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Sequential pediatric bilateral cochlear implantation: The effect of time interval between implants

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ABSTRACT

Objective: To examine speech intelligibility in children subjected to sequential bilateral cochlear implants (CI) surgery and to assess the influence of the inter-stage interval duration.
Introduction: Binaural hearing recovery can have additional benefits, especially in speech and language development in patients with congenital profound sensorineural hearing loss; so recently there has been an increase in the number of children receiving bilateral CI.
Methods: Twenty-seven children who underwent sequential bilateral cochlear implant (SBCI) with a short (1–3 yrs), medium (4–6 yrs) and long (7–12 yrs) range interval between both implantations, respectively, were evaluated. All patients underwent periodic speech perception test in quiet and noise after second implant activation in three conditions: with the first or second implant alone and with both implants. Results were examined according to the inter-stage interval.
Results: Speech intelligibility in noise was significantly better under bilateral conditions than either ear alone, in all three groups. Small improvements were seen in quiet, especially in the third group (6–12 yrs).
Conclusion: Benefits of second implant in the early-implanted children and after a short inter-implant delay are more evident. However our study support that, even after a long period of deafness and despite a prolonged inter-stage interval, sequential bilateral cochlear implantation should be considered.
Level of Evidence: Level 4.

1. Background

The cochlear implant (CI) has drastically modified the approach to deafness allowing a normal life for persons who are born deaf or those who have become severely or profoundly deaf. Literature has given evidence of better results compared to traditional hearing aids and studies now prove that bilateral cochlear implantation (BCI) achieves better results than the unilateral one (UCI), with consequent improvement of the quality of life [1].

BCI can be carried out in two ways: two consecutive surgeries (sequential bilateral cochlear implant- SBCI) and a single surgery (simultaneous cochlear implant-SCI). In the first option, the second CI can be applied at a distance of a few months to several years [2].

Compared to listening with one ear, binaural hearing improved speech understanding in noise and enabled sound localization [1,3]; moreover, the patients subjected to simultaneous bilateral implantation seem to acquire a better and precocious capacity for acquisition of perceptive ability compared to patients subjected to sequential cochlear implantation [2,4].

In the pediatric population, binaural hearing recovery may have additional benefits, especially in speech and language development; so recently there has been an increase in the number of children receiving BCI [5–7].

Besides families may choose to wait for a second implant for a variety of nonmedical reasons [4,8].

At a surgical level, SCI involves certain difficulties: positioning of patients, possible bilateral vestibular alterations, prolonged duration of intervention, detailed planning, risk of infection [2,4].

Although there are no randomised trials, observational studies generally show that the SCI is associated with higher speech and linguistic development than is achieved with the SBCI [9].

Despite the importance of early bilateral cochlear implantation has been recognized, variable results in speech perception between

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implanted patients are reported, concerning age at the time of implantation, duration, degree of the hearing loss, timing of the second implant and rehabilitation methodologies used [2]. The reason behind this variability is not completely understood, and there is no accurate way to predict outcome after implantation [10].

One of these variables, the inter-implant interval, has been the subject of several studies with conflicting opinions. The international consensus on bilateral cochlear implants and bimodal stimulation has not defined the maximum delay between the two implantation procedures, but a short interval of months might be helpful in achieving good performance without additional training and rehabilitation in prelingually deaf children [11].

Neurophysiological studies indicate that a long inter-implant interval is associated with prolonged latency peaks of the auditory brainstem and can have negative effects on its maturation process due to the temporal differences it can produce in hearing activity [9].

In this sense, the SBCI produces a discrepancy between the two sides of central processing and, consequently, delays in linguistic development.

Recently studies have emerged which hypothesize improvement of the auditory performance with the application of a second cochlear implant even after a long time interval following the first implant [12–14]. These considerations are found to be in contrast with other authors who come to the conclusion that after a long time interval, exceeding 3–5 years, no significant improvement will be obtained with the application of a contralateral implant [15,16].

The object of our retrospective study is to assess whether there is actually a direct relation between the inter-implant time and the postoperative results in the hearing ability of patients or whether the latency between the two surgeries, even of several years, influences the final results of the application of devices.

