Available online at www.sciencedirect.com
SCIENCE DIRECT®
Hearing Research 203 (2005) 2–9
HEARING RESEARCH
www.elsevier.com/locate/heares

Preoperative differences of cerebral metabolism relate to the outcome of cochlear implants in congenitally deaf children

Hyo Jeong Lee [a], Eunjoo Kang [b], Seung-Ha Oh [a,*], Hyejin Kang [b], Dong Soo Lee [b], Myung Chul Lee [b], Chong-Sun Kim [a]

[a] Department of Otolaryngology-Head and Neck Surgery, College of Medicine, Seoul National University
[b] Department of Nuclear Medicine, College of Medicine, Seoul National University, 28 Yongon-dong, Chongro-gu, Seoul 110-744, Republic of Korea

Received 10 March 2004; accepted 15 November 2004
Available online 22 December 2004

Abstract

In congenitally deaf children, chronological age is generally accepted as a critical factor that affects successful rehabilitation following cochlear implantation (CI). However, a wide variance among patients is known to exist regardless of the age at CI [Sarant, J.Z., Blamey, P.J., Dowell, R.C., Clark, G.M., Gibson, W.P., 2001. Variation in speech perception scores among children with cochlear implants. Ear Hear. 22, 18–28]. In a previous study, we reported that prelingually deaf children in the age range 5–7 years at implantation showed greatest outcome variability [Oh S.H., Kim C.S., Kang E.J., Lee D.S., Lee H.J., Chang S.O., Ahn S.H., Hwang C.H., Park H.J., Koo J.W., 2003. Speech perception after cochlear implantation over a 4-year time period. Acta Otolaryngol. 123, 148–153]. Eleven children who underwent CI between the age of 5 and 7 1/2 years were subdivided into a good (above 65%: GOOD) and a poor (below 45%: POOR) group based on the performance in a speech perception test given 2 years after CI. The preoperative ^{18}F-FDG-PET (F-18 fluorodeoxyglucose positron emission tomography) images were compared between the two groups in order to examine if regional glucose metabolic difference preexisted before the CI surgery. In the GOOD group, metabolic activity was greater in diverse fronto-parietal regions compared to the POOR group. In the POOR group, the regions related to the ventral visual pathway showed greater metabolic activity relative to the GOOD group. These findings suggest that the deaf children who had developed greater executive and visuospatial functions subserved by the prefrontal and parietal cortices might be successful in auditory language learning after CI. On the contrary, greater dependency on the visual function subserved by the occipito-temporal region due to auditory deprivation may interfere with acquisition of auditory language after CI.

Keywords: Cochlear implants; Brain imaging; PET; Deafness

1. Introduction

Previous literature on the outcome of cochlear implantation (CI) has consistently reported large individual variations among implant users. Some prelingually deafened children show outstanding outcome following the CI, rapidly acquiring spoken language and producing intelligible speech. Other children, however, develop awareness of sounds but never reach the age-appropriate level of auditory language.

Several traditional demographic factors explained 35–51% of the observed variance of the outcome among implanted children. These factors included duration of deafness, age at implantation, mode of communication, duration of device use and coding

Abbreviations: CI, cochlear implantation; ^{18}F-FDG-PET, F-18 fluorodeoxyglucose positron emission tomography; MNI, Montreal Neurological Institute coordinates; FWHM, full-width-half-maximum; K-CID, Korean version of CID (Central Institute for the Deaf) sentence test; BA, Brodmann area

* Corresponding author. Tel.: +82 2 760 2442; fax: +82 2 745 2387.
E-mail address: shaoh@snu.ac.kr (S-H. Oh).

