

**Critical Review:  
The Effects of Age of Cochlear Implantation on Receptive Vocabulary Development**

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This critical review examines the effects of age of cochlear implantation on receptive language in children. A literature search was conducted and yielded the following article types: five prospective cohort studies and one retrospective cohort study. Overall, the literature yielded converging evidence to suggest that younger age of implantation may lead to more beneficial receptive vocabulary development. Further research on this topic is merited. Clinical implications were noted.

***Introduction***

It can be argued that receptive vocabulary development may be one of the most important language skills to acquire, not only due to its importance to one's overall language competency, but also because of its link to later literacy development and overall academic success (Hayes, Geers, Treiman & Moog, 2009). Children who are born with a profound hearing loss are at a great disadvantage in developing their receptive vocabulary skills, among other language domains. Cochlear implantation has become a common procedure for children with profound hearing loss, and recently, children as young as one year were approved to receive this life-changing surgery. Newfound controversy has been raised over whether receiving a cochlear implant at an earlier age outweighs the potential risks (Kirk, Miyamoto, Lento & Ying, (2002).

Researchers have studied this question by examining age of implantation as a predictor of greater receptive vocabulary success, and reported conflicting results. Uziel, Sillon, Vieul, Artieres, Piron, Duares and Mondain (2007) argued that age of implantation was a positive predictor of receptive vocabulary development, whereas Dawson, Blamey, Dettman, Barker and Clark (1995) made the opposite claim. This conflicting evidence has led to the current critical review aimed at evaluating current evidence pertaining to a direct relationship between age of cochlear implantation and receptive vocabulary skills.

It is important for Speech-Language Pathologists, working as a part of an interdisciplinary team, to be able to appropriately advise clients and their families regarding optimal times for cochlear implantation and the affects that it may have on receptive vocabulary development. It is therefore critical that such professionals have an evidence-based understanding of this relationship and what these implications mean for future academic and social success of children with

profound hearing loss. This would allow for the best outcomes to be achieved.

***Objectives***

The primary objective of this paper is to critically evaluate the existing literature to determine the effects of the age of cochlear implantation on receptive vocabulary development in children. From this review, recommendations regarding appropriate age of implantation to optimize receptive vocabulary development will be discussed.

***Methods***

**Search Strategy**

Literature was gathered through computerized online databases, including Web of Science, Proquest and PsychINFO, using the following search terms:

(age of cochlear implantation) AND (receptive vocabulary)

(age of cochlear implantation) AND (vocabulary)

The search did not have any limitations, except that articles must be written in English.

**Selection Criteria**

Studies included in this critical review were required to look at the direct relationship of age of cochlear implantation on receptive vocabulary development. Other language domains may also have been examined in the studies, but were not a major focus of this critical review. Three (3) articles that focused on special populations, treatment effects or age of implantation as a predictor variable in pre-post treatment were not included. Finally, two (2) articles that focused solely on early cochlear implantation without a later comparison were excluded.

**Data Collection**

Results of the literature search yielded the following types of articles: prospective cohort study (5) and retrospective cohort study (1).

### **Results**

Brackett and Zara (1998) evaluated the communicative performance of children who received cochlear implants before five years of age and the effects of age of implantation on language acquisition. Thirty-three children were grouped according to their age of cochlear implantation; two to three years old (n=17) and three to five years old (n=16), respectively. Receptive vocabulary was tested using the Peabody Picture Vocabulary Test (PPVT) pre-implantation and consecutively for three years post-implant.

The authors provided descriptive statistics of the different trends noted for growth over time. These descriptive results indicated that children implanted before the age of five continuously showed a delay in their receptive vocabulary development, but this delay did not widen over time, which has been seen previously with children who are deaf, wearing traditional amplification. Furthermore, when comparing the younger to older groups of children, it was observed that children in the younger group were able to make consistently larger gains over the three years, whereas the older children made less vocabulary growth. Although both groups exhibited a language delay post-implantation, the older group's delay was more severe. Despite these trends, an appropriate mixed repeated measures analysis of variance showed that no significant differences were found between the two groups in any language domain, including receptive vocabulary for either group. Overall, the authors suggested that children who are implanted by the age of five will show increased receptive vocabulary development. It was also suggested that children implanted by two to three years old may show a slightly greater receptive vocabulary growth.

