Speech Acquisition with Cochlear Implants Across the Life Span

Jillian Rubin

SUNY New Paltz

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Abstract

Hearing is the foundation for acquiring verbal speech and speech perception. For many of us, hearing came naturally, and we learned to engage in meaningful exchanges of languages from an early age. However, for those born deaf and/or hard of hearing or who acquire hearing loss later on, speech, language, and communication can be more difficult to develop and comprehend. Language acquisition starts from an early age, and those who are deaf or hard of hearing typically have delays in speech development, social pragmatic skills, reading skills, and more. Cochlear implantation surgery is becoming an increasingly common choice for deaf and/or hard of hearing patients who wish to be a part of the auditory world and cannot benefit from the use of hearing aids. Generally, the younger a person is implanted with a cochlear device, the better their speech and spoken language acquisition will be. Likewise, many studies show that the later in age a person is implanted, the harder speech acquisition will be. During this process I will research auditory training and speech and language development in both children and adults with cochlear implants. I will research therapies and success rates utilized by adults who are implanted at an older age and compare them to those implanted at a younger age.

Key Words: Communication Sciences and Disorders, Cochlear Implants, Auditory Training

Introduction

Hearing loss affects millions of people every day. Children can be born with it, individuals can acquire it, and disease can cause it. Hearing loss can affect multiple aspects of a person's life. It can affect language acquisition, social interaction, and the psyche of someone diagnosed with it. As medical advances are continuously developing with cochlear implants, we see a rise in the number of people undergoing this surgery across the lifespan. The age of the individual being implanted, social variables, and the biology of the person can affect the success of acquiring speech and hearing with a successful implantation. In this literature review, I will synthesize and discuss hearing loss, cochlear implantation, and attributes that go into successful auditory training and speech acquisition therapies in the pediatric and adult population.

Hearing Loss

Hearing loss affects millions of people and can manifest in multiple forms. According to the World Health Organization [WHO] (n.d.), approximately 466 million people worldwide have a disabling hearing loss. Peripheral hearing loss can range anywhere from a mild to profound degree and can be located in any part of the ear. There are three distinct parts to the peripheral ear; the outer, middle, and inner ear (ASHA, n.d.a). Conductive hearing loss occurs when the outer and middle ear systems are not working properly. This can be due to fluid buildup, cerumen (ear wax) blockage, tumors, and anatomical malformations. Medicine and surgeries can often correct conductive types of hearing loss (ASHA, n.d.b). Another type of hearing loss is sensorineural hearing loss [SNHL]. SNHL occurs when damage is done to the inner ear and/or nerve pathways from the inner ear to the brain. SNHL can stem from illness such as meningitis, ototoxic drugs, hereditary hearing loss, aging, brain injury, malformations, and noise exposure (ASHA, n.d.e). Cochlear implants can help restore hearing loss due to SNHL. There is also a

third type of hearing loss called Mixed Hearing Loss, which is a combination of both conductive and SNHL.

Hard of hearing is the term given to people with hearing loss that ranges mild to severe. This means their hearing loss is within the 26 decibel range to 90 decibel range (Martin & Clark, 2019). People with mild to severe hearing loss can typically use hearing aids or assisted listening devices to help compensate for their hearing loss and can do well communicating with others through spoken language. Due to degraded residual hearing loss, those with more severe hearing loss may not benefit from typical hearing aids and may opt to receive a cochlear implant instead. People diagnosed with deafness typically have hearing loss in the profound range, which is considered greater than 90 decibels , have little to no hearing, and may choose to communicate through manual sign language (Martin & Clark, 2019).

In addition, the onset of hearing loss can occur at any stage of life. Newborns can either be born with it, known as congenital hearing loss, or it can be acquired after birth. About 1 out of 1,000 newborns in the United States are born with a detectable level of hearing loss in one or both ears (Kemperman et al., 2002). Congenital hearing loss is also called pre-lingual hearing loss, since it occurs before language is obtained (Kemperman et al., 2002). Causes of congenital hearing loss can vary, and about 50% of congenital hearing losses are due to hereditary factors. Non-hereditary causes may be environmental, and can result from infections during pregnancy, premature birth, drug abuse during pregnancy, and other pregnancy factors that could affect the newborn in utero (ASHA, n.d.c; Eppsteiner, 2014).

