

The Influence of Age at the Time of Cochlear Implantation on Hearing Threshold in Prelingually Deaf Children

S. Abdi, H. Tavakoli¹, M. Naderpour²,
M. Amirabadi³

Abstract

Background: There always has been a question about the best age for cochlear implantation (CI) in prelingual deaf children. The age factor in the outcome of cochlear implantation in prelingual deaf children has been the subject of many studies. The aim of the present study was to find the effect of age at the time of implantation on hearing threshold of these children.

Methods: One hundred and nine prelingual deaf children who had undergone CI were enrolled. The mean hearing threshold (HT) at octave intervals from 125 to 8000 Hz at different periods from the operation time were compared between those patients whose age at the time of implantation were less than 24 months and those whose age were equal or greater than 24 months.

Results: The mean age of patients at the time of implantation was 38.9 months and a half of them had less than 28 months. There was no difference in mean HT between the two age groups across different measurement periods. A multiple regression model showed that device type was the sole significant predictor of mean HT at the first and third months after implantation, where age replaced it at the sixth month.

Conclusion: These results suggest that what had been found in other studies as a favorable effect of younger age at the time of implantation on speech perception cannot be explained by a better hearing, and there are other important factors including rehabilitation programs beginning at a younger age that may explain those findings.

Iran J Med Sci 2007; 32(3): 147-151.

Keywords • Cochlear implantation • age effect • cochlear implants

Introduction

Since the late 1960s, cochlear implantation (CI) has been considered an acceptable clinical practice, although its use has become much more widespread in recent years. Many studies have shown the effectiveness of cochlear implantation in children.¹⁻⁴ The CI has been proved to provide substantial levels of speech perception and to develop the oral language skills of prelingually deaf children with profound hearing loss.^{1,5-8}

Clinical investigators have tried to define the best time for implantation in prelingually deaf patients.⁹⁻¹³ However, there

Department of Cochlear Implantation
Clinic, ¹General Surgery,
Tehran University of Medical Sciences,
Tehran, Iran.

²Department of ENT Surgery,
Tabriz University of Medical Sciences,
Tabriz, Iran.

³Iranian National Oil Hospital,
Shiraz, Iran.

Correspondence:

Susan Abdi PhD,
Department of Cochlear
Implantation Clinic,
Tehran University of Medical Sciences,
Tehran, Iran.

Tel/Fax: +98 21 88734095

Email: Susan_abdi@yahoo.com

have been speculations about a higher age boundary for the implantation in this group. Studies of CI in prelingual populations have indicated that the benefits gained in terms of speech discrimination and production are greater as the age of CI recipients decreases.^{10,15-17} However, it is still unclear whether the potential advantages of performing CI in children younger than 2 years worth the effort of carrying out the necessary tests to confidently diagnose profound sensorineural hearing loss and the specific problems of CI surgery, tuning-up, and habilitation. For these reasons, the use of CI before the age of 2 years is still infrequent and somewhat questioned. But we found that CI was very effective to return the patients deprived of hearing back to the normal life before 2 years old.¹⁸⁻²⁰

The present study assesses an important issue concerning the use of CI in infants younger than 2 years old. We have compared hearing threshold in children with prelingually hearing impairment subjected to CI before they reach 2 years of age and at a later age.

Patients and Methods

Study Design & Subjects

The present study was designed as a prospective study with repeated measures. Prelingually deaf children who underwent CI for their deafness at the Hearing Research Center, Amir Aalam Hospital, Tehran, were recruited to the study from the time of implantation from December 1996 to December 2004. The cochlear implant devices were chiefly different models of Clarion[®] and Nucleus[®]. The protocol of the study was reviewed and approved by Tehran University of Medical Sciences (TUMS). Informed consent was obtained from the parents or legal representatives of the children for inclusion in this study and for the follow-up tests.

These children were divided into two groups according to their age at implantation: one group of children were less than 2 years old (n=49) and the other group aged from 2 to 6 years (n=60).

