Performance differences between electroacoustic and electric alone cochlear stimulation using complex tests in noise. A pilot study

Italo Cantore, Carmen De Nicola, Alessandro Santandrea, Gabriella Carelli, Paola Valente, Lorenzo Santandrea & Rocco Cantore

To cite this article: Italo Cantore, Carmen De Nicola, Alessandro Santandrea, Gabriella Carelli, Paola Valente, Lorenzo Santandrea & Rocco Cantore (2016) Performance differences between electroacoustic and electric alone cochlear stimulation using complex tests in noise. A pilot study, Hearing, Balance and Communication, 14:4, 194-200, DOI: 10.1080/21695717.2016.1236596

To link to this article: http://dx.doi.org/10.1080/21695717.2016.1236596

Published online: 15 Dec 2016.

Submit your article to this journal

Article views: 2

View related articles

View Crossmark data
Performance differences between electroacoustic and electric alone cochlear stimulation using complex tests in noise. A pilot study

Italo Cantorea, Carmen De Nicolaa, Alessandro Santandreaa, Gabriella Carellia, Paola Valenteb, Lorenzo Santandreaa and Rocco Cantorea

aOtolaryngology, Head and Neck Surgery Unit, Regional Reference Center for Cochlear Implants, San Carlo Regional Hospital, Potenza, Italy; bOphthalmology Unit, Bambino Gesù Paediatric Hospital, Potenza, Italy

ABSTRACT

Objectives: Hybrid cochlear implants enable very interesting performances in bisyllabic words recognition, mainly in noisy conditions. In this paper, we studied patients with implants performing some very difficult timbral tasks in quiet and noisy conditions.

Methods: We studied three adult patients with hybrid implants (group A-hybrid implants) and three adult patients with traditional ones (group B-traditional implants). We made the following tests (in quiet and noise): bisyllabic words recognition; voice kind recognition; common melodies identification and recognition; musical instrument identification and recognition.

Results: Mean results in quiet: test 1: 35% A, 47% B; test 2: 92% A, 42% B; test 3: identification scores 88% A, 100% B; test 4 identification scores 50% A, 20% B. As for tests in noise: test 1: 28% A, 46% B; test 2: 75% A, 25% B; test 3: identification scores 81% A, 87.5% B and recognition 56% A, 50% B; test 4: identification 60% A, 30% B and recognition 50% A, 20% B.

Conclusion: Patients with hybrid implants seem to have better results, mainly in noisy timbral tasks. This could be explained by the better quality of low frequency stimulation and could be an encouragement for further studies and a larger diffusion of this kind of implant in the future.

KEYWORDS: Hybrid cochlear implants; residual hearing; speech recognition; voice kind recognition; melodies recognition; musical instruments recognition

Introduction

Cochlear implants represent a real innovation for otolaryngology in the last 20 years. Recent improvements in cochlear implantation have enhanced performance and expectations for patients and their families. One of the new major topics is the possibility to preserve and use the residual hearing in low frequencies in order to obtain better results than those with electric stimulation alone. Hybrid cochlear implants are indicated for slight to moderate hearing loss in frequencies less than 500 Hz and severe to profound hearing loss for frequencies over 1500 Hz.[1] As reported in previous studies,[1–5] electroacoustic stimulation on the same ear allows better results in terms of speech recognition and in musical tests, mainly in the presence of noise, than those achievable with electric stimulation alone. This is possible through a soft surgical procedure [2,6,7] that enhances the possibility of residual hearing preservation and the opportunity to use some particular kinds of device such as Cochlear™ Hybrid Implant (Cochlear Corp., Australia) or Med-El® Duet (Med-El AG, Austria), characterized by the integration, in the same external device, of an electric stimulation traditional component and an endomeatal hearing-device acoustic stimulation component, under the control of the same speech processor. A special procedure is needed for activation and fitting that includes the selection of a cut frequency between the electric stimulation and the acoustic stimulation and the modulation of qualitatively different parameters in order to obtain homogeneous thresholds, a slightly more difficult procedure than electric-only stimulation. The aim of this study is to report and compare results obtained on six cochlear implant patients, three with traditional electric-only stimulation implants and three with electroacoustic stimulation implants. Patients were submitted to various tests, with and without background noise: bisyllabic words recognition, voice-type recognition, common melodies identification and recognition, musical instrument identification and recognition. To our knowledge, no previous studies have been reported with these kinds of mainly timbral tasks, in quiet and noisy modes, comparing electroacoustic stimulation results with electric-only results.
Methods and materials

