Development of Speech in Children with Cochlear Implants

Bilinguistics Inc.

This course is offered by Bilinguistics, an ASHA Approved CE Provider

Content Area: Professional

Instructional Level: Intermediate

Continuing Education Units: .1

Objectives:

Participants will be able to demonstrate knowledge in and identify:

- The historical background of cochlear implantation leading up to current use
- Speech acquisition following cochlear implant
- Consonant and vowel productions occurring typically post implant
- Extrinsic factors that influence speech acquisition following implant
- Influence of language and educational exposure on implanted students

BILINGUISTICS

Introduction

Advances in technology have caused major changes in how hearing impairment is being treated. Already today, many people with a hearing impairment will use frequency modulation (FM) systems, hearing aids, or even cochlear implants. As new technologies improve, speech-language pathologists are increasingly coming in contact with children using hearing devices or are being asked to collaborate in identifying how a child with a hearing impairment might best be served. Whether working directly with someone with a hearing impairment (HI), or working in an environment where such people are being served, it is important for a professional to have some familiarity with topics surrounding hearing devices. This paper highlights the historical progress, suitable candidates, and current research surrounding cochlear implants.

History

Cochlear implantation began in the United States in the mid 1970s. From the initial studies on electrical stimulation, to the implantation surgeries of today, the advancement of the field has been related to the ability to measure success through outcomes and results. When successes were quantifiable and repeatable, implantation gained support and popularity and new discoveries were made. When outcomes were negligible or were not quantifiable, the efficacy of implantation was called into question and the practice was even abandoned for short periods of time. In the 12-year period from 1972 and 1984, only 1,000 people received cochlear implants. Since 1984, cochlear implantation has become an established procedure and is now seen as a viable option for nearly anyone who does not derive benefit from traditional amplification (Niparko & Wilson, 2000).

Identifying candidates for cochlear implantation has been an evolving process where the pool of candidates was expanded with each success. Initially implantation began with post-lingually deaf adult males. Successive trials focused on differences in age, gender, oral language abilities, and severity of hearing loss. The science has now expanded to include recipients as young as 12 months, both male and female, and with different levels of hearing loss (Niparko, 2000). Restrictions on the age of children have been reduced in an effort to take advantage of periods of greater language emergence (Ertmer & Mellon, 2001). Equally so, restrictions on severity of hearing loss have also relaxed as increases in language use have been reported by individuals who retained a percentage of their hearing prior to being implanted (Niparko 2000). This growth in cochlear implantation created a need for research that documented and described speech development.

Much available research describes children on a case-by-case basis with a few studies doing comparisons across individuals or varying groups (Geers & Tobey, 1992). In comparison studies however, it is not easy to correlate data because each child differs in age of implantation, severity of hearing loss, concomitant issues (e.g. motor impairment), preexisting speech, and pre- and post-lingual deafness (Kirk, 2000). However, data on children with cochlear implants can be collectively summarized to provide projections of speech development. Additionally, those individual differences that confound studies have been found to serve as predictors of later intelligibility (Yoshinaga-Itano, 1998a).

Research indicates that cochlear implants result in increased intelligibility. Levels of intelligibility have increased since early cochlear implants (Flipsen, 2008a) yet there is still considerable variability in intelligibility rates. In a study by Khwaileh and Flipsen (2010), intelligibility rates of children with cochlear implants varied from 1.6% to 96.5%, with amount of implant experience being the factor that correlated highest with intelligibility.

Speech Acquisition

Cochlear implantation improves the rate at which a child with HI moves through early speech developmental stages (Ertmer, 2002a; Moore & Bass-Ringdahl, 2002). In a study on vocal development in young children with cochlear implants, Ertmer et al. (2002) documented the speech development of two implanted children. Eighty-five percent of one participant's vocalizations were pre-canonical prior to implantation and only 14% one year after. The second subject's development was less dramatic but still showed an increase in canonical sounds following implantation (Ertmer et al., 2002). On the average, children with cochlear implants begin canonical babble at 6.5 months post implant (Moore & Bass-Ringdahl, 2002).

