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Age-Appropriate Listening and Spoken Language Abilities for Children with Hearing Loss

2019

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FOREWORD

For more than 25 years, it has been my privilege to support families on the journey of hearing loss, from the despair of diagnosis, to the hope that arrives when their child speaks their first words, to the sheer joy of watching their child achieve listening, spoken language and literacy outcomes on par with their hearing friends.

Today, the possibilities for children with hearing loss are beyond anything we could have imagined when I began my career. Astonishing advancements in hearing technology, the refinement of Listening and Spoken Language (LSL) as a communication outcome, and the incorporation of newborn hearing screening as standard care mean that children with hearing loss can and do achieve developmental milestones at the same level as children with typical hearing. As a professional, I have seen firsthand the impact these advancements have made on countless families.

At last, we have research that confirms definitively what we've seen in practice. In the following paper, leading research scientist and audiologist, Dr. Jace Wolfe, compiles groundbreaking studies from our colleagues in Australia. The results are breathtaking. Of note, we now have compelling empirical evidence that cochlear implantation before 12 months of age and consistent, exclusive use of LSL contribute to better language outcomes for children with hearing loss. In the second part of the paper, Dr. Wolfe provides outstanding context for how parents and professionals can incorporate the findings into their work to support children with hearing loss learning to listen and speak.

At Hearing First, we are unwavering in our mission to empower children who are deaf or hard of hearing to reach their full potential through LSL. Moments like this one, that affirm one's mission with such clarity, are worthy of celebration. Whether you are a professional or a family member of a child with hearing loss, or you have hearing loss yourself, I hope that you find the following report as inspiring, affirming, and helpful as I have.

With you on the journey,

Dr. Teresa H. Caraway, PhD, CCC-SLP, LSLS Cert. AVT
CEO, Hearing First

Facing Mission: Impossible in the 1990s

Just over 20 years ago, most children born with severe to profound hearing loss did not develop age-appropriate Listening and Spoken Language (LSL) abilities. Prior to Congress's passage of the Newborn Hearing and Infant Screening and Intervention Act of 1999, most states did not have legislation mandating universal newborn hearing screening. Consequently, significant congenital hearing loss was typically not identified until a child was 2.5 to 3 years old or older (NIH, 1993).

Additionally, digital hearing aids were not routinely fitted for children in the 1990s. The early digital hearing aids that were available usually did not contain advanced features such as acoustic feedback reduction, digital noise reduction, and speech enhancement technologies. Also, real ear probe microphone measurements were not routinely used to verify that the output of a child's hearing aids was set to optimize the audibility of speech and important environmental sounds while also preventing discomfort from excessive amplification levels.

Moreover, only a select number of clinics around the country were recommending cochlear implants for children, and most children did not receive their cochlear implants until after their second birthday (Cochlear Americas, personal communication). Most children who did receive a cochlear implant only received an implant for one ear and did not use a hearing aid for the non-implanted ear. Considering these limitations in the 1990s and earlier, the families of children who were born with hearing loss likely felt they faced Mission: Impossible when embarking on a quest to support their child in developing LSL abilities.

21st Century Breakthroughs in the Hearing Healthcare Landscape

The 21st century brought new hope and opportunities for children with hearing loss and their families. Universal newborn hearing screening programs were created in every state, and currently, over 97% of infants born in the USA undergo newborn hearing screening during the first few weeks of their lives (CDC, 2016). Digital hearing aid technology has evolved over the past 20 years. Current devices now feature sophisticated technologies that allow for consistent audibility of even low-level speech for most children with mild to moderately severe hearing loss. Cochlear implants are routinely provided and allow for exceptional outcomes for children with severe to profound hearing loss, and many infants with severe to profound hearing loss receive their cochlear implant(s) at 12 months of age or earlier. Bilateral cochlear implantation is relatively commonplace for children who have severe to profound hearing loss in each ear. Moreover, remote microphone systems allow children to have access to important audio signals in noisy and reverberant environments.

These positive changes in pediatric hearing healthcare have fostered unprecedented possibilities and extraordinary outcomes for children with hearing loss. As children with hearing loss have had access to better hearing healthcare, research has shown improvements in their outcomes with some children achieving LSL abilities that match or exceed those of children with normal hearing.

(CHING ET AL., 2018; DETTMAN ET AL., 2016; EISENBERG ET AL., 2004; GEERS ET AL., 2003, 2007)

Variable Research Results in the Early 2000s

However, most research papers published from the early 2000s and into the early 2010s note a high degree of variability in the outcomes of children with hearing loss. Although some children did achieve age-appropriate LSL abilities, many children still showed significant deficits in their speech and language abilities. For instance, Geers and colleagues (2003) evaluated LSL outcomes of 181 children who were 8 to 9 years old and who had received a cochlear implant prior to 5 years of age. Geers et al. (2003) reported that only 30% of the children had developed language comprehension abilities comparable with those of their peers with normal hearing.

Additionally, Ching and colleagues (2013) evaluated LSL outcomes of 451 children who were 3 years old and who were diagnosed with hearing loss and received auditory intervention from Australian Hearing Services prior to the child's third birthday. Like Geers et al. (2003), Ching et al., found that some children with hearing loss achieved LSL abilities that were similar to those of children with normal hearing.

On average, though, the children's expressive and receptive language and speech production were below the level attained by children with normal hearing at 3 years old.

What are the causes for the variability in outcomes seen in these and other studies? Why did a fairly sizable proportion of children with hearing loss not achieve LSL abilities that were commensurate with children who have normal hearing? Several recent, large-scale research studies have provided us with insight into the factors responsible for the variability in outcomes observed in children with hearing loss.

Most importantly, recent research has shown that excellent outcomes are not only possible for children with hearing loss but probable when we provide evidence-based, audition-centered hearing healthcare in a timely fashion.

When we do what it takes, families no longer face Mission: Impossible.

Today, we can support families on a journey toward listening and talking that is better described as Mission: Probable.

Purpose

The purpose of this paper is to highlight several recent research studies that provide valuable evidence of the outstanding Listening and Spoken Language (LSL) outcomes possible for infants and children with hearing loss as well as the various factors that influence those outcomes.

PART 1

PAGES 10-59

The first part of this paper will summarize the findings of several landmark research studies including:

PART 2

PAGES 60-73

The second part of this paper will integrate the results of these studies and provide essential steps families and hearing healthcare providers can take to optimize the outcomes of children with hearing loss.

PART 1

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A Review of Recent Research Studies

Exploring Outcomes of Children with Hearing Loss

THE LONGITUDINAL OUTCOMES OF CHILDREN WITH HEARING LOSS (LOCHI) STUDY

FUNDED BY: THE NATIONAL INSTITUTES OF HEALTH (NIH) AND HEARINGCRC
CONDUCTED BY: THE NATIONAL ACOUSTIC LABORATORIES AND COLLEAGUES IN AUSTRALIA

PART 1

Longitudinal Outcomes of Children with Hearing Loss (LOCHI)

About the LOCHI Study

The LOCHI study is a multi-center research initiative funded by the National Institutes of Health (NIH) and conducted by the National Acoustic Laboratories in Australia to explore the listening, language, educational, and psychosocial outcomes of children with hearing loss. The LOCHI study is tracking the outcomes of children who were born with hearing loss between 2002 and 2007 and who received hearing healthcare from Australian Hearing audiology clinics in three states: New South Wales, Victoria, and southern Queensland.

The LOCHI study is one of the most important studies ever conducted to examine outcomes of children with hearing loss for the following reasons.

AUSTRALIA IS AN AUDIOLOGY POWERHOUSE.

The National Acoustic Laboratories (NAL), which is located in Australia, has long been a leader in audiology and hearing aid research. For instance, researchers at NAL developed the NAL-NL2 prescriptive method for verifying the appropriateness of hearing aid fittings and the Parents' Evaluation of Aural/Oral Performance of Children (PEACH) questionnaire for validating the functional auditory progress a child makes after being fitted with hearing technology. Many of the innovative developments of NAL are implemented in the hearing healthcare provided for individuals with hearing loss in Australia and around the world. Moreover, the global headquarters of Cochlear Ltd., the largest cochlear implant manufacturer in the world, is also located in Australia, so cochlear implant technology and services are readily available to individuals with severe to profound hearing loss.

THE LOCHI STUDY INCLUDES A LARGE NUMBER OF PARTICIPANTS.

Whereas many studies of children with hearing loss include a relatively small number of participants, the LOCHI study includes a large number of children with hearing loss of various degrees ranging from mild to profound (n = 451 children with hearing loss). Studies with a small number of subjects are less than ideal, because the study results may be exaggerated by the inclusion of outliers (i.e., children with outcomes that are exceptionally good or poor). Also, the inclusion of a small number of subjects reduces the statistical power of a study which subsequently reduces the likelihood of detecting a significant difference that may exist between two groups that are truly different from one another.

IT IS A PROSPECTIVE, LONGITUDINAL STUDY.

Specifically, children are enrolled into the study when they are identified with hearing loss within the first 3 years of life and their outcomes are evaluated periodically throughout childhood. A prospective study that enrolls children upon identification of hearing loss prevents selection bias (e.g., only including subjects who are achieving a high level of performance, who are compliant with intervention, etc.). Prevention of selection bias allows the LOCHI study to provide a comprehensive description of the outcomes of the entire population of children with hearing loss rather than focusing on best-case scenarios. Also, the longitudinal nature of the study allows the LOCHI researchers to determine the outcomes that are achieved throughout childhood rather than just examining outcomes achieved during the first few years of life.

PARTICIPANTS HAVE EQUAL ACCESS TO HEALTHCARE SERVICES.

Australia has a government-funded universal health-care system that provides the necessary audiology services and hearing technology (e.g., hearing aids, cochlear implants, etc.) for individuals from birth to 25 years of age. As a result, all of the children in the LOCHI study had early and ongoing access to the hearing technology required to optimize their LSL outcome.

NOT ALL PARTICIPANTS WERE IDENTIFIED WITH HEARING LOSS AS INFANTS.

Newborn hearing screening was not routinely implemented across all Australia states during the first few years that children were recruited into the LOCHI study. For example, universal newborn hearing screening (UNHS) was generally available in most hospitals in New South Wales, but not in Queensland and especially not in Victoria (of note, Melbourne is located in Victoria). Consequently, some children were identified with hearing loss and received appropriate intervention during the first few months of life, whereas children who were born in areas without UNHS may have been diagnosed with hearing loss at a much later age and may not have received appropriate intervention until much later (e.g., at 12 months of age or later in some cases).

STATE-OF-THE-ART AUDIOLOGY SERVICES ARE BEING MEASURED.

Australian Hearing is a government-funded program that provides strong audiology leadership with clinical protocols that dictate the provision of evidence-based, state-of-the-art audiology services (e.g., tone burst auditory brainstem response assessment, hearing aid fitting with real-ear-to-coupler [RECD] measurement and real ear probe microphone verification).

As a result, diagnostic testing was conducted according to best-practice standards, and the type, degree, and configuration of hearing loss was likely to be accurately diagnosed. Additionally, hearing aids and cochlear implants were selected and fitted according to best-practice guidelines, which improves the likelihood that audibility is optimized to meet the individual needs of each child.

PART 1

About the LOCHI Study Participants

The LOCHI study included a diverse group of children with hearing loss:

- 451 total children with hearing loss ranging from mild to profound
- 144 children had received at least one cochlear implant by 3 years of age
- 107 children were diagnosed with additional disabilities in conjunction with hearing loss
- 46 children received their cochlear implant prior to 12 months of age
- 44 children were diagnosed with auditory neuropathy spectrum disorder (ANSD)

Communication Methods of Participants at 3 Years of Age (Ching et al., 2013)

- 67% of the children used LSL
- 23% used Sign Language and Listening and Spoken Language
- 10% of the families used an unknown communication modality

NOTE: THE COMMUNICATION MODE USED BY EACH CHILD AND FAMILY MAY HAVE BEEN SUBJECT TO CHANGE THROUGHOUT THE STUDY.

PART 1

LOCHI Study Results at 3 and 5 Years of Age

About the LOCHI Study

Currently, LOCHI researchers have evaluated and reported on the outcomes obtained by children with hearing loss at 3 and 5 years of age. The most important findings of the evaluations completed at 3 years of age are summarized in a paper published by Ching and colleagues in the journal, Ear and Hearing (CHING ET AL., 2013). The most relevant findings of the evaluations completed at 5 years of age are summarized in a special issue of the International Journal of Audiology (CHING ET AL., 2018).

The highlights of these manuscripts are summarized below with an emphasis on the outcomes of the children in the study and the factors that influenced the outcomes the children achieved.

Outcomes at 3 Years of Age

CHING, T.Y.C. ET AL. (2013)

Outcomes of early-and-late-identified children at 3 years of age: findings from a prospective population-based study, Ear and Hearing.

