Rehabilitation of Severe to Profound Sensorineural Hearing Loss in Adults: Audiological Outcomes

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Abstract
The aim of this article is to describe the audiological patterns of 71 adult patients presenting severe to profound sensorineural hearing loss, who were rehabilitated by cochlear implants (CIs) and hearing aids. This is a retrospective study in a university setting, where the clinical records of 71 adult patients were reviewed and processed. Speech intelligibility was evaluated at one aided ear (CI) or at both aided ears (double CI or a combination of CI and hearing aid [HA]). Patients with a bilateral CI or with a bimodal hearing setup (CI and HA) performed better than those with a single CI; data from the phonetic matrices test showed that there was a statistically significant difference among patients aided by a single CI versus binaural setup (double CI or CI + HA). In particular, patients aided by a bilateral CI, or by a CI and HA, showed an improvement in the functional results of the speech tests, compared to patients using a single CI. Binaural hearing (either with a bilateral CI or bimodal) allows an improvement in the functional results at the speech tests, compared to the use of a CI only.

Keywords
sensorineural hearing loss, profound hearing loss, rehabilitation, cochlear implants, hearing aids

Introduction
Cochlear implantation (CI) is nowadays considered a safe and efficient procedure to rehabilitate severe to profound sensorineural hearing loss, both in adults and in children. The standardized guidelines for rehabilitating an adult with a CI are (1) severe to profound bilateral sensorineural hearing loss, with little or insufficient benefit from conventional hearing aids and (2) a speech discrimination score lower than 50%. When the hearing loss is bilateral, different strategies are available for the restoration of the binaural hearing, including bilateral CIs or a combination of a CI and a hearing aid (HA) in the contralateral ear. The benefits of binaural hearing are well described in the literature1-5 and can be summarized to (1) a binaural redundancy and summation effect, allowing a better discrimination of phonemes, words, and phrases, either in quiet or in noisy ambient conditions and (2) a better localization of incoming sound stimuli due to the head shadow effect. The aim of this article is to describe the different rehabilitation audiological patterns of 71 adult patients, affected by severe to profound sensorineural hearing loss, aided by CIs and HAs.

Patients and Methods
This is a retrospective study assessing information from past clinical records. Data from adult patients presenting severe to profound sensorineural hearing loss who received a CI, between February 2011 and December 2018, at the Audiology department of our University Hospital, were considered.

The various cases were assigned to the study after satisfying the following criteria: (1) patient’s age > 20 years and (2) the

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case was related to a single or a double CI surgery. A total of 71 cases (30 females and 41 males) were considered suitable for the analysis, and the data assessed from the corresponding clinical records included the following:

- The age at the time of the surgery: According to the patient’s age at the time of the surgery, patients were assigned in 3 age groups, such as group A: 20 to 39 years; group B: 40 to 64 years; and group C >65 years;
- the hearing loss etiology (if available);
- the date of the first/second CI surgery;
- the use of hearing aids prior to the CI;
- the auditory threshold (pure tone average at 500-1000-2000-4000 Hz) at pre and at 6 months postoperation; and
- Data from the speech recognition tests: A speech audiometry (without background noise at 60 dB) was performed in order to evaluate speech recognition at 6 months postsurgery. Additional speech tests, using the disyllabic words repetition test and the phonetic matrices test were conducted at 12 months postsurgery. Binaural hearing in speech audiometry (without background noise competition at 60 dB) was also tested, using the disyllabic words repetition test and the phonetic matrices test.

The research protocol was conducted in compliance with the Helsinki Declaration (2008); the study was observational; it was performed retrospectively through a case record review and therefore did not affect patient care in any way. However, all patients were informed about the project during their consequent visits and provided their participation consent.

**Statistical Analysis**

The data were analysed using SPSS version 23 for windows. The t-test and analysis of variance procedures were used to evaluate quantitative normal parameters. Statistical significance was considered at $P < .05$.

**Results**

The patients were assigned to 3 age groups, with the following characteristics:

1. Group A (20-39 years) included 20 (28%) patients: Four patients with a unilateral CI, 9 patients with a sequential bilateral CI, and 7 patients with unilateral CI and a hearing aid at the contralateral ear.
2. Group B (40-64 years) included 25 (35%) patients: Four patients with a unilateral CI, 7 patients with a sequential bilateral CI, and 14 patients with unilateral CI and a hearing aid at the contralateral ear.
3. Group C (>65 years) included 26 (37%) patients: Eight patients with a unilateral CI, 5 patients with a sequential bilateral CI, and 13 patients with unilateral CI and a hearing aid at the contralateral ear.