Upon analysis of the Brackett and Zara (1998) study, apparent methodological limitations were noted. Study procedures, including who tested the subjects, as well as testing times and locations were not mentioned, which would affect any replication of this study. The participant group had little exclusion criteria and was therefore a heterogeneous population. As well, a small sample size may have reduced the power of the study to detect significant results. Although statistical analysis did not support the original descriptive findings, important trends of growth patterns and variability were noted over time and therefore should not be discredited. Overall, Brackett and Zara (1998) provided suggestive evidence that younger implantation may have larger positive receptive vocabulary development.

Hayes, Geers, Treiman and Moog (2009) evaluated whether the age and year of cochlear implantation would affect receptive vocabulary skills and growth

rates. A group of sixty-five children who were deaf were included in the study. At the time of testing, participants ranged from approximately three to nine years old. An experienced teacher of the deaf tested the subjects annually using the PPVT.

An appropriate multilevel modeling statistical analysis, which was used to analyze data with a large amount of within-subject variability, was completed. The younger group of children showed significantly higher receptive vocabulary growth rates of more than average gains in a year initially, but this pattern tapered. Older children, however, showed a slower but more consistently positive vocabulary growth rate. Other potential variables that would affect vocabulary scores were calculated, including gender, highest parental education level and nonverbal intelligence, but did not have a significant effect. Year of implantation was the only variable that had significant effects on initial vocabulary, but not on vocabulary growth. Expected growth curves were also calculated using average vocabulary development and age of implant (2.69 years old). Results were interpreted to suggest that children implanted by the average age would improve on their vocabulary skills, though a delay would persist. Children implanted by age two, however, would achieve normal-age receptive vocabulary skills after approximately four years of implant use. Furthermore, it was suggested that children who were implanted before the age of five would make greater than average gains within a year, therefore lessening the delay gap.

Upon analysis of this study, it was evident that Hayes et al. (2009) designed a statistically and methodologically sound research design. A longitudinal study was used and participant variability was taken into account, using correct statistical analysis, therefore increasing the validity and reliability of the study. Inadequate sample size was noted as a limitation, however, and may have led to reduced ability to detect significance. This study provided compelling evidence to suggest that children implanted at an earlier age may see greater to near-normal receptive vocabulary development.

James, Brinton, Rajput and Goswami (2007) evaluated the effects of age of implantation on receptive vocabulary. Nineteen children who were congenitally deaf were divided into two implant groups: younger (two to 3.6 years, n=9) and older children (five to seven years, n=10). Participants had used their cochlear implants for a minimum of three years at the time of testing. The children were tested twice annually using the British Picture Vocabulary Scale (BPVS).

Descriptive statistics and multiple t-tests were used to compare early and later test results. Results indicated

that both age groups showed a persistent delay in receptive vocabulary throughout the study. The older group had significantly poorer results than the younger group at the initial time of testing, but improved significantly more in their vocabulary development than the younger group. Individual variation was also studied, indicating that some of the highest scorers came from both groups. Poorer performance levels at the initial time of testing, as judged by individual variation, did not predict a more rapid vocabulary growth rate. Additional results that did not hold a direct link to the current study were also reported. Results of phonological testing indicated that younger children were more likely to fall within normal limits and have significantly larger growth rates. Significant differences between the two groups were found in word reading as well. Overall, it was suggested that children implanted at a later age may make more receptive language gains over time, but there was still a wide range of variation between and within the two groups that may not be accounted for solely by age of implantation.

Although the authors incorporated descriptive statistics and used t-tests to compare the two groups, overall statistical analysis was weak. By using multiple t-tests, the authors increased their chances of having a type I error. As well, statistical power may be low due to the small sample size, leading to a reduced ability to detect a significant difference. Despite these limitations, this study provides fairly compelling evidence to suggest that younger children may see large gains, especially in the initial period after implantation, but older children also benefit in their receptive vocabulary over time.