We introduced a new protocol for children under CI which was based on well-calibrated stimulation by the help of two expert examiners, one in sound field and the other in control room. We accepted visual reinforcement audiometry reflexes such as the auro-palpebral reflex (APR: an eye blink), investigatory responses, orientation responses, and spontaneous responses.^{21,22}

Statistical Analysis

The results of each test and other items of interest were recorded in a database and analyzed with SPSS 10.0.5 statistical package (Chicago, IL). To search the influence of age at the time of device implantation on hearing threshold of patients, statistical tests of correlation and Student's *t* test were used and multiple regression analysis were used for searching possible cofounders. Using a multiple linear regression, we entered the hearing threshold as the dependent variable and age at the time of implantation and implant type as the independent variable both in an "enter" model and a "stepwise" model. The significance level was considered $p < 0.05$.

Results

One hundred and nine patients made our first cohort, with ages at the time of implantation ranged from seven months to 6 years. Their mean age was 38.9 months, the median was 28.0, and the standard deviation was 29.57 months. Of these patients, 80 (73.4%) children had received Clarion[®] and 29 (26.4%) had received Nucleus[®] devices.

Their mean hearing threshold at different time intervals is shown in table. As shown in this table, mean hearing thresholds had not changed markedly during the four-year period. To assess the crude effect of age on the hearing threshold we first tried to find if there was a linear correlation between age and mean hearing threshold. The only statistically significant Pearson correlation coefficient was between age at the time of implantation and mean hearing threshold three months after implantation ($r = 0.332$, $p = 0.002$).

Table: Hearing threshold in patients at different time intervals in the two groups.

more than 2 years old	Month 1	3	6	12	24
250 Hz	35.19	35.17	35	34.98	34.8
500 Hz	30.58	30.51	30.41	30.4	30.29
1000 Hz	32.5	32.3	32.2	32	31.82
2000 Hz	34.23	34.22	34.2	34	33.9
4000 Hz	40	39	38.9	38.8	38.5
8000 Hz	49	48	47.9	47.5	47
less than 2 years old					
250 Hz	33.85	33.82	33.8	33.7	33.5
500 Hz	30.77	30.7	30.5	30.36	30.25
1000 Hz	31.54	31.5	31.45	31.4	31.35
2000 Hz	33.46	33.4	33.29	33.27	33.25
4000 Hz	38.46	38.45	38.4	38.35	38.33
8000 Hz	47.63	47.6	47.55	47.5	47.23

We compared the hearing thresholds of children who underwent implantation before age of 24 months or after it. Interestingly we found that there was no difference in the mean hearing thresholds between these two groups across a wide range of post-operative follow ups, ranging from one month to four years.

Using a multiple linear regression model, we found that in the first month after implantation, the implant type and not the age was a good predictor of hearing threshold ($B = 5.43$, and standardized beta = 0.255), in the third month the same pattern was found ($B = 5.73$, and standardized beta = 0.242). This pattern was changed at the sixth month while the age became the predictor and implant type was excluded from the model ($B = 0.107$, and standardized beta = 0.307). At the first, second, and third years after implantation, neither age nor device type were good predictors of hearing threshold. In the fourth year of follow up, it was found that while device type was a good predictor of hearing threshold variance ($B = 9.93$, and standardized beta = 0.921), the age was a negative moderate predictor of hearing threshold ($B = -0.07$ and standardized beta = -0.547). This finding indicate that while implant type continued to work in the same direction as before, age changed its role and higher ages predicted better results.

There was no side-effect or complication in both groups except for one child whose graft was rejected.

Discussion

In the present study, we found that hearing threshold did not correlate with age at the time of implantation in a general term. We have found that three months after implantation there was a positive correlation between age and hearing threshold. However, since this finding was not corroborated with a trend before or after this milestone, we assume that this finding is incidental.

Another post-hoc finding that deserves further clarification and corroboration in specific studies being designed to find that result, was the effect of device type on hearing threshold, an effect which did not disappear after adjustment for age.

The results of the present study may disagree with other studies showing a negative effect of age on hearing abilities, such as Snik and Nikolopolous studies.^{11,23} This is due to that all those studies have measured speech recognition abilities as a proxy for hearing ability. In a study conducted by Kileny et al. the speech recognition abilities assessed in relation to the age at implantation and duration of cochlear implant use in children who received

the Nucleus® CI22M cochlear implant. The first group of 48 patients at seven years of age on assessment of speech recognition performance as a function of length of time with a cochlear implant compared with another group of 53 patients evaluated 36 months after implantation on assessment of speech recognition performance as a function of age at implantation.²⁴ They found that patients performed significantly better as length of cochlear implant use increased and age at implantation decreased. They also found a trend in patients who had received their implants at a lower age toward better performance despite the shorter duration of wearing those implants, a finding which failed to reach statistical significance level.

