining candidacy is a team approach.

Cochlear implant device components and component functions. A cochlear implant consists of both external and surgically implanted internal parts. Both the internal and the external devices vary in appearance depending on manufacturers (Peterson, Pisoni, & Miyamoto, 2010). The external parts include: a microphone, speech processor, and a transmitter, as shown in Figure 1. Sound is picked up by the microphone, located at ear level, on the external device worn behind the ear (Hodges & Balkany, 2002). The sound is converted into an analog electronic signal (Carlson et al., 2012; Moore & Teagle, 2013). The electronic signal is sent to the speech processor to be filtered and coded. The electronic code represents the intensity, frequency range, and timing of the signal (Moore & Teagle, 2013). The function of the speech processor is to divide the

electronic signal into frequency bands that match up with the electrodes in the electrode array in the cochlea. A typical CI has a frequency range of 200 to 7500 Hz (Moore & Teagle, 2013). The external transmitter coil sends the signal across the skin by frequency modulated radio signal to the internal receiver-stimulator (Moore & Teagle, 2013).

The internal component is called the receiver-stimulator, which is comprised of a computer chip, receiving coil, and electrodes (Hodges & Balkany, 2002). The signal is further processed in the internal component and becomes an electrical signal sent through the electrode array, which is inserted into the cochlea and stimulates the residual auditory neurons in the auditory nerve for central processing (Carlson, Driscoll, Gifford, & McMenomey, 2012; Peterson, Pisoni, & Miyamoto, 2010). The electrode array in modern CIs have between 11 and 24 electrode contacts. Manufactures use a ground/reference electrode to complete the electrical circuit. In Cochlear Americas' devices, the ground electrode is placed under the temporalis muscle, often called the stimulation mode (Moore & Teagle, 2013). In Advanced Bionics and Med-El the ground electrode is built into the body of the implant. The three most common modes used are monopolar, bipolar, and common ground. The audiologist makes this decision based on the internal device and the processing strategy (Moore & Teagle, 2013). The complexity of these components and their function make precision of implantation important.



Figure 1. Cochlear Nucleus 6 Sound Processor. External device components are labeled: 1= Microphones, 2= Speech processor, 3= Transmitter.

Implantation. A surgeon, an otolaryngologist or neuro-otologist, implants the internal components of the CI. The surgery takes approximately one and a half to two hours and is done under general anesthesia (Carr, 1993; Hodges & Balkany, 2002; Toner, Jackson, & Toner, 2013). The surgeon begins by making a small incision, 3-4 cm, behind the auricle of the ear and performing a mastoidectomy to access the middle ear (Hodges & Balkany, 2002). The surgeon typically inserts the electrode array either through the round window at the base of the cochlea or by drilling a hole and placing the electrode array just below the round window. Both approaches lead to the scala tympani (Wilson & Dorman, 2008). Round window insertion may also be less traumatic to the cochlea. The electrode array must be inserted slowly to minimize damage in attempt to preserve any residual hearing. The opening of the cochlea is then sealed with soft tissue and the receiver stimulator component is tied into place (Hodges & Balkany, 2002). After the procedure is completed the patient is stitched up and brought to a recovery room until they are deemed stable to be discharged. This procedure is typically an outpatient surgery and recovery is quick. Patients who opt for the CI surgery are counseled on having realistic expectations and the potential risks.

Risks. During the CI surgery the patient is under general anesthesia. During surgery the facial nerve is often monitored to ensure it does not get damaged, which would lead to facial paralysis. Other risks include: infection, temporary or permanent taste disturbance, tinnitus, and vertigo (Zwolan, 2015). Internal device failure requiring re-implantation is rare, reported less than 3% (Carlson et al., 2012; Hodges & Balkany, 2002). A major part of implantation is the follow up care after implantation. Follow up care ensures maximum benefit to the device user.

Follow up care. After surgery, the patient follows up with the surgeon to ensure proper healing of the implantation site (Hodges & Balkany, 2002). The next appointment the patient will attend is with their audiologist for the initial programming of their device. Wait time for this appointment varies on the implant center (Zwolan, 2015). The patient may have their speech processor turned on just a few days after their surgery or a few weeks after surgery. The speech processor is typically turned on once the site of implantation is fully healed (Hodges & Balkany, 2002). At the initial activation appointment, the patient will come into the audiologist's office to have the device both turned on and programmed (mapped). Usually the adult patient will be seen by the audiologist two times during the first month, and then 3, 6, and 12 months after activation (Zwolan, 2015). Selection of an optimal speech coding strategy to program the speech processor is also done at the initial visit (Moore & Teagle, 2013). Selecting a speech coding strategy is called mapping (Moore & Teagle, 2013). Speech processing strategies can be placed into three broad categories of how they each represent components of speech: frequency, temporal or timing, or a combination of frequency and temporal emphasis. All three CI companies have the continuous interleaved sampling (CIS) coding strategy as an option for their speech processor. But, in general, speech processing strategies vary between each CI manufacturer. The patient will come for follow up appointments regularly so that the device can be fine tuned for comfort and maximal benefit.

The need for surgical implantation of the internal device makes getting a CI a lifelong commitment as compared to hearing aids, which can simply be returned if satisfaction is not met. Both the internal and external devices of a CI must be worn

together for it to work. The decision to discontinue use of a CI is one that should be avoided. A comprehensive pre-implantation assessment and extensive counseling must be done to reduce non-use. The possible advantages of CIs for people who do not receive enough benefit from hearing aids cannot be minimized.

Outcomes. Hearing with a CI is different than hearing with natural sound or hearing aids because a CI doesn't just make sound louder it translates acoustic information to electrical stimulation. Therefore, the brain has to adapt to the new auditory stimulation, which will occur over time. Patients must be counseled on what to expect after implantation *before* they receive the implant. This counseling should include a discussion of how to maximize the benefits of the CI. There are many factors that may influence performance outcomes post-operatively with a CI, which include: duration of loss, onset, degree of hearing loss, auditory skill performance, and age at implantation (Di Nardo, Anzivino, Schinaia, & Paludetti, 2014; Dowell, Hollow, & Winton, 2004). Studies have been done on CI recipients, post-implantation, to look at a variety of outcomes.

NIH's 1995 CI statement reported that a majority of people who were post-lingually deafened and were implanted achieved higher than 80% correct on high context sentences. Performance on single words was found to be poorer than sentences, however there was still improvement seen in speech recognition when compared to pre-implantation results. Pre-lingually deafened adults had poorer performance outcomes but still reported high satisfaction with the CI for improvement in sound awareness (NIH, 1995).

ASHA's 2003 technical report for CIs highlighted the benefits of CIs. ASHA (2003) reported post-lingual onset of hearing loss in adults average auditory only word recognition scores at 35-45% correct and sentence recognition scores at 65-80% with SPEAK processing. Adults who are pre-lingually deafened do not often achieve open set word recognition abilities post-implantation. However, they do minimally report benefits in the form of recognizing environmental sounds for sound awareness (ASHA, 2003). More recent studies have been conducted to assist with making conclusions about performance outcomes in people with some residual hearing and adult CI outcome performance.

A study conducted by Dowell et al. (2004) looked at 45 adult CI candidates with residual hearing and how they performed on pre- and post- implantation assessments. The test battery consisted of open-set sentence testing using the City University of New York (CUNY) sentences, open-set monosyllabic word testing (consonant-nucleus-consonant (CNC) words scored by phonemes and words correct, and open-set sentences in background noise at +10 dB signal-to-noise ratio. There are several factors that can impact pre- vs. post-lingually deafened performance outcomes post-implantation. Results confirmed that duration, onset, and degree of hearing loss impact post-implantation auditory skill performance. The amount of time that the auditory system is deprived of auditory input negatively correlates with post-implantation performance outcomes (Dowell et al., 2004). Typically post-lingually deafened patients will perform better with a CI than pre-lingually deafened patients, having better post-operative performance outcomes. The amount of residual hearing a patient has is a direct advantage for implantation (Dowell et al., 2004). Overall, >75% of candidates showed greater speech

perception with a CI than in their best-aided pre-operative condition. Most candidates showed greater improvement (average improvement 20.5%) on speech perception with open set sentences (CUNY) and open set sentences in background noise in +10 dB signal-to-noise ratio than they did on words (CNC). However, performance outcomes varied greatly between subjects in this study. While most showed improvement the degree of improvement was more difficult to quantify because of the wide range of performance (Dowell et al., 2004). The variance in post-operative performance outcomes shows the importance of accurate counseling prior to implantation. Each CI candidate will have different post-operative outcomes.

Yeagle, Ceh, & Francis (2010) reviewed studies on the increasing number of elderly patients seeking CIs. CIs can provide improved communication and improved health related quality of life (HR-QOL) to elderly patients. Hearing loss is more likely to lead to feelings of depression, social isolation, loneliness, and loss of independence in elderly patients as compared to younger patients. Studies on CI outcomes for elderly patients provide evidence of improved aided hearing thresholds as well as improved speech recognition abilities post-implantation (Yeagle et al., 2010). Speech recognition improvement post-implantation is found to be directly correlated to improved HR-QOL (Yeagle et al., 2010). CIs can become a great option for elderly patients who no longer receive enough benefit from hearing aids.

Another study was performed to investigate CIs in the elderly (Budenz et al., 2011). The study compared results from two groups: a younger group implanted between the ages of 18 and 69 (mean age at implantation was 47.9) and an older group implanted at age 70 and older (mean age at implantation was 76). The test battery consisted of CNC

words and phonemes and the CUNY sentence test in quiet and in noise. Post-operative measures were recorded over a two-year observation period after implantation. Results revealed that performance increased over time with increased CI experience for both groups, greatest performance increase noted within the first three months after implantation. When age and speech recognition scores were correlated, results revealed that as age increased, scores on CNC words and phonemes decreased. The duration of deafness also impacted speech recognition performance, longer duration correlated to poorer performance. Overall, both groups of participants improved on all speech recognition tests after implantation. Results emphasize the benefit of older adults being implanted when they become candidates because at least some level of benefit is achieved (Budenz et al., 2011).

Di Nardo et al. (2014) conducted a study looking at older adults (mean patient age 72) and younger adults (mean patient age 52) in terms of their QOL and auditory performance post-implantation. To measure speech recognition abilities participants were tested with bisyllabic words (using Turrini et al. words) in quiet and sentences (using Burdo-Orsi sentences) in quiet. Findings of this study indicated improvement in speech recognition ability skills in both groups post-implantation as compared to pre-implantation results. Another measure of benefit with CIs used in this study was the health related quality of life questionnaire (HR-QOL). HR-QOL is generally completed pre- and post-operatively for comparison. In this study the short form 36 (SF-36) and the “Questionnaire for Self-Assessment of CI Benefit” were used to measure the QOL. Results on the SF-36 showed no differences in QOL between the older adult group and the younger adult group. The older adult group showed higher overall satisfaction on the

Questionnaire for self-assessment of CI benefit. Both questionnaires showed an increase of QOL for both groups after cochlear implantation (Di Nardo et al., 2014).