The first major publication from the LOCHI researchers summarized the outcomes children in the study achieved at 3 years of age. Ching and colleagues reported that about half of the children (56%) were fitted with hearing aids prior to six months of age. Of note, the median age of hearing aid fitting was 3.3 months for children who received UNHS. Given the Joint Committee on Infant Hearing (JCIH) mandate that calls for all children with congenital hearing loss to be fitted with hearing aids by 6 months of age, the LOCHI study provides evidence of the value of UNHS to ensure prompt provision of amplification for children born with hearing loss.

On average, the outcomes of the entire group of children with hearing loss in the LOCHI study were at or below one standard deviation of the normative mean. However, several factors were associated with higher outcomes (i.e., outcomes that were on par with children with normal hearing).

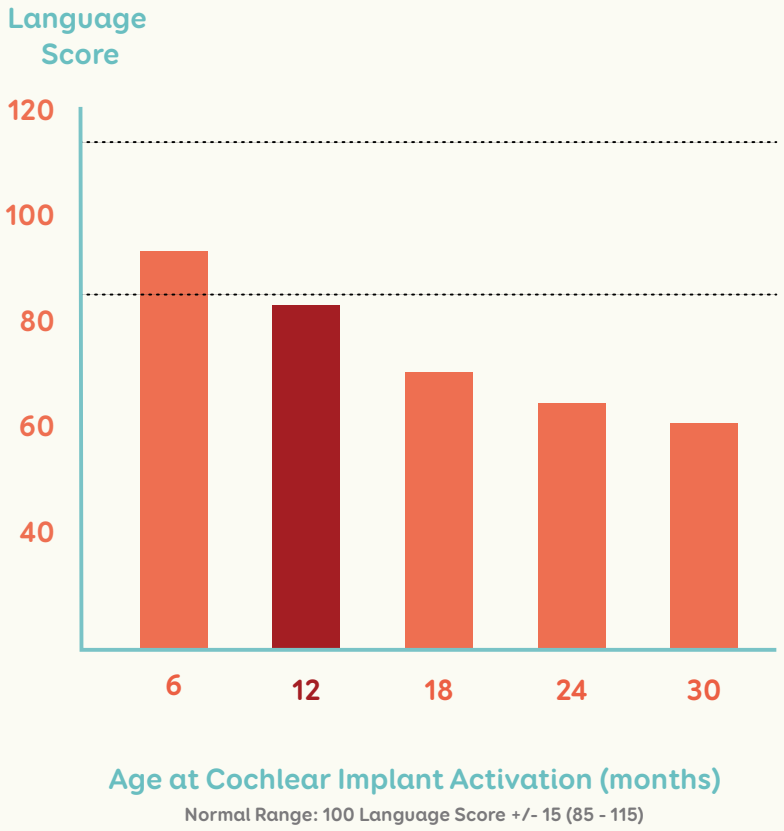
Cochlear Implantation Prior to 12 Months of Age Associated with Better Outcomes

One of the most important factors influencing outcomes was age at cochlear implantation. Children who received a cochlear implant prior to 12 months of age were significantly more likely to obtain age-appropriate LSL skills by 3 years of age than children who obtained a cochlear implant after their first birthday.

Specifically, language outcomes decreased by about half of a standard deviation when cochlear implantation was delayed from 6 months to 12 months of age and another half of a standard deviation when implantation was delayed until 24 months of age (SEE FIGURE 1).

FIGURE 1

Language Outcomes as a Function of Age at Implantation



The outcomes observed at 3 years of age in the LOCHI study provide a clear message: Children with severe to profound hearing loss (or ANSD) are more likely to achieve age-appropriate LSL skills when cochlear implantation is provided by 12 months of age. Several other factors affected the outcomes achieved by children with hearing loss at 3 years of age.

FACTORS THAT CONTRIBUTED TO BETTER LANGUAGE OUTCOMES AT 3 YEARS OF AGE:

- Communicating solely through LSL
- Mothers with higher levels of education
- Families with higher income levels

FACTORS THAT CONTRIBUTED TO POORER LANGUAGE OUTCOMES AT 3 YEARS OF AGE:

- Additional disabilities other than hearing loss
- Lower birthweight
- Greater levels of hearing loss. However, this was only true for children who used hearing aids. Specifically, children who used hearing aids and had mild hearing loss were likely to achieve better outcomes than children who used hearing aids and had moderate to severe hearing loss.

FACTORS THAT DID NOT INFLUENCE OUTCOMES AT 3 YEARS OF AGE INCLUDED:

1. There was no difference in language outcomes measured at 3 years of age for children with cochlear implants versus children with hearing aids. Of note, children with cochlear implants achieved language outcomes that were similar to those of children who had hearing aids and a four-frequency pure tone average (500, 1000, 2000, and 4000 Hz) in the better ear of 66 dB HL, a finding that suggests that cochlear implantation should be strongly considered for children who have severe hearing loss. This finding also suggests that degree of hearing loss no longer serves as an absolute deterrent to the development of LSL. Children who have severe to profound hearing loss can develop functional LSL abilities with the use of cochlear implants.

2. Children with ANSD achieved similar language outcomes as children with sensorineural hearing loss at 3 years of age. Ching and colleagues attributed relatively good outcomes of children with ANSD to the fact that these children received hearing aids and cochlear implants in a timely fashion. Australian Hearing used a combination of electrophysiologic measures (e.g., cortical auditory evoked response [CAER] measures), functional measurements (e.g., questionnaires such as the PEACH, speech and language assessment, etc.), and behavioral audiologic assessments to guide hearing aid and cochlear implant selection and management (GARDNER-BERRY ET AL., 2015).

3. Age at hearing aid fitting did not impact language outcomes measured at 3 years of age. Ching and colleagues (2013) postulated that the lack of an effect of age at hearing aid fitting on language outcomes at 3 years of age may have been attributed to the fact that very few children with hearing aids had hearing loss in the severe range. Ching et al. noted that "perhaps the auditory stimulation these children received unaided was sufficient to enable development of the auditory cortex, such that when hearing aids were later provided, the children were able to make just as good use of the signals received as children who received their hearing aids earlier." Also, they noted that children who eventually received cochlear implants may have had hearing loss in the profound range, and as a result, they received little to no benefit from hearing aid use, regardless of the age at which the hearing aids were fitted.

PART 1

Outcomes at 5 Years of Age

CHING, T.Y.C. ET AL. (2018)

Learning from the Longitudinal Outcomes of Children with Hearing Impairment (LOCHI) study: summary of 5-year findings and implications, International Journal of Audiology.

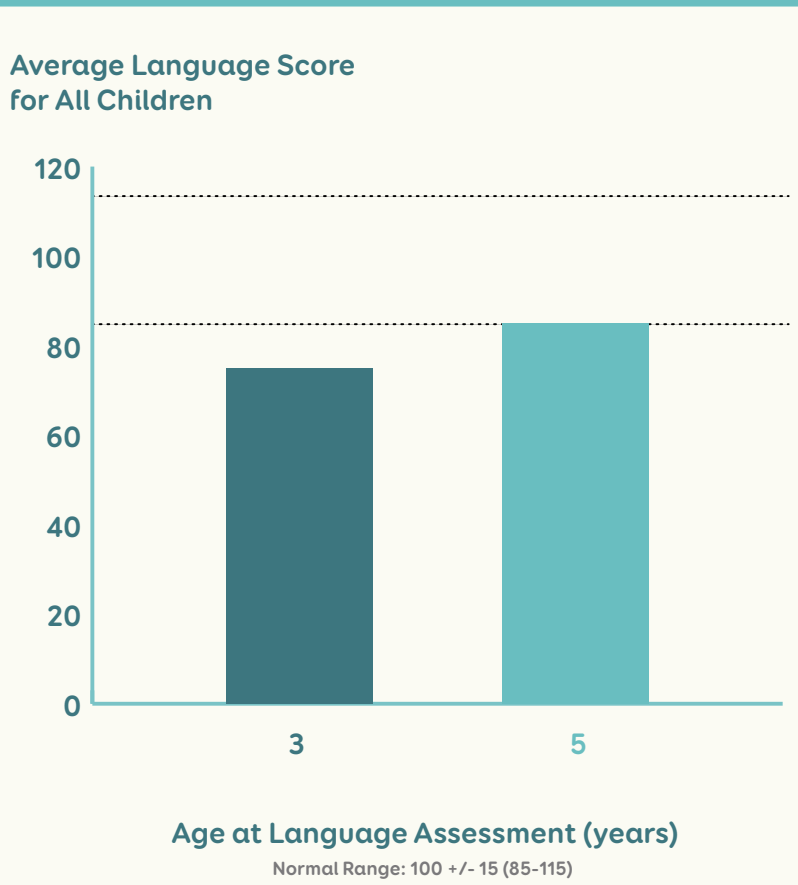
The Ching et al. (2018) publication provides an update on listening, language, and psychosocial outcomes at 5 years of age of the same group of children who were included in the Ching et al. 2013 manuscript. The Ching et al. 2018 paper summarizes the highlights of a series of papers that were included in a special issue of the International Journal of Audiology.

Cochlear Implantation Prior to 12 Months of Age Continues to be Associated with Higher Outcomes

As with the findings obtained when the children were 3 years of age (Ching et al., 2013), one of the most compelling and significant factors impacting LSL outcomes of children at 5 years of age was the age at which the children received their cochlear implants. Specifically, children who received cochlear implants at an early age (e.g. 6 to 12 months) achieved better auditory and language outcomes than children who received cochlear implants at later ages.

FIGURE 2

Language Outcomes Improved Between 3 and 5 Years of Age



In contrast to findings obtained at 3 years of age, children who were fitted with hearing aids at an early age (e.g. younger than 6 months) also achieved better speech, language, and auditory outcomes than children who received hearing aids at later ages.

It is important to note that children whose hearing loss was identified by a newborn hearing screening were fitted with hearing aids at a median age of 3.5 months, whereas children who did not receive a newborn hearing screening were fitted with hearing aids at a median age of 16.4 months. Again, the LOCHI study provides what is quite possibly the most convincing evidence of the vital importance of universal newborn hearing screening (UNHS) programs.

Language Outcomes Improved Between 3 and 5 Years of Age

Another encouraging difference that emerged between the language outcomes measured at 3 and 5 years of age was an improvement in language scores. Specifically, most children had language scores that were at least one standard deviation below normative values at 3 years of age. In contrast, most children achieved language outcomes that were within one standard deviation of normative values when measured at 5 years of age (SEE FIGURE 2). The finding of improved language outcomes from 3 to 5 years of age suggests that the provision of modern audiology services and audition-based habilitative intervention may contribute to closing the language gap that has historically existed between children with hearing loss and their normal-hearing peers. It is important to note that the language abilities of many children with hearing loss continued to fall on the lower end of the normative range. However, it is also important to recognize that many children in this study were not identified in a timely fashion and did not receive hearing aids and cochlear implants (when needed) at an early age. It is reasonable to expect that the outcomes of the group, as a whole, would be even better if all the children received optimal hearing healthcare within the first few months of life.

FACTORS THAT AFFECTED OUTCOMES AT 5 YEARS OF AGE:

- Communicating through LSL alone resulted in higher language outcomes when compared to outcomes of children who used sign language along with LSL.
- Children whose mothers had higher levels of education tended to obtain better language outcomes.
- For children with hearing aids, children with less hearing loss achieve better outcomes. Also, the positive impact of an early age of hearing aid fitting was greater for children who had greater levels of hearing loss.
- Children with higher nonverbal IQ scores tended to obtain better language outcomes.

- Children who had additional disabilities other than hearing loss achieved language outcomes that were poorer than the outcomes obtained by children without additional disabilities.

Additional Highlights at 5 Years of Age

The children in the LOCHI study used hearing aids that were fitted within 3 dB of evidence-based prescriptive target levels for their hearing loss. As a result, the hearing aids were likely set to optimize audibility of speech and other important environmental sounds. Poorer outcomes may have been observed if the children used hearing aids that provided an inappropriate output level for their hearing loss.

Ching and colleagues (2018) reported that 62% of the children in the LOCHI study used their hearing aids and cochlear implants for "more than 75% of their waking hours by 3 years of age," and 85% of the children used their hearing aids more than 75% of their waking hours by 5 years of age.

In the LOCHI study, outcomes most certainly would have been poorer if the children had not frequently used their hearing technology.

However, one could also make the case that the LOCHI outcomes would have been even better if a higher proportion of children had used their hearing aids during all waking hours during the first 3 years of life.
(Tomblin et. al., 2015)

The LOCHI researchers reported that children with hearing loss experienced more difficulty understanding speech in noise than children with normal hearing. Families of children with hearing loss and the clinicians who serve them should facilitate routine use of remote microphone technology for children with hearing loss to optimize hearing performance in noisy situations.