Upon moving into the canonical stage, children with cochlear implants tend to acquire sounds in relatively the same manner and order as hearing children (McCaffrey et al., 1999). This is contrary to infants with profound deafness wearing hearing aids who typically exhibit delayed and reduced vocal productions (Oller et. al. 1988). However, it should be noted that hearing aid technology and early identification may also lead to more normal sequences of development than the set of children reported by Oller in the mid-1980's. Ertmer and Mellon (2001) followed the vocal development of a child implanted at 20 months. Their study measured the vocal development of a child with a cochlear implant to see how her gains appeared against typical development. Utterances were evaluated monthly for a twelve-month period and coded using a standard assessment tool for vocal development. Reliability was checked through intra- and inter-coder measures on 10% of the utterances each session. Measurements included frequency and type of vocal production as well as the order in which the sounds were produced. Results showed utterance productions that resembled typical developmental patterns but that began later than normal (post-implant). However, the child's progression occurred faster than normal development supporting the notion that implantation during a linguistically rich period can aid in the acquisition of language (Ertmer & Mellon 2001).

Consonant-Vowel Inventory

A child's consonant and vowel inventory is believed to be related to, if not evolve from, the auditory cues that a child receives (Yoshinaga-Itano, 1998a; Oller et.al, 1988). This being said, it is predicted that gains in the speech production of a cochlear implant recipient should begin once his or her auditory exposure begins. In the study of a child implanted at 25 months, McCaffrey et al. (1999) found that the child's pre-implant productions primarily consisted of labial-stop consonants, nasals, and mid-central vowels. This is consistent with literature on deaf speech acquisition. Following implantation however, the child's productions expanded to include a variety of vowels, an increase in intra-oral sounds such as alveolars, and an overall increase in monosyllable production and variegation (McCaffrey et al., 1999).

Ertmer et al. (2002a) provide a clear account of consonant and vowel acquisition following cochlear implant in their study of D, a profoundly deaf female implanted at 28 months. Pre-implant data shows a reliance on the consonants /b/ and /m/. Her consonant repertoire expanded to include eight additional sounds within the first year post-implant. The consonants /b/ and /m/ were still favored but /p/, /w/,/g/, and /j/ also appeared. D's vowel repertoire pre-implant consisted of central (/ʌ /), mid-back (/o/), and low-back (/u/) vowels. Following the implant, the central vowel (/ʌ /) remained high in frequency but was joined by six additional vowels and three diphthongs. All of the sounds that D produced by the end of the 12 months were canonical or post-canonical. That is to say that D produced a variety of consonant and vowel combinations creating a dynamic range of syllables (Ertmer et al., 2002a). The following chart shows D's consonant and vowel inventory across the data collection year.

Consonant and Vowel Inventory for D.

	m	b	p	w	g	d	j	k	t	ʃ	ʌ	i	o	u	ɛ	ɪ	e	ɑ	æ	ʊ	aɪ	aʊ	ɔɪ
P1	1	2									14	2	2	2									
P2			1								1	2			5	3	1						
1				1							12	1	1		7	2		3	4				
2					1						11												
3											8							3		1			
4	2	1		1							11	3			4	5	2	4		1			
5		1		1							6	9			1	4	1						
6	1			1							12					1		3	5		1		
7	1	1		2		1						2	2			9	4	3		1	1		
8	2				1		1				11		1			1		2				4	
9			1		1						12	1			1	3	2						
10	1							2			12	6	2			1		7			1		
11							1		1	1	5	2	10		1	2		4		1	6	2	2
12						1	1				8	2	3			4		4		1	2	3	1

Note: Taken from: Ertmer et al. (2002a).

Degree of Hearing Loss

One of the greatest predictors for determining later-developing intelligibility is identifying the degree of hearing loss (Yoshinaga Itano, 1998b; Geers, 2002; Geers & Tobey, 1992). Yoshinaga-Itano (220; 1998b) found that "children with profound hearing loss had significantly poorer speech than children with mild through severe hearing loss." Added to this, early onset of hearing loss has devastating effects on speaking skills

(Geers & Tobey, 1992). Yoshinaga-Itano suggests that even a minor amount of residual hearing vastly improves speech output. She states that the difference is so great that only two categories of hearing loss are needed, hearing impaired (mild through severe) and profound (Yoshinaga-Itano, 1998b).