Concerning the onset of hearing loss, 10 (14%) patients had prelingual hearing loss, 2 (3%) patients had perlingual hearing loss, and 59 (83%) patients had postlingual hearing loss.

The etiology of hearing loss was identified only in 62% of cases (see Table 1) and the main causes were infections (14%), such as meningitis or chronic recurrent otitis media; otosclerosis (5%); Ménı¨ere disease (9%); ototoxic drugs (3%); acoustic trauma (1%); autoimmune diseases (1%); and congenital forms (25%). Among the latter, the etiology remained unknown for 4 cases; inner ear malformation was identified in 1 case; nonsyn-dromic deafness was identified in 7 cases; and syndromic deafness was identified in 5 patients. The identified genetic diseases were the Kearns-Sayre syndrome, the Usher syndrome, the Cogan syndrome, and the Marfan syndrome (see Table 1).

According to the rehabilitative choice for the contralateral ear, the patients were divided into 3 groups:

- group 1: 16 (22.5%) patients with a unilateral CI;
- group 2: 21 (29.5%) patients with a bilateral CI; and
- group 3: 34 (47%) patients with a unilateral CI and a hearing aid in the contralateral ear (bimodal stimulation).

All patients underwent tonal audiometry testing before and after CI; The postimplantation pure tone average (PTA) values did not show any statistically significant differences, considering the rehabilitative choice of the contralateral ear and the age-group.

Data on binaural hearing were available for only 55 patients: 21 with a bilateral CI and 34 with bimodal hearing. In particular, at 6 months from the CI surgery, all 55 patients were assessed by a speech recognition vocal test at 60 dB in a soundproof cabin obtaining a mean value of 78.9% ± 19.8% (no significant differences were observed considering the rehabilitative choice of the contralateral ear and the age-group). At 12 months postsurgery, speech recognition was tested by repeating bisyllabic words and phonetic matrices (vowel, consonant, vowel), obtaining a mean value of 82.6% ± 16.8 and 77.5% ± 14.3%, respectively, with the age group C (40-60 years).
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impairment usually have a significant loss or dysfunction of
Patients affected by severe to profound sensorineural hearing
communication problems of the affected individuals. 6,7

Nowadays, hearing rehabilitation of severe to profound sensor-

Discussion

binaural group (bilateral CI OR CI

Abbreviation: CI, cochlear implants.

The unilateral CI group data were compared to the data from
binaural group with a vocal test at 60 dB and by repeating
bisyllabic words and phonetic matrices (vowel, consonant,
vowel; see Tables 2 and 3). At the vocal test, there were no
statistically significant differences among the groups. By
repeating bisyllabic words and phonetic matrices, statistically
significant differences were observed between the unilateral
CI patients (81.3% ± 18%) and the patients from the
binaural group (bilateral CIs = 87.3% ± 14%; CI + HA =
81.1% ± 15%).

Table 2. Single CI Versus Bilateral CI Versus Bimodal Hearing: Patients With Bilateral CI and Bimodal Hearing Perform Better Than Those With a Single CI Even if There Are No Statistically Significant Differences.

| Speech Audiometry              | Monolateral CI | Bilateral CI | Bimodal Hearing |
|-------------------------------|----------------|--------------|-----------------|
| I60 dB                        | 76.9%, 13 patients | 82.5%, 16 patients | 83.3%, 18 patients |
| Bisyllabic words              | 80.4%, 15 patients | 90.7%, 17 patients | 86.8%, 17 patients |
| Vocal-Consonant-Vocal         | 77%, 12 patients | 91.5%, 11 patients | 85.0%, 7 patients |

Abbreviation: CI, cochlear implants.

Table 3. At the Phonetic Matrices Test, There Was a Statistically Significant Difference Among Patients Aided by a Single CI and the Binaural Group.

| Speech Audiometry              | Monolateral CI | Bilateral CI |
|-------------------------------|----------------|--------------|
| I60 dB                        | 76.9%, 13 patients | 82.9%, 34 patients |
| Bisyllabic words              | 80.4%, 15 patients | 88.8%, 34 patients |
| Vocal-Consonant-Vocal         | 77%, 12 patients | 89%, 18 patients |

Abbreviation: CI, cochlear implants.

having the worst performance, especially with bisyllabic
words.