Considerations for Children with Additional Disabilities

For children who have additional disabilities along with hearing loss, better language outcomes were associated with earlier hearing aid fitting, lesser degree of hearing loss, use of LSL for communication rather than sign language, and higher nonverbal cognitive ability. Indeed, the benefits of early identification of hearing loss and early provision of intervention (e.g., hearing aid fitting, cochlear implantation, LSL therapy, etc.) are of critical importance for children with additional disabilities.

Moreover, children who have disabilities other than hearing loss have the potential to develop age-appropriate LSL abilities, particularly when their nonverbal IQ is within the normative range and they receive evidence-based hearing healthcare in an expeditious manner.

Children who have hearing loss and additional disabilities often receive considerable benefit from hearing aids, cochlear implants, and audition-based intervention. Children who have disabilities that negatively impact their cognitive ability may struggle to develop age-appropriate LSL abilities. However, with modern hearing technology and evidence-based auditory services, children who have additional disabilities should be expected to develop LSL abilities consistent with their nonverbal cognitive abilities. In many cases, the development of their LSL abilities become one of their strengths and allow them to interface with their family and community in the natural language of the family.

The presence of additional disabilities other than hearing loss should not exclude a child from consideration for cochlear implantation nor does it necessarily preclude a child from communicating through Listening and Spoken Language (LSL).

UNIVERSITY OF MELBOURNE STUDY: EVALUATING OUTCOMES OF CHILDREN WITH COCHLEAR IMPLANTS

BY: SHANI DETTMAN, JAIME LEIGH, CINDY CHU, RICHARD DOWELL, AND COLLEAGUES

PART 1

University of Melbourne Research Evaluating Outcomes of Children with Cochlear Implants

The LOCHI research project has received a considerable amount of interest from pediatric hearing healthcare providers around the world, and rightfully so. However, clinicians should also be aware of another series of Australian-based research studies examining the outcomes of children with hearing loss.

A group of researchers from the University of Melbourne, including Shani Dettman, Jaime Leigh, Cindy Chu, and Richard Dowell, have recently published a series of papers and presentations that explore the outcomes of children with hearing loss and the factors that influence their outcomes. Several of these papers will be summarized in the following section.

The Impact of Age at Cochlear Implantation

DETTMAN, S.J. ET AL. (2016)

Long-term communication outcomes for children receiving cochlear implants younger than 12 months: a multi-center study, Otology & Neurotology.

Dettman and colleagues (2016) sought to determine the impact of the age at which children receive cochlear implants on the LSL (LSL) outcomes they achieve.

About the Participants

The LSL outcomes of 403 children with cochlear implants were evaluated when the children were entering elementary school (i.e. 5 to 6 years old).

PART 1

The study participants were characterized by the following attributes:

- Severe to profound congenital hearing loss for both ears
- Received cochlear implants prior to 6 years of age
- Cognitive skills in the low-normal range or higher (approximately 1/6th of the children had low-normal cognitive skills)
- Regularly attended their audiology assessment and mapping appointments
- Used a variety of communication modalities including auditory-verbal, auditory-oral, and Total Communication
- Used Cochlear Nucleus cochlear implants with sound processors that were current at the time of assessment
- A variety of etiologies
- Some had additional disabilities

NUMBER OF PARTICIPANTS	AGE AT IMPLANTATION
151	PRIOR TO ONE YEAR OF AGE
61	13-18 MONTHS
66	19-24 MONTHS
82	25-42 MONTHS
43	43-72 MONTHS

For the purpose of the study, the children were categorized by age at implantation as follows:

Evaluating Vocabulary, Language, Speech Production, and Speech Perception

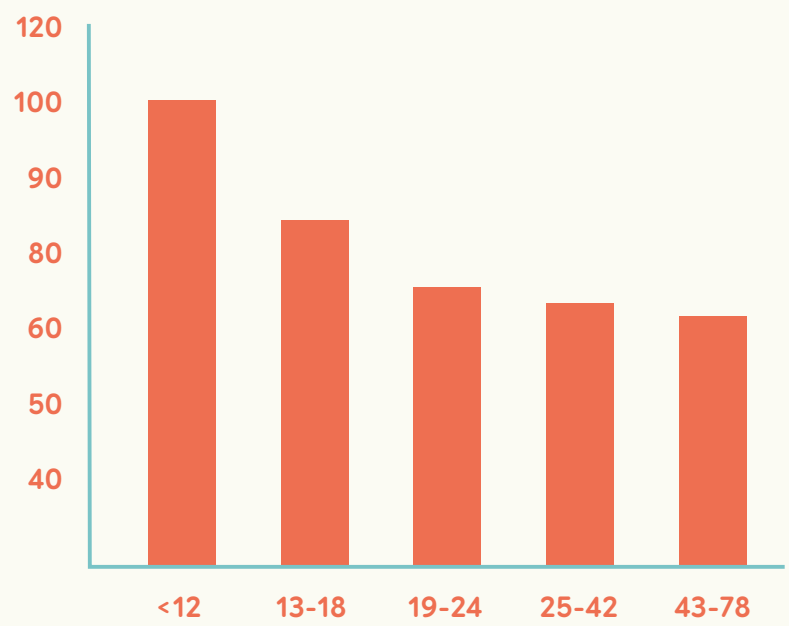
The Melbourne researchers evaluated the children's vocabulary, language, speech production, and speech perception when they were entering elementary school (5 to 6 years old). The children who received cochlear implants prior to one year of age had a mean standard score of 100 on the Peabody Picture Vocabulary Test (PPVT). In other words, their vocabulary level was on par with children with normal hearing at school entry.

More than 80% of the children implanted prior to one year of age had vocabulary aptitude that was characterized as being within normal limits. In contrast, only one-half of the children implanted within the 13-to-18-month range had normal vocabulary levels with a mean standard score of 83.

Figure 3 provides a summary of the PPVT outcomes of the children in the Melbourne study. As shown, children who received implants before 12 months of age achieved age-appropriate vocabulary levels, whereas children implanted after 12 months generally exhibited delays in vocabulary development.

FIGURE 3

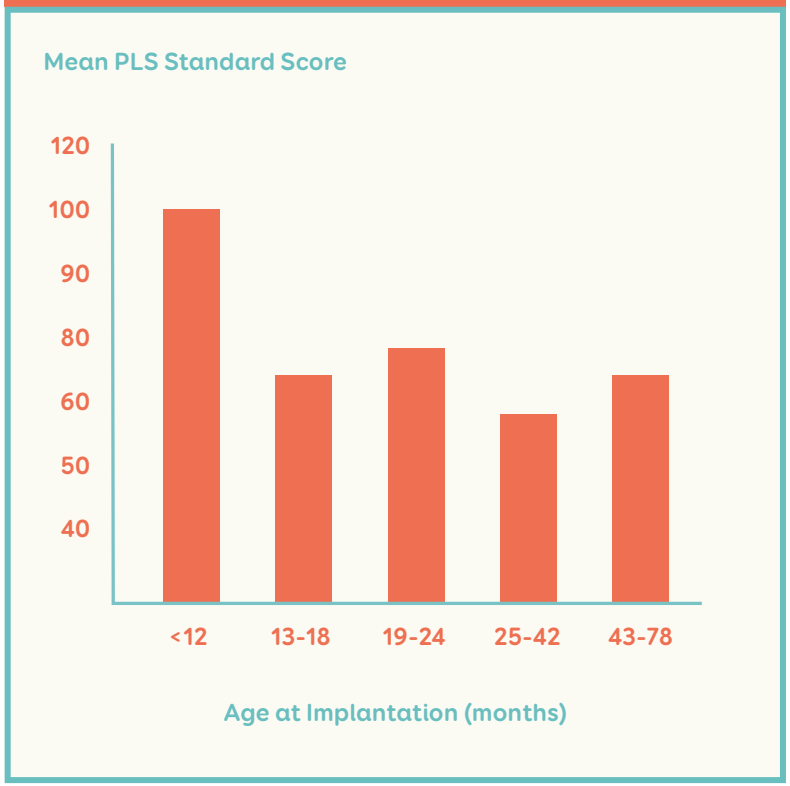
The Impact of Age at Cochlear Implantation on Vocabulary Development



In short, the language and speech production scores of children implanted prior to 12 months of age were similar to those of children with normal hearing, whereas children who were implanted after 12 months of age experienced relatively poorer outcomes and tended to exhibit delays relative to their peers with normal hearing.

FIGURE 4

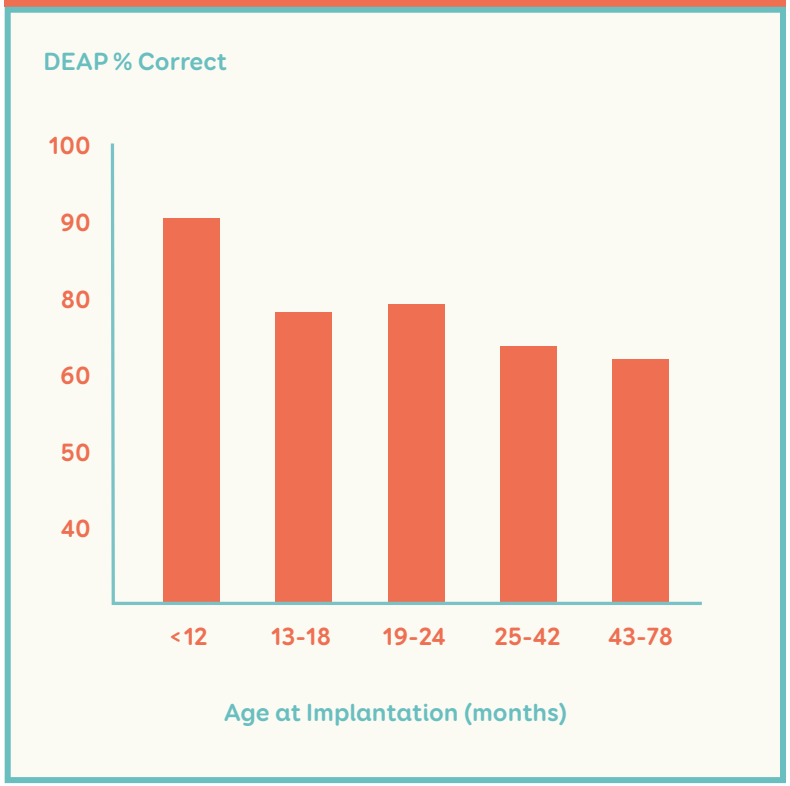
The Impact of Age at Cochlear Implantation on Language Development



Likewise, a similar trend existed for the language and speech production outcomes obtained by the children implanted at various ages.

FIGURE 5

The Impact of Age at Cochlear Implantation on the Development of Speech Production



Figures 4 and 5 provide a summary of the language and speech production outcomes of the children in the Melbourne (2016) study.

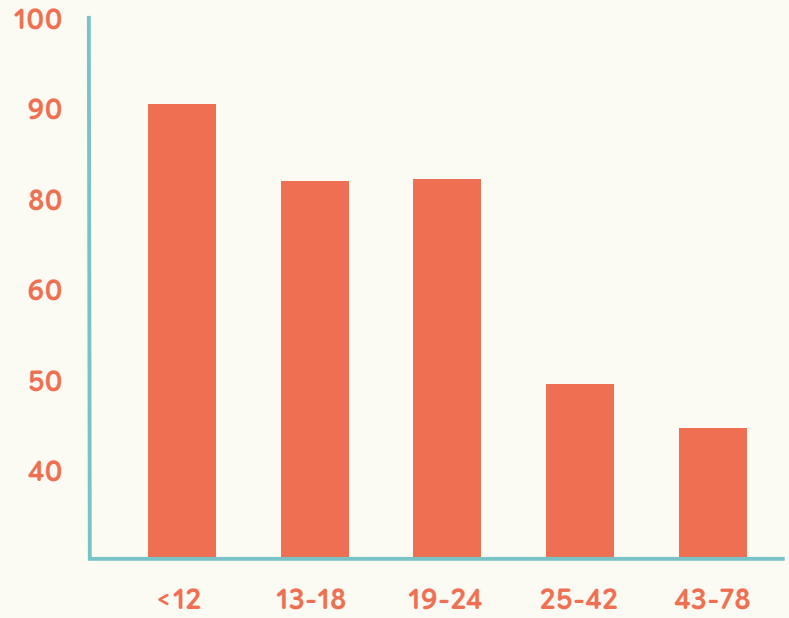
Additionally, children who were implanted prior to their first birthday generally had age-appropriate, typical speech production at school entry, whereas children implanted after 12 months tended to develop poorer speech production abilities.

Hearing healthcare clinicians and researchers have long understood that children's speech and language abilities are intimately tied to their ability to hear clearly. Given the superior language and speech production abilities observed in the children who received cochlear implants prior to 12 months of age, it is not surprising that children who received cochlear implants during their first year of life also had better speech perception at school entry. Specifically, at school entry, children implanted prior to 12 months of age generally had very good to excellent word recognition (i.e. mean word recognition was 85% correct), whereas children implanted after 12 months tended to have fair to poor word recognition (SEE FIGURE 6).