This study was particularly focused on measuring the effects of inter-stage interval after activation of the second implant on speech intelligibility performance.

2. Materials and methods

2.1. Subject selection

A retrospective study was conducted on 27 native Italian children who underwent sequential cochlear implantation between 2000 and 2015 at the Department of Otolaryngology and Audiology ASMN-IRCCS Hospital of Reggio Emilia (Italy). All children had congenital bilateral profound sensorineural hearing loss with no benefit from conventional hearing aids. To make the study population uniform, the forms of severe hypoacusia associated with inner ear anomalies or additional disabilities are excluded. Patients who underwent a bimodal hearing trial with hearing aids on the contralateral ear in the inter-stage interval between first and second cochlear implant were excluded. All subjects had a monolateral implant from the age of 1–6 years with good performance in the development of auditory perception and speech intelligibility. The choice of applying the second cochlear implant is due to the difficulties concerning patients with clear listening in noisy situations and limited opportunities for incidental learning in their daily lives with the first implant alone. All the patients included had a high level of compliance to achieve binaural benefits from the second implant despite the correct functioning of the first implant. Two patients were excluded because they no longer applied the second cochlear implant at the end of the follow-up at one year.

The subjects were classified into three groups according to the inter-stage intervals: group I (1–3 years); group II (4–6 years); group III (7–12 years) [Table 1].

2.2. Audiological test

A speech audiometry test in quiet and noise condition was conducted in free field in a soundproof booth and the scores (Word Recognition Score-WRS) were based on percent-correct of repeating a spoken word at a sound pressure level (SPL) of 65 dB. Italian bisyllabic word lists (Turrini et al., 1993) [17] were chosen to describe the patients' hearing abilities more accurately within the context of the native spoken language. The WRS in quiet condition was measured with the subject sitting one meter from the front loudspeaker. Speech recognition in noise condition was measured with a frontal speech and noise presentation (SoNo) and the signal-to-noise was fixed at + 10 dB.

Audiological tests were performed for each subject at 3, 6 and 12 months after the first fitting of the second cochlear implant in three different conditions: with the first CI alone, with both implants and with only the second CI activated in a repeated-measures analysis.

2.3. Statistical analysis

Audiological results of WRS were analysed retrospectively.

Patients with only the first implant activated act as the control group. The results of the WRS test of the control group were compared with the results obtained with only the second implant active and with the results obtained with both implants active (divided into three sub-groups according to the inter-implant interval).

Two-way repeated-measures analysis of variance was used to analyse statistical significance among device configurations and performance over time.

T test was used to compare the scores for the speech recognition test at time point of 12 months in all three conditions (with the first CI alone, with both implants and with only the second CI activated). Statistical significance was accepted at $p < 0.05$.

Mean WRS values of the three sub-groups, classified according to the inter-stage intervals, were compared by two-way ANOVA and Kruskal Wallis test.

All statistical analyses were performed using SPSS Statistics 20 (IBM, Armonk, NY) software.

3. Results

Twenty-five of all 27 participants completed the one-year follow-up protocol and they reported that bilateral CI was helpful to them in improving life listening situations.

Data measured by bisyllabic word lists in quiet condition are shown in Table 2 and Table 3.

Table 2 shows the results with the second implant alone vs results with the first implant alone, dividing the cases into three groups according to the duration of the inter-implant interval.

In the group 1 (1–3 years) and group 2 (4–6 years) the T test shows no statistically significant difference between the WRS with the 1st CI and the WRS with the 2nd implant alone at 12 months (respectively $p = 0.43$ and $p = 0.28$) although the positive responses percentage is better with the 1st CI.

In the group 3 (7–12 years) the T test shows a statistically significant difference between the WRS with the 1st CI and the WRS with the 2nd implant at 12 months ($p = 0.01$); the performances with the 2nd CI alone are the worst.

On the whole, the first implant works better than with the second used alone at 12 months (the difference between the mean values is significant [$p = 0.008$]).

However at look at the sub-groups, data shows that, in group 1 and group 2, the mean values between the first implant and second implant are not statistically significant (the performances with the