All of the studies discussed report that CIs provide benefit on speech recognition abilities as well as QOL for adults who do not receive benefit from best-fit hearing aids. However, it is difficult to quantify an exact percentage of benefit that will be received for individual patients because of factors that influence success with a CI. Cochlear implants have been a successful option for people that do not benefit from hearing aids because their hearing and/or word recognition abilities are poor. Unfortunately, cochlear implants have been limited to people that were profoundly deaf or had severe-to-profound hearing losses. These criteria didn't account for the people with better hearing thresholds but limited benefit from hearing aids. The Hybrid device and modified electrode arrays have allowed the candidacy criteria to be broadened to include adult individuals with more residual hearing. Hearing loss in older adults is found to have adverse effects on physical, psychosocial, and social components of life.

Recent advancement. Audiologists commonly have patients present with high frequency sloping SNHLs with low frequency residual hearing (Turner, Gantz, & Reiss, 2008). Even when a hearing aid is meeting all objective targets, subjectively patients may still complain they cannot understand speech, especially in complex listening environments.

The high frequency hearing loss occurs in the basal end of the cochlea (Turner et al., 2008). By inserting a shorter electrode array or shortening the depth of insertion of the electrode array into the more basal end of the cochlea speech recognition skills will be improved by electrically stimulating high frequencies, where the more severe degree

of hearing loss is present, while preserving the residual low frequency hearing. The Hybrid uses a combination of acoustical and electrical stimulation to increase speech recognition performance in patients who do not receive benefit from best-fit hearing aids (Turner et al., 2008; Incerti, Ching, & Cowan, 2014). The device is a cochlear implant that is intended to provide mid and high frequency information coupled with a hearing aid in the same ear to provide low frequency information (Incerti, Ching, Cowan, 2013). Incerti et al. (2013) showed significant improvement in speech recognition scores when comparing patients with a Hybrid (combination of electrical and acoustical stimulation) versus patients with a CI (electrical stimulation only). This device has a shorter electrode array (16 mm) and uses natural hearing or amplification to stimulate the low frequencies acoustically while the high frequencies are stimulated electrically by the CI. It has been found that natural residual hearing will also result in better outcomes in terms of speech recognition, hearing in noise, and sound localization as opposed to electrical or acoustical stimulation. Therefore, the Hybrid device, and hybrid hearing, is potentially a good option for people who have low frequency residual hearing with substantial high frequency hearing loss (Incerti et al., 2014).

Another recent advancement to preserve low frequency residual hearing is to shorten the depth of insertion of the electrode array. The array is 25 mm in length and can be inserted to the 20 mm marker or the full 25 mm marker. The electrode array is inserted using the soft surgical technique. The shorter depth of insertion will allow for preservation of low frequency residual hearing

Statement of Purpose

Only 5-10% of adults with hearing loss that are candidates for cochlear implants have been implanted despite the fact that Medicare, Medicaid, and other private insurance carriers often pay for the procedure (Miller et al., 2015). The advancement in technology and devices has led to changes in CI candidacy criteria. People with low frequency residual hearing who do not benefit from hearing aids may now be considered for a CI device or the Hybrid device, a newer device that uses electro-acoustic stimulation. Studies on performance outcomes support the idea that cochlear implantation can lead to improved aided audiometric thresholds, speech recognition abilities, and overall quality of life (Dowell et al., 2004; Yeagle et al., 2010; Budenz et al., 2011; DiNardo et al., 2014)

This study aimed to identify patients who are not receiving any (or minimal) benefit from best-fit hearing aids. A retrospective chart review from a large clinic was conducted to identify people who met the new audiometric and speech recognition criteria set forth by Cochlear Americas. Any person found to be a CI candidate received a short survey about their current listening abilities and interest in CIs.

Chapter 3

Methodology

A retrospective chart review was performed in the Towson University Hearing & Balance Clinic (TU-HBC) in Baltimore, Maryland. International Review Board approval was obtained prior to data collection.

Equipment

The Noah 4 computer software on a Dell Optiplex 990 desktop computer was used to search for patients at TU-HBC using age and degree of hearing loss to narrow the search. The advanced search tool in Noah 4 assisted in creating a shortlist. The CI candidacy criteria guidelines for the Cochlear Americas cochlear implants, including the new Hybrid device, were used to identify possible candidates.

Software

To conduct an advanced search in Noah 4 the advanced search window on the left pane of the screen was expanded. Then demographic data (i.e., gender, age, etc.) was selected. Next, the hearing loss tab across the top of the screen was selected and desired audiogram data entered for the search. Search criteria for this study were age and audiometric threshold data. Age minimum was 18 years old and age maximum was 100 years old.

The first search conducted was for the Cochlear Americas' Nucleus device. Audiometric threshold criteria for the Cochlear Americas Nucleus are displayed in Table 6. After the search was conducted the results were exported to Comma Separated Values (CSV) format. This format allowed the results to be converted into Microsoft Excel format. The search results were exported by clicking file, and then export files. The

export options window was displayed and the patients being exported was selected and then exported to a specific location. The short list of results was displayed on the left pane. The new file was saved for analysis.

The second search process was the same for the Cochlear Americas' Hybrid device except the criteria for the Hybrid device was used (see Table 7).

Table 6

Audiometric Threshold Criteria for the Cochlear Americas Nucleus

| Frequency | Threshold |
|-----------|-----------|
| 500 Hz | 40 dB HL |
| 1000 Hz | 90 dB HL |
| 2000 Hz | 90 dB HL |
| 4000 Hz | 90 dB HL |

Note. Information displayed in the table is modified from Cochlear Americas.

Table 7

Audiometric Threshold Criteria for the Hybrid

| Frequency | AC min. dB level | AC max. dB level |
|-----------|------------------|------------------|
| 500 Hz | 0 dB HL | 60 dB HL |
| 2000 Hz | 75 dB HL | 120 dB HL |
| 4000 Hz | 75 dB HL | 120 dB HL |

Note. Information displayed in the table is modified from Cochlear Americas. Criteria indicated for ages 18+.

Chart Review

Active, inactive, and archived files were reviewed. Active files were designated as patients who were currently being seen or were last seen no later than 2012. Inactive files were designated as patients who have not been seen recently but in the past seven years. Archived files were designated as patients who have not been seen for over seven years. The short list of candidates derived from the Noah 4 advanced searches were created and

separated based on candidacy for individual devices (Traditional CI vs. Hybrid). The short lists were used as a cross checks after all audiology charts in the clinic had been reviewed. Charts based on the short list were used as confirmation that those charts were retrieved and reviewed.

The identification of a cochlear implant “candidate” was based solely on audiometric data. Additionally, age, gender, pure tone thresholds (air conduction and bone conduction) at 250-8000 Hz for both ears, most recent word recognition score in unaided condition, etiology of hearing loss if known, patient use of hearing aids, and patient satisfaction with amplification were collected to further describe this population. People who met hearing loss and onset of hearing loss criteria were included for data analysis. Criteria are displayed in Table 8 and 9.

Table 8

Adult CI Candidacy Criteria for Cochlear Americas

| | |
|-----------------------|------------------------------------------------------------------------------------------------------------------|
| Hearing loss | Moderate to profound SNHL |
| Onset of hearing loss | Pre-, peri-, post-lingual |
| Speech perception | 50% or less on sentences in ear to be implanted and 60% or less in opposite ear on open-set sentence recognition |

Note. Information displayed in the table is modified from Cochlear Americas.

If **no**, proceed to question 5.

3. Rate your perceived benefit on a scale from 0-5, 0 indicating no benefit perceived and 5 indicating maximal benefit perceived. Circle one.

No benefit 0 1 2 3 4 5 Maximum benefit perceived

4. How long have you worn your hearing aids for? Circle one.

0-5 years 6-10 years 11-15 years 16+ years

5. Do you wish you heard better or more clearly? Circle one.

Yes No

6. Would you be interested in learning more about cochlear implants? Circle one.

*Yes No

*If so, please provide your preferred method of contact on the line below.

Name: _____

Phone: _____

Email: _____

Data Analysis

Audiometric data obtained was evaluated using descriptive statistics. Data from patient charts and survey responses were analyzed using descriptive and inferential statistics. Specifically, independent t-tests and Fisher's exact test were used to compare means and relationships between candidate data and obtained survey responses.

Demographic and audiometric data were analyzed using Microsoft Excel and Statistical Package for the Social Sciences (SPSS) to perform descriptive statistics and graphical representations of data collected.

Chapter 4

Results

Results from the Noah 4 advanced search revealed 46 potential traditional CI candidates and 82 potential Hybrid candidates. These short lists were used to cross check data collection from the chart review. The retrospective chart review was conducted on 2,554 audiology charts. Of the 2,554, 156 charts (6.1%) were identified as potential traditional CI and/or hybrid candidates in one or both ears. There were a total of 100 active charts (64.1%), four inactive charts (2.6%), and 52 archived charts (33.3%).

Chart Review

Demographics. Of the 156 potential candidates identified included 84 males (53.8%) and 72 (46.2%) females (Figure 2). All potential CI candidates identified were > 18 years of age (Table 10). The mean age was 69 years old. Ages ranged from 20-101 years old.

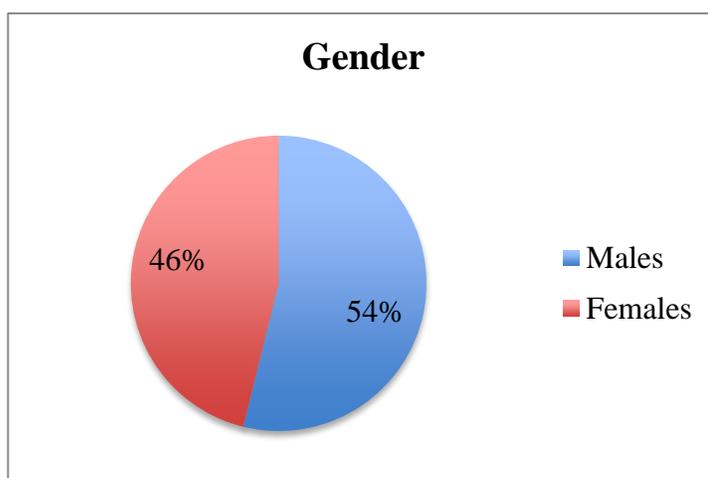


Figure 2. Percentage of male and female candidates.