Subjects

We studied six adult patients, three males and three females, with age range of 57–75 years. Three were fitted with Hybrid Cochlear Implants based upon a Cochlear™ freedom processor with integrated endo-\textit{meatal} device and CI 422 arrays (group A), another three underwent traditional cochlear implantation with Cochlear™ CP-810 processors and CI24RE(CA) arrays (group B). As shown in Table 1, all patients were adults, at 12–18 months from the time of first activation. They all used implants every day. Nobody used bimodal stimulation on the contralateral side. Patients’ candidacy and preparation was the same for the two groups and included computed tomography (CT) and magnetic resonance imaging (MRI), audiological tests, speech therapist evaluations and, only for group A, outer ear stamp collection for the acoustic device.

Surgical procedures

Two different surgical techniques were used. For the traditional cochlear implant group (group B), we performed mastoidectomy, posterior tympanotomy, cochleostomy anteroinferiorly to the round window niche, receiver niche drilling, electrode array insertion. For group A, the hybrid implant patients, we employed the same surgical steps, except that cochleostomy was not executed. Instead, a slight round window incision was made followed by 0.5 mL of 0.1 mg of bethametasone 1:10 and 0.5 mL of Healon injection, gentle electrode insertion and small muscular tissue flap positioning across the round window. In all six cases, activation was performed 3 weeks after surgery.

Audiology assessment

We had tried to select, from among our traditional cochlear implant patients, those with similar preoperative audiological characteristics to those in group A. The preoperative mean auditory abilities of all patients are summarized in Figure 1.

Patients were submitted to two kinds of verbal tests and two kinds of musical tests, both with and without background noise. Tests were executed inside a Mercury NG-3 enlarged (Mercury-GN Hearing Srl, Italy) silent room, with an Interacoustics AC-40 (Interacoustics AS, Denmark) audiometer, using Telephonics 296d000-1 (Telephonics Corp., NY) headphones, and amplaid 335a (Amplifon Biomedica, Italy) speakers. For musical tests, a keyboard ROLAND BK-5 (Roland Corporation, CA)
was used with a MIDI synthesizer and a SONY cdp-395 CD player (SONY Corporation, NY). Background noise was a 65dB SPL cocktail party noise introduced on the contralateral side. All tests were conducted twice with and without background noise.

The first test was bisyllabic words recognition. In order to measure the intensity, a sound level meter (Extech mod. 407355, Extech Inc., NH) was placed inside the test room each time the test was performed.

In the second test, patients were asked to recognize different kinds of voices. The Italian phrase ‘il papà ha un paio di pipe ma non fuma’ (the dad has two pipes but he does not smoke) was used and the following voices: male child (about 275 Hz), female child (about 290 Hz), adult man (about 175 Hz), adult woman (about 225 Hz), elderly man (about 150 Hz) and elderly woman (about 190 Hz). The same phrase was presented in a random order pronounced by a different voice, asking the patient to recognize it.

The third test concerned identification and recognition of musical melodies. Selected melodies are the followings: Adriano Celentano ‘chi non lavora non fa l’amore’, the Italian National Anthem ‘Inno di Mameli’, Gino Paoli ‘Sapore di Sale’, Orietta Berti ‘Finch’è la barca va’, Mina ‘Tintarella di luna’, Nilla Pizzi ‘Papaveri e papere’, the war song ‘Bella ciao’ and Domenico Modugno ‘Nel blu dipinto di blu’. All are well-known and very famous Italian songs. A single melody each time was proposed to the patient, with the patient disposed in front of the speaker, at 65dB HI, asking the patient to try to recognize it (open set). The identification task (closed set) was conducted in the same way, as for all the tests, with and without background noise.

The last test was musical instrument recognition and identification. A well-known melody named ‘Fra’martino, campanaro’ was introduced to the patient, with the same tonalities, time and musical beats, repeated 5 times, each one synthesized with a different musical instrument, by means of a random sequence. The musical instruments list included violin, guitar, piano, flute and accordion. The test frequency range was 392–880 Hz. Patients had to recognize the instrument each time (open set) and, after that, to identify (closed set) the instrument among all the ones used during the test.

Due to the small number of recipients, it was not possible to apply statistical analysis concerning the significance of the test results.