The Dettman et al. (2016) study clearly demonstrates that children with severe to profound hearing loss are likely to develop LSL abilities on par with children with normal hearing when cochlear implantation is provided prior to 12 months of age.

FIGURE 6

The Impact of Age at Cochlear Implantation on Speech Recognition



The vastly disparate outcomes obtained by children who received cochlear implants prior to 12 months of age compared to those who receive cochlear implants between 13 to 18 months of age provide convincing evidence of the urgent necessity to pursue cochlear implantation within the first year of the life of a child with severe to profound hearing loss.

Age at Implantation is Not the Only Factor for Better Outcomes

However, one should acknowledge that age of implantation may not have been solely responsible for the differences in outcomes observed between children implanted before 12 months and those implanted after 12 months of age. As previously discussed, the LOCHI study identified several factors that impact the LSL outcomes of children with hearing loss including maternal education, the family's socioeconomic status (SES), the robustness and complexity of the audition-based linguistic model provided throughout the child's daily life (e.g. the number of intelligible words the child hears per day along with the elaboration of the language model to which the child is exposed), the severity of additional disabilities other than hearing loss, among other factors.

It is entirely possible that the children who received implants prior to 12 months of age also came from homes with greater levels of maternal education, a higher SES, and more favorable linguistic models. Also, it is possible that children in the later-implanted groups were more likely to have concomitant disabilities that not only delayed implantation, but also adversely impacted their language outcomes (although it should be noted that Dettman and colleagues only included children in the study if nonverbal IQ was within normal limits).

A confluence of variables ultimately determines the LSL outcomes of children with hearing loss. However, the Dettman et al. (2016) data demonstrate that excellent outcomes are possible when cochlear implantation is provided prior to 12 months of age. Hearing healthcare professionals should strive to provide early access to cochlear implantation for all children with severe to profound hearing loss.

The Optimal Age for Cochlear Implantation

LEIGH, J.R. ET AL. (2016)
Evidence-based guidelines for recommending cochlear implantation for young children: audiological criteria and optimizing age at implantation, International Journal of Audiology.

Leigh et al. of the University of Melbourne (2016) conducted a similar study with two primary objectives:

1. **Define an audiometric pure tone threshold criterion (i.e. hearing loss level) that identifies infants who need cochlear implants, and**

2. **Identify the optimal age at which infants with congenital severe to profound hearing loss should receive cochlear implants**

About the Participants

Leigh and colleagues evaluated the aided word recognition of 78 children with cochlear implants and 62 children with hearing aids. For 32 children who had received cochlear implants prior to 2.5 years of age, language outcomes were evaluated pre-operatively and one year post-operatively using the Rosetti Infant-Toddler Language Scale (RI-TLS), and vocabulary was evaluated at one, two, and 3 years post-operatively and also at school entry (5 to 6 years old) using the Peabody Picture Vocabulary Test (PPVT).

All children in the Leigh, et al. (2016) study met the following inclusion criteria:

- Normal to borderline normal neurocognitive status (nonverbal IQ ≥ 85)
- No medical condition affecting communication development
- English as the primary language spoken in the home
- No specific language impairment as indicated by a speech-language pathologist

- Received hearing aids or cochlear implants prior to 3 years of age
- Children with cochlear implants had Cochlear Nucleus 24 or Nucleus Freedom cochlear implants
- Children using hearing aids had sensorineural hearing loss ranging in degree from mild to profound

Comparing Aided Word Recognition of Cochlear Implant Users Versus Hearing Aid Users

To determine an audiometric pure tone threshold criterion to identify infants and young children who should be considered for cochlear implantation, Leigh and colleagues compared aided word recognition of the cochlear implant users versus the hearing aid users. Based on the word recognition scores of the cochlear implant and hearing aid users, Leigh et al. reported that children with hearing loss have a 75% likelihood of improvement in word recognition with use of a cochlear implant (relative to performance with a hearing aid), if their hearing loss (i.e., pure tone average at 500, 1000, and 2000 Hz) is greater than 60 dB HL.

TABLE 1

Percentage of Children with Cochlear Implants who Exceeded Average Score of Children with Hearing Aids	Degree of Hearing Loss
75%	60 dB HL
80%	67 dB HL
85%	73 dB HL
90%	78 dB HL
95%	82 dB HL

As shown, children with severe sensorineural hearing loss are highly likely to achieve better speech recognition with a cochlear implant when compared to speech recognition that would typically be obtained with hearing aids.

Table 1 provides a breakdown of the likelihood of improvement in word recognition with a cochlear implant as a function of a child's degree of hearing loss.

Similar to the findings of Dettman and colleagues (2016), Leigh et al. (2016) reported impressive vocabulary and language outcomes for children with cochlear implants, particularly when implantation occurred during the first year of life. At 3 years post-implantation, vocabulary development was within normal limits for almost 75% of the participants, and the average score for the entire group of children with cochlear implants was within normal limits.

Furthermore, the children who received cochlear implants prior to a year of age achieved age-appropriate language development, whereas children who received implants after 12 months of age were more likely to experience delays in their language development. Leigh and colleagues noted that the children with severe to profound hearing loss typically made about .33 to .43 years of language growth per chronological year prior to receiving a cochlear implant.

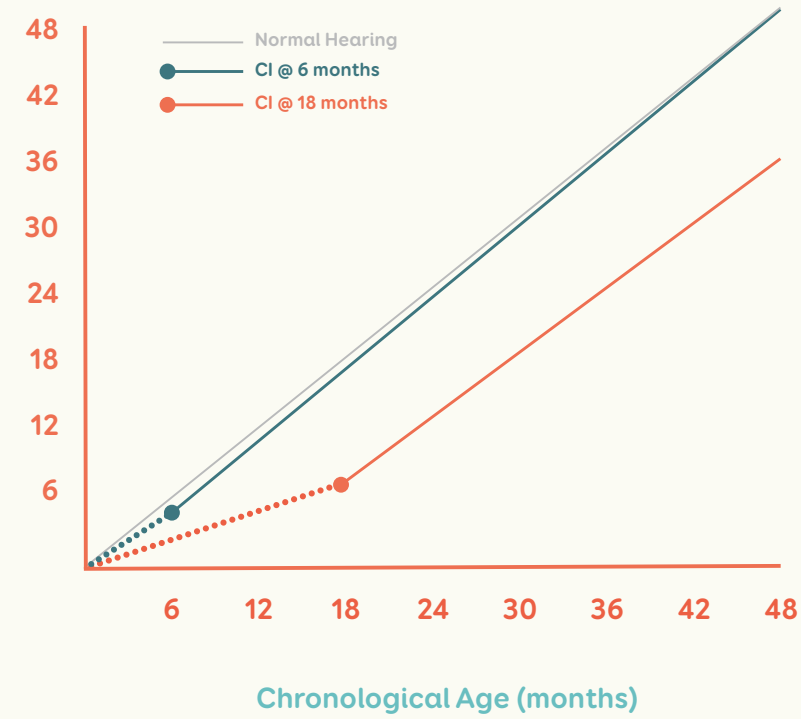
However, after receiving cochlear implants, the children made an average of 1.04 years of language growth in one calendar year.

Figure 7 provides a representation of the relationship between age at implantation and language delay measured when the children were entering school.

As shown, when children receive their cochlear implants prior to 1 year of age, they have little to no language delay, and given an average rate of 1.04 years of language growth for each chronological year, the children's language outcomes are within normal limits. In contrast, children who receive their cochlear implants at 18 months of age have an approximate language delay of just over one year at the time of implantation. Although they make approximately one year of language growth for each chronological year, their one-year language delay will persist across time based on the typical rate of language development after a child receives a cochlear implant.

FIGURE 7

Age Associated with Cochlear Implantation Outcomes



Of note, the Leigh (2016) study only included children who were implanted prior to 3 years of age. Children who receive cochlear implants after 3 years of age are deprived of language input through audition throughout most or all of the critical period of language development. Consequently, they will likely make a poorer rate of language progress after implantation and may experience even greater language delays across time.

TO CONCLUDE, LEIGH AND COLLEAGUES STATE:

"The results suggest that if a child receives a cochlear implant before 2.5 years, they have the potential to make age-appropriate language progress.

They will, however, demonstrate a language delay closely related to their age at implantation. This result provides compelling evidence that a cochlear implant should be offered **as young as possible** in order to minimize this language delay as long as a child meets the audiological guidelines outlined above, and other medical and otological issues have been considered."

The Relationship Between Language Outcomes and Family Factors

CHU, C. ET AL. (2016)

Early intervention and communication development in children using cochlear implants: the impact of service delivery practices and family factors. Podium presentation delivered at the Audiology Australia National Conference 2016, 22-25 May, Melbourne, Australia.

Chu and colleagues (2016) conducted a study with the primary objective of determining the relationship between language outcomes of children with cochlear implants and family factors (e.g., family involvement, maternal education level, socioeconomic status [SES]), age at implantation, and dose (i.e., frequency) and type (e.g., LSL, Total Communication [i.e., use of sign language with spoken language]) in early intervention.

About the Participants

Chu et al. evaluated the language outcomes of 146 children who received cochlear implants at varying ages ranging from 6 months to 6.8 years. The children presented with a range of neuro-cognitive abilities, demographics, etiologies, and additional disabilities.

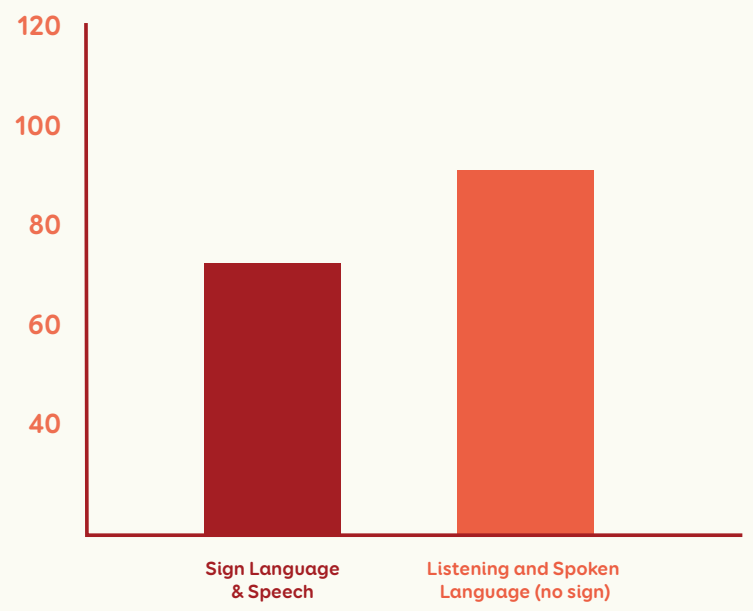
Language Abilities Are Significantly Better When Only LSL is Used

Chu and colleagues reported several noteworthy findings regarding the outcomes of children with cochlear implants.

The language abilities of children who communicated solely via LSL were significantly better than children who used sign language.

FIGURE 8

Expressive Language Score as a Function of Mode of Communication



Of note, the children who communicated solely through LSL had receptive language abilities and mean language abilities that were within normal limits when compared to children with normal hearing, whereas the children who used sign language had receptive language abilities that were more than two standard deviations from the normative mean (SEE FIGURE 8).

Surprisingly, the children who received therapy on a monthly basis achieved significantly better language outcomes than the children who received therapy on a weekly or bi-weekly basis (SEE FIGURE 9).

This seemingly paradoxical finding may be explained by the following:

The children who received therapy on a monthly basis typically received their cochlear implants between the ages of 6 to 18 months of age.