0378-5955/$ - see front matter
doi:10.1016/j.heares.2004.11.005

strategy (O'Donoghue et al., 2000; Miyamoto et al., 1994; Sarant et al., 2001; Hammes et al., 2002). Of these, the age at implantation has been reported to be the major determinant of pediatric cochlear implant candidacy (Nikolopoulos et al., 1999). Other previous work have demonstrated that children who undergo implantation at a younger age achieve a significantly better communication outcome and develop spoken language faster than those who undergo implantation at an older age (Fryauf-Bertschy et al., 1997; Hammes et al., 2002; Kirk et al., 2000; Waltzman and Cohen, 1998). Almost all the deaf children who receive CI surgery at a very young age such as before 2 or 3 years old do very well with the device unless the children have any other disadvantage (Waltzman and Cohen, 1998; Hammes et al., 2002). On the other hand, congenitally deaf patients implanted in later childhood show a widely variable outcome. They are likely to have poorer outcome than those implanted earlier but some adult congenitally deaf were reported to show considerable open set speech understanding (Waltzman et al., 2002). It needs to investigate what determines this wide variability in the older children besides the well known demographic factors.

In fact, the pediatric cochlear implant candidates are widely heterogeneous with respect to several characteristics, e.g., audiologic status, language ability and cognitive function. These factors may account for CI outcome but they have not been fully investigated because of the lack of valid and reliable measuring tools.

Biological factors have also been investigated in past. For example, a histopathological study (Nadol et al., 2001) examined the relationship between the residual spiral ganglion cell populations in the temporal bones of CI patients with their speech perception ability during life. However, the unexpected negative correlation between them suggested that certain processes in the central auditory pathway are at least as important as peripheral factors.

Further research using a new approach is needed to understand the large individual variance observed in the CI performance outcome. Several neuroimaging studies have shown brain activity differences in various brain regions between cochlear implant users and normal hearing individuals (Naito et al., 1997, 2000; Roland et al., 2001; Giraud et al., 2000). However, few neuroimaging studies have been undertaken to identify those differences in the central auditory pathway that predict the functional outcome of implantation. Our past work (Lee et al., 2001) showed an association between better speech perception after CI and a greater extent of presurgical hypometabolism (decreased glucose metabolism) in superior temporal regions, including primary auditory area. However, the deaf patients with various duration of implant use and various age at implantation (i.e., duration of deafness in case of the congenitally deaf) were included in the past study although those factors were corrected statistically.

Recently, we reported the CI outcomes based on a 4-year follow-up (Oh et al., 2003) where a statistically significant negative correlation was found between the age at implantation and speech perception ability in the prelingually deaf child group, which was in accord with the findings of other researchers (Nikolopoulos et al., 1999; O'Donoghue et al., 2000). In addition, it was brought to our attention that there was an apparent age transition zone between 5 and 7 years old, where the most variable outcomes were found even though subjects were in a narrow age range.

In the present study, we were interested in identifying preoperative brain regional differences which were associated with the variable degree of CI outcome in the congenitally deaf children at this transitional age period (5–7 years old). Resting cortical metabolic activity was assessed using ^{18}F-FDG-PET in these patients before CI. We included only a group of patients who were similar in the known prognostic factors such as duration of deafness, age at implantation, cause of deafness, developmental history, and educational setting. These children, nevertheless, showed a wide range of outcomes following CI. We removed the age factor as a potential variable of CI outcome by including the pediatric patients only in this age group. We compared two groups of deaf children (one with a 'good' and the other with 'poor' outcome) who were comparable in implantation age (5–7.5 years old) and in the length of rehabilitation (about two years after implantation) in order to find if there were differences in preoperative brain metabolic status.

2. Materials and methods

2.1. Subjects

From November 1988 to April 2001, 111 profoundly hearing impaired children received cochlear implants at Seoul National University Hospital, and 61 children with congenital deafness were followed for 2 years after implantation. Of these, 26 children, between the ages 5 and 7.5, have had cochlear implants since we started an ongoing ^{18}F-FDG-PET study in 1997. Ten children with a history of medical illness known to affect neurological development (meningitis, neonatal jaundice, congenital rubella), or any known psychological illness (autism), or any evidence of inner ear anomaly proven by high resolution computed tomography of the temporal bone were excluded. Five children were excluded because their parents did not agree to the PET scan. Finally, 11 children (7 boys and 4 girls) aged from 5 to 71/2 years at implantation were included and their