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Isabelle Mosnier, Olivier Sterkers, Yann Nguyen, Ghizlene Lahlou

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1 **Benefits in noise from sound processor upgrade in**
2 **thirty-three cochlear implant users for more than 20 years**

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

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

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

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23 **Running Title:** Cochlear implant for life.

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29
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39 **Abstract**

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

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

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

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

53

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

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56 **Introduction**

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

70 **Methods**

71 A monocentric study was prospectively conducted on CI recipients, implanted between 1989
72 and 1997 with the first generation of CI (CI22M, Cochlear, Sydney, Australia), to test the
73 benefit of the more recent compatible SP (CP 900). Among 63 implanted patients, 17 were
74 either lost of follow-up or deceased, 11 others were not eligible for a reimbursement of a
75 new SP, and 2 had incomplete data. Finally 33 daily CI22M users for 21 ± 2.2 years (range: 19-
76 26) were included. Among them, 16 pre-lingual, 2 peri-lingual, and 15 post-lingual subjects
77 with a profound to total hearing loss were implanted at 5 years (range: 3-16), at 37 and 38
78 years, and at 36 years (range: 16-60), respectively. Demographic data of the population are
79 described in Table 1. The current SP at the time of the upgrade was a Freedom and an ESPrit

80 3G SP for 31 and 2 subjects respectively, and all of them used the SPEAK coding strategy.
81 Characteristics of the three generations of SP were indicated in Table 2. The CP 900 SP was
82 fitted with the same SPEAK strategy and the same MAP characteristics as was used in the
83 original processor. Three programs were available: 2 new automatic signal processing
84 algorithm programs (SCAN) and a non-SCAN program with the same options used as in the
85 original SP (Table 1). CI users were tested with their current revised SP, and at 2 months
86 post-upgrade with the CP900 with their preferred program, in a soundproof room with two
87 lists of monosyllabic words presented at 60 dB SPL in quiet (Lafon list) and for the best
88 performers, with an automated adaptive test in quiet and noise (Framatrix [8]), with the
89 current revised SP and the CP900 at 2 months post-upgrade. Subjective perceptions were
90 evaluated using the Abbreviated Profile of Hearing Aid Benefit (APHAB) questionnaire [9].
91 The results for each test session were compared independently. Scores for words in quiet,
92 the Framatrix test and the APHAB questionnaire were not normally distributed, so a non-
93 parametric Wilcoxon paired test were used. A p value of less than 0.05 was considered to be
94 significant.

95 **Results**

96 Two months after upgrading first generations of internal receiver (CI22M) with the CP900
97 SP, 31 out of the 33 patients used the SCAN programs all day long (Table 1). No change was
98 observed in quiet for median scores of words (41% vs 43%) and phonemes (72% vs 67%)
99 recognition of the monosyllabic words list. Using adaptive test, speech reception threshold
100 measurement in quiet was feasible before upgrading, in 18 out of 33 CI 22M recipients in
101 quiet (54%) and 13 out of these 18 patients in noise (39%). In this population, the median
102 speech reception threshold was decreased by 6dB (range: -27, +5; $p < 0.05$) with CP900 as
103 compared to previous SP (Fig. 1A). In noise, it decreased with CP900 by 5.3dB (range: -16, -

104 0.4; $p < 0.0005$) as compared to older SP, and even became measurable at +12.4dB in 6 other
105 subjects (Fig. 1B). The benefit in noise was observed in pre-lingual and in post-lingual CI22M
106 recipients. APHAB scores were available before and after upgrading in 30 out of 33 CI 22M
107 recipients and was unchanged with the CP900 SP (Fig. 2).

108 **Discussion**

109 Over the last 15-20 years, the series of SPs from Cochlear Limited has introduced a number
110 of refinements designed to enhance CI performance mainly in noise. The processor CP810,
111 introduced with the 5 system implant was a technological breakthrough for hearing in noisy
112 conditions by an electrical stimulation of the deaf cochlea. Being compatible with previous
113 CI, upgrading Nucleus® 24 with CP810 noise program improved by more than 20%
114 performance in 77% of users, thanks to the two adaptive omni-directional microphones and
115 new front-end processing options[5]. In the Nucleus 6 (CP 900 series), an automatic signal
116 processing algorithm (SCAN) has been added allowing automatic transition between six
117 scenes based on the analysis of environmental signal. Because CI is a highly reliable
118 implanted device (cumulative survival percentage of 92.1% over 29 years for CI22M reported
119 by the company)[10], reimplantation would not be necessary to upgrade ancient CI22M
120 devices which have been implanted more than 20 years ago with new technologies if also
121 compatible. Once made possible, upgrading the old CI with the compatible new generation
122 CP900 SP, yielded to significant improvement in noise intelligibility for more than half of
123 CI22M users in a short period of time. The number of CI22M implantees who reached the
124 level of intelligibility in noise using the Framatix test increased from 39% to 58% with
125 previous SPs and CP900 SP, respectively and most patients prefer new automatic algorithms.
126 No change was observed in quiet regardless of the test used. These results confirm a study
127 including two groups of 15 and 24 CI22M recipients recruited from six North American

128 clinics, showing no change in quiet for CNC words but speech intelligibility improvement in
129 noise with the CP900 compared with the Freedom SP, for AzBio sentences at fixed signal-to-
130 noise ratio [11]. This suggests that after such a long duration of cochlear implantation, the
131 frequency mapping should be located in the auditory cortex which may allow a rapid
132 adaptation to new coding strategy and audiological technology. However, the patients
133 implanted more than 20 years ago were different from those who have been implanted
134 more recently and have already benefit from new technologies. Early CI candidates with a
135 prelingual deafness were implanted later than nowadays, a critical period for hearing
136 maturation [12]. Further post-lingual CI users had a more profound deafness and for longer
137 time than during the last 10 years [13]. This may explain that, before upgrade, only 54% of CI
138 recipients in quiet and 39% in noise were able to perform adaptive tests which are more
139 sensitive to show a benefit with the new SP but also more difficult. Moreover, the benefit in
140 noise of upgrading CI22M with CP900 appears to be less striking than upgrading Nucleus®
141 24 with CP810 [5] and APHAB questionnaire was probably not sensitive enough to capture a
142 weaker subjective benefit.

143 **Conclusion**

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

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186 **Figure legend**

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

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

196