Furthermore, Connexin 26 mutations are the most common cause of autosomal recessive deafness (Kemperman et al., 2002). Connexin 26 is hypothesized to be important in the process of maintaining a high potassium concentration in the inner ear fluid called endolymph. Research

has shown that children with Connexin 26 mutations do not solely have a family history of this mutation but can also be born from parents with normal hearing. There are about 27.8% familial cases and 7.9% sporadic cases of Connexin 26 mutations (Kemperman et al., 2002). While the Connexin 26 mutation results in sensorineural hearing loss, patients are found to have an intact auditory nerve, which is necessary for being a candidate for cochlear implantation (Kemperman et al., 2002).

Acquired hearing loss can occur at any point during the life span. Individuals who acquire hearing loss before language development have pre-lingual hearing loss. Furthermore, those who have hearing loss after language acquisition have post-lingual hearing loss. There is also the category of perilingual hearing loss which occurs while speech and language is beginning to be acquired. Acquired hearing loss can occur for a multitude of reasons such as infectious disease, excessive exposure to loud noise, head injury, aging, and more (ASHA, n.d.d). Additionally, acquired hearing loss can be both sensorineural and conductive.

Hearing loss can present in a multitude of ways due to various pathologies of the ear. While some hearing loss such as conductive may be treatable with medicines, surgeries, or cerumen removal, sensorineural hearing loss is typically permanent. Depending on the degree of hearing loss and the integrity of the residual hearing, people with sensorineural hearing loss may use hearing aids or assisted listening devices to perceive sound. Also, people with severe SNHL may consider getting a cochlear implant, if hearing aids are unsuccessful or not an option. If hearing loss goes undetected and/or untreated, it can affect a person's speech development.

Hearing and Speech Acquisition

Hearing loss affects multiple aspects of a person's life. These can be functional, social, emotional, and educational consequences. People with hearing loss may find themselves having difficulty communicating with others. "Spoken language development is often delayed in children with unaddressed hearing loss" (Deafness and hearing loss, n.d.). These children may also experience delays in education, which may be more likely if placed in a mainstreamed school. Additionally, their social life may also be affected if they cannot communicate with their classmates, causing feelings of isolation, frustration, and depression (Deafness and hearing loss, n.d.). Early identification can help mitigate these effects of hearing loss.

Spoken language acquisition starts from an early age and those who are deaf or hard of hearing may experience delayed speech development. I choose the words "spoken language" because there are other types of communication as well, such as nonverbal communication (i.e. sign language). Spoken language is learned through listening. As young children we listen to those around us and acquire language through incidental, or unplanned, learning. This could happen while watching television, listening to parents speak, and/or during other times language is spoken around the child. As children start to speak on their own, they learn from themselves through self-concept and feedback. When the child speaks and tries to imitate those around them they can hear themselves and change the way they pronounce words or sounds to better match that person. Those who are deaf or hard of hearing cannot learn speech through incidental learning and/or feedback and may not be able to acquire spoken language typically.

Moreover, studies show that the later in age a person is implanted, the harder it will be for them to acquire speech and the less intelligible their speech will be. Research shows that by 6 months of age, children start to discriminate the sounds of the language spoken in their

environment (Schow & Nerbonne, 2017). Therefore, the younger a person is implanted the higher their success rate will be. That is why it is critical to identify and manage hearing loss within these first six months. With this early identification and management of hearing loss, the child can develop age-appropriate speech and language skills (Schow & Nerbonne, 2017). In order to comprehend and express speech, children must be able to hear speech sounds. Children with profound SNHL do not have access to these speech sounds and therefore cannot imitate them, establish meaning, and learn the rules of language (Markman et al., 2011). Late identification and management of hearing loss can result in spoken language delays, academic difficulties, social difficulties, and vocational limitation (Schow & Nerbonne. 2017).