Results

Group A patients had good residual hearing preservation at 1 month after surgery. On the implant side, patient A1 had a 10 dB HI threshold switch for 125 Hz, 5 dB HI for 250, 1000 and 2000 Hz; patient A2 a 5 dB HI switch for 125, 250 and 500 Hz and lost residual hearing for 2000 Hz; as for patient A3, his threshold was 15 dB HI lower for 125 and 250 Hz, without any variation for other frequencies. All hybrid implant patients reported good residuals thresholds, useful for acoustic combined stimulation.
Auditory abilities for patient A1 were 90% for identification, 92% for recognition and 95% for comprehension. Hearing handicap of the elderly inventory (HHEI) test documented a mild–moderate handicap with a total score of 18.

Patient A2 obtained 95% of identification, 92% of recognition and 100% of comprehension with no hearing handicap reported on the elderly inventory (HHEI) test (total score of 6).

For patient A3, we had 80% of identification, 90% of recognition and 85% of comprehension.

Hearing handicap on the elderly inventory (HHEI) test showed no handicap with a total score of 0.

Patient B1 achieved 100% for identification, recognition and comprehension with a hearing handicap of the elderly inventory (HHEI) test total score of 10.

Patient B2 auditory abilities were 90% of identification and recognition, 95% of comprehension. Hearing handicap of the elderly inventory (HHEI) test report was no handicap (total score = 0).

As for the last patient, B3, he achieved 95% for identification, 95% for recognition and comprehension with a hearing handicap on the elderly inventory (HHEI) test showing no handicap, summarizing a total score of 0.

The mean auditory abilities comparisons are summarized in Figure 1. As it can be seen, improvements are evident for all patients, with no substantial detectable differences.

Despite auditory abilities results, as for other tests, it can be appreciated that there are differences between the two groups, with and without background noise. Without background noise, it can be seen that there are better results for group A patients concerning voice-kind recognition and musical instrument identification. In contrast, with background noise, percentages of correct responses are higher for hybrid implant patients in musical instrument identification and recognition and voice kind recognition (Figure 2).

Comparing the two groups, mean results in quiet were the following: test 1 (bisyllabic words recognition): 35% group A, 47% group B; test 2 (kinds of voices test): 92% group A, 42% group B; test 3 (melodies): identification scores 88% group A, 100% group B, recognition scores: 37.5% group A, 50% group B; test 4 (musical instruments): identification scores 50% group A, 20% group B, recognition scores 30% group A, 20% group B. Mean differences without background noise are reported in Figure 3.

As for tests in noise: test 1: 28% group A, 46% group B; test 2: 75% group A, 25% group B; test 3: identification 81% group A, 87.5% group B and recognition 56% group A, 50% group B; test 4: identification 60% group A, 30% group B and recognition 50% group A, 20% group B. Graphical representation of mean differences with background noise are shown in Figure 4.

Despite the differences detected between the two groups with higher results mainly in noise for group A patients and for timbric tasks, due to the small number of patients, it was not possible to reliably test for significance.

![Figure 2. Comparison of tests scores with and without background scores.](image-url)
Discussion

In the literature, there are papers showing that, in terms of auditory abilities and global auditory patient performances with electroacoustic stimulation, it is possible to obtain better results with hybrid implants than with electric-only stimulation, mainly in noise\cite{1,2,4,5,8}. Furthermore, other studies have examined the audiological aspects of musical abilities for traditional cochlear implants and electroacoustic implants\cite{3,9–13}. However, the verbal and musical tests reported do not include some timbric aspects, such as different kind of voice recognition and musical instrument recognition, with and without background noise, as those proposed as the main aim of this pilot study.

Turner et al. and Stickney et al.\cite{8,14} reported the lowering of cochlear implant patients’ performances in the presence of background noise was mainly attributed to the inadequate possibility of pitch component extraction in the presence of multiple irregular frequencies of the noise.