Table 10

*Age of Potential Candidates
Divided by Age Band*

| Age range | # |
|-----------|----|
| 20-29 | 13 |
| 30-39 | 10 |
| 40-49 | 8 |
| 50-59 | 11 |
| 60-69 | 23 |
| 70-79 | 24 |
| 80-89 | 34 |
| 90-99 | 30 |
| 100-101 | 3 |

Candidate profiles. After a thorough review of charts the following data was collected: etiology of hearing loss, hearing aid use, speech testing, and device candidacy. Etiology of hearing loss was noted, if it was recorded in the chart. As shown in Table 11, of the 156 potential candidates, 127 (81.4%) had unreported or unknown etiology of hearing loss. Other reported etiologies included: noise exposure, genetics, meningitis, trauma, Meniere's disease, measles, mumps, otosclerosis, pneumonia, sudden sensorineural hearing loss, and neurofibromatosis Type 2 (NF2).

Table 11

Potential Candidates Etiology of Hearing Loss

| Etiology | # |
|--------------|-----|
| Unknown | 127 |
| Noise | 6 |
| Genetic | 5 |
| Meningitis | 4 |
| Trauma | 3 |
| Meniere's | 2 |
| Measles | 2 |
| Mumps | 2 |
| Otosclerosis | 2 |
| Pneumonia | 1 |
| SSNHL | 1 |
| NF2 | 1 |

Hearing aid use. Hearing aid use as of date of most recent appointment was also noted. As shown in Figure 3, 13% (n=21) of CI candidates did not use a hearing aid at all, 15% (n=23) of the CI candidates used one hearing aid, and 72% (n=112) of CI candidates used two hearing aids.

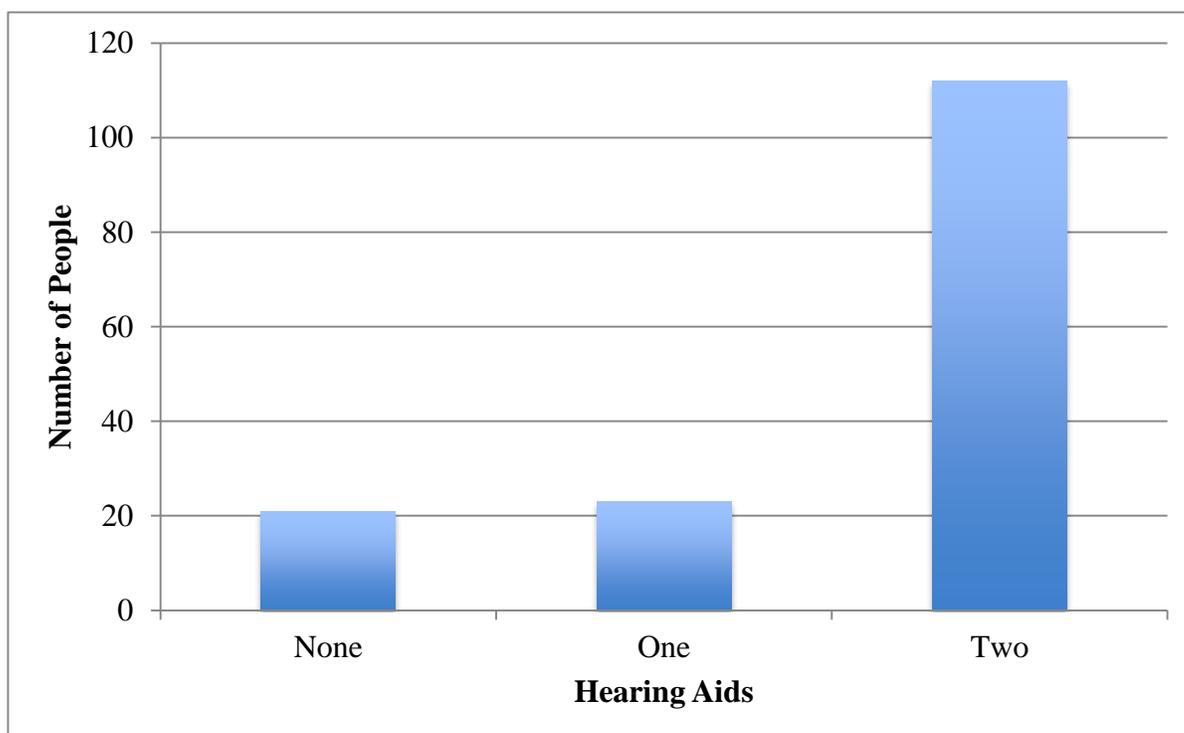


Figure 3. Hearing aid use among potential candidates.

Speech testing. The most recent word recognition scores (WRS) in the unaided condition were noted when recorded on the audiogram. The average WRS was 44% (*SD*: 22, range: 0-100) for the right ear and 43% (*SD*: 24, range: 0-92) for the left ear.

Candidacy. When looking at the poorer ear (in terms of audiometric threshold), 46% of people were traditional CI candidates and 54% of people were Hybrid candidates based on the pure tone thresholds alone (Figure 4). A majority were bilateral candidates (87%) with the remaining unilateral CI candidates (13%) (Figure 5).

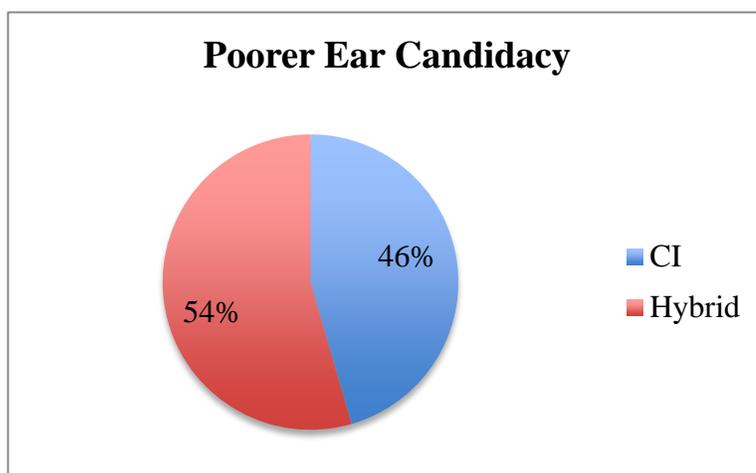


Figure 4. Candidacy for poorer ear audiometric thresholds.

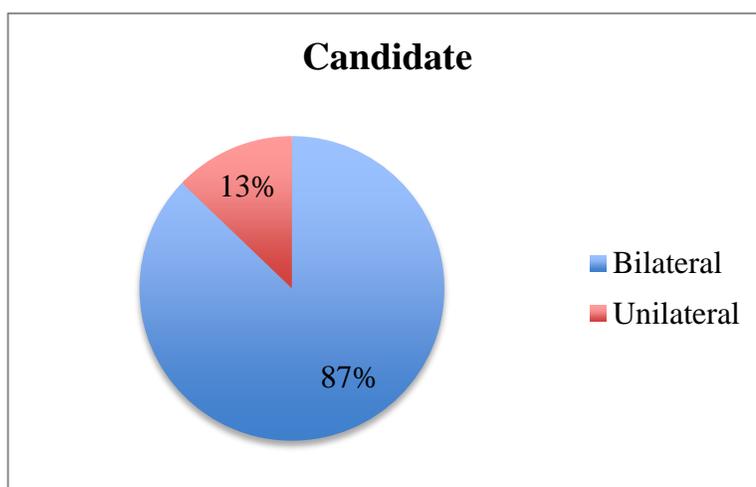


Figure 5. Bilateral or unilateral CI/Hybrid device candidacy.

A series of independent t-tests were performed to compare PTA, age, and gender between traditional CI candidates ($n=71$) and Hybrid candidates ($n=85$). When comparing PTA between traditional CI candidates and hybrid candidates the mean PTA for traditional CI candidates ($M=97.6$, $SD=16.8$) was greater than the mean PTA for Hybrid candidates ($M=52.5$, $SD=13.9$). This difference was significant $t(154) = 18.31$, $p < 0.05$. When comparing age between traditional CI candidates and hybrid candidates the mean age of participants was significantly greater for Hybrid candidates ($M=77.2$,

$SD=18.8$) than for traditional CI candidates ($M= 60.44, SD=23.6$). Due to potential violation of homogeneity of variance, a Mann-Whitney U test was used and indicated that this difference was significant for Hybrid candidates than for traditional CI device candidates, $p=.000$. When comparing gender between traditional CI candidates and Hybrid candidates there was no significant difference in gender with CI candidacy ($M=1.41, SD=.495$) and gender with Hybrid candidacy ($M=1.52, SD=.503$), $t(154) = 1.364, p > 0.05$.

Audiometric thresholds. Audiometric threshold data was compared by better versus poorer ear, right versus left ear, and hybrid versus traditional CI candidacy. Where no response was reported the dB limit of the audiometer was used plus five dB (e.g., if the limit of audiometer is 110 dB HL at 8000 Hz and NR was recorded, then 115 dB HL (110+5) was used for the purpose of statistical analysis). The average thresholds for unilateral candidates ($n=20$), traditional CI and Hybrid, are separated by poorer ear and better ear, shown in Figure 6. The average thresholds for bilateral candidates ($n=136$) are separated by right ear and left ear, shown in Figure 7. The average thresholds for candidates poorer ear is separated by device candidacy (Hybrid versus traditional CI), shown in Figure 8.