Language has three main components: form (phonology, syntax, and morphology), content (vocabulary and semantics), and use (pragmatics). Children with hearing loss may use shorter, simpler sentences, incorrect word order, delete morphemes, and have limited vocabulary. They may also have a limited understanding of idioms, metaphors, and other figurative language. Furthermore, multiple word meanings may be confusing to them as well. In regard to social skills, they may not be able to initiate conversation or lack the knowledge of conversational conventions, such as changing the topic or closing conversations (Schow & Nerbonne, 2017). This can be detrimental, especially during the preschool age where social interaction is how children learn through play.

For the adult population, acquired hearing loss can also affect speech and communication. Kishon-Rabin et al (1999) found specific errors in the speech of post-lingually deafened adults that included decreased vowel space due to centralization of the first two formants, inaccurate production of high-frequency sounds, substitution of /r/ with /w/, and the deletion of consonants in the final positions of words. However, Kishon-Rabin et al (1999) also

reported that after receiving cochlear implants, post-lingually deafened adults showed significant improvements in speech.

Cochlear Implants

Cochlear implants are continuously being researched and advanced. While cochlear implants are still controversial in the Deaf community, 90% of deaf babies are born to a hearing family (Quick Statistics About Hearing, 2018). In addition, there are more cases of adults with either congenital or acquired hearing loss getting cochlear implant surgery as well.

Cochlear implants can be analogous to a prosthetic limb (Drennan et al., 2014). Inner hair cells are conductors of energy. Sound waves come in through the outer ear, travel to the middle and inner ear, and hair cells convert the acoustic energy into electrical stimuli into the auditory nerve to the brain. People diagnosed with sensory deafness no longer have the inner hair cells to make this process work. This can be due to the hair cells being distorted or damaged, making the usage of hearing aids unsuccessful. Cochlear implants replace the function of inner hair cells with electrodes to conduct the electrical stimuli to the eighth nerve, or auditory nerve. There are two parts to the cochlear implant, the internal and external parts. The external portion of this implant is attached behind the ear and connects with the internal part via magnets. The external part contains the microphone, speech processor, and battery. The microphone converts sound waves into electrical signals like the inner hairs typically would. These signals are then sent to the speech processor, which codes the information and sends it to the external coil. Through the skin, the external coil sends information using frequency modulation [FM] waves to the internal receiver. The internal receiver sends the information into the electrodes that then stimulate the auditory nerve. Finally, the auditory nerve acts as a pathway the information uses to travel to the brain in order for the individual to perceive sound (Schow & Nerbonne, 2017). While the process

seems extravagant, the cochlear implant surgery has low complication rates and failure occurs in just 2 to 4% of patients (Lenarz, 2018).

Not all individuals who are deaf are candidates to receive a cochlear implant. Many factors go into determining if the patient is viable for an implant. These factors may also be determined by the brand of implantation used. For pediatrics, there needs to be a significant hearing loss and no show of auditory development with hearing aids. Children 12 to 24 months old have to have a severe to profound SNHL. The Food and Drug Administration [FDA] recommends the age of 12 months as the earliest implantation age. For adults, there must be moderate to profound hearing loss and limited benefit from amplification devices. Adults must receive a word recognition test and score 50% or less in the ear to be implanted, as well as 60% or less in the opposite, or good, ear (Gifford, 2011). Additionally, candidates must also have an intact auditory nerve. Without the auditory nerve the electrical stimuli will not reach the brain to be encoded into meaningful sounds (Gifford, 2011). The anatomy of the cochlea must be intact as well. The surgeon must be able to place the electrode within the cochlea in order for the implantation to work. Other variables are also considered, such as the onset of deafness, meaning the longer a person is deaf without auditory language, the less successful their outcomes may be.

Importantly, before implantation and aural rehabilitation there is counseling that needs to take place to evaluate the needs, desires, and goals of the patient and family. The Self-Assessment of Communication, Significant Other Assessment of Communication, and the Hearing Handicap Self-Inventory for Adults are self-assessments that patients and/or family members fill out before cochlear implant surgery (Estabrooks et al., 2014). These assessments are necessary in order for the clinician to be able to establish appropriate goals during aural

rehabilitation. The patient needs to be self-motivated and be made aware of the difficulties that may come along after surgery. Cochlear implants are not a cure-all and after implantation multiple follow-up sessions are needed, as well as continuous auditory rehabilitation and therapy.