FIGURE 9

Expressive Language Score as a Function of Frequency of Intervention

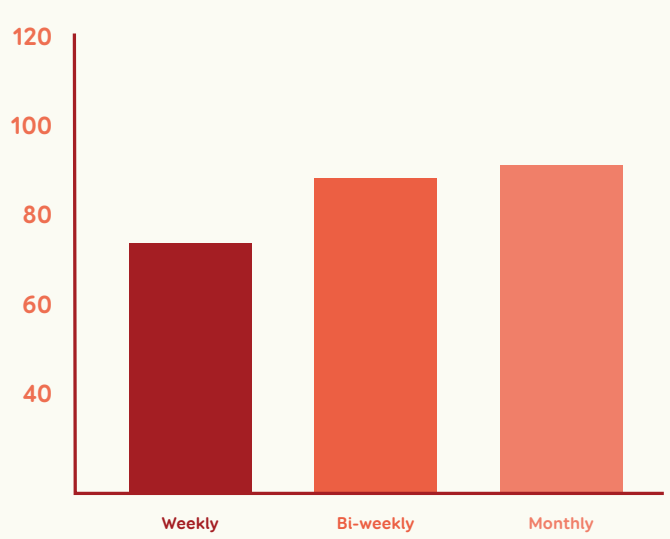
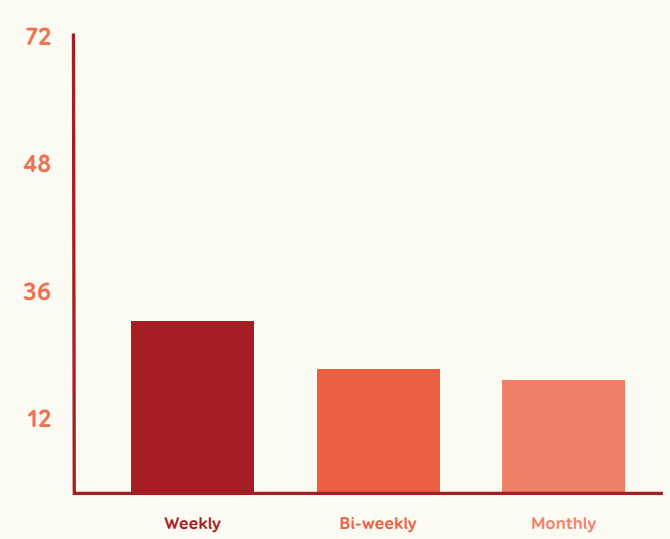


FIGURE 10

Relationship of Frequency of Intervention and Age at Implantation



In contrast, the children who received therapy on a weekly or bi-weekly basis typically received their cochlear implants after 18 months of age (SEE FIGURE 10).

Cochlear implantation during the first year of life prevented a substantial language delay, facilitated age-appropriate language development, and eliminated the need for frequent and intensive therapy to mitigate language delay and achieve typical LSL development.

In short, the provision of a cochlear implant prior to 12 months is not only beneficial because normal LSL development is likely, but also because the family is less likely to need as much expensive and time- and labor-intensive intervention to achieve age-appropriate outcomes.

Chu and colleagues also showed that children with cochlear implants achieve better LSL outcomes when their families are more attentive and responsive to the children's needs. To develop spoken language, children must be exposed to a robust, language-rich listening environment during the first few years of life. The family typically serves as the best model for spoken language, so it stands to reason that LSL outcomes will be better for children whose families are heavily invested in and engaged with the child's development. Hearing healthcare clinicians must equip families with knowledge and skills to foster the development of optimal listening-rich language environments.

PART 1

The Impact of Communication Mode on Listening and Spoken Language Abilities

DETTMAN, S. ET AL. (2013)

Communication outcomes for groups of children using cochlear implants enrolled in auditory-verbal, aural-oral, and bilingual-bicultural early intervention programs, Otology & Neurotology.

About the Participants

Dettman et al. (2013) evaluated language outcomes and speech perception in 39 children with a cochlear implant with the objective of determining the impact of communication mode on LSL abilities.

The study included 23 children from auditory-oral programs (i.e., the children communicate through LSL with speechreading in natural environments with each child's parents and teachers serving as language models and facilitators), eight children from auditory-verbal programs (i.e., an emphasis is placed on LSL with a de-emphasis on visual cues, and a certified auditory-verbal therapist coaches the parents to serve as the primary language models and facilitators), and eight children from Total Communication programs (i.e., the children communicate via sign language and spoken language).

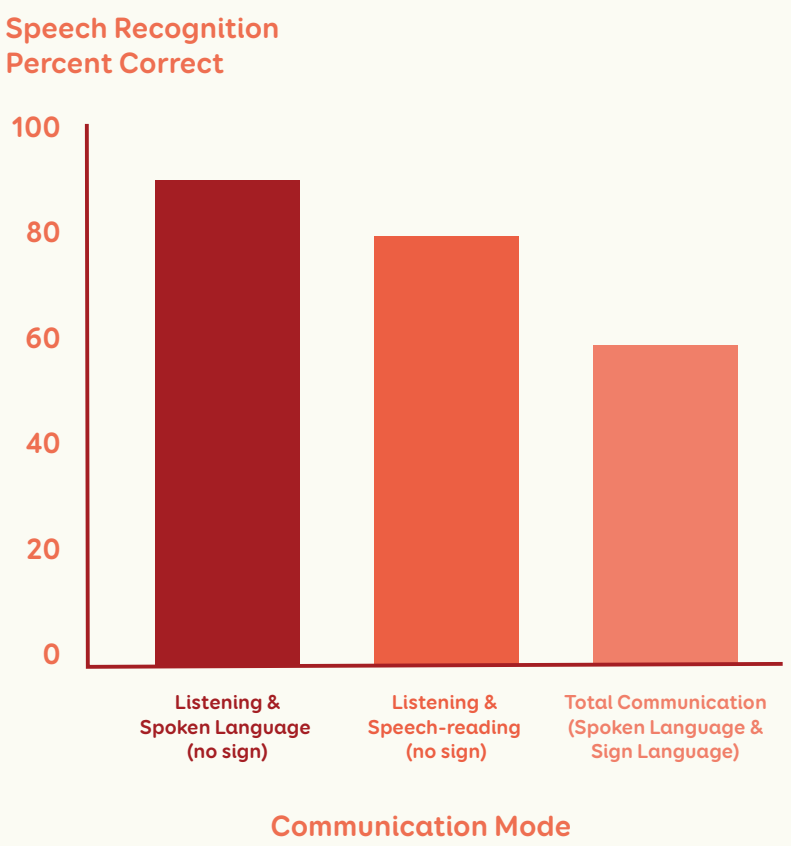
Emphasize the Child's Access to Language Through Listening for Better Outcomes

Dettman and colleagues found that language outcomes of children from auditory-verbal programs were significantly better than the language outcomes of children from auditory-oral programs, which were better than the language outcomes of children from Total Communication programs. Moreover, the children from auditory-verbal programs had significantly better word recognition than the children from auditory-oral programs. Also, children from auditory-oral programs had better word recognition than children from Total Communication programs (SEE FIGURE 11).

The Dettman et al. (2013) findings support the notion that the most effective method to optimize listening and spoken language outcomes is to emphasize the child's access to language through audition.

FIGURE 11

Speech Recognition as a Function of Communication Mode



SUMMARY

The findings of the Melbourne research studies are exciting and provocative.

Without a doubt, we have moved into a new era in which children who are born with severe to profound hearing loss are likely to develop LSL skills on par with children who have normal hearing if they receive appropriate hearing technology within the first several months of life (i.e., hearing aid fitting within three months and cochlear implantation if needed within six to nine months), when the children's families are coached to create robust listening-rich language environments, and when families are actively engaged in the development of their children's LSL development.

THE OUTCOMES OF CHILDREN WITH HEARING LOSS (OCHL) STUDY

FUNDED BY: THE NATIONAL INSTITUTES OF HEALTH (NIH)

CONDUCTED BY: THE OCHL INVESTIGATIVE TEAM

Outcomes of Children with Hearing Loss (OCHL)

About the OCHL Study

The Outcomes of Children with Hearing Loss (OCHL) study is an NIH-funded, multiple-center research project that focuses on the outcomes of children with bilateral, mild-to-severe hearing loss during infancy and their preschool years (MOELLER & TOMBLIN, 2015). The primary objectives of the OCHL study are to characterize the auditory and language outcomes of children who are hard-of-hearing and to examine the factors that influence the longitudinal outcomes achieved by children with mild to severe hearing loss.

Over the past two decades, a great deal of research examining the outcomes of children with hearing loss has focused on children who have cochlear implants or children who have minimal or unilateral hearing loss. There has been a paucity of studies that have explored the longitudinal outcomes of a large group of children who have mild to severe hearing loss and who use hearing aids. The researchers conducting the OCHL study sought to fill that void. The OCHL study was conducted by researchers at Boys Town National Research Hospital, the University of Iowa, and the University of North Carolina.

About the Participants

The OCHL study examined the outcomes of 317 children who met the following inclusion criteria:

- Between 6 months and 7 years old at the time of recruitment into the study
- Pure tone average (500, 1000, and 2000 Hz) between 25 to 75 dB HL in the better ear
- Over 90% of the participants had a better ear pure tone average that was better than 70 dB HL
- Had not received a cochlear implant
- Spoke English as their primary language
- No cognitive or motor disabilities

The OCHL study also included 117 children with normal hearing sensitivity (i.e. pure tone average better than 20 dB HL).

The children with normal hearing also spoke English as their primary language, and they had no cognitive or motor disabilities. The children with normal hearing served as a control group, particularly for measurements that were norm referenced. The children with normal hearing had similar home and family backgrounds as the children with hearing loss.

The OCHL study has provided hearing healthcare clinicians and families with a wealth of information regarding the outcomes of children with hearing loss (MOELLER ET AL., 2015).

A High-Quality Hearing Aid Fitting is Critical

Hearing healthcare professional guidelines call for the use of real ear probe microphone measurements to verify that hearing aids are fitted appropriately for children (AMERICAN ACADEMY OF AUDIOLOGY, 2013; ONTARIO MINISTRY OF CHILDREN AND YOUTH SERVICES, 2014; KING, 2010). Real ear probe microphone measurements allow the hearing healthcare clinician to measure the output level (in dB SPL) of a child's hearing aids and ensure that the output level is safe and optimized to restore audibility for soft, average, and loud speech. Ideally, the hearing aid output level is matched to an evidence-based target output level that is prescribed for the child's hearing loss level.

FIGURE 12

Speechmap / DSL

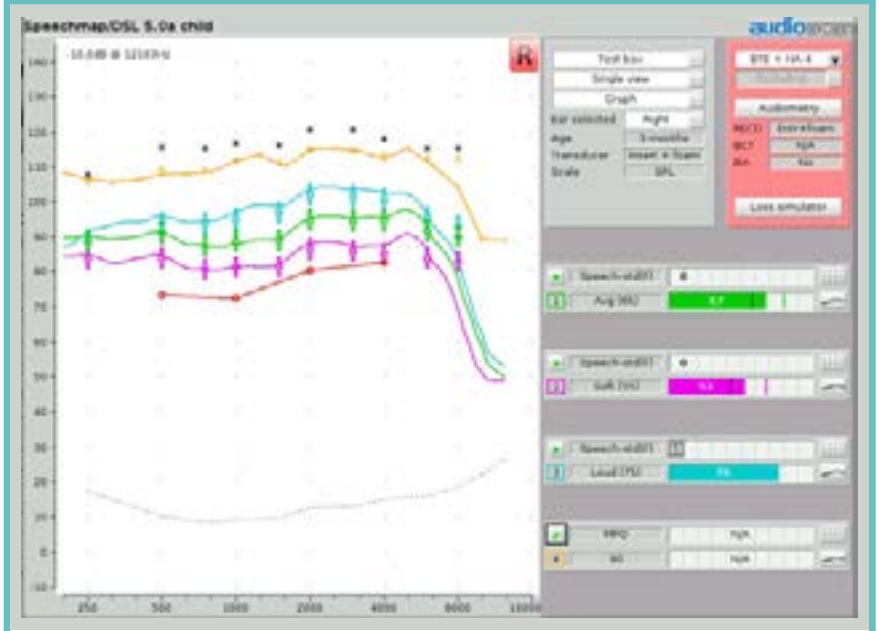


Figure 12 provides an example of a series of real ear probe microphone measurements which show a child's hearing aid is set appropriately.

The OCHL study revealed several discouraging findings that indicated many children with mild to severe hearing loss were using hearing aids that did not optimize their access to speech (MCCREERY ET AL., 2015A). Specifically, the OCHL study researchers reported that 35% of the children were using hearing aids that provided inadequate aided audibility for speech. Additionally, just over one-half of the children were using hearing aids that provide an output level more than 5 dB from evidence-based prescriptive targets on each of the four study visits.

Inadequate audibility of speech was associated with a larger deviation from the evidence-based prescriptive target.

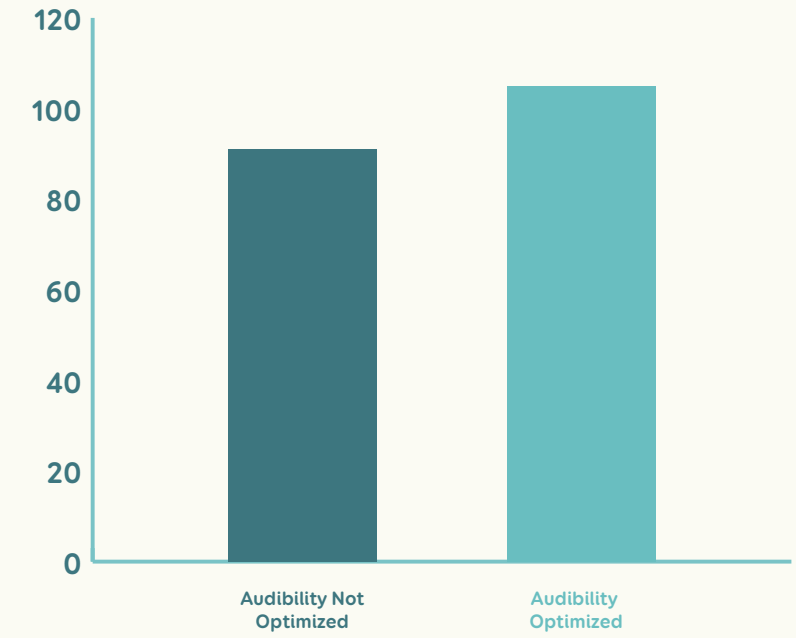
Also, children with a greater amount of hearing loss were more likely to have hearing aids that were not fitted to prescriptive targets and did not provide sufficient audibility of speech.