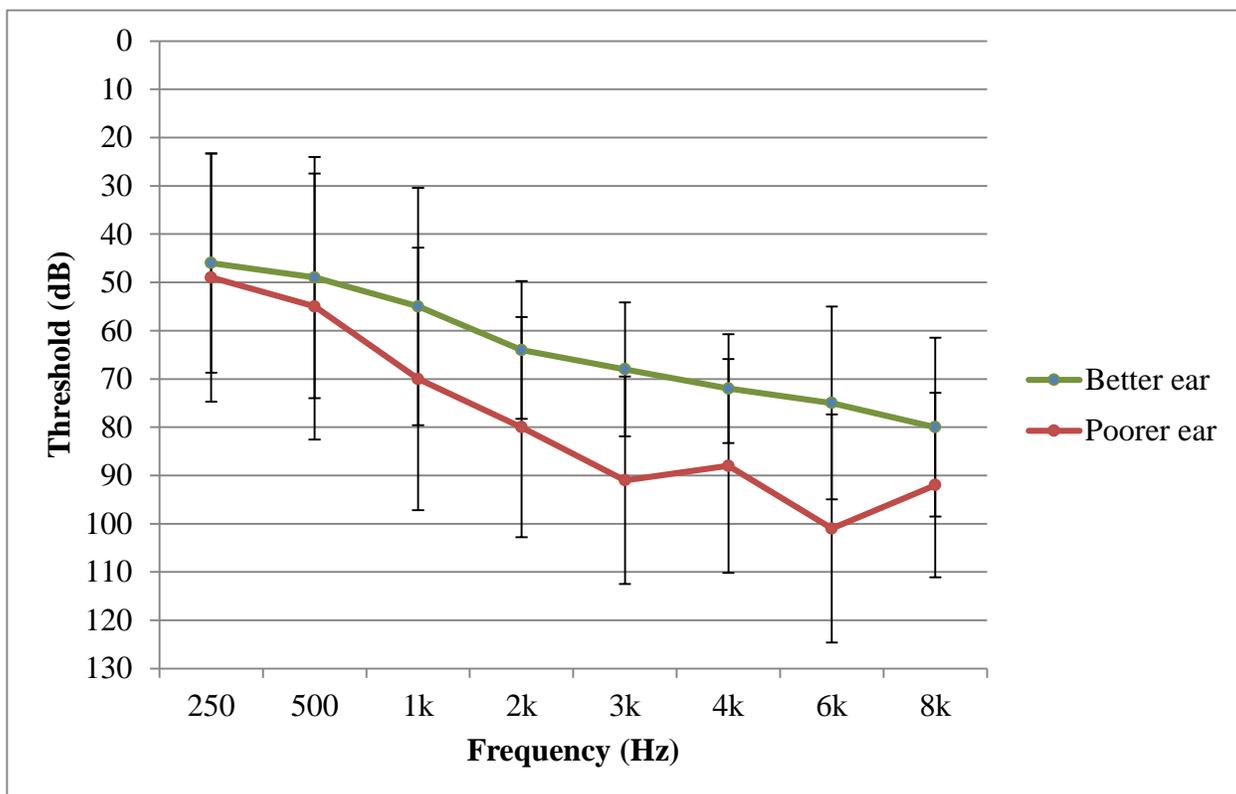


Figure 6. Average thresholds for unilateral candidates (n=20), traditional CI and Hybrid. The poorer ear (red line) to be implanted and the better ear (green line) are displayed.

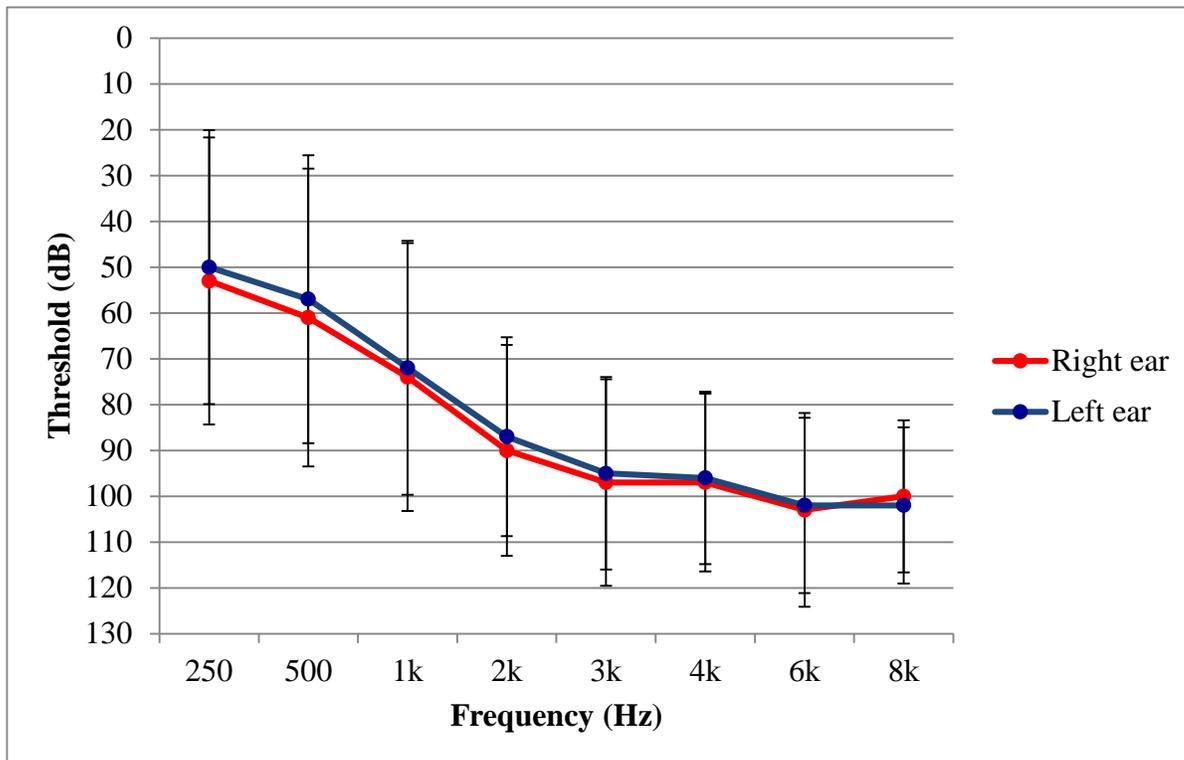


Figure 7. Average thresholds for bilateral candidates (n= 136) for right ear (red line) and left ear (blue line).

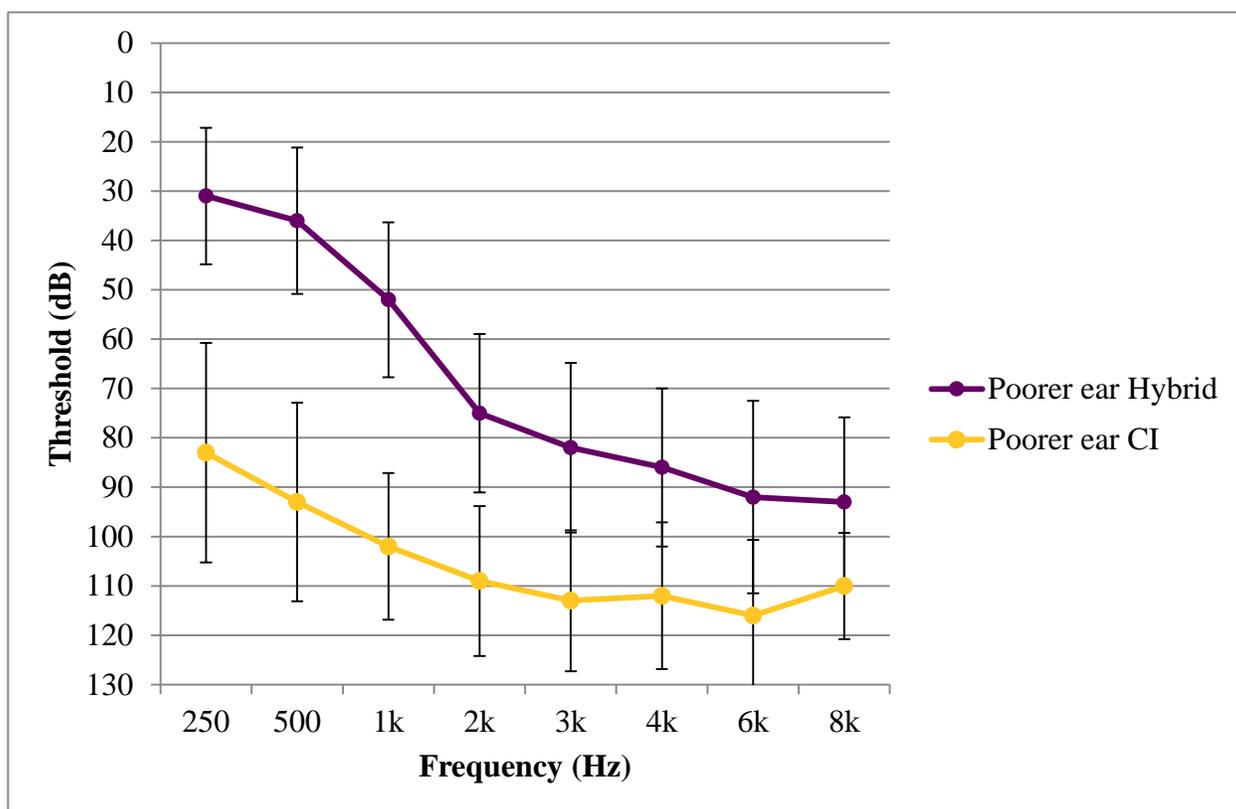


Figure 8. All candidates averaged audiometric thresholds for their poorer ear. Separated by device candidacy, Hybrid (purple line, n=85) and traditional CI (yellow line, n=71).

Survey data

Response rate. Of 156 potential candidates, 153 surveys were sent out. The other three potential candidates had no contact information listed in their chart. Eleven (9.4%) out of the 153 surveys were returned with either completed information or the option not to participate selected, 36 (23.5 %) surveys were returned to sender, and 106 (69.2%) people did not respond.

Demographics. All 11 survey responses came from active charts. Respondents included eight males (73%) and three (27%) females (Figure 9). All of the respondents who responded to the survey were between 30 and 90 years old (Table 12). The mean age was 71 years old ($SD = 14.9$).

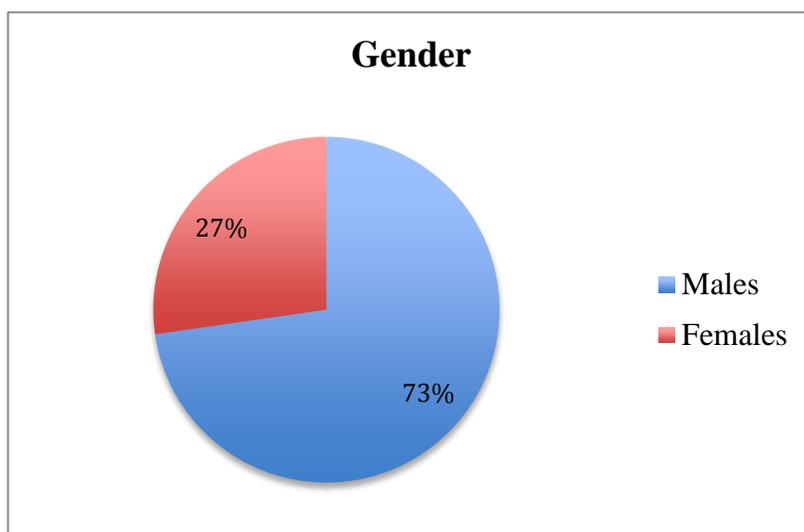


Figure 9. Percentage of male and female candidates (n=11).