As shown in previous studies\cite{1,3,4}, hybrid cochlear implants allow for obtaining a higher performance in terms of auditory abilities with background noise than electric-only stimulation implants. With hybrid cochlear implants, a lower signal-to-noise ratio is sufficient to obtain 50% of words recognition compared to the higher S/N ratio needed with traditional cochlear implants to obtain the same percentage. These reports could be explained as due to the better quality of stimulation for lower frequencies for these patients, frequencies so well known as fundamental for the verbal message\cite{8,15,16}. The Polish group of Skarzynski et al., which could be considered a pioneer research group in Europe in this field, confirm the encouraging performances of electroacoustically stimulated patients in background noise\cite{17,18}. Having few available channels, even with codify strategy implementation, should be considered one of the most limiting factors in terms of pitch for electric-alone stimulation systems. Furthermore, this limited number of channels often stimulates inappropriately some apical portions of the cochlea with consequently inadequate low frequency stimulation. For example, an apical electrode with software assigned frequency band of 210–360 Hz, not only stimulates mainly the same cochlear region for each frequency included in this range, but can stimulate an apical region that evoked effective frequency can be lower or higher than the software assigned one. These pitch-mismatch effects were demonstrated by means of comparison of pitches evoked by acoustic stimulation of residual hearing and those obtained with electric stimulation\cite{19}. Furthermore, electrical stimulation cannot evoke frequencies lower than 150–180 Hz\cite{19,20}. However, with hybrid cochlear implants, it is reasonable to anticipate better results for cochlear apical turn stimulation, as we and others authors have reported, due to the higher quality and frequency matching of acoustic stimulation on lower frequencies.

We can approach the reason for the good results obtained for musical tasks through the higher quality of pitch representation with hybrid implant patients. Reports in the literature with hybrid patients and
music melody tasks [21] show very interesting results. Golub et al. [22] reported data on musical tasks for hybrid implant patients’ spectral-ripple discrimination and clinical assessment of music perception. Pitch performance was significantly better in hybrid users when compared with standard implant controls and the spectral-ripple analysis test was significantly better in the hybrid group. This confirms that residual low-frequency acoustic hearing is advantageous for pitch perception and that the clinical benefits enjoyed by hybrid implant recipients are mainly due to improved spectral discrimination provided by the residual hearing. As for results of this study, we can confirm the importance of residual hearing and its usage with electroacoustic combined stimulation for music tasks, despite the small number of patients. Further studies are needed with greater numbers, as with only few patients in the study it was not possible to perform statistical testing to determine the significance of the differences found. Further studies with a higher number of patients and/or meta-analysis are necessary in the future.

It is the authors’ opinion that the value of the improved fidelity of pitch representation for lower frequencies can be appreciated mainly for the timbral tasks submitted to our patients: kind of voice and musical instruments identification and recognition. These types of test are in our opinion among the most difficult ones for cochlear implant patients, as are all timbral trials. To our knowledge, there are no comparable studies in the literature for hybrid implant patients, with and without background noise. One of the main difficulties for these recipients is to distinguish a voice from another or, even harder, one musical instrument from another, without visual feedback. The higher performance in these kinds of timbral test could be explained through the theoretical capability to exploit the better quality of stimulation and the higher number of different pitches detectable for low frequencies by hybrid implant patients, with the possibility of being able to manage and separate multiple frequencies overlying the sound to be identified or recognized. However, it has to be remarked that the better results obtained with electroacoustic stimulation in background noise are often, as in this paper, reported with only a small number of patients. Larger studies with meta-analysis should be awaited in order to appropriately assess these points.

As for the surgical aspects, one of the main fears concerning electroacoustic stimulation is the possibility of not preserving residual hearing. Various studies reported percentages of between 70% and 90% of hearing preservation with soft surgery techniques and the possibility of preserving residual hearing even after re-implantation procedures.[6] The use of a short electrode (as Cochlear L24 or 10 trial) despite a longer one (as Cochlear CI422) seems not to influence significantly better residual hearing preservation.[2,5,17,21–23] So, in the event of the necessity to obtain a better low frequency electric stimulation in the case of complete residual hearing loss after surgery, it would be better to consider the possibility of using a longer, slimmer and softer electrode array, such as Cochlear CI422, when approaching this kind of surgery.[4] These considerations concerning the safety of the procedure, in addition to the good performances reported, should advance the use of electroacoustic stimulation even in countries where it is not yet approved.

**Conclusion**

Hybrid cochlear implants patients seem to show better performances in terms of auditory abilities in background noise than traditional cochlear implants. Better results can be obtained in musical tests with electroacoustic stimulation mainly due to the higher qualitative and quantitative pitch representation in lower frequencies. Furthermore, the higher performances of hybrid patients in timbral tasks with background noise should encourage the diffusion of residual hearing preservation surgical procedures and arrays, even in children, in order to allow a possible subsequent electroacoustic combined stimulation. However, further studies with a larger number of patients are necessary to validate these encouraging results.

**Disclosure statement**

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

**References**


