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The effect of device use after sequential bilateral cochlear implantation in children: An electrophysiological approach

Marloes Sparreboom *, Andy J. Beynon, Ad F.M. Snik, Emmanuel A.M. Mylanus

Donders Institute for Brain, Cognition and Behaviour, Department of Otorhinolaryngology, Head and Neck Surgery, Hearing and Implants, Radboud University Medical Centre Nijmegen, The Netherlands

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ABSTRACT

Objectives: In many studies evaluating the effect of sequential bilateral cochlear implantation in congenitally deaf children, device use is not taken into account. In this study, however, device use was analyzed in relation to auditory brainstem maturation and speech recognition, which were measured in children with early-onset deafness, 5–6 years after bilateral cochlear implantation. We hypothesized that auditory brainstem maturation is mostly functionally driven by auditory stimulation and is therefore influenced by device use and not mainly by inter-implant delay.
Methods: Twenty-one children participated and had inter-implant delays between 1.2 and 7.2 years. The electrically-evoked auditory brainstem response was measured for both implants separately. The difference in interaural wave V latency and speech recognition between both implants were used in the analyses. Device use was measured with a Likert scale.
Results: Results showed that the less the second device is used, the larger the difference in interaural wave V latencies is, which consequently leads to larger differences in interaural speech recognition.
Conclusions: In children with early-onset deafness, after various periods of unilateral deprivation, full-time device use can lead to similar auditory brainstem responses and speech recognition between both ears. Therefore, device use should be considered as a relevant factor contributing to outcomes after sequential bilateral cochlear implantation. These results are indicative for a longer window between implantations in children with early-onset deafness to obtain symmetrical auditory pathway maturation than is mentioned in the literature. Results, however, must be interpreted as preliminary findings as actual device use with data logging was not yet available at the time of the study.

1. Introduction

Cochlear implantation has led to major changes in auditory, speech and language development for deaf children. The outcomes between children, however, vary considerably [1,2]. Age at implantation is one of the most important predictors for outcomes [1,3,4]. For maturation of the auditory pathways, cochlear implants (CIs) should be implanted preferable as young as possible. Worldwide, children with congenital deafness are increasingly provided with bilateral cochlear implants (BiCIs) [5]. As a result, more congenitally deaf children and their parents opt for a sequentially placed second cochlear implant (CI) after longer periods of unilateral CI use. Some studies show that the period of unilateral deprivation in these sequentially implanted children might have a detrimental effect on the outcomes with BiCIs [6–8]. In addition, the performance with the second CI (CI2) often lags behind that of the first CI (CI1) [8–10]. Many studies, however, did not consider the effect of device use of the CI2 on the outcomes. Some studies showed that in these sequentially implanted children, BiCI use was not full time. Irrespective of the delay between the two implantations, device use is likely to have an influence on the performance with a CI2 or on the bilateral benefit to be obtained. In agreement, Sparreboom et al [11] showed that, in sequentially implanted children, the less the CI2 device was used, the larger the difference in speech recognition was obtained by the CI1 and CI2 separately. It may be possible that both inter-implant delay and device use of the CI2 influence to what extent the performance becomes symmetric between CI sides. It is plausible to assume that after longer periods of unilateral CI use, the auditory system is no longer able to adapt to the input of a CI2. A more objective manner to measure plasticity of the auditory system is to use auditory evoked potentials.

In congenitally deaf children, the auditory system starts to develop after unilateral cochlear implantation. A relatively easy and robust measure to gain insight into auditory maturation is the auditory brainstem response (ABR). The ABR is the result of a far-field brainstem activity evoked by the onset of a stimulus [12]. The ABR consists

* Corresponding author at: Department of Otorhinolaryngology, Head and Neck Surgery, Hearing and Implants, Radboud University Medical Centre, 383 KNO-CI, P.O. Box 9101, 6500 HB Nijmegen, The Netherlands. Tel.: +31 24 361 48 17; fax: +31 24 354 02 51.
E-mail address: Marloes.Sparreboom@Radboudumc.nl (M. Sparreboom).