Table 12

*Age of Potential Candidates
Divided by Age Band*

| Age range | # |
|-----------|---|
| 20-29 | 0 |
| 30-39 | 1 |
| 40-49 | 0 |
| 50-59 | 0 |
| 60-69 | 4 |
| 70-79 | 2 |
| 80-89 | 3 |
| 90-99 | 1 |
| 100-101 | 0 |

Candidate profiles. Of the 11 respondents who responded to the survey, nine (81.8%) had an unknown etiology for their hearing loss, one person had Meniere's disease, and one person had a reported genetic hearing loss (Table 13).

Table 13

Potential Candidates Etiology of Hearing Loss

| Etiology | # |
|--------------|---|
| Unknown | 9 |
| Noise | 0 |
| Genetic | 1 |
| Meningitis | 0 |
| Trauma | 0 |
| Meniere's | 1 |
| Measles | 0 |
| Mumps | 0 |
| Otosclerosis | 0 |
| Pneumonia | 0 |
| SSNHL | 0 |
| NF2 | 0 |

All respondents reported hearing aid use. As shown in Figure 10, 20% (n=2) of people reported using one hearing aid and 80% (n=8) of people reported using two hearing aids. One respondent did not complete the survey because they had received a CI.

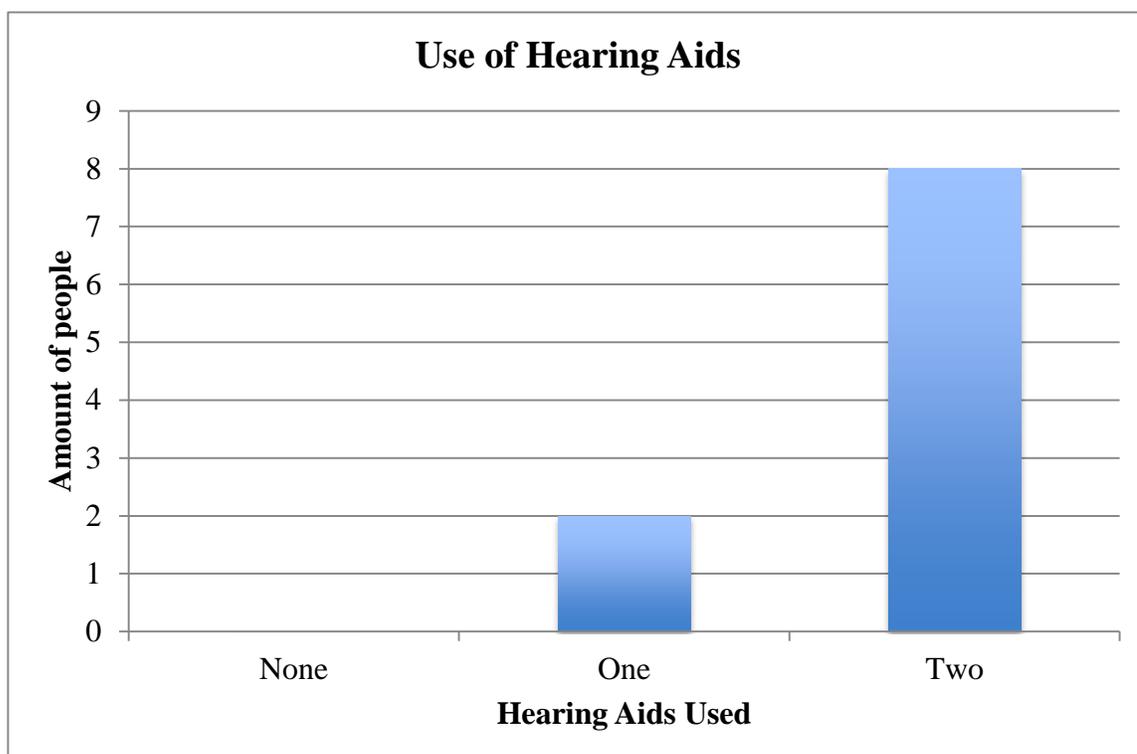


Figure 10. Reported use of hearing aids among survey participants (n=10).

Survey respondents' poorer ear candidacy (in terms of audiometric threshold data from their chart) showed that 27.3% (n=3) are traditional CI candidates and 72.7% (n=8) are Hybrid candidates (Figure 11). All survey respondents were bilateral candidates according to their audiograms (n=11, 100%).

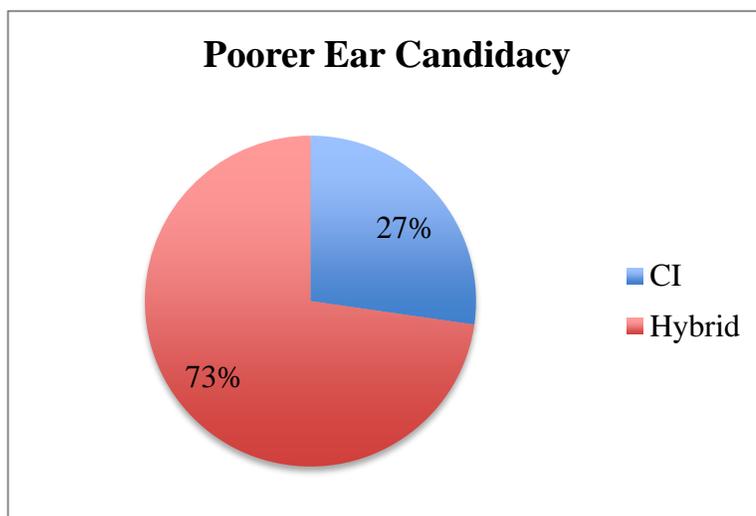


Figure 11. Candidacy for poorer ear based on audiometric thresholds (n=11).

Survey Responses

Of the 11 surveys sent back 10 were completed. One survey was not completed because the respondent had already received a CI through GBMC. The survey consisted of six questions about their current listening abilities and interest in CIs. A summary of the survey responses by question can be seen in Appendix D. Each survey question will be discussed below.

In question one, respondents were asked how long they have had hearing loss. Of the participants (n=10), 30% (n=3) reported they have had hearing loss for 11-15 years and 70% (n=7) reported they have had hearing loss for 16+ years. In question two, respondents were probed about hearing aid use. Of the respondents (n=10), 20% (n=2) reported wearing one hearing aid and 80% (n=8) reported wearing two hearing aids.

Question three briefly asked about QOL and asked the respondents to rate their perceived benefit with their hearing aids on a scale of 0-5, 0 indicating no benefit perceived, 3 indicating moderate benefit, and 5 indicating maximal benefit perceived. Of the respondents (n=9), one person rated their benefit a one, 33% (n=3) rated their benefit a two, 44% (n=4) rated their benefit a three, and one person rated their benefit a four, as shown in Figure 12.

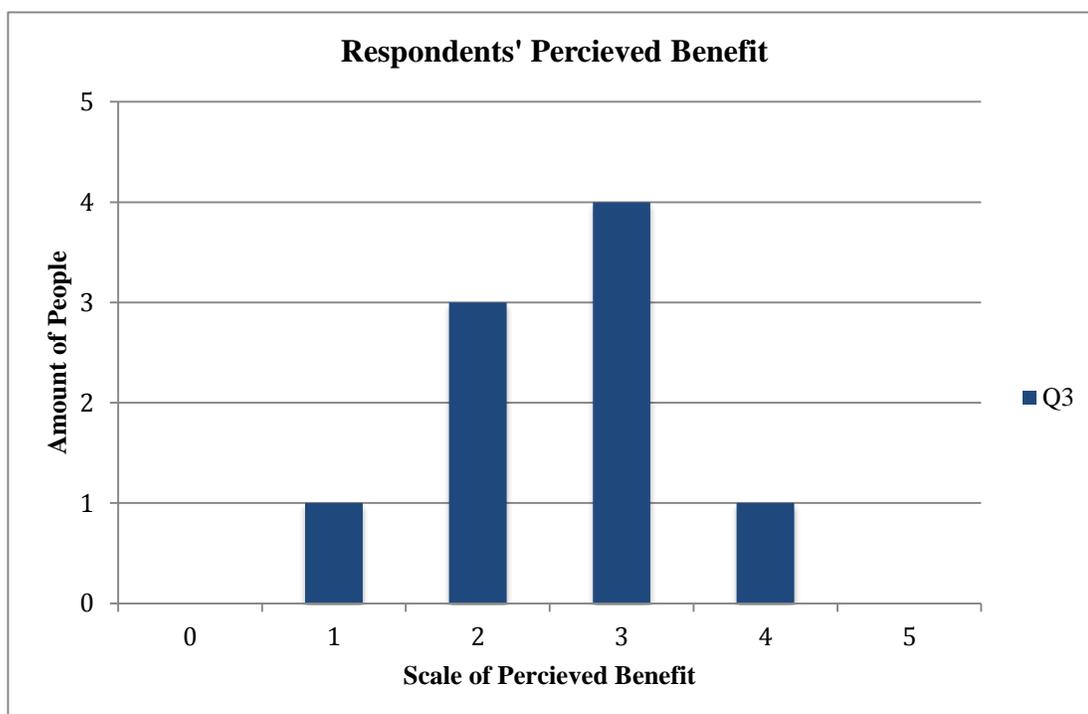


Figure 12. Survey responses to Q3: rate your perceived benefit on a scale from 0-5, 0 indicating no benefit perceived and 5 indicating maximal benefit perceived (n=10).

In question four, respondents were asked how long they have worn hearing aids. Of the respondents (n=10), 30% (n=3) reported wearing hearing aids for 0 to 5 years, one person reported wearing hearing aids for 6 to 10 years, one person reported wearing hearing aids for 11 to 15 years, and 50% (n=5) reported wearing hearing aids for 16+ years.

Additionally, question five asked respondents if they wish they heard better or more clearly. Of the respondents (n=10), 90% (n=9) reported yes and one person reported no. Finally, respondents were asked if they were interested in learning more about a CI. Of the respondents (n=10), 90% (n=9) reported yes and one person reported no.

Comparison between responses

When respondents were asked to report amount of time with hearing loss, the majority of respondents (n=10) reported having hearing loss for at least 11 years. Similarly, when respondents were asked to report amount of time using hearing aids the majority of respondents (n=6) reported using hearing aids for at least 11 years. This comparison between amount of time with hearing loss and amount of time using hearing aids is shown in Figure 13.