Age of Onset, Age of Implantation

The age of onset and the age that a child is implanted dramatically alter the timeframe in which a child is learning to speak (Yoshinaga-Itano, 1998b; Ertmer et al, 2002; Blamey et al., 2001). Ertmer et al. (2002) present data on two children who received cochlear implants. D, lost his hearing at 3 years and was implanted at 7 years, 6 months. B was identified with a hearing loss at 5 months and was implanted at age 3. D showed higher pre-implant speech variability, probably due to 3 years of hearing exposure. After being implanted he had rapid success in producing intelligible sounds with errors involving stop consonants and omitting fricatives. B's pre-implant speech was minimal. Post-implant he began producing /m/, /b/, and many vowels but most of his utterances were non-meaningful. His speech developed slowly though the pre-canonical and canonical stage before making meaningful sound. The authors note that B had other impairments that slowed his growth. However, the exposure to language that D received before becoming deaf offered him a quicker, more accurate access to the sound system (Ertmer et al., 2002). Currently, children are being implanted as young as one year or 12 months (Austin Ear Clinic, 2007)

Influence of Language and Educational Exposure

Speech productions should additionally be viewed within the natural context of language. In a study describing factors that affect the development of speech, language, and literacy, in children with early cochlear implantation, Geers (2002) studied a population of 15 cochlear implant recipients 4-6 years after implantation. Few studies have demonstrated the effects of implants on aspects of language and literacy. This study isolated the effects of family, individual child characteristics, and implant characteristics in order to identify which educational factors had the greatest effect on this population. The children were equated for age at test, age of onset of deafness, and age of implant. Intelligence scores were matched, as was standard of living. Most children came from a two parent, two children family with an income between $50,000 and $80,000. More than half of the families included one college student. Finally, all children had been implanted with the same cochlear implant and with the same electrode array (Geers, 2002).

In order to ascertain how educational factors are influenced by implantation, the parents were probed about different educational exposure, how much they worked with their child, and therapy after implantation. Speech perception and production, language, total communication, and reading were analyzed and then summarized with a single comparable score. Each aspect of education was analyzed for its contribution to communication (Geers, 2002).

Classroom communication (either oral or total) had no significant contribution to language. Other aspects such as private or public schooling influenced specific skills such as speech and perception. However, when figured in with the other variables their input was negligible. The author concluded that a child’s education is affected to an extent by all educational exposure but the variables that most greatly contributed to education were implantation before five-years-of-age, non-verbal intelligence, using the most updated implant coding strategy, and reliance on oral-aural communication (Geers, 2002).

Additional Factors Influencing Successful Implantation

Aspects relating solely to the child's abilities and personality influence the success of cochlear implantation (Yoshinaga-Itano, 1998b; Pisoni et al., 1999; Tait, Lutman, & Robinson, 2000). Research suggests that it is not entirely the treatment or the time period in which everything occurs that determines the overall outcome of speech development after implantation. Cognitive, motoric, neurological, and linguistic (signing) abilities of a child have influence over what and how the child will learn (Ertmer & Mellon, 2001; Pisoni et al., 1999). Additionally, Tait et al. (2000) showed that children who "demonstrate autonomy in preverbal interactions, whether by means of vocalization or by gesture" demonstrate greater outcomes with auditory devices (Tait et al., 18; 2000). Mental abilities, regarding intelligence and personality, affect every population's ability on perception, attention, learning and memory tasks. These tenants should not be disregarded when examining a cochlear implant population (Pisoni et al, 1999).

Conclusion

Much is known about the development of speech following cochlear implantation due to the multifaceted nature of existing literature. Case studies and group designs offer insight into the effects of age of implantation, severity of hearing loss, situational influences, as well as intelligence. By documenting speech production patterns, tentative norms and developmental expectancies have been established. However, nearly all of the research currently available has been derived from single-case studies and rely heavily on English-speaking recipients. Studies have begun to identify developmental norms that can be compared across implanted children as well as seeking norms and data from implantation that can be used to serve a culturally diverse population.

The following document provides general information for parents or clients that are interested in cochlear implants. While the use of cochlear implants is general known, many misconceptions about cochlear implants exist relating to, ease of implantation, price, predictive post hearing status, and who can be a potential candidate. Parents, clients, and school personal who deal with a cochlear implantation candidate can benefit from information on the successes and limitations of cochlear implants. Familiarize yourself with the truths and misconceptions of cochlear implantation in the final exercise.

General Information on Cochlear Implants

From: http://www.nidcd.nih.gov/health/hearing/coch.asp

What is a cochlear implant?