In a retrograde cohort study of 70 prelingually deaf children with cochlear implants, Harrison et al. used a binary partition algorithm to optimally divide the results of open- and closed-set speech perception for up to five years of follow-up based on age at implantation.²⁵ They found that for the closed set test the optimal dividing occurs at 4.4 years of age at the time of implantation and for the open set tests this occurs at a higher range from 5.6 to 8.4 years, in both of tests the lower age divisions had a better test result than the upper one.

In a follow-up study of 33 prelingually deaf children who had received Combi 40/40+ cochlear implants, Baumgartner et al. compared the results of the Evaluation of Auditory Response to Speech (EARS) test battery at regular intervals up to 36 months after implantation between children based on their age at the time of surgery.²⁶ They found that children who had received their implants before age of 3 achieved higher levels of speech perception performance than children who had received their implants after age of 3. In a study designed to assess the model at which age at the time of implantation acts as an influencing variable on speech perception, El-Hakim et al. found that although the growth rate of speech understanding was related to age at implantation, this did not occur in a simple fashion.²¹ They used binary partitioning in an attempt to find the age at implantation that best separates the performance of children with younger versus older ages at implantation and they found that there was no on "critical age" and much appeared to depend on the nature and difficulty of the tests used.

In another study, Kirk et al. studied the effect of age at the time of implantation in a group consisted of 73 participants who were prelingually deaf children received cochlear implantation before age of five years.¹³ They measured the speech and language outcomes at successive six-month post-implantation intervals and

using a mixed model analysis they found that the children who had received their implants before age of 3 years showed faster rates of language development.

On the other hand, there are some other studies who have not found this effect of age. For example, Gantz et al. in a study consists of a five-year cohort of 55 prelingually deaf children, have reported that the age of implantation of the prelingually deaf cochlear implant users only had a slight effect on their performance with the cochlear implant.⁶ They suggested that the influence of age will disappear after some years of training. Also, in a physiologic study aimed to define the physiologic basis of the effect of age at implantation on speech recognition abilities, Sharma et al. used the P1 latencies in auditory evoked potentials as a measure of central auditory deprivation.²² They compared this measure between a group of 18 congenitally deaf children who were fitted with cochlear implants by 3.5 years of age and a group of age-matched normally hearing children. They found that the P1 latencies of cochlear implanted children had not differed significantly from the control group and they attributed the better speech recognition abilities in this group of cochlear implanted children to the better preserved central auditory system.

One of our limitations was measuring the outcome. To achieve precise results, it is necessary to perform the audiometry with expert and trained audiologist.

The findings of the present study suggest that the main effect of age found in other studies were not due to an effect on hearing abilities of patients and other factors, such as better rehabilitation at younger age, should be assumed as the possible explanation for previous findings. We now have started specific studies to explore these possibilities.

