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Isabelle Mosnier, Olivier Sterkers, Yann Nguyen, Ghizlene Lahlou

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Isabelle Mosnier, MD; Olivier Sterkers, MD, PhD ; Yann Nguyen, MD, PhD ; Ghizlene Lahlou, MD

Sorbonne Université-APHP6, Groupe Hospitalo-Universitaire Pitié-Salpêtrière, Service ORL, Unité fonctionnelle Implants auditifs, Paris, France.

Corresponding author : Isabelle Mosnier, MD
GHU Pitié-Salpêtrière, UF Implants auditifs et explorations fonctionnelles, Bâtiment Paul Castaigne,47-83 Boulevard de l'Hôpital, 75013 Paris, France
email : isabelle.mosnier@aphp.fr
phone : +(33) 1 42 16 26 06
fax : +(33) 1 42 16 26 05

Running Title: Cochlear implant for life.

No conflict of interest
No funding.
Written informed consent was obtained from each subject before enrolment into the study (CNIL n° 2040853v0).

Acknowledgements: We gratefully acknowledge the help of Solange Lator for assistance in data collection.

Abstract

Purpose: Some oldest patients rehabilitated with a cochlear implant more than 20 years ago could still be upgraded with new generations of speech processor (SP). The aim of this study was to show the benefit of a recent generation of SP in this population.

Methods: A monocentric prospective study was designed to evaluate the performance of 33 ancient CI22M users implanted between 1989 and 1997 and upgraded with the late compatible sound processor CP900. Performance were evaluated in quiet and noise with Framatix, an automated adaptative test.

Results: Performance using Framatix significantly improved with the CP900, with a decrease of the median speech perception threshold of 6 dB in quiet ($p<0.05$) and 5,3 dB in noise ($p<0.0005$). No subjective benefit using the APHAB questionnaire was observed.

Conclusion: Upgrading of cochlear implant recipients who were implanted more than 20 years ago with recent compatible and new technological SP provide benefit in speech recognition in noise.

Key words: long-term benefit, hearing in noise, upgrading, speech processor.

Introduction

Deafness has been established to play a key role on cognitive functions all along the life, as early deafness restoration permits development of language [1], deafness at mid-age is the main modifiable factor for dementia [2], and profoundly deaf rehabilitation by cochlear implant (CI) in elderly reduces dramatically cognitive impairment and its evolution to dementia [3]. Multichannel CI available since the late 1980s has changed the life of severe to profoundly deaf people [4], who would further gain benefit from new technologies by upgrading the external sound processor (SP). New SP generation has improved dramatically CI performance in noise intelligibility for most patients [5-7]. However, some oldest CI implanted more than 20 years ago could not be upgraded with new SPs due to the lack of compatibility for some brands of CI. It raised the question of surgical reimplantation of the internal part in this population which would have concerned at most more than 600 recipients implanted before 2000 in France. The aim of this study was to show the benefit of a recent generation of SP in the oldest CI population.

Methods

A monocentric study was prospectively conducted on CI recipients, implanted between 1989 and 1997 with the first generation of CI (CI22M, Cochlear, Sydney, Australia), to test the benefit of the more recent compatible SP (CP 900). Among 63 implanted patients, 17 were either lost of follow-up or deceased, 11 others were not eligible for a reimbursement of a new SP, and 2 had incomplete data. Finally 33 daily CI22M users for 21±2.2 years (range: 19-26) were included. Among them, 16 pre-lingual, 2 peri-lingual, and 15 post-lingual subjects with a profound to total hearing loss were implanted at 5 years (range: 3-16), at 37 and 38 years, and at 36 years (range: 16-60), respectively. Demographic data of the population are described in Table 1. The current SP at the time of the upgrade was a Freedom and an ESPrit 3G SP for 31 and 2 subjects respectively, and all of them used the SPEAK coding strategy. Characteristics of the three generations of SP were indicated in Table 2. The CP 900 SP was fitted with the same SPEAK strategy and the same MAP characteristics as was used in the original processor. Three programs were available: 2 new automatic signal processing algorithm programs (SCAN) and a non-SCAN program with the same options used as in the original SP (Table 1). CI users were tested with their current revised SP, and at 2 months post-upgrade with the CP900 with their preferred program, in a soundproof room with two lists of monosyllabic words presented at 60 dB SPL in quiet (Lafon list) and for the best performers, with an automated adaptive test in quiet and noise (Framatrix [8]), with the current revised SP and the CP900 at 2 months post-upgrade. Subjective perceptions were evaluated using the Abbreviated Profile of Hearing Aid Benefit (APHAB) questionnaire [9]. The results for each test session were compared independently. Scores for words in quiet, the Framatrix test and the APHAB questionnaire were not normally distributed, so a non-parametric Wilcoxon paired test were used. A p value of less than 0.05 was considered to be significant.

Results

Two months after upgrading first generations of internal receiver (CI22M) with the CP900 SP, 31 out of the 33 patients used the SCAN programs all day long (Table 1). No change was observed in quiet for median scores of words (41% *vs* 43%) and phonemes (72% *vs* 67%) recognition of the monosyllabic words list. Using adaptive test,speech reception threshold measurement in quiet was feasible before upgrading, in 18 out of 33 CI 22M recipients in quiet (54%) and 13 out of these 18 patients in noise (39%). In this population, the median speech reception threshold was decreased by 6dB (range: -27, +5; $p<0.05$) with CP900 as compared to previous SP (Fig. 1A). In noise, it decreased with CP900 by 5.3dB (range: -16, -0.4; $p<0.0005$) as compared to older SP, and even became measurable at +12.4dB in 6 other subjects (Fig. 1B). The benefit in noise was observed in pre-lingual and in post-lingual CI22M recipients. APHAB scores were available before and after upgrading in 30 out of 33 CI 22M recipients and was unchanged with the CP900 SP (Fig. 2).