Follow-Ups and Auditory Training

After implantation there are many tests and follow-up procedures in order to ensure maximum efficiency of the device. After surgery, the patient must wait approximately two to three weeks before being fit for the external processor (Schow & Nerbonne, 2017). During this initial fitting and programming of the cochlear implant, the audiologist programs the speech processor in order to create a "MAP". The programming system helps determine the levels of hearing comfortability for the patient (Schow & Nerbonne, 2017). Other objective techniques are used to estimate the ranges of comfortability in children and other difficult to test patients. After levels are established and the MAP is created, the microphone is then activated.

After another week, another follow-up programming session is typically scheduled to reflect on the patient's experiences with the implant and re-evaluate the MAP. For the adult patient, follow-ups are typically six visits in the first two months of use, then at three months, six months, and finally annually. For the pediatric patient, programming is weekly for two months, then at six months, nine months, and eventually every six months. These schedules can be modified depending on the patient and how well they are or are not adjusting to the cochlear implant (Schow & Nerbonne, 2017). After the implant is activated, the patient does not initially know how to verbalize or understand speech.

Parents of children with hearing loss can be presented with multiple routes of communication that their child can utilize. These include manual sign language, a sign language and English bilingual approach, total communication, and verbal approaches. For purposes of

this paper I will mainly be discussing listening and spoken language approaches that focus on spoken language through the use of auditory training. Auditory-verbal practice uses hearing assistive devices, such as aids or cochlear implants to promote speech acquisition through auditory listening. Using this method, patients learn to listen to others and themselves in order to learn language and speech (Estabrooks et al., 2014). According to Fu and Galvin (2008), studies have shown that targeted auditory training can significantly improve cochlear implant patients' speech recognition performance.

Auditory training is required and takes time in order for patients to identify and comprehend the sounds around them. The ability to perceive and understand speech involves a number of components. According to Erber (1984), there are four key components to hearing: detection, discrimination, identification, and comprehension. Detection is defined as the awareness of sound. In addition, discrimination is the ability to distinguish different sound. Speech discrimination occurs when the individual is able to distinguish individual speech stimuli, such as syllables and phonemes. Next, identification is the ability to identify or label what the sound is. Finally, comprehension is the perception and understanding of the auditory message (Rosenzweig, 2014). To test whether or not the cochlear implant is working correctly, parents can perform the Ling Six Sound test daily on their child. The Ling Six Sound test is a detection task and can be used to evaluate if the child can hear speech sounds from low to high frequency with their cochlear implant (Madell, 2018).

Furthermore, learning these components can be done in a multitude of ways. Auditory training methods, such as speech tracking, help in both treatment and monitoring progress after the implant is activated. The cochlear implant company may also send resources to patients and families to use during auditory training. Three companies approved by the FDA are Advanced

Bionics, Med El, and Cochlear Corporation. Cochlear Corporation has a website page called "Communication Corner," which provides resources and age-appropriate programs to develop and enhance listening skills (The Communication Corner, n.d.). Additionally, Med-El also has a variety of programs and activities for ages across the lifespan to practice speech in noise listening and speech recognition (SoundScape, n.d.) Finally, Advanced Bionic provides free activities and resources through "The Listening Room" to help facilitate speech, language, and listening skills for cochlear implant patients (The Listening Room, n.d.).

There are other auditory training programs that clinicians may have their patients use at home as well. A popular program is Angel Sounds. Angel Sounds is used at home on the computer and allows the patient to control their rehabilitation difficulty. It utilizes programs that help patients practice the discrimination and identification of sounds and improve speech perception in noise (Angel Sound, n.d.).

Aural rehabilitation and intervention for children is more family based while the adult population is typically provided self-help and computer-generated therapy programs (Estabrook et al, 2014). When considering auditory training for adults, there are two general objectives. The first is learning to maximize the use of auditory and other related cues available for the perception of speech, and the second is the adjustment and orientation to facilitate the optimum use of hearing aids and cochlear implants (Show & Nerbonne, 2017).

