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Auditory brainstem implant outcomes and MAP parameters: Report of experiences in adults and children

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ABSTRACT

The auditory brainstem implant (ABI) was first developed to help neurofibromatosis type 2 patients. Recently, its use has been recently extended to adults with non-tumor etiologies and children with profound hearing loss who were not candidates for a cochlear implant (CI). Although the results has been extensively reported, the stimulation parameters involved behind the outcomes have received less attention.

Objective: The aim of this study is to describe the audiologic outcomes and the MAP parameters in ABI adults and children at our center.

Methods: Retrospective chart review. Five adults and four children were implanted with the ABI24M from September 2005 to June 2009. In the adult patients, four had Neurofibromatosis type 2, and one had postmeningitic deafness with complete ossification of both cochleae. Three of the children had cochlear malformation or dysplasia, and one had complete ossified cochlea due to meningitis. Map parameters as well as the intraoperative electrical auditory brainstem responses were collected. Evaluation was performed with at least six months of device use and included free-field hearing thresholds, speech perception tests in the adult patients and for the children, the Infant-Toddler Meaningful Auditory Integration Scale (IT-MAIS) and (ESP) were used to evaluate the development of auditory skills, besides the MUSS to evaluate.

Results: The number of active electrodes that did not cause any non-auditory sensation varied from three to nineteen. All of them were programmed with SPEAK strategy, and the pulse widths varied from 100 to 300 μs. Free-field thresholds with warble tones varied from very soft auditory sensation of 70 dBHL at 250 Hz to a pure tone average of 45 dBHL. Speech perception varied from none to 60% open-set recognition of sentences in silence in the adult population and from no auditory sensation at all to a slight improvement in the IT-MAIS/MAIS scores.

Conclusion: We observed that ABI may be a good option for offering some hearing attention to both adults and children. In children, the results might not be enough to ensure oral language development. Programming the speech processor in children demands higher care to the audiologist.

1. Introduction

Cochlear implants (CIs) are considered the gold standard of treatment for severe to profound sensorineural hearing loss. Nevertheless, there are situations in which the CI cannot be performed or there is no auditory nerve conduction, and auditory brainstem implants (ABIs) are the remaining option [1]. The Auditory Brainstem Implant (ABI) was the first device specifically designed to bypass the cochlea and the auditory nerve to transmit sound directly to the cochlear nucleus in the brainstem. It has been used in neurofibromatosis type 2 patients since it received FDA-approval as a medical device in 2000, but it is has recently been implanted in children and adults who have no indication to receive who cannot receive cochlear implants. Recently, data pointed out by the literature demonstrated that the ABI may provide open-set speech recognition in adults with non-tumor etiologies [2] and in children, with results that may be comparable to those of cochlear implants in children [3].

Grayeli et al. [4] reported the results of 23 NF2 patients with excellent and good results in more than 50% of the sample. Nevertheless, five NF2 patients could not get any auditory response

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with the ABI. Maini et al. [5] studied 10 post-lingually deaf patients who received ABIs due to NF2 at the Melbourne CI Clinic since 1995, with ages ranging from 17 months to 46 years. After a five-year follow up, seven patients were regular users, while two opted for sign language. One patient died of disease but was a regular user for up to two years after ABI. The authors observed a slight improvement of open-set detection over the years.

The fitting process with ABI patients is more complex than that with cochlear implant patients. As the ABI24M distributes the signal to the surface of the cochlear nucleus, and the frequency tonotopicity of the cochlear nucleus is not organized in its surface [6], the pitch sensation does not follow a predetermined order. Besides, the stimulation at threshold or comfort levels may induce non-auditory sensations which demands higher attention and care, especially in children.

Considering the complexity of programming and the variability in ABI patients outcomes, it is of clinical importance to understand the underlying factors involved in this process to improve the patient selection criteria and device programming.

The aim of this study was to describe the audiological outcomes and the MAP parameters in adults and children with ABI at a tertiary university hospital and to discuss the subtle differences in children and adults.

2. Materials and methods

This study was a retrospective chart review of nine subjects who received auditory brainstem implants between 2005 and 2009 at our institution. Four adults had neurofibromatosis type II (NF2) deafness, one adult and one child had post-meningitic deafness with complete cochlear ossification, and three children had cochlear malformations or aplasia. None of the children had any disabilities other than deafness. All NF2 patients received the ABI on their second side VIIIth tumor removal. All of them were implanted with a Nucleus 24 Multichannel ABI (Cochlear Ltd., Sydney, Australia), with either the retrolabyrinthine or translabyrinthine approach pending the presence of a tumor, for which the surgical technique has been reported elsewhere [7,8]. Adult and children in this sample had profound deafness in both ears, and the ear to be implanted was chosen according to the best anatomical and surgical conditions. None of them have useful hearing with hearing aids in the contralateral ear.