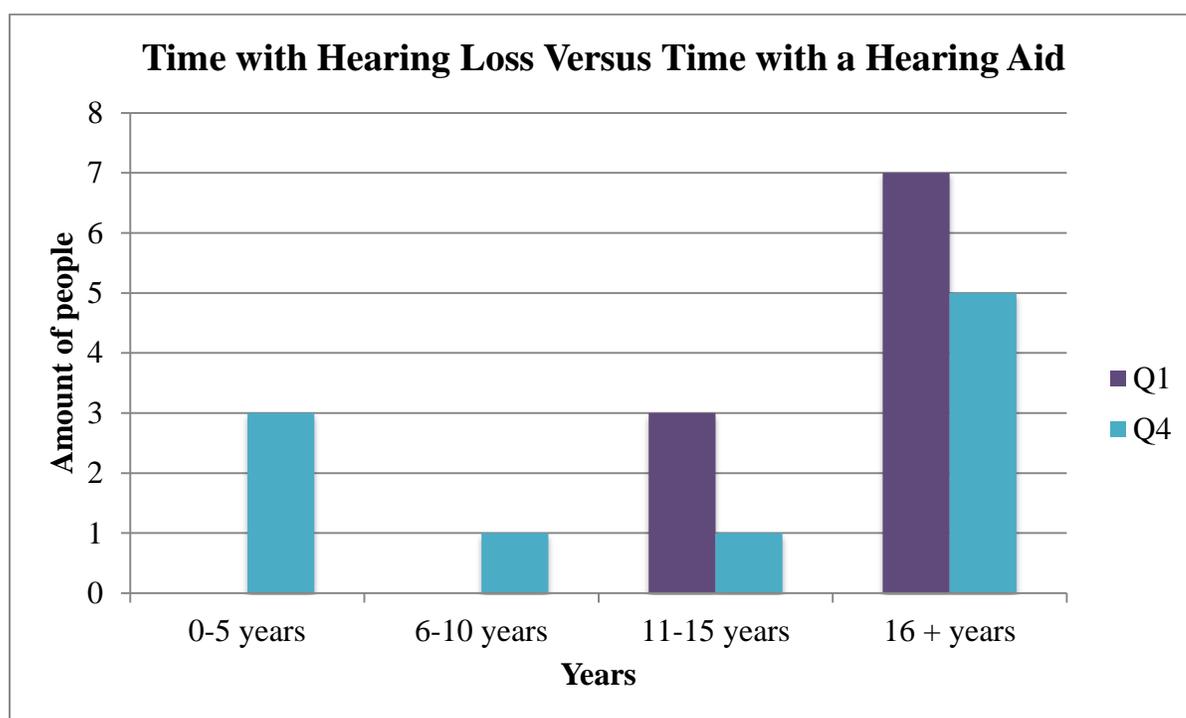


Figure 13. Survey responses to Q1: how long have you had hearing loss? indicated by the purple bars, and Q4: how long have you worn hearing aids?, indicated by the blue bars (n=10).

When respondents were asked if they wanted to hear better or more clearly the majority of respondents (n=9) reported yes. Similarly, when respondents were asked if they were interested in learning more about a CI the majority of respondents (n=9) reported yes. The respondent who reported no when asked about wanting to hear better or more clearly also reported no when asked about wanting to learn more about a CI. This comparison between respondents is shown in Figure 14.

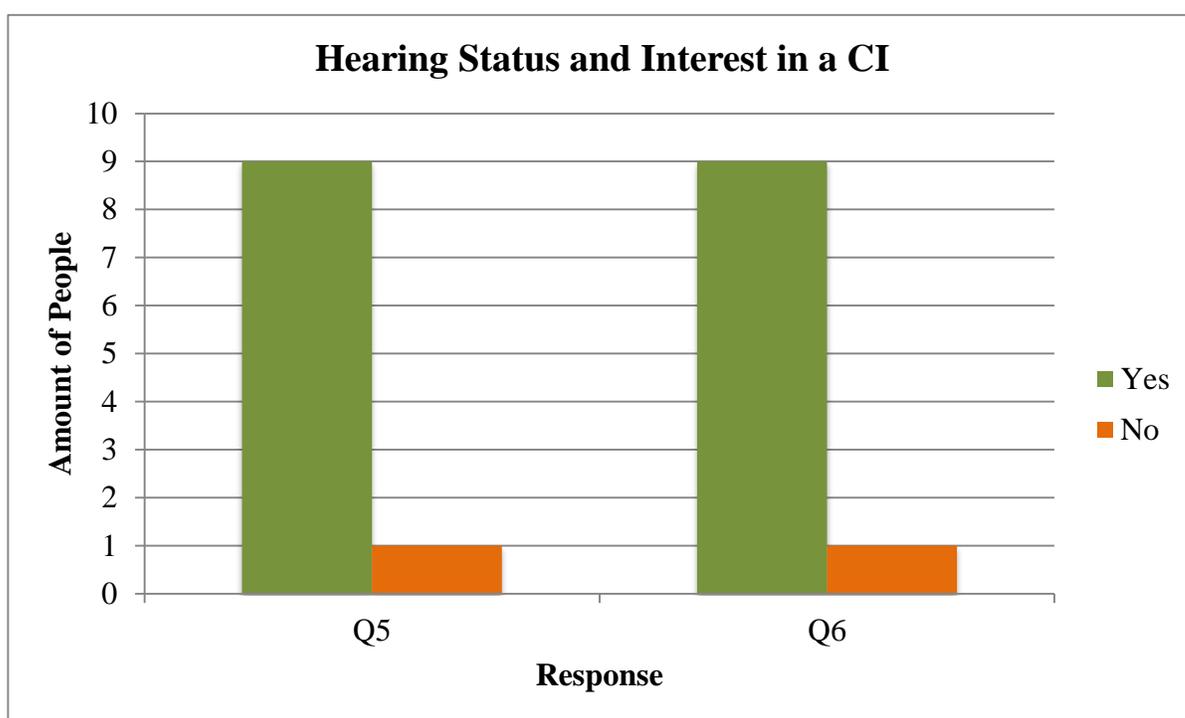


Figure 14. Survey responses to Q5: do you wish you heard better or more clearly? and Q6: would you be interested in learning more about a cochlear implant? The green bar indicates yes responses and the orange bar indicates no responses (n=10).

A series of independent t-tests were run to compare PTA, age, and gender between survey respondents ($n=11$) and people who did not respond to the survey ($n=106$). On average, there was no significant difference in the three frequency PTA of survey respondents ($M=60.27$, $SD=27.68$) as compared to people who did not respond ($M=71.70$, $SD=28.48$); $t(117) = 1.269$, $p >.05$.

When comparing age between groups there was no significant difference in age in survey respondents ($M=71$, $SD=14.9$) compared to the people who did not respond ($M=71.20$, $SD=21.97$); $t(117) = .029$, $p >.05$. When comparing gender between groups there was no significant difference in gender in survey respondents ($M=1.27$, $SD=.467$) compared to the people who did not respond ($M=1.50$, $SD=.502$); $t(117) = 1.437$, $p >.05$. Due to potential violation of homogeneity of variance, a Mann-Whitney U test was used and gender differences remained not significant, $p >.05$.

A series of Fisher's exact tests were run to look for associations between specific survey questions and PTAs as well as device candidacy (hybrid vs. CI) with survey respondents ($n=10$). When looking at respondents' hearing aid usage and their PTA there was not a significant association found between respondents wearing one versus two hearing aids and their three-frequency pure tone average, $\chi^2 (7) = 5.83$, $p > .05$.

When looking at respondents' perceived benefit with hearing aids and their three-frequency PTA there was also not a significant association found, $\chi^2 (18) = 17.5$, $p > .05$. When looking at respondents' reported amount of time (years) wearing hearing aids and their three-frequency PTA there was not a significant association found, $\chi^2 (21) = 15.3$, $p > .05$.

Lastly, no significant association was found between the respondents' responses to wanting to hear better or more clearly with their device candidacy (traditional CI and Hybrid), $\chi^2 (7) = 2.59, p > .05$.

Chapter 5

Discussion

CI candidacy criteria have expanded to include people with lesser degrees of hearing loss due to the advancements in technology, speech coding strategies, and surgical techniques (Cosetti et al., 2013; Gifford, 2011; Gifford, Shallop, & Peterson, 2008). Now people with residual hearing can obtain devices that take advantage of their remaining low frequency hearing by providing acoustic amplification to that region, while electrically stimulating the higher frequencies that has minimal or no residual hearing (Incerti, Ching, Cowan, 2013). The addition of Hybrid CI devices has given surgeons and audiologists the ability to treat more people that are receiving minimal benefit with their hearing aids with CIs (Weaver, 2015). CIs have been shown to vastly improve the recipient's life (Gifford, 2011). However, despite vast improvements and proven efficacy with the devices, only 5-10% of Americans who could benefit from a CI have one (Miller et al., 2015; Sorkin, 2013). The purpose of this study was two-fold, one to perform a comprehensive file review to identify potential candidates for the traditional CI or the Hybrid CI device and two, to then survey the people identified as potential CI candidates about their current experience with their hearing aids.

Chart Review

Demographics. A retrospective chart review was performed at the TU-HBC to identify potential CI candidates using their most recent audiogram on file. A total of 6.1% (n=156) of our patient population at TU-HBC were identified as potential traditional CI and Hybrid candidates (based on puretone thresholds only). Comparatively, five audiology practices in the U.S. conducted a chart review on their patients to identify CI

candidates by audiogram and found that approximately 3.2% (n=257) of their patient population was CI candidates (Huart & Sammeth, 2009). This study was published in 2009, before the Hybrid CIs were available in the US. When looking at our candidates, 2.8% (n=71) fit the traditional CI candidacy criteria, which is similar to the Huart & Sammeth (2009) finding. The candidacy for our study was solely based on puretone thresholds, but several other things were evaluated when looking at the candidates' profiles.

Candidate profiles. Etiology of hearing loss, hearing aid usage, and device candidacy were also reviewed. The most common etiology of hearing loss recorded in patient charts was unknown or idiopathic (81.4%). Roland et al. (2016) conducted a clinical trial on Hybrid candidates and found that 50% of the etiologies were unknown. Cosetti et al. (2013) conducted a study on traditional CI candidates and found that 51% of the etiologies were unknown. The report of idiopathic or unknown cause for the hearing loss in our study was higher than Roland et al. (2016) and Cosetti et al. (2013). This difference may be due to how etiology was obtained from the patient and/or reported in the TU-HBC files.

The majority of potential candidates found in this study (72%) were noted as having two hearing aids, 15% had one hearing aid, and 13% did not wear a hearing aid. It is estimated that 70% of people with a severe degree of hearing loss and 90% of people with a profound degree of hearing loss use hearing aids (Sorkin, 2013). The prevalence of hearing aid use of CI candidates in our study is consistent with this estimate.