References

- 1 Miyamoto RT, Kirk KI, Svirsky MA, Sehgal S. Communication skills in pediatric cochlear implant recipients. *Acta Otolaryngol* 1999; 119: 219-24.
- 2 Tyler RS, Fryauf-Bertschy H, Kelsay DM, et al. Speech perception by prelingually deaf children using cochlear implants. *Otolaryngol Head Neck Surg* 1997; 117: 180-7.
- 3 Osberger MJ, Kalberer A, Zimmerman-Phillips S, et al. Speech perception results in children using the Clarion Multi-Strategy Cochlear Implant. *Ann Otol Rhinol Laryngol Suppl* 2000; 185: 75-7.
- 4 Waltzman SB, Cohen NL, Gomolin RH, et al. Open-set speech perception in congenitally deaf children using cochlear implants. *Am J Otol* 1997; 18: 342-9.
- 5 Fryauf-Bertchy H, Tyler RS, Kelsay DM, Gantz BJ. Performance over time of congenitally deaf and postlingually deafened children using a multichannel cochlear implant. *J Speech Hear Res* 1992; 35: 913-20.
- 6 Gantz BJ, Tyler RS, Woodworth N, et al. Results of multichannel cochlear implants in congenital and acquired prelingual deafness in children: five year follow-up. *Am J Otol* 1994; 15: 1-7.
- 7 Robbins AM, Kirk KI, Osberger MJ, Eetmer D. Speech intelligibility of implanted children. *Ann Otol Rhinol Laryngol* 1995; 166: 399-401.
- 8 Cohen NL, Waltzman SB, Roland JT, et al. Early results using the nucleus CI24M in children. *Am J Otol* 1999; 20: 198-204.
- 9 Snik AF, Makhdom MJ, Vermeulen AM, et al. The relation between age at the time of cochlear implantation and long-term speech perception abilities in congenitally deaf subjects. *Int J Pediatr Otorhinolaryngol* 1997; 41: 121-31.
- 10 Fryauf-Bertchy H, Tyler RS, Kelsay DM, et al. Cochlear implant use by prelingually deafened children: the influences of age at implant and length of device use. *J Speech Lang Hear Res* 1997; 40: 183-99.
- 11 Nikolopoulos TP, O'Donoghue GM, Archbold S. Age at implantation: its importance in pediatric cochlear implantation. *Laryngoscope* 1999; 109: 595-9.
- 12 Hammes DM, Novak MA, Rotz LA. Early identification and cochlear implantation: critical factors for spoken language development. *Ann Otol Rhinol Laryngol Suppl* 2002; 189: 74-8.
- 13 Kirk KI, Miyamoto RT, Lento CL, et al. Effects of age at implantation in young children. *Ann Otol Rhinol Laryngol Suppl* 2002; 189: 69-73.
- 14 Baumgartner WD, Pok SM, Egelierler B, et al. The role of age in pediatric cochlear implantation. *Int J Pediatr Otorhinolaryngol* 2002; 62: 223-8.
- 15 El-Hakim H, Abdolell M, Mount RJ, et al. Influence of age at implantation and of residual hearing on speech outcome measures after cochlear implantation: binary partitioning analysis. *Ann Otol Rhinol Laryngol Suppl* 2002; 189: 102-8.
- 16 Kileny PR, Zwolan TA, Ashbaugh C. The influence of age at implantation on performance with a cochlear implant in children. *Otol Neurotol* 2001; 22: 42-6.

- 17 Harrison RV, Panesar J, El-Hakim H, et al. The effects of age of cochlear implantation on speech perception outcomes in prelingually deaf children. *Scand Audiol Suppl* 2001; (53): 73-8.
- 18 Baumgartner WD, Pok SM, Egelierler B, et al. The role of age in pediatric cochlear implantation. *Int J Pediatr Otorhinolaryngol* 2002; 62: 223-8.
- 19 Abdi S, Khalessi MH, Khorsandi M, Gholami B. Introducing music as a means of habilitation for children with cochlear implants. *Int J Pediatr Otorhinolaryngol* 2001; 59: 105-13.
- 20 Sharma A, Dorman M, Spahr A, Todd NW. Early cochlear implantation in children allows normal development of central auditory pathways. *Ann Otol Rhinol Laryngol Suppl* 2002; 189: 38-41.
- 21 Jack Katz. Hand book of clinical audiology. 3rd ed. Buffalo, New York; 1985. p. 650.
- 22 Delaroche M, Thiebaut R, Dauman R. Behavioral audiometry: protocols for Measuring hearing thresholds in babies aged 4-18 months. *Int J Pediatr Otorhinolaryngol* 2004; 68: 1233-43.
- 23 Gray RF, Jones SE, Court I. Cochlear implantation for progressive hearing loss. *Archives of Disease in Childhood* 2003; 88: 708-11.
- 24 Copeland BJ, Pillsbury HC 3rd. Cochlear implantation for the treatment of deafness. *Annual Review of Medicine* 2004; 55: 157-67.
- 25 Horn DL, Davis RA, Pisoni DB, Miyamoto RT. Behavioral inhibition and clinical outcomes in children with cochlear implants. *Laryngoscope* 2005; 115: 595-600.
- 26 Paatsch LE, Blamey PJ, Sarant JZ, Bow CP. The effects of speech production and vocabulary training on different components of spoken language performance. *J Deaf Stud Deaf Educ* 2006; 11: 39-55.