Manrique, Cervera-Paz, Huarte and Molina (2004) studied the effects of age of implantation on speech perception and production in children with congenital hearing loss. One hundred and thirty children were divided into two age-of-implant groups: a younger group (less than two years old, n=36) and an older group (two to six years old, n=94). In order to test receptive language, children were given the PPVT for up to five years after implantation.

Descriptive statistics were used to show the changes in receptive vocabulary over time. Results indicated that children who were implanted before two years of age demonstrated fairly normal receptive vocabulary development, whereas the children who were between two and six years old showed a two year delay. Pure-tone audiometry and logaudiometric testing were also measured and were found to have a significant positive difference for both the younger and older groups, pre- to post-implant. Results of expressive language testing indicated that the younger group continued to experience a one year delay while the older group had

approximately a three year delay. Overall, the authors indicated that children before the age of two experience better achievement of receptive vocabulary skills and should therefore be implanted as early as possible.

Although a longitudinal study with a large sample size was used, many statistical and methodological limitations were noted in this study. Statistical analysis was not used to measure variation for receptive vocabulary. As well, methodologically, the study was not described in such a way that would be conducive for replication in further studies. Information about participant inclusion was not reported and testing conditions were not explained. As well, participant groupings were not equally distributed, which may have skewed results. Given these limitations, some cautions are warranted and thus this work is considered to provide somewhat suggestive information to propose that younger children, implanted under the age of two, would show the greatest improvement in receptive vocabulary.

Conner, Craig, Raudenbush, Heavner and Zwolan (2006) examined the relationship between age of implantation and growth curves for speech and receptive language. In this study, one hundred children who were congenitally deaf were divided into four groups, according to age of implant: ages one to 2.5 years (n=21), 2.6 to 3.5 years (n=15), 3.6 to seven years (n=20) and 7.1 to ten years (n=44). The children were tested semi-annually for two years, then annually in subsequent years, using the PPVT. On average, each child was tested four times.

An appropriate multi-level linear model was employed in order to account for variability among the subjects and timing. Propensity scores were also used to take into account any possible selection bias by controlling for variables that may affect the age of implantation variable. Results indicated that the youngest group exhibited significantly better receptive vocabulary growth rates for three years after implantation than any of the other groups and exhibited a 'growth burst'. The second youngest group showed a greater growth rate than the older two groups, but only for one year after implantation and showed a similar but smaller burst. The two older groups did not show any significant differences in growth rates. Overall, all of the groups had similar growth rates after four years of implantation experience. Furthermore, a child between 1 and 2.5 years of age was predicted to have a lower-end normal score by the age of six. As age of implantation increased, a greater delay was predicted. Significant increases in speech scores were also noted and results showed a similar pattern to receptive vocabulary development and predicted growth rates. Overall, the

authors indicated that children who were implanted before the age of 2.5 would see greater development and a burst of speech and receptive vocabulary that would diminish with later ages of implantation.

Analysis of this research paper indicated that the study was well designed. The study was longitudinal and had a relatively large sample size considering the small size of the intended population. It would be assumed that statistical power would be adequate, therefore increasing the likelihood of correctly identifying statistical significance. Finally, participant criteria and methodology were well described and could be replicated in further studies. As well, participant variability was taken into account by using appropriate statistical analysis. Overall, the abovementioned study provides compelling evidence to indicate that younger implantation yields greater receptive vocabulary outcomes.

El-Hakim, Levasseur, Papsin, Panesar, Mount, Stevens and Harrison (2001) examined whether receptive vocabulary development was predicted by age of implantation. In this retrospective study, sixty prelingually deaf children who had two or more receptive assessment scores within a database were included. The subjects were separated into two age-of-implantation groups: younger (less than five years old) and older (greater than five years old). The authors did not indicate how many participants were included in each age group. Each subject was tested at the time of implantation, every six months for two years thereafter, then once a year subsequently, using the PPVT. Rate of growth and gap indices were measured.