Advancements in technology have allowed for more people to be considered a CI candidate who were not originally considered because of their residual hearing in the low

frequencies (Gifford, 2011). The poorer ear thresholds for the potential candidates identified in this study were used to determine that of the 156 potential candidates identified, 46% (n=71) met traditional CI candidacy criteria and 54% (n=85) met Hybrid candidacy criteria. The entire candidate sample was reviewed to determine if they were CI candidates in one ear or both. Bilateral candidates accounted for the majority (87%) while unilateral candidates accounted for the remaining 13% of potential candidates. It is well documented in the literature that two CIs are better than one when both ears meet CI candidacy criteria (Schwartz, Watson, & Backous, 2012; Noble, Tyler, Dunn, & Bhullar, 2008). However, some candidates are only candidates in one ear and their best performance may be achieved with one CI and a hearing aid worn on the contralateral side, also known as bimodal stimulation (Schwartz, Watson, & Backous, 2012; Morera et al., 2005). Hearing loss is typically symmetrical therefore it was not surprising that a majority of the people identified in our study were bilateral candidates.

Survey Data

Response rate. A response rate of 7.2% was achieved for the survey portion of this study. According to the literature, expected response rates depend on various factors including: delivery method, length of survey, survey design, and gender of the respondent (Hardigan, Popovici, & Carvajal, 2016). Average response rate of postal mail surveys is around 53% (Shih & Fan, 2008). Postal mail surveys yield higher response rates than electronic or email surveys (Hardigan, Popovici, & Carvajal, 2016; Shih & Fan, 2008). Surveys sent multiple times can also yield higher response rates (Shih & Fan, 2008), but this was not possible for this study due to time restrictions. Our response rate was significantly lower than the average response rate for postal mail surveys which may be

attributed to the years between the patient coming in to our clinic for healthcare services and the date the survey was mailed out. It is possible that people moved or are now deceased, therefore a potential negative to our methodology is that the surveys were sent to the last known address on file and not a known more recent address. This was most problematic for the surveys out to our patients with inactive and archived charts.

Demographics. Ten surveys were returned and complete. One survey was returned but not completed because she had received a CI between the last time she was seen in our clinic and the date the survey was mailed out.

All 10 survey respondents were patients that had active charts. Of the returned surveys, 80% (n=8) were males and 20% (n=2) were females, inconsistent with the literature, which found gender to be fairly equal amongst candidates (Roland et al., 2016; Cosetti et al., 2013). This gender imbalance may be due to the small sample size of respondents, because the genders were more balanced (54% male and 46% female) in the total sample of people identified as potential candidates. The age of the survey respondents in this study ranged from 30 to 90 years with an average age of 71 years. A recent study found that the age of their sample of Hybrid candidates (n=50) ranged from 23-86.2 years with an average age of 64.1, which is relatively consistent with the findings from our sample (Roland et al., 2016). The average age found in our sample is somewhat similar to another recent study on traditional CI recipients who ranged in age from 19-91 years with an average age of 58.8 years at the time of their implantation (Cosetti et al., 2013). The differences observed in age range and average age in the other studies when compared to our findings may be due to the fact that both Roland et al. (2016) and Cosetti et al. (2013) have larger sample sizes.

Candidate profiles. The profiles of the people that responded to the survey were also reviewed. The majority (80%) of respondents had an unknown etiology of hearing loss, which is not consistent with other findings in literature that conducted similar studies (Roland et al., 2016; Cosetti et al., 2013).

All 10 survey respondents reported using hearing aids, eight (80%) reported using two hearing aids and two (20%) reported using one hearing aid, consistent with the findings from Roland et al. (2016), which found that 75% of their participants that were CI candidates wore two hearing aids, 18% wore one hearing aid, and 6% did not wear hearing aids (Roland et al., 2016).

The poorer ear thresholds of potential candidates were used to determine candidacy. Thirty percent of people responding to the survey met traditional CI candidacy criteria and 70% of people met Hybrid candidacy criteria (using their pure tone thresholds on their most current audiogram only). The majority of people in our study were candidates for the Hybrid. This finding isn't surprising because the criteria for the traditional CI is relatively well known amongst audiologists. The knowledge of when to refer for a traditional CI is clear when this candidacy criteria is known. The relatively new Hybrid CI has expanded who can get a CI by opening up candidacy to people who did not previously fit the traditional CI criteria. Therefore most audiology practices, when evaluating their patient charts, will have more Hybrid candidates. This is because their patients that are dissatisfied hearing aid users haven't been referred to a CI center yet, because they most likely didn't previously fit the better known traditional CI candidacy criteria.

Responses to survey questions. The respondents that completed the survey answered to a range of questions providing more information about how they are doing with their hearing aids. The survey responses will be discussed below.

Duration of hearing loss. When respondents were asked about how long they have had hearing loss all respondents (n=10) reported a minimum duration of 11 years, with the majority reporting their duration of hearing loss for 16 years or more. In contrast, a study looking at traditional CI recipients found the average duration of hearing loss before implantation was 26.7 years (Cosetti et al., 2013). Another study reported the average duration of hearing loss was 28.1 years before cochlear implantation for the Hybrid recipients (Roland et al., 2016). The seemingly different duration of hearing loss for CI candidates/recipients found between this study and Cosetti et al. (2013) and Roland et al. (2016) may be because the survey respondents in this study were not asked to report the exact number of years with hearing loss but to circle a range in years that best represented how long they have has hearing loss. Therefore the average duration of hearing loss may be more similar to the other studies if exact years were known.

Perceived hearing aid benefit. When respondents were asked to rate their perceived benefit with their hearing aids on a scale from (no benefit) zero to five (maximum benefit perceived) the majority of survey respondents rated their perceived benefit at a three or below, indicating moderate benefit perceived with hearing aids. This was expected given the degree of hearing loss reported in the participants' chart. Research has shown that people who meet the Hybrid candidacy criteria often are not benefiting from traditional amplification because they aren't getting clear high frequency sound from hearing aids, which leads to communication difficulties (Roland et al., 2016).

Similarly, research conducted on factors that contributed to discontinued hearing aid use and participants' perception of their hearing aid experience pre-implantation revealed their experience as negative due to poor sound quality, limitations of the device, and no longer perceiving benefit (Fitzpatrick & Leblanc, 2010).

Interest in improved listening. When respondents were asked if they wish they heard better or more clearly all respondents, except one, reported "yes". This finding is expected with the respondents' degree of hearing loss, which qualifies them as potential CI candidates. Research states that acoustic amplification of high frequencies, where no residual hearing exists, does not result in improved speech understanding (Roland et al., 2016). In comparison, when respondents were asked if they were interested in learning more about a CI the same nine people who reported wanting to hear better and more clearly also reported interest in learning about a CI. This finding suggests that the study has found nine motivated people with hearing loss that are potential CI candidates. Research confirms that people with sloping high frequency sensorineural hearing loss have difficulty with audibility and clarity of speech even with best-fit hearing aids (Moran, Dowell, Umansky, Briggs, & Corbett, 2014). CI recipients of either the traditional CI or the Hybrid device show significantly improved speech perception post-operatively as compared to their speech understanding pre-operatively (Incerti, Ching, & Cowan, 2014; Moran et al., 2014).

Clinical relevance

Improved performance. The majority of respondents in this study expressed their perceived benefit as moderate with their hearing aids. They also indicated they wanted to hear better and more clearly. Also, a majority of respondents reported an

interest in learning more about CIs. Of the nine people that want to pursue their CI candidacy, six are Hybrid candidates and three are traditional CI candidates.

Research has shown that CI recipients with residual hearing have better hearing in noise, better sound perception for music, improved spectral discrimination and pitch perception, continuous sound awareness, and less “mechanical” sound quality (Cosetti et al., 2013). In a U.S. Hybrid device clinical trial using the sound quality scale (SQS), only 8% of the participants indicated they were satisfied with their listening abilities before they received their CIs but an astonishing 79% of people reported being satisfied with their listening six months post-operatively (Roland et al., 2016). This finding supports the fact that people who do not perceive benefit with their hearing aid(s) have a greater listening satisfaction with a CI. Research also shows that CI recipients describe their CI as superior to their hearing aid(s) because of the vastly improved quality of hearing and understanding perceived post-implantation (Fitzpatrick & Leblanc, 2010). Therefore it is important for audiologists to review their new patients and active charts to see if anyone that is dissatisfied or not perceiving benefit with their hearing aid(s) fits the criteria for a Hybrid (or a traditional CI). The methodology used in this study could be performed by any audiologist in their practice to identify potential candidates.

Quality of life. Numerous studies have been conducted to assess quality of life post-implantation (Cheng & Niparko, 1999; Hallberg & Ringdahl, 2004; Hallberg, Ringdahl, Holmes, & Carver, 2005; Roland et al., 2016). Cheng and Niparko (1999) conducted a meta-analysis on health utility scores. These scores were assessed using the quality-adjusted life years (QALY) scale, zero indicated death and one indicated perfect health. The health utility score post-implantation was found to be 0.80 as compared to

0.54 pre-implantation indicating the CI improved their health. Hallberg and Ringdahl (2004) also conducted a study on quality of life (QOL) using qualitative questionnaires for CI recipients and found that QOL increased post-implantation; making life easier, increasing participation in society, increasing self-confidence, and increasing self-worth to be able to participate in social events again. Participants in the study described their satisfaction with a CI as “becoming a part of the living world” (Hallberg and Ringdahl, 2004, p. 120). It was also found that younger recipients had a larger problem in their general psychological well-being/QOL than older recipients. This was an expected finding due to the typically more active and social demands of younger people’s lifestyles (Hallberg, Ringdahl, Holmes, & Carver, 2005). Research on QOL post-implantation shows that recipients of CI devices reported increased satisfaction and overall improved QOL with CIs as compared to their satisfaction with hearing aids (Hallberg and Ringdahl, 2004). In this study, respondents reported minimal benefit perceived from wearing their hearing aids. Respondents reported wanting to hear better and more clearly than they do now with their hearing aids. Research supports that improved quality of life as well as improved speech understanding can be achieved with CIs when people no longer perceive benefit from their best-fit hearing aids. These findings support the importance of identifying people who are not benefiting from their hearing aid(s) and are CI candidates to give them the opportunity to access to a wider range of sounds, which may inherently result in an improved QOL.

Clinical utility. Other audiologists, starting a CI program in their practice, could use the content of this study as a model to identify potential candidates from their current patient records. The methodology not only serves as a guide to finding potential

candidates and expanding services in a practice but it also highlights the importance of assessing a patient's QOL with their hearing aids. This goes beyond checking to see if their hearing aids are fitted appropriately and verified for their type of hearing loss, but evaluating their perception of benefit. The findings from this study indicate that at least 5% of a clinic's patient population may be CI candidates.