A cochlear implant is a small, complex electronic device that can help to provide a sense of sound to a person who is profoundly deaf or severely hard-of-hearing. The implant consists of an external portion that sits behind the ear and a second portion that is surgically placed under the skin (see figure). An implant has the following parts:

- ☐ A microphone, which picks up sound from the environment.
- ☐ A speech processor, which selects and arranges sounds picked up by the microphone.
- ☐ A transmitter and receiver/stimulator, which receive signals from the speech processor and convert them into electric impulses.
- ☐ An electrode array, which is a group of electrodes that collects the impulses from the stimulator and sends them to different regions of the auditory nerve.

An implant does not restore normal hearing. Instead, it can give a deaf person a useful representation of sounds in the environment and help him or her to understand speech.

How does a cochlear implant work?

A cochlear implant is very different from a hearing aid. Hearing aids amplify sounds so they may be detected by damaged ears. Cochlear implants bypass damaged portions of the ear and directly stimulate the auditory nerve. Signals generated by the implant are sent by way of the auditory nerve to the brain, which recognizes the signals as sound. Hearing through a cochlear implant is different from normal hearing and takes time to learn or relearn. However, it allows many people to recognize warning signals, understand other sounds in the environment, and enjoy a conversation in person or by telephone.

Who gets cochlear implants?

Children and adults who are deaf or severely hard-of-hearing can be fitted for cochlear implants. According to the Food and Drug Administration's (FDA's) 2005 data, nearly 100,000 people worldwide have received implants. In the United States, roughly 22,000 adults and nearly 15,000 children have received them.

Adults who have lost all or most of their hearing later in life often can benefit from cochlear implants. They learn to associate the signal provided by an implant with sounds they remember. This often provides recipients with the ability to understand speech solely by listening through the implant, without requiring any visual cues such as those provided by lipreading or sign language.

Cochlear implants, coupled with intensive postimplantation therapy, can help young children to acquire speech, language, and social skills. Most children who receive implants are between two and six years old. Early implantation provides exposure to sounds that can be helpful during the critical period when children learn speech and language skills. In 2000, the FDA lowered the age of eligibility to 12 months for one type of cochlear implant.

How does someone receive a cochlear implant?

Use of a cochlear implant requires both a surgical procedure and significant therapy to learn or relearn the sense of hearing. Not everyone performs at the same level with this device. The decision to receive an implant should involve discussions with medical specialists, including an experienced cochlear-implant surgeon. The process can be expensive. For example, a person's health insurance may cover the expense, but not always. Some individuals may choose not to have a cochlear implant for a variety of personal reasons. Surgical implantations are almost always safe, although complications are a risk factor, just as with any kind of surgery. An additional consideration is learning to interpret the sounds created by an implant. This process takes time and practice. Speech-language pathologists and audiologists are frequently involved in this learning process. Prior to implantation, all of these factors need to be considered.

What does the future hold for cochlear implants?

With advancements in technology and continued follow-up studies with people who already have received implants, researchers are evaluating how cochlear implants might be used for other types of hearing loss.

NIDCD is supporting research to improve upon the benefits provided by cochlear implants. It may be possible to use a shortened electrode array, inserted into a portion of the cochlea, for individuals whose hearing loss is limited to the higher frequencies. Other studies are exploring ways to make a cochlear implant convey the sounds of speech more clearly. Researchers also are looking at the potential benefits of pairing a cochlear implant in one ear with either another cochlear implant or a hearing aid in the other ear.

Where can I get more information?

NIDCD maintains a directory of organizations that can answer questions and provide printed or electronic information on cochlear implants. Please see the list of organizations at www.nidcd.nih.gov/directory.

Use the following keywords to help you search for organizations that are relevant to cochlear implants:

- ☐ Cochlear implants
- ☐ Assistive technology
- ☐ Assistive listening device

For more information, additional addresses and phone numbers, or a printed list of organizations, contact:

NIDCD Information Clearinghouse
1 Communication Avenue
Bethesda, MD 20892-3456
Toll-free Voice: (800) 241-1044
Toll-free TTY: (800) 241-1055
Fax: (301) 770-8977
E-mail: nidcdinfo@nidcd.nih.gov