In short, a significant number of the children in the OCHL study did not have optimal access to speech and other important environmental sounds because their hearing healthcare clinicians had not programmed their hearing aids appropriately to match evidence-based prescriptive targets.

The OCHL researchers identified a strong link between the quality of a child's hearing aid fitting and the child's language outcomes. Children whose hearing aids were in the top 25% of aided audibility (i.e., aided speech intelligibility index as measured via real ear probe microphone measurements) achieved significantly better language outcomes than the remainder of the children with hearing loss. In contrast, children whose hearing aids were in the bottom 25% of aided audibility achieved significantly poorer language outcomes than their counterparts (SEE FIGURE 13).

FIGURE 13

Language Abilities as a Function of Aided Audibility



Almost a full standard deviation of difference (i.e. almost 15 points on a standardized test) existed between the mean language score of children with optimized aided audibility versus those with the poorest aided audibility (i.e. bottom 25th percentile). Also of note, the children whose aided audibility was in the upper 25th percentile achieved mean language outcomes that exceeded the normative mean. (MCCREERY ET AL., 2015; TOMBLIN ET AL., 2015)

Full-Time Hearing Aid Use Results in Better Language Outcomes

The OCHL research team also examined the effect of hearing aid usage on language outcomes (Tomblin et al., 2015; Walker et al. 2015). Hearing aid usage was determined using two methods. The children's parents completed a questionnaire indicating the number of hours per day the children used their hearing aids. Also, hearing aid usage was determined by the data-logging technology within the hearing aids, a feature that logs the number of hours per day the hearing aid is powered on. Of note, the number of hours of hearing aid use per day as indicated by data-logging was typically less than the number of hours reported by the parents, which suggests that parents typically overestimated the number of hours per day their children used their hearing aids.

Language outcomes were directly related to hearing aid usage. At school entry (i.e., 5 to 6 years old), children who used their hearing aids at least 10 hours per day achieved language outcomes that were on par with the normative mean for children with normal hearing.

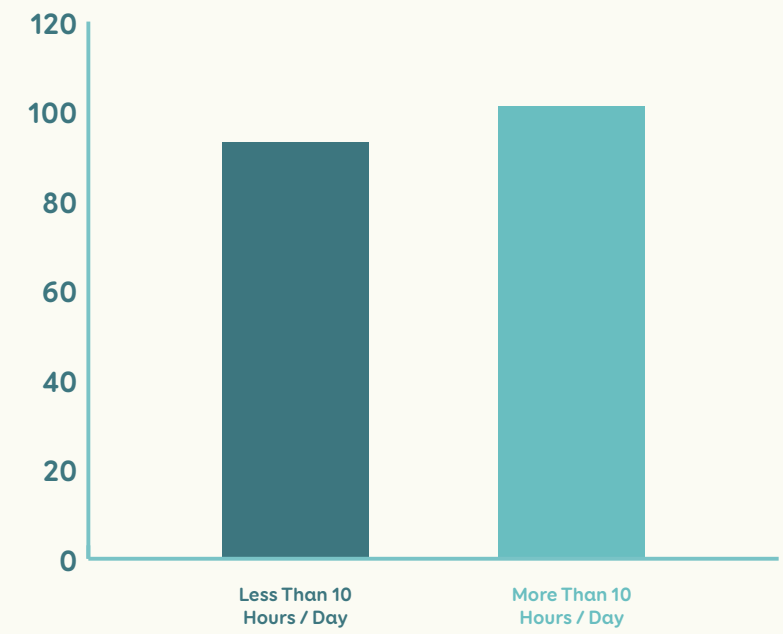
In contrast, children who used their hearing aids for fewer than 10 hours per day were likely to experience language deficits (SEE FIGURE 14).

Furthermore, the children who used their hearing aids for at least 10 hours per day achieved a greater rate of language growth between 2 to 6 years of age when compared to the children who used their hearing aids fewer than 10 hours per day. Also of interest, infants used their hearing aids for an average of almost four hours per day, whereas elementary-age children used their hearing aids for an average of almost 10 hours per day. At school age, children with greater hearing loss levels were more likely to use their hearing aids for at least 10 hours per day.

Given these findings indicating the relationship of hearing aid use to language outcomes, the OCHL researchers recommended that hearing healthcare clinicians should equip families with strategies that will facilitate hearing aid use during all waking hours (e.g., retention strategies such as two-sided wig tape, pilot's caps, retention cords, etc.).

FIGURE 14

Hearing Aid Use Time



Clinicians should also share the findings of the OCHL study with families to stress the importance of full-time hearing aid use on language outcomes and consider providing simulations of hearing loss for the family, demonstrating speech recognition with and without hearing aids, and informing the family of the proper care, use, and maintenance of hearing aids.

Parents Should Provide Early Exposure to High Quantity of High-Quality Words

In accordance with the LOCHI and Melbourne studies, the OCHL researchers also emphasized the importance of early access to speech and environmental sounds (Ambrose et al., 2015; Tomblin et al., 2015). The OCHL results indicated that children who received their hearing aids prior to 6 months of age had better language outcomes than children who were fitted after 6 months of age. Of note, almost half of the children in the OCHL study were fitted with hearing aids after 12 months of age, a finding that exemplifies the urgent need for changes in Early Hearing Detection and Intervention (EHDI) programs in the United States to ensure expeditious provision of hearing aids for children who are born with hearing loss.

The OCHL researchers also stressed the importance of early linguistics on the language development of children with hearing loss. They noted that better language outcomes were associated with the parent's use of a high quantity of high-quality words and conversational-eliciting speech.

The parents of children with hearing loss used a lesser quantity of words during the first 3 years of the children's lives and were more likely to interact with lower-quality language input such as direct utterances (e.g., "stop that," "come here," "no," etc.). In contrast, the parents of children with normal hearing typically used a larger quantity of words during the child's first 3 years of life and were more likely to interact with higher-quality language such as conversational-level utterances (e.g., "Tell me about your day at school?") and real utterances (e.g., "How do you feel about that?").

The OCHL researchers noted that "it is important that we encourage early intervention practices of coaching caregivers to provide CHH with high amounts of quality linguistic input and to adopt an interaction style that is conversational eliciting as opposed to directive."

Finally, the OCHL researchers explored aided speech recognition of children with mild to severe hearing loss (MCCREERY ET AL., 2015B). The OCHL study showed that children who are hard of hearing often achieve good to excellent aided word recognition in quiet. In fact, the aided word recognition in quiet of the children with hearing loss was fairly similar to that of children with normal hearing. In contrast, the aided speech recognition in noise of the children with hearing loss was substantially poorer than the speech recognition in noise of children with normal hearing. Specifically, the aided speech recognition in noise of children with hearing loss was almost 30 percentage points poorer than that of children with normal hearing.

The difficulties that children with hearing loss experience with speech recognition in noise highlight the importance of the use of hearing aid noise management technologies such as adaptive noise reduction, adaptive directional microphones, and most important, remote microphone systems.

THE CHILDHOOD DEVELOPMENT AFTER COCHLEAR IMPLANTATION (CDACI) STUDY

FUNDED BY: THE NATIONAL INSTITUTES OF HEALTH (NIH)

CONDUCTED BY: THE CDACI INVESTIGATIVE TEAM

Childhood Development after Cochlear Implantation (CDaCI)

About the CDaCI Study

The Childhood Development after Cochlear Implantation (CDaCI) study is an NIH-funded, multiple-center study that longitudinally evaluates the auditory, language, psychosocial, and quality-of-life outcomes of children with cochlear implants in the United States.

The primary objective of the CDaCI study was to examine the development of oral language skills across time in children who receive cochlear implants during their first few years of life (FINK ET AL., 2007). Additionally, the CDaCI researchers sought to identify factors (e.g. age at implantation, communication mode, family factors, etc.) that influence the outcomes of children with cochlear implants. Moreover, the CDaCI study sought to characterize language, social, early academic, and behavioral outcomes of children with cochlear implants relative to age-matched children with normal hearing. The cochlear implant centers participating in the CDaCI included the House Ear Institute, Johns Hopkins University, the University of Michigan, the University of North Carolina, the University of Texas at Dallas, and the University of Miami.

About the Participants

The CDaCI researchers enrolled children in the study between November 1, 2002 and December 31, 2004 according to the following inclusion and exclusion criteria:

Inclusion Criteria

- Younger than 5 years old at time of enrollment
- Pre- or post-linguistically deaf
- Normal to low-normal neuro-cognitive abilities
- Use of a unilateral or bilateral cochlear implant
- Educated in English-speaking school

Exclusion Criteria

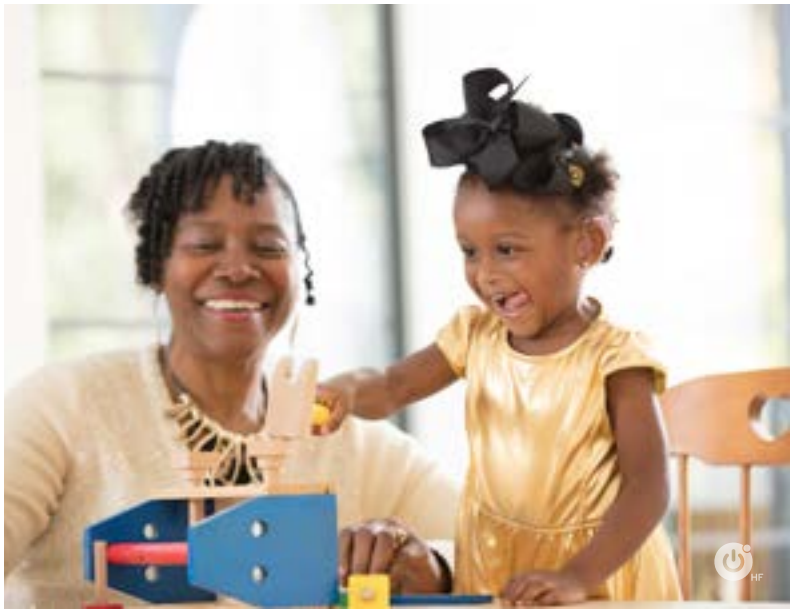
- Family unable to commit to follow-up appointments for intervention and evaluation
- Post-surgical cochlear implant complications
- No English used in the child's household

A total of 188 children with cochlear implants and 97 children with normal hearing were enrolled into the CDaCI study. The children's outcomes were evaluated at baseline and every six months for 3 years after enrollment into the study. Of note, the mean age, gender, and race were similar between the children with cochlear implants and the children with normal hearing.

Early Implantation, a Language-Rich Environment, and Well-Programmed Devices Matter

The findings of the CDaCI study have been in close agreement to the major findings of the LOCHI, the University of Melbourne, and OCHL studies and include:

- Children who received cochlear implants at an earlier age achieved better language outcomes than later-implanted children (NIPARKO, ET AL., 2010; TOBEY ET AL., 2013).
- Children with higher quality and quantity of parent-child interactions achieved better language outcomes following cochlear implantation (NIPARKO ET AL., 2010).
- Better language outcomes were found in children who had better speech recognition in quiet and in noise, a finding that underscores the urgent need to provide children with consistent access to speech via the use of well-programmed cochlear implant sound processors and hearing assistive technology (e.g. remote microphone systems) (EISENBERG ET AL., 2015).



The Impact of Sign Language on the Development of Spoken Language

GEERS, A.E., ET AL. (2017)

Early sign language exposure and cochlear implantation benefits. Pediatrics.

More recently, the CDaCI research team has published an important paper describing the impact of the use of sign language on the development of speech recognition, spoken language development, and literacy skills. Due to the novelty of this study along with the importance of the research findings, the study is summarized in the following paragraphs.

The CDaCI research team sought to determine whether the family's use of sign language before and after a child receives a cochlear implant influences spoken language development, aided speech recognition, and literacy outcomes. Geers and colleagues of the CDaCI research team noted that a national survey of 27,000 school-age children with hearing loss indicated that only 3.9% had two parents who also had hearing loss. Consequently, the overwhelming majority of parents of children with hearing loss will communicate through LSL and will not be proficient in the use of sign language.