Adding a QOL questionnaire to routine clinical practice could also help to assist audiologists with counseling for CI candidacy. The short survey in this study used a few questions to gauge satisfaction with hearing aids. The survey revealed that the majority of respondents were not satisfied with their current hearing aids. If QOL questionnaires were used more routinely then audiologists could begin to review the patient's potential for a CI when patients are not satisfied with their hearing aids.

Future Directions

In the U.S., 5-10% of people who could benefit from CIs have one (Miller et al., 2015). Sorkin (2013) proposes seven factors that impact CI utilization: low awareness, hearing healthcare providers are unaware of candidacy criteria and outcomes, political issues associated with deafness, clinic and hospital financial issues, lack of guidelines for best clinical practice, up to date cost-effectiveness data, and lack of dedicated organization for CIs. The methodology in this study addressed: awareness, healthcare providers knowledge of candidacy, and use of the guidelines for candidacy. This is a start to improving CI utilization.

Future studies should develop a thorough but easy to read CI information handout that people with hearing loss could receive to make them aware of the option for a CI if they're not satisfied with their best-fit hearing aids. If patients are interested in pursuing a

CI, then a candidacy evaluation may be conducted but the information sheet will help the potential patient understand the process.

Future research could also include administering and evaluating responses to more extensive QOL questionnaires to the nine respondents from this study both pre- and post-operatively, should they decide to be implanted with a CI.

Conclusion

CIs have been proven to be effective and safe and therefore they have become a standard of care for people with hearing loss who do not benefit from hearing aids (Sorkin, 2013). Due to recent advancements in device technology, speech coding strategies, and surgical techniques, CI candidacy has expanded to include people with some residual hearing. Unfortunately, audiologists may not know about the expanded criteria which means there are even more potential candidates out there who are struggling with their hearing but do not know there are options beyond hearing aids (Huart & Sammeth, 2009; Miller et al., 2015, Sorkin, 2013). People who meet CI candidacy criteria and no longer benefit from best-fit hearing aids should be seen for a CI evaluation, even if their audiologist or healthcare practitioner aren't sure if they're a candidate. Research supports improved quality of life post-implantation (Hallberg & Ringdahl, 2004; Yeagle, Ceh, & Francis, 2010; etc.). Results from this study identified 156 patients at the TU-HBC who meet the newly expanded CI candidacy criteria according to their audiogram. There were nine patients that are interested in obtaining more information about CIs as a results of this retrospective chart review.

Appendix A

IRB Approval



APPROVAL NUMBER: 16-A048

To: Jennifer Smart
8000 York Road
Towson MD 21252

From: Institutional Review Board for the Protection of Human
Subjects Debi Gartland, Chair *ALT*

Date: Thursday, December 03, 2015

RE: Application for Approval of Research Involving the Use of
Human Participants

Office of Sponsored Programs
& Research

Towson University
8000 York Road
Towson, MD 21252-0001

t. 410 704-2236
f. 410 704-4494
www.towson.edu/ospr

Thank you for submitting an Application for Approval of Research Involving the Use of Human Participants to the Institutional Review Board for the Protection of Human Participants (IRB) at Towson University. The IRB hereby approves your proposal titled:

Re-Evaluating Candidates for Cochlear Implantation: Traditional Cochlear Implantation vs. Hybrid

If you should encounter any new risks, reactions, or injuries while conducting your research, please notify the IRB. Should your research extend beyond one year in duration, or should there be substantive changes in your research protocol, you will need to submit another application for approval at that time.

We wish you every success in your research project. If you have any questions, please call me at (410) 704-2236.

CC: Alexandra Fickey; Amanda Kozlowski
File



Date: Thursday, December 03, 2015

NOTICE OF APPROVAL

TO: Jennifer Smart **DEPT:** ASLD

PROJECT TITLE: *Re-Evaluating Candidates for Cochlear Implantation:
Traditional Cochlear Implantation vs. Hybrid*

SPONSORING AGENCY: None

APPROVAL NUMBER: 16-A048

The Institutional Review Board for the Protection of Human Participants has approved the project described above. Approval was based on the descriptive material and procedures you submitted for review. Should any changes be made in your procedures, or if you should encounter any new risks, reactions, injuries, or deaths of persons as participants, you must notify the Board.

A consent form: is is not required of each participant

Assent: is is not required of each participant

This protocol was first approved on: 03-Dec-2015

This research will be reviewed every year from the date of first approval.

A handwritten signature in blue ink, appearing to read "Debi Gartland for".

Debi Gartland, Chair

Towson University Institutional Review Board

Appendix B

Department of Audiology, Speech-Language Pathology,
and Deaf Studies

INFORMED CONSENT**Project Title: RE-EVALUATING CANDIDATES FOR COCHLEAR
IMPLANTATION: TRADITIONAL COCHEAR IMPLANTATION
VS. HYBRID****Principal Investigator:**

Jennifer L. Smart, Ph.D., CCC-A

Co-investigators:

Alexandra Fickey, B.S.

Amanda Kozlowski, Au.D., CCC-A

Dept. of Audiology, Speech-Language Pathology and Deaf Studies
8000 York Road
Towson, MD 21252

Purpose of the Study:

The purpose of this study is to identify people who are past or present patients at the Towson University Hearing & Balance Center who do not receive optimal benefit from their hearing aids.

You have been identified as someone who may benefit from a cochlear implant. Enclosed is an information sheet about cochlear implants and a survey for you to complete. We are interested in learning more about your hearing. If you are interested in learning more about cochlear implants then we have left space at the end of the survey so you can provide your contact information to be invited to a free information session at the Towson University Hearing and Balance Center.

Procedures:

If you choose to participate, you complete the 2nd page of this form and the survey. Please complete the entire survey and indicate if you are interested in receiving more information about cochlear implants. Provide your phone number and/or email address that is best to contact you.

Risks/Discomfort:

There are no known personal risks or potential discomfort for those participating in this study. Your services at the Towson University Hearing and Balance Center will not be affected based on your responses or if you choose not to participate.

Benefits:

The researchers will learn more about your hearing and you will have the opportunity to learn about the recent advancements in technology that have led to expanded cochlear implant candidacy guidelines (more people can receive cochlear implants).

Participation:

Participation in this study is voluntary. Participants can abstain from answering any survey question if they choose. Participants can withdraw from the study at any time.

Compensation:

There is no compensation or payment for participating in this study.

Confidentiality:

All information obtained in the present study will remain strictly confidential. If the findings of the study become published, no personal names and/or identifying information of participants will be disclosed.

If you agree to participate in this study, please indicate that you have read and understood information by checking the box below. By writing your initials on the provided line you are giving your consent to participate in the research study.

_____ I have read and understood the information on this form. (Patient's Initials)

Participant's Name

If you have any questions regarding this study please contact one of the Principal Investigators or the Institutional Review Board Chairperson. Their contact information is listed below.

Dr. Jennifer L. Smart
Principal Investigator
Phone: (410) 704-3105
Email: JSmart@towson.edu

Dr. Deborah Gartland
Institutional Review Board Chairperson
Office of University Research Services
Phone: (410) 704-2236
Email: irb@towson.edu

THIS PROJECT HAS BEEN REVIEWED BY THE INSTITUTIONAL REVIEW BOARD FOR THE PROTECTION OF HUMAN PARTICIPANTS AT TOWSON UNIVERSITY (PHONE: 410-704-2236).

Name: _____

Phone: _____

Email: _____

**Please put completed consent form and survey in the enclosed self-address stamped
envelope.**

Thank you!

Appendix D

(Survey responses)

Q1. How long have you had hearing loss?

| | % | n |
|-------------|----|---|
| 0-5 years | 0 | 0 |
| 6-10 years | 0 | 0 |
| 11-15 years | 30 | 3 |
| 16+ years | 70 | 7 |

Total number of respondents=10

Q2. Do you currently wear hearing aids?

| Hearing aid(s) | % | n |
|----------------|----|---|
| 0 | 0 | 0 |
| 1 | 20 | 2 |
| 2 | 80 | 8 |

Total number of respondents=10

Q3. Rate your perceived benefit on a scale from 0-5, 0 indicating no benefit perceived and 5 indicating maximal benefit perceived.

| Benefit | n |
|---------|---|
| 0 | 0 |
| 1 | 1 |
| 2 | 3 |
| 3 | 4 |
| 4 | 1 |
| 5 | 0 |

Total number of respondents=9

Q4. How long have you worn hearing aids?

| | % | n |
|-------------|----|---|
| 0-5 years | 30 | 3 |
| 6-10 years | 10 | 1 |
| 11-15 years | 10 | 1 |
| 16+ years | 50 | 5 |

Total number of respondents=10

Q5. Do you wish you heard better or more clearly?

| | % | n |
|-----|----|---|
| Yes | 90 | 9 |
| No | 10 | 1 |

Total number of respondents=10

Q6. Would you be interested in learning more about cochlear implants?

| | % | n |
|-----|----|---|
| Yes | 90 | 9 |
| No | 10 | 1 |

Total number of respondents=10

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Curriculum Vita

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Education:

Towson University, Towson, MD May 2017
 Doctor of Audiology (Au.D.)

Ohio University Athens, OH May 2013
 Bachelors of Science in Hearing, Speech, and Language Sciences

Clinical Experience:

Hearing And Speech Agency, Baltimore, MD
Audiology Extern, accepted for May 2016- May 2017

ENTAA Care, Columbia, Glen Burnie, Odenton, MD
Audiology Intern, May 2015- July 2015, January 2016- May 2016

- Performed audiologic, electrophysiologic, and vestibular testing on adult patients in a fast-paced Ear, Nose, and Throat practice. Proficient with multiple hearing aid companies.

Saint Agnes Hospital, Baltimore, MD
Audiology Intern, September 2015- Present

- Performed comprehensive audiologic evaluations and vestibular testing for children and adults. Conducted newborn hearing screenings. Assisted with adult hearing aid evaluations, fittings, adjustments and repairs (Widex, ReSound, Phonak).

York Learning Center, Lincoln Intermediate Unit #12, York, PA
Audiology Intern, January 2015- May 2015

- Performed comprehensive audiologic evaluations for children and adults, including central auditory processing evaluations. Conducted classroom visits to schools in York County to assist children with their assistive listening devices (Phonak, Oticon)

Towson University Hearing & Balance Center, Towson, MD
Audiology Intern, January 2014- December 2014

- Performed supervised comprehensive audiologic evaluations for adults and children. Responsible for hearing aid evaluations, fittings, real-ear measurements, adjustments, and repairs (all manufactures). Conducted an aural rehabilitation group for hearing aid users
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Professional Organizations:

- Student Academy of Audiology, Towson University, 2013- Present
- American Academy of Audiology, 2013- Present