Discussion

Over the last 15-20 years, the series of SPs from Cochlear Limited has introduced a number of refinements designed to enhance CI performance mainly in noise. The processor CP810, introduced with the 5 system implant was a technological breakthrough for hearing in noisy conditions by an electrical stimulation of the deaf cochlea. Being compatible with previous CI, upgrading Nucleus® 24 with CP810 noise program improved by more than 20% performance in 77% of users, thanks to the two adaptive omni-directional microphones and new front-end processing options[5]. In the Nucleus 6 (CP 900 series), an automatic signal processing algorithm (SCAN) has been added allowing automatic transition between six scenes based on the analysis of environmental signal. Because CI is a highly reliable implanted device (cumulative survival percentage of 92.1% over 29 years for CI22M reported by the company)[10], reimplantation would not be necessary to upgrade ancient CI22M devices which have been implanted more than 20 years ago with new technologies if also compatible. Once made possible, upgrading the old CI with the compatible new generation CP900 SP, yielded to significant improvement in noise intelligibility for more than half of CI22M users in a short period of time. The number of CI22M implantees who reached the level of intelligibility in noise using the Framatix test increased from 39% to 58% with previous SPs and CP900 SP, respectively and most patients prefer new automatic algorithms. No change was observed in quiet regardless of the test used. These results confirm a study including two groups of 15 and 24 CI22M recipients recruited from six North American clinics, showing no change in quiet for CNC words but speech intelligibility improvement in noise with the CP900 compared with the Freedom SP, for AzBio sentences at fixed signal-to-noise ratio [11]. This suggests that after such a long duration of cochlear implantation, the frequency mapping should be located in the auditory cortex which may allow a rapid adaptation to new coding strategy and audiological technology. However, the patients implanted more than 20 years ago were different from those who have been implanted more recently and have already benefit from new technologies. Early CI candidates with a prelingual deafnesswere implanted later than nowadays, a critical period for hearing maturation [12]. Further post-lingual CI users had a more profound deafness and for longer time than during the last 10 years [13]. This may explain that, before upgrade, only 54% of CI recipients in quiet and 39% in noise were able to perform adaptive tests which are more sensitive to show a benefit with the new SP but also more difficult. Moreover, the benefit in noise of upgrading CI22M with CP900 appears to be less striking than upgrading Nucleus® 24 with CP810 [5] and APHAB questionnaire was probably not sensitive enough to capture a weaker subjective benefit.

Conclusion

More than half of the upgraded old CI recipients with a compatible recent SP performed better the difficult Framatix test in quiet and noise in a short period of time. Although it was thought that reimplantation of the internal receiver should be necessary several times during life-spanning of the majority of profound to total deaf patients, this study evidences that cochlear implantation would be performed only once, especially in children operated on nowadays before 1 year old.

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Figure legend

Figure 1: Performance using Framatrix in quiet (A, n=18) and in noise (B, n=19) of CI 22 M recipients upgraded with CP900. In noise, evaluation was made in 13 patients before upgrade with previous SP, and became possible in 6 additional patients with CP 900 SP. Results are expressed as the speech reception thresholds (SRT, dB). The *box plots* show the first and third quartiles values and the *central line* the median value. Comparisons were made using Wilcoxon paired tests. Significances were considered at a p value <0.05.

Figure 2: APHAB scores of CI 22 M recipients upgraded with CP900. The *box plots* show the first and third quartiles values and the *central line* the median value. Comparisons were made using Wilcoxon paired tests. No change of the scores was observed after upgrade.

Table 2: Sound processing features of the processor types evaluated in the study.

Speech processors	Esprit 3G™	Freedom™	CP 900™
Microphones	Dual port directional	Dual port + omnidirectional	Two matched omnidirectional
Frequency range (Hz)	75 – 10823	188 - 7980	63 - 7938
Default IIDR (dB)	30	40	40
SmartSound (front-end processing) options	Auto-sensitivity Whisper™	Auto-sensitivity, Whisper™, ADRO, Beam	Auto-sensitivity, Whisper™, ADRO, Beam, Zoom™, SNR-NR, WNR, SCAN

Autosensitivity: automatic sensitivity control which reduces the sensitivity of the microphone based on the level of detected background noise;
Whisper: algorithm which extend the lower limit of the IIDR in order to improve access to quiet speech;
ADRO: adaptive dynamic range optimization algorithm which regulates individual channel gains to improve comfort and intelligibility
Beam: adaptive algorithm which modifies its polar characteristics according to direction of the dominant sound source;
Zoom: strong directional response, similar to Beam, but fixed rather than adaptive
SNR-NR (Signal-to-Noise Ratio based Noise Reduction): attenuate steady-state background noises irrespective of the direction to reduce instantaneously background noise levels
WNR (Wind Noise Reduction): algorithm to reduce the low frequency noise from wind
SCAN: automatic analyze of the environmental signal classified in 6 scenes (quiet, noise, speech, speech in noise, wind or music) allowing an automatic transition between these 6 scenes.