Also, Geers et al. noted that "most parents with normal hearing would like their child who is deaf to learn to communicate using spoken language and choose a cochlear implant to facilitate this outcome."

Furthermore, Geers and colleagues proposed that "a major question for parents and the professionals who work with them is whether speech recognition, speech production, spoken language, and reading skills are best developed by focusing exclusively on spoken language or if early exposure to sign language provides an important foundation for learning spoken language."

GROUP 1	**NO SIGN**	Parents reported no use of sign language prior to or after cochlear implantation.
GROUP 2	**SHORT-TERM SIGN**	Parents reported use of sign language prior to cochlear implantation and/or at 12 months post-activation of the cochlear implant, but not at 24 and 36 months post-activation of the cochlear implant.
GROUP 3	**LONG-TERM SIGN**	Parents reported use of sign language prior to cochlear implantation and/or at 12 months post-activation and also at 24 and 36 months post-activation of the cochlear implant.

Ninety-seven children were selected from the CDaCI database and categorized into three groups based on the results of a written questionnaire completed by each child's parents to indicate the extent to which the child was exposed to sign language prior to (i.e. baseline) and after receiving a cochlear implant at 12, 24, and 36 months post-activation of the implant.

The CDaCI research team reported that children who did not use sign language (i.e., "no sign" group) achieved significantly better speech recognition after 3 years of cochlear implant use when compared to children whose families used sign language (i.e., the "short-term sign" and "long-term sign" groups).

Additionally, the children whose families did not use sign language achieved significantly better oral language skills and speech production abilities when compared to children whose families used sign language on either a short-term or long-term basis.

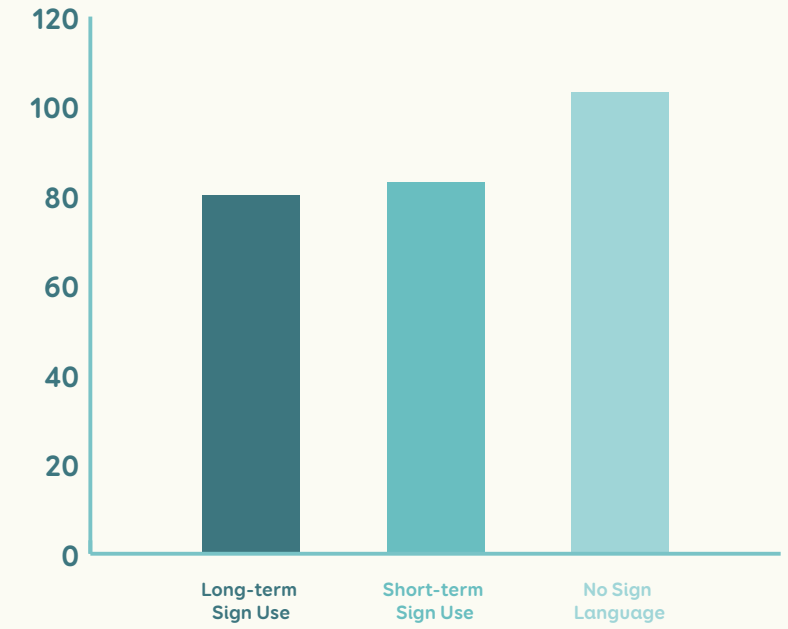
When measured during the late elementary grade years, the children whose families did not use sign language had developed language skills that were within normal limits relative to children with normal hearing, whereas the children whose families used sign language had delayed language abilities (i.e. standard scores of 83.8 and 74.6 for the short- and long-term sign language groups, respectively) (SEE FIGURE 15).

Finally, all three groups of children developed literacy skills that were within normal limits compared to children with normal hearing.

However, the reading abilities of children whose families did not use sign language were significantly better than the reading abilities of children whose families did use sign language either on a short- or long-term basis.

FIGURE 15

Use of Sign Language Prior to and/or after Cochlear Implantation



SUMMARY

To conclude, the results of the Geers et al. (2017) study are consistent with the findings of the LOCHI and OCHL studies ...

... and indicate that the LSL development of a child with hearing loss is optimized by the family's emphasis on creating a language-rich listening environment with early and abundant access to a high quantity of high-quality, intelligible speech obtained through listening.

PART 2

HEARING FIRST | MISSION: PROBABLE

Doing What It Takes

To Optimize The Listening and Spoken Language Outcomes of Children with Hearing Loss

PART 2

Get It Done Before One

The prevailing theme of hearing healthcare providers and families of children with hearing loss should be "get it done before one." In other words, ensure the provision of cochlear implantation before one year of age for children with severe to profound hearing loss. Children born with hearing loss must have early access to speech and environmental sounds throughout their formative years of speech and language development.

What the Research Says

- Research suggests that the outcomes of children who have mild to moderate hearing loss are optimized when they are fitted with hearing aids by 3 to 6 months of age.
- Research also conclusively indicates that the outcomes of children with severe to profound hearing loss are optimized when cochlear implantation is provided by 6 to 9 months of age.
- The LOCHI study has shown that language outcomes decrease by ½ of a standard deviation (i.e. approximately 7.5 points on a standardized assessment of language ability) for every six-month delay in implantation after 6 months of age.
- Research out of the University of Melbourne suggests that normal vocabulary development will be achieved by over 80% of children who receive their cochlear implant before 12 months of age.

PART 2

What it Means for Families and Hearing Healthcare Providers

Hearing healthcare providers should strive to accurately diagnose hearing loss by no later than three months of age so that hearing aids may be provided shortly thereafter (i.e. within the first three to four months of life).

For children with severe to profound hearing loss, hearing healthcare providers should seek to provide a cochlear implant (or cochlear implants) within the first six to nine months of the child's life.

PART 2

Eyes Open, Ears On

Children who have hearing loss must use their hearing aids and cochlear implants during all waking hours to optimize LSL development. The overriding motto should be "eyes open, ears on." When a child's eyes are open, his or her hearing aids or cochlear implants should be on and providing him or her with access to the speech and environmental sounds necessary to optimize auditory brain development. The end goal is optimizing listening, spoken language, literacy, academic, and psychosocial-emotional development.

What the Research Says

The OCHL study found that children with hearing loss achieved age-appropriate outcomes when they used their hearing aids for at least 10 hours per day. Poorer outcomes were achieved by children who used their hearing aids for shorter periods of time each day.

What it Means for Families and Hearing Healthcare Providers

Many families may believe that there will be no harm if hearing aids and cochlear implants are worn a few hours each day. Families may assume that it is perfectly fine to pursue full-time hearing aid or cochlear implant use when the child is older and the "eyes open, ears on" goal is more easily achieved. Furthermore, it can be a challenge to keep hearing aids and cochlear implants on the ears of babies.

However, hearing healthcare providers should go to great lengths to support families in the goal of achieving full-time hearing aid or cochlear implant use. Hearing healthcare providers must inform families of the relationship that exists between full-time use of hearing technology and the developmental outcomes of children with hearing loss. We must remember that many families are unaware of the critical period of language development (i.e., the first two to 3 years of a child's life in which the brain is primed to learn and develop language; language outcomes will be irreparably harmed if the child does not have access to a language model during these first few years of life).

MAKE THE LINK BETWEEN HEARING TECHNOLOGY USE AND AUDITORY BRAIN DEVELOPMENT.

Hearing healthcare professionals have an ethical obligation to talk to families of children with hearing loss about auditory brain development. Families must be informed that their children's potential developmental outcomes will be impacted by the efforts to keep hearing technology on during all waking hours. When hearing healthcare professionals inform families of the critical link between full-time hearing aid/cochlear implant use during the first few years of life and auditory brain development and developmental outcomes, families will be motivated to conquer the "eyes open, ears on" challenge.

PROVIDE FAMILIES WITH SIMULATIONS OF THE IMPACT OF HEARING LOSS.

Hearing healthcare professionals should also provide families with simulations of the impact of hearing loss and demonstrate the child's listening experience with and without hearing aids. Some hearing aid analyzers and online resources may be used to facilitate hearing loss simulations and the potential benefit of hearing aids.

OFFER FAMILIES TIPS AND STRATEGIES TO HELP KEEP HEARING TECHNOLOGY ON THEIR CHILDREN.

Additionally, hearing healthcare professionals must be equipped to provide families with helpful tips and strategies to facilitate full-time use of hearing technology. Specifically, families must be informed of the proper function, care, use, maintenance, and troubleshooting of modern hearing aids and cochlear implants, retention strategies that keep hearing aids and cochlear implants on the child's ears and prevent the child from removing the hearing aids, methods to tamper-proof batteries and push button controls, among other tips.

PART 2

Be a Radio Commentator

Research has suggested that children should hear as many as 46 million words by their fourth birthday in order to optimize language development (HART & RISLEY, 1995). Hearing healthcare professionals must equip families with the necessary information, resources, and support to allow for the creation of a listening-rich language model that will provide children with the requisite access to intelligible speech required to facilitate auditory brain development.

What the Research Says

- The LOCHI, Melbourne, OCHL, and CDaCI studies all found that better listening and spoken outcomes were obtained when families provided children with hearing loss with a language model that was replete with a high quantity of high-quality spoken language.
- The OCHL study found that better language outcomes were associated with the family's use of open-ended, complex speech.
- The Melbourne and CDaCI researchers concluded that better LSL outcomes were achieved when the families of children with hearing loss communicated via LSL, and that outcomes suffered when families used visual forms of communication such as sign language or speech reading.
- The LOCHI, Melbourne, OCHI, and CDaCI studies support the notion that children with hearing loss and their families should be connected with an LSL Specialist (i.e. a clinician who is specially trained and certified to support a family in the endeavor of optimizing the LSL of children with hearing loss) with the goal of creating a language-rich listening environment that will facilitate LSL development.
- Collectively, the results of these studies provide strong evidence that LSL outcomes are optimized when families and hearing healthcare providers emphasize spoken language through listening.

PART 2

What it Means for Families and Hearing Healthcare Providers

Hearing healthcare professionals must respect the family's' right to choose the way in which they communicate with their children. However, hearing healthcare professionals are also obligated to ensure that families are equipped with information that allows them to make informed choices regarding their children's communication abilities.

Given estimates that suggest 97% of families of children with hearing loss communicate in the home through LSL, it is reasonable to assume that most families will desire for their children to reach their full potential in their ability to communicate through LSL. The research reviewed in this study provides evidence that the best LSL outcomes are obtained when families choose to communicate through LSL.

Dr. Teresa Caraway and Joanna Smith, Listening and Spoken Language Specialists (LSLS), and co-founders of Hearts for Hearing, sum it up best when they encourage families to "be radio commentators." This means that parents should provide a running oral narrative of everything that is unfolding in front of the baby's eyes. For example, "OK, now we are going to the fridge to get a drink. Brrr, it's cold! Hmmm, what should we get? I see the orange juice, and the milk, and the yellow apple juice..."

PART 2

Give Me Five

Almost assuredly, the outcomes of children with cochlear implants will also be delayed if the cochlear implant stimulation levels are not optimized to meet the child's needs. Pediatric audiologists must adhere to evidence-based best practice protocols when providing clinical services for children with hearing loss. The catchphrase with regard to the fitting of hearing aids should be, "Give me five! But no more!"

What the Research Says

- Unfortunately, the OCHL researchers found that over 50% of children used hearing aids that produced output that differed by more than 5 dB from evidence-based prescriptive targets at each of the four study visits in which real ear probe microphone measurements were completed.
- The OCHL study revealed the critical importance of well-fitted hearing aids.
- The LOCHI researchers also showed a considerable amount of variability in the stimulation levels used by cochlear implant recipients.

In short, children who used hearing aids that were matched to evidence-based prescriptive targets via probe microphone measures had optimal access to speech and environmental sounds and achieved age-appropriate LSL development.

In contrast, children whose hearing aids were not programmed to meet evidence-based prescriptive targets exhibited delays in their speech and language development.

What it Means for Families and Hearing Healthcare Providers

A number of excellent evidence-based protocols exist to guide the clinician in the completion of an accurate diagnostic assessment and the fitting of hearing aids:

Ontario Infant Hearing Program's Audiologic Assessment Protocol (OIHP, 2016)

British Columbia Early Hearing Program's Audiology Assessment Protocol (BCEHP, 2012)

England's National Health Service's Guidelines for the Auditory Brainstem Response Assessment in Infants (NHS, 2013a)

England's National Health Service's Guidelines for the Assessment and Management of Auditory Neuropathy Spectrum Disorder in Young Infants (NHS, 2013b)

Guidelines for Identification and Management of Infants and Young Children with Auditory Neuropathy Spectrum Disorder (Guidelines Development Conference at NHS, 2008)

ABR Assessment in Infants—Summary of Protocols and Standards (Wolfe, 2014a)

Considerations in ABR Assessment in Infants (Wolfe, 2014b)

Ontario Infant Hearing Program: Protocol for the Provision of Amplification (OIHP, 2014)

National Protocol for Paediatric Amplification in Australia. King, A.M. (2010)

Evidence-based protocols are not as readily available to guide clinicians in the programming of cochlear implants for children with hearing loss. However, the following resources do provide evidence-based information regarding clinical cochlear implant services for children.