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of seven peaks, of which waves I, III and V are most commonly described in the literature. In children with normal hearing, the ABR latencies decrease after birth, which is presumably caused by synaptic efficacy, myelinization and greater neural synchronization [12]. In case of click stimuli, these latencies show mature values after approximately 2 years of age. In children with CIs, the ABR can also be elicited electrically (EABR), although the response will appear 1.0–1.5 ms earlier due to lack of acoustic wave traveling time. In contrast to the ABR, wave I of the EABR is often not visible due to the electrical stimulus artifact. After unilateral cochlear implantation, the EABR wave V in children with early-onset deafness shows similar decrements in latency as in children with normal hearing [13]. Thai-Van et al [13] suggested that the duration of auditory deprivation had no impact on EABR maturation, as these children received a CI between 1.2 and 12.4 years. It is therefore likely to hypothesize that brainstem maturation is activity dependent, without a critical time window for stimulation. This implicates that in congenitally deaf children with longer periods of unilateral CI use, EABRs of the secondly implanted side will become similar with those of the experienced side after sequential bilateral cochlear implantation. In children with sequential BiCIs, at initial stages of BiCI use, children showed prolonged EABR wave V latencies evoked by the CI2 in comparison with those evoked by the CI1 [14]. In agreement with the above mentioned hypothesis, these interaural latency differences were no longer significant after 1 year of BiCI use. In contrast, Gordon et al [15] showed that in children with an inter-implant delay of more than two years, large interaural wave V latency differences remained after 9 months of BiCI use. These interaural latency differences were larger than those of children with short or no delays between both implantations [15]. These data suggest that longer periods of unilateral CI use before receiving a CI2 have a detrimental effect on brainstem development. Some studies indicate that a period of longer than 1.5 years between implantations leads to distorted maturation of the binaural pathways [7]. To our knowledge, however, the effect of device use on auditory brainstem maturation has never been investigated. On average, we know that approximately 25–35% of the children implanted sequentially are not full-time CI2 users [11,16,17]. When this factor is taken into account, the critical period for sequential bilateral cochlear implantation might be extended. We hypothesize that auditory brainstem maturation is activity-dependent to a certain extent and therefore, we investigated the effect of device use on the interaural EABR wave V latencies after long-term BiCI use.

The primary aim of the present study was to assess the long-term effect of sequential bilateral cochlear implantation on auditory brainstem maturation in children with early-onset deafness, when both device use and inter-implant were taken into account. We hypothesize that the maturation of the auditory brainstem is mostly functionally driven by stimulation and is therefore influenced by device use. The influence of inter-implant delay might be smaller than expected from the literature.

The secondary aim of this study was to assess the effect of device use and inter-implant delay on the long-term difference in speech recognition scores between the CI1 and CI2.

2. Material and methods

2.1. Subjects

A cohort of 30 children with early-onset deafness was followed longitudinally after sequential bilateral cochlear implantation (Nucleus® multichannel devices, Cochlear Corp. Australia). In the current prospective study, the data after 5–6 years of BiCI use are presented. After 5–6 years of BiCI use, 5 of the 30 children ceased wearing the CI2 for various reasons. Of the remaining 25 children, the parents of 24 children provided written consent to let their children participate in the study. Twenty-one of these children were willing to participate in the electrophysiological experiment. The study was approved by the Central Committee on Research Involving Human Subjects of the Radboud University Medical Centre.

Table 1
Subject characteristics of the 21 children participating in the study.

	Mean (SD)	Range
Age at CI1 (years)	1.7 (0.4)	0.9–2.3
Age at CI2 (years)	5.0 (1.7)	2.4–8.5
Inter-implant delay (years)	3.3 (1.6)	1.2–7.2
Age at testing (years)	10.8 (2.0)	8.2–14.6
Onset of deafness (months)	0.7 (2.8)	0.0–13.0
Etiology		
Acquired (%)	19.0	
Non-syndromic (%)	19.0	
Syndromic (%)	23.9	
Unknown (%)	38.1	

The eligibility criteria for bilateral cochlear implantation were: a unilateral CI before the age of 3 years; no residual hearing in the non-implanted ear; at least one year of unilateral CI use; no ossified cochleae or anatomic malformations that may compromise full insertion of the electrode array; no developmental, learning and/or behavioral deficits; and younger than 9 years of age. The mean age of unilateral implantation for the current study group was 1.7 years (range: 0.9–2.3 years). The mean age at bilateral cochlear implantation was 5.0 years (range: 2.4–8.5 years) and the mean inter-implant delay was 3.3 years (range: 1.2–7.2 years). All children were congenitally deaf, except for two who acquired deafness at 2 and 13 months, respectively. In Table 1, the subject characteristics are depicted.

2.2. Device use

At the time of the study, data logging was not yet available. Therefore, device use was defined in the same manner as Sparreboom et al [11]. Device use of both processors was categorized on a 5-point Likert scale as follows:

1. full-time user of CI2 (with the exception of use during sleep and bathing time)
2. wearing CI2 most of the time (e.g. sometimes not wearing CI2 after school or in weekends)
3. limited amount of CI2 use (e.g. only wearing at school)
4. CI2 non-use

As the children who ceased wearing their CI2 did not participate in the current study, only three of the four categories were applicable. During the test day, the child and his/her parents were interviewed and subsequently, device use was categorized by an experienced clinician.

2.3. Electrophysiologic recordings

The same electrophysiologic setup as described in Sparreboom et al [14] was used to measure EABRs. EABRs were evoked by biphasic pulses with a pulse width of 50 μs and an interphase gap of 7 μs, presented at a rate of 39 Hz, delivered on one medial electrode (electrode 11) from both implants separately. Stimuli were alternating in pulse polarity and were produced with Custom Sound EP 3.1 software (Cochlear Ltd.). Responses were obtained with four Ag/AgCl electrodes placed at both mastoids (noninverting electrodes), the vertex (reference electrode) and the cheek (ground electrode) using a Medelec Synergy multi-channel EP-system (Oxford Instruments, Oxfordshire, UK). High and low pass filter settings were set at 10 and 5000 Hz, respectively. The artifact rejection level was set at 50 μV.