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Analysis of electrical thresholds and maximum comfortable levels in cochlear implant patients

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ABSTRACT

Objective: It is well known that a proper fitting of the cochlear implant processor is relevant to provide good quality in speech perception. The aim of this study is to extract statistical information to be applied for fitting the processor.

Methods: This study is based on the programming maps of 121 patients, aged from 18 months to 68 years at the moment of implantation. All subjects were implanted with the COMBI 40+ cochlear implant at San Cecilio University Hospital, Granada (Spain). The patients were classified into groups based on their age at implantation: younger than 5 years, between 5 and 16 years, and older than 16 years. The patients in each age-based group were divided into two subgroups, considering whether they had recent hearing experience or not. A special group including patients affected by severe damages in the cochlea was also defined.

Results: Relationships between the programming parameters and factors like the age at implantation, the hearing experience and the presence of severe cochlear damage were found. The THR levels for patients younger than 5 years were significantly lower than those for patients implanted between 5 and 16 years, and this group presented significantly lower THR levels than adults. The MCL levels were not significantly influenced by the age at implantation. A significant increment was observed for both, MCL and THR levels, when patients were affected by severe cochlear damage. A significant increment in the THR levels were observed for patients with no recent hearing experience, while no significant differences were found for MCL levels. This study also analyzes the distribution along the cochlea of the stimulation levels. In the case of patients not affected by severe cochlear damage, the most basal electrodes presented a significant increment in the stimulation levels with respect to the rest of electrodes.

Conclusion: This work provides information of great value for programming the speech processors, particularly when the subjective responses of the patients are not sufficient. The application in our ENT Service has reduced substantially the average time needed to obtain an acceptable fitting of the processor, especially in children. Our study also shows that electrical thresholds are a good indicator of the functionality of the auditory nerve. The analysis of this parameter highlights the importance of an early intervention as well as a deep insertion of the electrode carrier in order to obtain the maximum functionality from the cochlear implant.

1. Introduction

Electrical stimulation of the auditory nerve using cochlear implants constitutes an important step forward in the treatment of profound deafness. In multichannel cochlear implant systems, the input audio signal is split into frequency bands and the stimulation of each region of the cochlea (the cochlear partition associated to each channel) depends on the power of the signal in the corresponding spectral band. The power in each band is mapped into electrical impulses emitted by each electrode according to the coding strategy and the programming parameters obtained during the fitting sessions [1,2]. Therefore, obtaining all the potential benefits from the cochlear implant system requires accurate programming of the speech processor.

In order to program the multichannel cochlear implant system, each channel must be checked in order to (a) verify the functionality of the electrode; (b) estimate the perceptual threshold (THR) of the electrical impulses, i.e. the minimum

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stimulation level the patient can perceive in this channel; and (c) estimate the maximum comfortable level (MCL), i.e. the maximum stimulation level the patient can accept without uncomfortable sensation. Based on these estimations, the dynamic range in each audio band is mapped into the electrical dynamic range in the corresponding channel, defined by the THR and MCL levels for this electrode. An improper programming of the processor degrades the quality of the hearing perception and it usually causes an uncomfortable perception of the sound [3,4].

Usually, the information necessary for programming the speech processor is obtained from subjective responses to series of electrical impulses presented to the patient on different electrodes. This procedure is relatively easy for postlingually deafened adults but becomes more difficult in the case of very young children, prelingually deafened subjects, and in general, in case of poor auditory experience or extreme limitations in the communication skills. In these cases, the information obtained from objective measures can be useful to evaluate the functionality of the electrodes and to estimate the THR and MCL levels [5–9] even though the objective methods present some limitations [6,7,10,11]. When the subjective response is not clear enough for the programming requirements, the audiologist can also obtain information from behavioral audiometry, behavioral observation techniques and other indirect observation-based methods [12–14]. In these situations, the estimation of an accurate map takes longer (in some cases several months since the first switch-on) which delays obtaining benefits from the cochlear implant.