Wolfe, Jace (2019). Cochlear Implants: Audiologic Management and Considerations for Implantable Hearing Devices. Plural Publishing, Inc. San Diego, CA.

Wolfe, Jace and Schafer, Erin C. (2014). Programming Cochlear Implants. Plural Publishing, Inc. San Diego, CA.

PART 2

All Hands on Deck for Children with Additional Disabilities

Children who have hearing loss and additional disabilities are likely to develop age-appropriate LSL development if nonverbal IQ is within normal limits and evidence-based audiologic care is expeditiously provided within a language-rich listening environment.

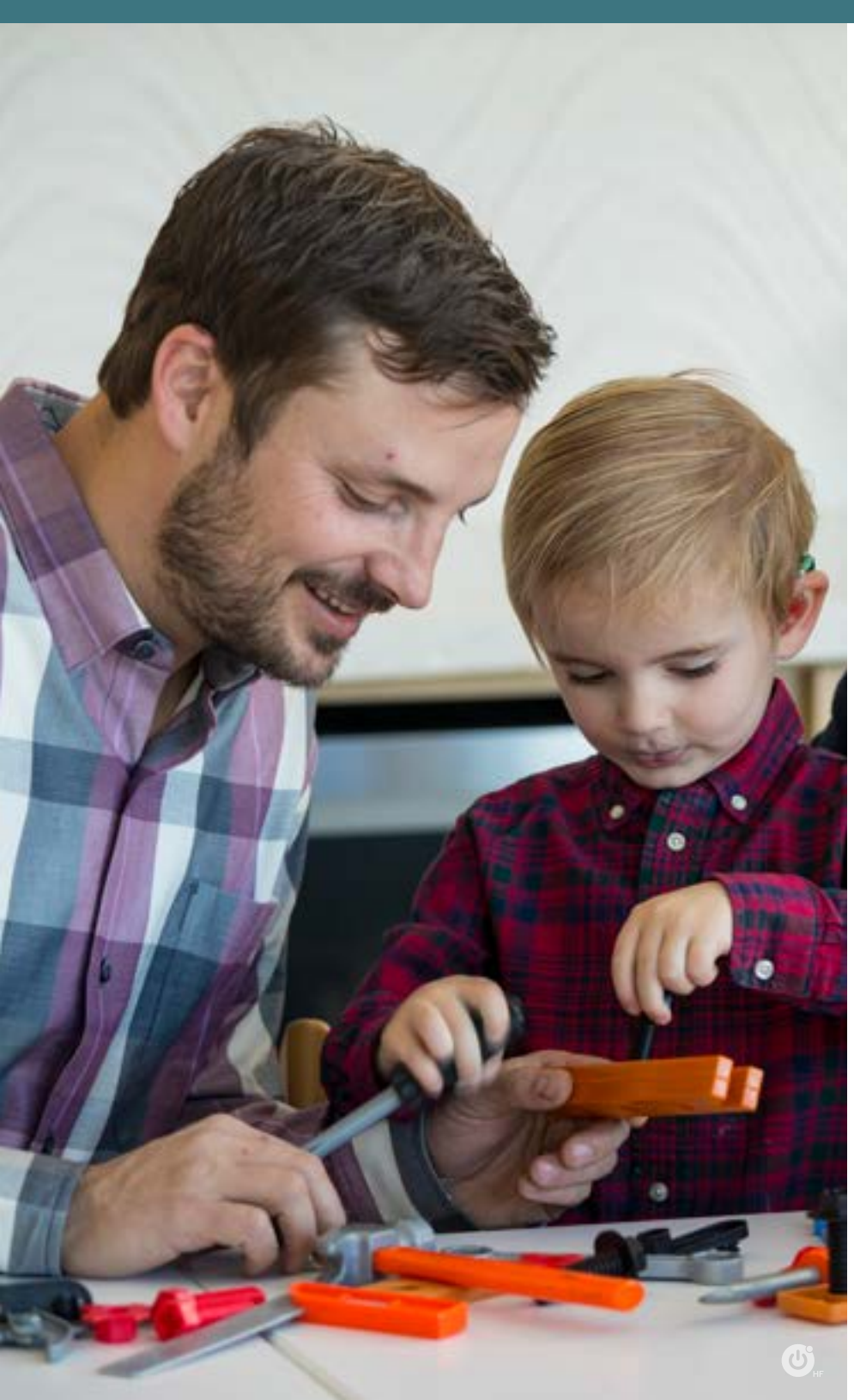
What the Research Says

- The LOCHI study researchers reported that children who had hearing loss and additional disabilities achieved poorer LSL outcomes than children whose only disability was hearing loss.

- As previously noted in the current review, the presence of additional disabilities other than hearing loss should not exclude a child from consideration for a cochlear implant nor necessarily preclude a child from communicating via LSL.

- For children who have deficits in their nonverbal IQ, spoken language development is likely to be commensurate with their neurocognitive abilities when optimal audiologic intervention is provided. In fact, for many children with additional disabilities, their listening skills can become a strength when their families seek to optimize LSL development.

- Once again, the LOCHI research showed that appropriately fitted hearing aids and cochlear implants should be provided in a timely fashion to allow the child who has hearing loss and additional disabilities to reach his or her full potential in LSL development.



What it Means for Families and Hearing Healthcare Providers

Hearing healthcare clinicians should proactively establish interdisciplinary relationships with other specialists (e.g. neurodevelopmental specialists, physical therapists, occupational therapists, early educators, vision specialists, etc.) who have expertise in the areas in which the child's additional disabilities reside, whether those disabilities include autism, cerebral palsy, visual impairment, or other conditions.

As stated by the LOCHI researchers (Ching et al., 2018):

"Children with additional disabilities will need extra support to optimize their language and other outcomes, support that will undoubtedly vary from child to child... a fact that underscores the importance of establishing collaborations among professionals in the management of children with hearing loss who have additional disabilities."

PART 2

Radio Makes the Listening Star

Children with hearing loss should have access to noise management technologies, with particular focus on the imperative use of remote microphone technology. With regard to the routine use of remote microphone technology for children with hearing loss, the hearing healthcare and family should adopt the slogan "radio makes the listening star."

What the Research Says

The LOCHI and CDaCI researchers both highlighted the difficulty their study participants experienced understanding speech in noise, a finding that is corroborated by previous research studies (WOLFE ET AL., 2013).

What it Means for Families and Hearing Healthcare Providers

The caregivers of children with hearing loss should be provided with information regarding the proper use of remote microphone technologies and when it is most critical to use these systems (e.g. in noisy environments, when the child is located at a distance from the caregiver, etc.).

Also, caregivers should be informed of strategies to optimize the acoustics of a child's listening environments (e.g. attempt to be within an arm's length of the child when talking, remove noise sources when possible, place rugs over hard floors, etc.).

PART 2

Support the Whole Family

Hearing healthcare providers must identify resources that will allow vulnerable families to support the developmental needs of their children with hearing loss. The rallying cry should be "support the whole family."

What the Research Says

- The LOCHI, Melbourne, OCHL, and CDaCI studies all revealed that children with hearing loss achieved better LSL outcomes when their families had higher levels of education and income.

- Studies show that families who have low incomes are likely to adhere to the recommendations healthcare providers make for the care of their children when 1) information is provided in an understandable way and 2) the family understands that their actions will provide their children with opportunities that will not exist if they do not adhere to the recommendations.

What it Means for Families and Hearing Healthcare Providers

Hearing healthcare providers must share information regarding auditory brain development and its link to LSL development in children with hearing loss in a manner commensurate with the health literacy level of the family.

Additionally, hearing healthcare providers should work with social workers and other local agencies to identify resources that will equip families to provide the care their children need to optimize their LSL development. Examples of resources that can assist families in overcoming obstacles to care include teletherapy, reimbursement for travel, and financial assistance to offset costs associated with hearing technology and services.

SUMMARY

Age-appropriate listening, spoken language, and literacy outcomes are not only possible but probable for children born with any degree of hearing loss.

Universal newborn hearing screening and advances in hearing aid and cochlear implant technologies provide every child with hearing loss the opportunity to listen and talk.

Age-appropriate LSL abilities should be the expectation for children with hearing loss when:

1. The child is appropriately fitted with hearing technology (Give Me Five) during the first year of a child's life (Get It Done By One),
2. The child uses the hearing technology during all waking hours, which should be at least 10 hours a day (Eyes Open, Ears On),
3. The child's caregivers provide the child with a language-rich listening environment (Be a Radio Commentator), and
4. The child's family is equipped with the resources and information needed to support the child in the goal of reaching his or her full potential in life (Support the Whole Family).

Excellent listening and spoken language outcomes are probable for children with hearing loss when we do what it takes. Hearing healthcare professionals and families should shoot for the moon.

The journey to age-appropriate LSL outcomes is Mission: Probable.

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FIGURE LEGENDS

FIGURE 1
An illustration of the relationship between language outcomes and age at which children received their cochlear implants.

FIGURE 2
An illustration of typical language outcomes of children with hearing loss when measured in the LOCHI study when the children were 3 and 5 years old.

FIGURE 3
An illustration of vocabulary outcomes for children who received cochlear implants at different ages in the Melbourne research study.

FIGURE 4
An illustration of language outcomes for children who received cochlear implants at different ages in the Melbourne research study.

FIGURE 5
An illustration of speech production outcomes for children who received cochlear implants at different ages in the Melbourne research study.

FIGURE 6
An illustration of speech understanding outcomes for children who received cochlear implants at different ages in the Melbourne research study.

FIGURE 7
An example of the language progress children achieved after cochlear implantation relative to each chronological (i.e., calendar) year. The solid gray line represents the typical language development for children with normal hearing. The dashed green line represents language progress made prior to cochlear implantation, and the solid green line represents language progress made after cochlear implantation for a child who receives a cochlear implant at 16 months of age. The dashed red line represents language progress made prior to cochlear implantation, and the solid red line represents language progress made after cochlear implantation for a child who receives a cochlear implant at 18 months of age. Rates of language progress prior to cochlear implantation are based on an estimate suggesting children with severe to profound hearing loss develop language at a rate of .3 to .4 year of language growth per calendar year before cochlear implantation and 1.03 year of language growth after cochlear implantation (Leigh et al., 2016).

FIGURE 8
An illustration of language outcomes achieved by children whose families communicated with oral speech and sign language compared to children whose families communicated only with the use of LSL (i.e., no sign language).

FIGURE 9
An illustration of language outcomes achieved by children who received therapy on a weekly, bi-weekly, and monthly basis.

FIGURE 10
An illustration showing the average age at which children received their cochlear implants for children who received therapy on a weekly, bi-weekly, and monthly basis.

FIGURE 11
An illustration of speech recognition achieved by children whose families communicated with oral speech and sign language, children whose families communicated with the use of LSL and also with speechreading, and children whose families communicated only with the use of LSL (i.e., no sign language).

FIGURE 12
An illustration of a hearing aid fitting in which the output of the hearing aid has been matched to evidence-based prescriptive targets (i.e., "crosses") for average, soft, and loud speech. Also, the maximum output level of the hearing aid has been verified to exist at an appropriate level.

FIGURE 13
An illustration of language outcomes achieved by children whose hearing aids had been programmed to provide optimal audibility compared to the language outcomes of children whose hearing aids had not been programmed to provide optimal audibility.

FIGURE 14
An illustration of language outcomes achieved by children who used their hearing aids for fewer than 10 hours per day compared to the language outcomes of children who used their hearing aids for more than 10 hours per day.

FIGURE 15
An illustration of language outcomes achieved by children whose families used sign language on a long-term basis (i.e., used sign language prior to cochlear implantation and for at least 3 years after their children received cochlear implants), on a short-term basis (i.e., used sign language prior to cochlear implantation and for no more than one year after their children received cochlear implants), and not at all.

TABLE 1
The hearing loss level (i.e., pure tone average in better ear) for a 75%, 80%, 85%, 90%, and 95% chance of improvement in word recognition if child receives a cochlear implant.

Acknowledgement

Hearing First gratefully acknowledges Dr. Jace Wolfe and his contributions to this white paper. The studies highlighted herein provide valuable evidence of the outstanding listening and spoken language outcomes possible for infants and children with hearing loss.

We appreciate the opportunity to collaborate with Dr. Wolfe in developing this resource, which promotes greater knowledge and understanding for the LSL professional field, families of children who are deaf or hard of hearing on the LSL journey, and the general public.

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