The unilateral CI group data were compared to the data from
the binaural group (bilateral CI OR CI + hearing aid) by testing
speech recognition with a vocal test at 60 dB and by repeating
bisyllabic words and phonetic matrices. At the vocal test, there were no
statistically significant differences among the groups. By
repeating bisyllabic words and phonetic matrices, statistically
significant differences were observed between the unilateral
CI patients (81.3% ± 18%) and the patients from the
binaural group (bilateral CIs = 87.3% ± 14%; CI + HA =
81.1% ± 15%).

Discussion

Nowadays, hearing rehabilitation of severe to profound sensori-
neural hearing loss includes the selection of CIs and/or eventu-
ally of hearing aids, with the aim of resolving the communication
problems of the affected individuals. 6,7

Patients affected by severe to profound sensorineural hearing
impairment usually have a significant loss or dysfunction of
their inner ears (hair cells and/or spiral ganglion neurons). In
fact, when fitting hearing aids, the range from threshold to
uncomfortable loudness is often very small for these individu-
als and with possible variations at each frequency. For these
reasons, the use of HA for the rehabilitation of these patients is
often limited as well as the information that can be transferred
through the auditory pathway by these devices. 6,7

On the other hand, nowadays, CIs represent a safe and efficient procedure
for those affected by severe to profound hearing loss. By
directly stimulating the spiral ganglion nerves fibres, these
devices can properly activate the auditory pathway, offering
an overall worth hearing performance. 6,7

If possible, a bilateral stimulation should be always pre-
ferred. Binaural hearing should be restored by using a bilateral
CI or a CI and hearing aid in the contralateral ear (bimodal
stimulation). Benefits of binaural hearing mainly include (1)
binaural redundancy and summation effects that allow a better
discrimination of speech including phonemes, words, and
phrases, either in quiet or in noisy situations and (2) localiza-
tion of sounds due to head shadow effect. However, binaural
hearing also improves listening in noise and influences a more
positive satisfaction of hearing-impaired patients. It has also
been reported that it can improve cognitive tasks such as short-
term memory as well as reducing social isolation and symp-
toms of depression. 6-12

The data from our study show the beneficial effects of
binaural hearing, and in particular at the phonetic matrices test,
as the binaural group performed statistically significantly better
than those aided by a single CI. A major drawback of this study
is the absence of data on spatial hearing of the studied group,
which were not collected in the past.

According to data in the literature, binaural hearing (CI and
hearing aid in the contralateral ear) offers better results at the
speech audiometry tests, at least 6 months after surgery,13-17
than a single CI. In particular, bilateral CIs have been reported
to offer a better hearing performance and an improved subjec-
tive quality-of-life perception than bimodal hearing (CI and
hearing aid in the contralateral ear). Also, according to Yawn
et al, bilateral CI patients perform significantly better when
testing consonant-nucleus-consonant speech recognition than
their pairs aided by a bimodal hearing. 10 Also, Granco et al
reported a greater satisfaction level for bilateral CIs adult users
examining their levels of speech perception. 9

Some considerations should be taken among the duration of
hearing deprivation, and/or the period of inadequate stimula-
tion, as these are reported to negatively influence the outcome
of hearing rehabilitation by several authors, as expected.18-28 In
fact, for adults affected by severe to profound sensorineural
hearing loss, it is often difficult to investigate and to estimate
with precision the length of hearing deprivation or of improper
hearing stimulation. 18-28 Unfortunately, we could not retrieve
these information in the present studied group.

For most adults with severe to profound sensorineural hear-
ing loss, especially if hearing loss is acquired progressively, the
loss of conversational fluency represents a major prob-
lem. 6,7,21-29 These patients, on the one hand, should be rehabi-
litated, bilaterally, by proper devices (CI and HA or bilateral
CI). In some cases, they should also be helped to set strategies
(such as such as maintaining eye contact and asking to face the
speaker; speaking more slowly and eventually rephrasing) in
order to experience an overall good hearing level in different auditory scenes.\textsuperscript{5,7,21-29}

In conclusion, according to the present data, binaural hearing (either with a bilateral CI or bimodal) allows an improvement in the functional results at the speech tests compared to the use of a CI only.

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