Based on our clinical experience with cochlear implanted patients, we have found in a previous work that a statistical analysis of the programming maps can provide useful information to be applied to program the processors [15]. The present paper is devoted to the analysis of the stimulation levels in cochlear implanted patients and its application for programming the speech processors. The study is based on the programming maps estimated for the patients implanted in our ENT department. We analyze relationships between stimulation levels (THR and MCL parameters) and factors like age at implantation, damage to the cochlear structures, and the etiology and duration of the deafness. We also analyze the variations along the cochlea of the stimulation levels. In this paper we present a statistical analysis of the programming maps and we discuss the application of the presented results for the first fittings of the cochlear implant processors, particularly for those patients providing poor information for the estimation of the THR and MCL parameters.

2. Materials and methods

2.1. Subjects

Our analysis is based on measurements taken from 121 patients implanted in our ENT department, with ages at implantation between 18 months and 68 years. The patients were implanted with the 12 channels COMBI 40+ implant device at San Cecilio University Hospital, Granada (Spain). The patients are distributed into groups based on their age at implantation: younger than 5 (36.4% of the subjects), between 5 and 16 (26.4%), and older than 16 years (22.3%). A special group including patients affected by meningitis, otosclerosis and other severe damages in the cochlea is also defined. This group is labeled as SCD (severe cochlear damage) and includes 14.9% of the patients. The age-based groups have been split into two subgroups taking into account the duration of the deafness (ranged from 4 months to 22 years) and the hearing experience. The criterion for the inclusion in the RHE (recent hearing experience) category is that the aided pure tone hearing threshold (averaged between 250 and 4000 Hz) is below 60 dB at least during the first half of the lifetime in the case of children implanted before 5 years, and at least until 3 years before the implantation for the rest of the patients. Otherwise the patients have been categorized in the No-RHE group. Table 1 shows the distribution of patients considered in this study taking into account the age-based groups, the presence of cochlear damage and the hearing experience. The study was approved by the Ethic Committee of San Cecilio University Hospital, Granada (Spain).

Table 1
Number of patients in each group considering the age at implantation, the presence of severe cochlear damage (SCD) and the recent hearing experience (RHE).

Age		RHE	
0–5	44	No-RHE	36
		RHE	8
5–16	32	No-RHE	21
		RHE	11
>16	27	No-RHE	6
		RHE	21
SCD	18		

2.2. Procedures

The present study is based on the analysis of the programming parameters in these cochlear implanted patients. The data presented in this paper is a statistical analysis of subjective measurements of the THR and MCL parameters obtained during the fitting sessions. The procedure to obtain the stimulation levels is described below.

The speech processor is fitted and switched-on at first time 4 weeks after the surgery. In this session the audiologist determines the functionality of the different electrodes taking into account X-ray images, telemetry information and the response of the patient to electrical stimuli. The audiologist also obtains a first estimation of the THR and MCL levels from the subjective responses to electrical stimuli presented at each electrode at different levels.

During the next weeks (typically between 2 and 8, depending on the case), the patient is treated and studied by a group of specialists (including speech therapist, psychologist and audiologist). They help the patient in the development of basic skills in perception, discrimination, identification of speech sounds or speech understanding, depending on his/her previous abilities and hearing experience. This team also evaluates the evolution in the perception capability of the patient by means of behavioral or pure tone audiometries, perception tests, discrimination tests and other indirect methods adapted to the age and abilities of each patient. During this period, this information is used by the audiologist as a feed-back for a more accurate estimation of the THR and MCL levels in order to improve the performance of the cochlear implant.

Obtaining an accurate enough programming map typically requires between 2 weeks and 4 months, depending on the collaboration of the patient, his/her expressiveness, the attention capability, etc. After 6 months from the first fitting, almost all the patients have an accurate map programmed in their processors. The validity of the programming parameters is confirmed by several tests and most of the patients provide responses in pure tone audiometries for levels between 25 and 40 dB (HTL).[1] In the present study, we have considered the data in the programming maps obtained at least 6 months after the first switch-on of the processor, according to the above described process. We have considered this minimum experience in order to guarantee the

[1] These thresholds are averaged over the frequencies 250, 500, 1000, 2000 and 4000 Hz.