Outcomes

There are factors both pre-operative and post-operative that can affect therapy success rates. According to the "The Childhood Development after Cochlear Implantation" [CDaCI] study, those who had their implants activated under 18 months of age performed better than those activated after 18 months of age (Markman et al., 2011). Children who receive an implant

at a young age generally perform better on a wide range of outcomes than children who are implanted at an older age. This outcome is due to neural plasticity. There have been many theories regarding the critical period of language learning. The critical period is a period of time, hypothesized to end around puberty, where the acquisition of language is most likely to occur. The brain does most of its developing and changing during childhood with the help of neural plasticity as well. After the critical period it takes more effort in order for language to be learned (Bench, 1992). Therefore, patients who receive cochlear implants at a later age have higher probabilities of continued language delays and lower intelligibility (Tobey, 2013).

There are additional studies regarding children who grew up in isolation without language that continue to fail to acquire language even after being exposed. This is due to being deprived of language during their critical period (Friedmann & Rusou, 2015) . For example, Genie was kept in isolation and deprived of language until the age of 13. After being discovered and introduced to language, she failed to develop normal syntax and the process of language development was slow and inefficient. In addition, it is found that children with congenital hearing loss also show difficulties with language if not exposed early on. According to Friedmann & Rusou (2015), if language input is received during their first year of life, they may later develop normal syntax. Moeller (2000) also found that children who receive intervention before the age of eleven months have a better vocabulary than children who receive therapy after the age of two. However, if a deaf child is born to a deaf family who communicates with sign language they experience normal language development, although it is not spoken language.

In addition, the age of implantation and duration also affect the success of speech acquisition after cochlear implantation. The CDaCI study showed results that children with cochlear implants progress in speech recognition within one year of having the implant. The

participants of this study were 188 children with SNHL. Results showed that children who had their implants activated before 12 months of age had the highest level of spoken language performances, while the participants who activated their implants after 18 months of age had lower levels of spoken language (Markman et al., 2012).

Early fitting of cochlear implants is another variable that can affect speech and language performance. The Longitudinal Outcomes of Children with Hearing Impairment [LOCHI] study investigated the effects of intervention on children with hearing loss. Researchers found that the earlier a child is fitted for hearing aid and/or cochlear implants, the better the speech perception outcomes by age five (Ching et al., 2018).

Furthermore, studies have tracked changes in performance over time in "naïve" or newly implanted CI users. These longitudinal studies showed that most gains in performance occur in the first three months of use (Fu & Galvin, 2008). In children, it is expected that within a four-year period in a listening and spoken language program, the gap between chronological age and language age will become nonexistent. Children who receive auditory based intervention score higher on speech production and recognition (Estabrooks et al., 2014). Data from a study also shows that after four to five years of implantation, children using oral communication outperformed children using signed communication in measures of speech perception and intelligibility (Archbold et al., 2000).

Moreover, early intervention and family engagement is a key component in the success of speech acquisition. Early intervention teaches the family techniques they can use at home with their child to make sure they are being exposed to language and are facilitating communication (Cole & Flexer, 2016). Children spend a majority of their day at home with their family, not with the clinician. Parents are responsible for bringing their child to appointments and are responsible

for their child's development (Ching et al., 2018). According to O'Donoghue & Pisoni (2014) language growth is greatly correlated with parent-child interaction while limited family support and interaction is associated with poor language outcomes.

Conclusion

In conclusion, hearing loss affects millions of individuals. It can be present from birth or be acquired over time. If hearing loss goes undetected, speech and language acquisition can be greatly affected. The reason being in order for individuals to acquire language, the auditory feedback loop must be intact. This loop allows these individuals to learn language through incidental learning.

As advancements in medicine and technology are made, there is also an increase in the amount of people with hearing loss opting to undergo cochlear implant surgery. However, candidates of cochlear implants must meet specific criteria. After receiving a cochlear implant, the cochlear implant must be programmed to the individual's hearing levels and the individual must undergo auditory training. There are many variables that can affect the success of a cochlear implant. These can include the age and duration the cochlear implant is received, support systems, and more. Given the right environment, aural rehabilitation, and time, cochlear implants can significantly close the gap of speech perception between typical hearing individuals and individuals with significant hearing loss.

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