Results indicated that, although the younger group showed a higher rate of change in age-equivalent scores, no significant differences between the younger and older groups were found. The group, as a whole, demonstrated a significant change in the gap index. The older group experienced a significant reduction in their receptive vocabulary gap, indicating that older children may benefit more over time from cochlear implantation. The younger group had a significantly lower receptive language gap index, indicating that implantation at an earlier age may reduce receptive vocabulary loss. The abovementioned results were also reported in a similar study (El-Hakim, Levasseur, Papsin, Panesar, Mount, Stevens and Harrison, 2001). Through a multiple regression analysis, sex and communication mode were found to be predictive variables for increasing receptive language. Expressive language was also examined in the study. Significant differences were found in the decrease of the gap index for both younger and older groups, and the group as a whole. Residual hearing was a significant predictor of better expressive vocabulary.

No other significant differences were found. Overall, trends indicated that older children may benefit more from cochlear implantation, and that age of implantation may not imply a more beneficial outcome, but may suggest a different pattern of development.

Although participant inclusion criterion, statistical analysis and most methodological means were well described, some design flaws were noted. The authors provided weak rationale as to the division of their younger and older groups. Because participant age groups were very close, with poor age group separation rationale, it would be hard to draw definitive conclusions based on this age group separation. Due to participant groups, as well as the overall weaker design of a retrospective study, the results of this study are equivocal and therefore should be interpreted with caution.

### *Discussion*

Based on the critically reviewed available literature on this topic, evidence appears to show a converging beneficial trend towards implanting younger children. These trends would suggest that children who receive cochlear implants by the age of five may see large increases in receptive vocabulary development, but children who receive their implant by two may achieve age-matched receptive vocabulary after a period of time. Other findings, however, suggested a different course of development, indicating that children who were implanted at an older age may see more long-term benefits. Overall, it seems that children, regardless of age of implantation, may show positive receptive vocabulary gains, but there is converging evidence to suggest that younger implanted children may see more significant gains initially.

All of the examined studies employed a cohort design which represents the highest level of evidence which can be reasonably executed for this research topic. More specifically, theoretical considerations would preclude a randomized clinical trial. Despite the strengths in the cohort design, the present studies were affected by limitations, including small sample sizes, participant variability and weak methodological layout. Some articles also presented with weak statistical or overall study design. These apparent limitations may have affected the overall reliability and validity of the studies.

Although patterns were noted throughout this critical review, many new questions have arisen and further research in this area is warranted. More conclusive results may be yielded from including a more homogenous group of participants, a comparison to a hearing aid population or studying the impact of mode

of communication. Researchers have begun to answer the latter question by studying total versus oral communication. Both Connor, Hieber, Arts and Zwolan (2000) and Kirk, Miyamoto, Ying, Perdew and Zuganelis (2000) indicated that communication mode did not effect rate of language development, whereas Kirk, Miyamoto, Lento and Ying (2002) indicated that children who used oral communication saw more gains in language. Further research in this area is warranted.

### **Conclusion**

The literature reviewed in this critical analysis yielded important first steps in deciphering an appropriate age-of-implant to improve receptive vocabulary development. Trends towards early implantation emerged, indicating that children may present with more than average receptive vocabulary gains after early implantation. Some research did indicate, however, that older children may see more long-term benefit in receptive vocabulary development. This would suggest that children, regardless of age, would benefit from cochlear implantation.

### **Clinical Implications**

As a part of an interdisciplinary team, it is important that Speech-Language Pathologists provide key, evidence-based information to parents and caregivers to guide them in their decision making process. Current evidence suggests that children will benefit in their language growth, despite their age of implantation, but quicker and larger gains may be seen initially in children who are younger at age of implantation.

Connor et al (2006) implied that one of the biggest factors in developing receptive language may be providing early language opportunities, regardless of age of implantation. Language-rich environments, the availability of hearing aids and cochlear implants as well as early and continued screening of hearing abilities may be the key to successful communication and development of receptive vocabulary skills in profoundly deaf children.

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