NIH Publication No. 00-4798
Content updated: May 2007

Familiarization Exercise – Cochlear Implants

	True	False
A cochlear implant is made up of four basic components.	○	○
A cochlear implant works just like a hearing aid does.	○	○
Cochlear implantation requires surgery and follow-up therapy sessions.	○	○
Implantation is restricted to only children.	○	○
A child has to be completely deaf before she can be implanted.	○	○
There is a microphone on a cochlear implant.	○	○
A child with a cochlear implant will need special electronic devices in the classroom to support him.	○	○
Early implantation has resulted in children who have highly understandable speech.	○	○

References

Austin Ear Clinic. Retrieved April 26, 2007 from http://www.austinear.com/cochlearimplants.html

Blamey, P., Barry, J., Bow, C., Sarant, J., Paatsch, L., & Wales, R. (2001). The development of speech production following cochlear implantation. *Clinical Linguistics and Phonetics*, 15(5), 363-82.

Ertmer, D. J., Young, N., Grohne, K., Melton, J. A., Johnson, C., Corbett, K, et al. (2002a). Vocal development in young children with cochlear implants: Profiles and implications for intervention. *Language, Speech, and Hearing Service in Schools*, 33, 184-195.

Ertmer, D. J., & Mellon, J.A. (2001). Beginning to talk at 20 months: Early vocal development in a young cochlear implant recipient. *Journal of Speech, Language, and Hearing Research*, 44. 192-206.

Flipsen, P., Jr. (2008a). Intelligibility of spontaneous conversational speech produced by children with cochlear implants: A review. International Journal of Pediatric Otorhinolaryngology, 72, 559-564.

Geers, A.E. (2002). Factors affecting the development of speech, language, and literacy in children with early cochlear implantation. *Language, Speech, and Hearing Services in the Schools*. 33, 172-183.

Geers, A.E., & Tobey, E. (1992). Effects of cochlear implants and tactile aids on the development of speech production skills in children with profound hearing impairment. *Volta Review,* (94)5, 135-63.

Khwaileh, F. & Flipsen, P., Jr. (2010). Single word and sentence intelligibility in children with cochlear implants. Clinical Linguistics & Phonetics, 24, 9, 722-733.

Kirk, K.I. (2000). *Challenges in the clinical investigation of cochlear implant outcomes*. In J. Niparko, K.I. Kirk, N.K. Mellon, A. McKonkey Robbins, D. L. Tucci, B. S. Wilson (Eds.), Cochlear Implants: Principles and Practices. Lippincott Williams &Wilkins. Philadelphia.

McCaffrey, H. A., Davis, B. L., MacNeilage, P.F., & Von Hapsburg, D. (1999). Multichannel cochlear implantation and the organization of early speech. *Volta Review*. 101, 5-28.

Moore, J. A., & Bass-Ringdahl, S. (2002). Role of infant vocal development in candidacy for efficacy of cochlear implantation. *Annals of Otol Rhinol Laryngology*, 111, 52-55.

Niparko, J. K. (2000). *Assessment of Cochlear Implant Candidacy*. In J. Niparko, K.I. Kirk, N.K. Mellon, A. McKonkey Robbins, D. L. Tucci, B. S. Wilson (Eds.), Cochlear Implants: Principles and Practices. Lippincott Williams &Wilkins. Philadelphia.

Niparko, J. K., & Wilson, B.S. (2000). *History of Cochlear Implants*. In J. Niparko, K.I. Kirk, N.K. Mellon, A. McKonkey Robbins, D. L. Tucci, B. S. Wilson (Eds.), Cochlear Implants: Principles and Practices. Lippincott Williams &Wilkins. Philadelphia.

Oller D. K., Eilers, R. E. (1988). The role of audition in infant babbling. *Child Development*, 59:441-9.

Pisoni, D.B., Cleary, M., Geers, A.E. & Tobey, E. A. (1999). Individual differences I effectiveness of cochlear implants in children who are prelingually deaf: New process measures of performance. *The Volta Review*, 101(3), 111-165.

Tait, M., Lutman, M.E., & Robinson, K. (2000). Preimplant measures of preverbal communicative behavior as predictors of cochlear implant outcomes in children. *Ear and Hearing,* 21(1), 18-24.

Yoshinaga-Itano, C. (1998a). Development of audition and speech: Implications for early intervention with infants who are deaf or hard of hearing. *The Volta Review*, 100(5), 213-235.

Yoshinaga-Itano, C. (1998b). Early speech development in children who are deaf or hard of hearing: Interrelationships with the language and hearing. *The Volta Review,* 100(5), 181-212.