Patients' records were reviewed for the presence of intra-operative electrical auditory brainstem responses (EABRs), speech processor MAP parameters, hearing thresholds and speech perception at least six months after activation.

For the EABRs, a Bio-logic Navigator Pro was connected to the Portable Programming System or Pod with the specific trigger cable. The NRT 3.1 or Custom Sound 2.1 software was used with a SPrint or Freedom speech processor connected to the patient by the coil and a cable for the stimulation channel. For the register of the evoked potentials, the Bio-logic Navigator Pro was configured as trigger in, with standard filters (30 and 3000 Hz), 500 averages, an amplifier gain of 50,000 and artifact rejection off. The electrode montage included a positive electrode on the vertex, a negative on C7 (spine) and the ground at the hairline of the neck. During surgery, after the positioning of the electrodes in the fourth ventricle, EABR was initiated, stimulating electrodes in bipolar channels in the medial and lateral portions of the implant. At least eight combinations were explored in the EABR assessment (20-3, 21-2, 20-15, 21-14, 14-9, 15-8, 8-3, 9-2) [9]. The presence of EABR was considered when at least one wave was consistently registered in both polarities in at least two bipolar pairs of electrodes.

Initial stimulation occurred eight weeks after surgery at the intensive care unit with electrocardiographic monitoring and the assistance of an anesthetist. During the activation of the ABI in children, the child was kept involved in watching a movie or playing with a toy while any reactions, such as increased attention, smiles, crying or looking for the mother, were observed by two examiners to determine the number and the level of stimulation intensity of the electrodes. During follow up, conditioned responses were sought at all programming sessions. Programming parameters started with SPEAK coding strategy, monopolar mode of stimulation, 100 μs of pulse width. We began with 10 current units of stimulation level with increasing steps of 10 units until the first reaction was observed to determine threshold level (T level), then steps of 2 current units were used to seek for the comfort level (C level).

The fitting and programming protocol for adults and children followed Otto et al. [10] and Colletti [11]. The T and C levels of each electrode were assessed in monopolar mode to identify those that elicit auditory sensations. Electrodes that induced non-auditory sensations were deactivated. At the follow-up programming sessions, pitch orders were ranked with the patients of the adult population and were in reverse order for the child population, i.e., electrode 22 was set for the highest frequencies [10,12]. At regular intervals, deactivated electrodes were again tested to check for the possibility of activation in cases where auditory perception appears with no (of very low) side effects.

Map parameters, such as the position of active electrodes with auditory-only sensation, pulse width, stimulation mode, number of active channels, number of maxima, lowest frequency and highest frequency in the frequency allocation table (FAT) range and non-auditory side effects, were collected to highlight differences among patients.

Hearing thresholds were measured in free-field sound booth with warble tones, with a Madsen Midimate 622 audiometer, using visual reinforcement when appropriate. Pure tone average followed BIAP (1996) [13] recommendation which considers the average of the thresholds at 500, 1000, 2000 and 4000 Hz.

For the adult population, speech performance was assessed with closed- and open-set speech recognition tests included vowel identification, words and sentences in quiet presented in live voice at 70 dBSPL. For the children, Infant-Toddler Meaningful Auditory Integration Scale (IT-MAIS) and Early Speech Perception (ESP) were used to evaluate the development of auditory skills, and the Meaningful Use of Speech Scale (MUSS) was used to detected early outcomes on speech production skills according to the Brazilian Portuguese protocol [14,15]. The cognitive style of the child was scored based on Bevilacqua et al. [16]. Regarding the cognitive profile or style, Bevilacqua and colleagues [16] had selected 20 behaviors that are expected in the child development and some others that, when present, might be indicators of deviant development. These behaviors are scaled by frequency of occurrence in a 5-point scale, from never observed (0%), rarely observed (25%), occasionally observed (50%), frequently observed (75%) to always observed (100%).

3. Results

All of the patients, except for one NF2 adult, were regular users of the device, with more than 6 h a day of implant use. The other patient (case 2) was a daily user for at least 2 h a day because of her poor health conditions.

Table 1 shows their demographics such as gender, age at implantation, side of implantation, and pre-implant residual hearing. The presence of residual hearing was considered when some access of speech sounds (pure tone thresholds $\leq$ 50 dBHL) was achieved with hearing aids in either ear. Fig. 1 shows an example of the intraoperative EABRs of one of the implanted patients. Although in this case we could identify 4 waves (from II to V), it is not a typical EABR response, considering generally 1 or 2